THE AMERICAN JOURNAL OF SCIENCE.

EDITORS

JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS JOSIAH P. COOKE, GEORGE L. GOODALE AND JOHN TROWBRIDGE, OF CAMBRIDGE.

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

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XXXIX.—[WHOLE NUMBER, CXXXIX.]

Nos. 229—234.

JANUARY TO JUNE, 1890.

WITH VIII PLATES.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1890.

PRESS OF TUTTLE, MOREHOUSE & TAYLOR.

CONTENTS OF VOLUME XXXIX.

Number 229.

Number 230.

Number 231.

SCIENTIFIC INTELLIGENCE.

Number 232.

SCIENTIFIC INTELLIGENCE.

Number 233.

SCIENTIFIC INTELLIGENCE.

Number 234.

SCIENTIFIC INTELLIGENCE.

VOL. XXXIX. JANUARY, 1890.

Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN JOURNAL OF SCIENCE.

EDITORS

JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS JOSIAH P. COOKE, GEORGE L. GOODALE AND JOHN TROWBRIDGE, OF CAMBRIDGE,

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

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XXXIX.—[WHOLE NUMBER, CXXXIX.]

No. 229.—JANUARY, 1890.

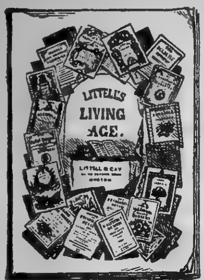
WITH PLATE I.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1890.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

LITTELL'S LIVING AGE.



IN 1890 THE LIVING AGE enters upon its forty-seventh year. Approved in the outset by Judge Story, Chancellor Kent, President Adams, historians Sparks, Prescott, Ticknor, Bancroft, and many others, it has met with constant commendation and success.

A WEEKLY MAGAZINE, it gives fifty-two numbers of sixty-four pages each, or more than **Three and a Quarter Thousand** double-column octavo pages of reading-matter yearly. It presents in an inexpensive form, considering its great amount of matter, with freshness, owing to its weekly issue, and with a completeness nowhere else attempted,

The best Essays, Reviews, Criticisms, Tales, Sketches of Travel and Discovery, Poetry, Scientific, Biographical, Historical, and Political Information, from the entire body of Foreign Periodical Literature, and from the pens of

The Foremost Living Writers.

The ablest and most cultivated intellects, in every department of Literature, Science, Politics, and Art, find expression in the Periodical Literature of Europe, and especially of Great Britain.

The Living Age, forming four large volumes a year, furnishes from the great and generally inaccessible mass of this literature the only compilation that, while within the reach of all, is satisfactory in the COMPLETENESS with which it embraces whatever is of immediate interest, or of solid, permanent value.

It is therefore indispensable to every one who wishes to keep pace with the events or intellectual progress of the time, or to cultivate in himself or his family general intelligence and literary taste.

OPINIONS.

"He who subscribes for a few years to LITTELL'S LIVING AGE gathers a choice library, even though he may have no other books." — *New-York Observer.*

"There is no other publication of its kind so general in its bearing and covering the entire field of literature, art, and science, and bringing between the same covers the ripest, richest thoughts and the latest results of the time in which we live. . No one who values an intelligent apprehension of the trend of the times can afford to do without it. . There can indeed be no better teacher, friend, and companion in any family than this incomparable publication." — *Christian at Work, New York.*

"Certain it is that no other magazine can take its place in enabling the busy reader to keep up with current literature. . By the careful and judicious work put into the editing of THE LIVING AGE, it is made possible for the busy man to know something of what is going on with ever-increasing activity in the world of letters. Without such help he is lost." — *Episcopal Recorder, Philadelphia.*

"To all who have ever taken it, it is a necessity; those who have yet to make its acquaintance will find it the best possible means of keeping abreast of current foreign thought." — *New-York Evangelist.*

"It holds an undisputed position in the front rank of periodicals. . Replete with all the treasures of the best current thought, the best fiction, and the best poetry of the day." — *The Presbyterian, Philadelphia.*

"It is one of the few periodicals which seem indispensable. . It contains nearly all the good literature of the time." — *The Churchman, New York.*

"Biography, fiction, science, criticism, history, poetry, travels, whatever men are interested in, all are found here." — *The Watchman, Boston.*

"Unlike the majority of magazines, it is published weekly instead of monthly. . It loses nothing of its old-time attractiveness." — *The Congregationalist, Boston.*

"As it grows older it grows better. . The foremost writers of the time are represented on its pages. . It is in the quantity and value of its contents *facile princeps.*" — *Presbyterian Banner, Pittsburgh.*

"There may be some things better than THE LIVING AGE, but if so we have not seen them. . For the man who tries to be truly conversant with the very best literature of this and other countries, it is indispensable." — *Central Baptist, St. Louis.*

"It is edited with rare discrimination and tact, and admirably combines instruction and variety." — *Christian Intelligencer, New York.*

"To have THE LIVING AGE is to hold the keys of the entire world of thought, of scientific investigation, psychological research, critical note, of poetry and romance." — *Boston Evening Traveller.*

"It keeps the reader in the intellectual life of the time. No better outlay of money can be made than in subscribing for THE LIVING AGE." — *Hartford Courant.*

"For the amount of reading-matter contained the subscription is extremely low." — *Christian Advocate, Nashville.*

"Nearly the whole world of authors and writers appear in it in their best moods. . The readers miss very little that is important in the periodical domain." — *Boston Journal.*

"It may be truthfully and cordially said that it never offers a dry or valueless page." — *New-York Tribune.*

"It is one of the indispensable literary publications of the day. . To read it is itself an education in the course of modern thought and literature." — *Buffalo Commercial Advertiser.*

"It maintains its lead in supplying the latest and the best productions of current literary effort." — *North-Carolina Presbyterian, Wilmington.*

"It saves much labor for busy people who wish to keep themselves well informed upon the questions of the day." — *The Advance, Chicago.*

"It enables its readers to keep fully abreast of the best thought and literature of civilization." — *Christian Advocate, Pittsburgh.*

"In this weekly magazine the reader finds all that is worth knowing in the realm of current literature. . It is indispensable." — *Canada Presbyterian, Toronto.*

PUBLISHED WEEKLY at $8.00 a year, *free of postage.*

CLUB PRICES FOR THE BEST HOME AND FOREIGN LITERATURE.

["Possessed of LITTELL'S LIVING AGE, and of one or other of our vivacious American monthlies, a subscriber will find himself *in command of the whole situation.*" — *Philadelphia Evening Bulletin.*]

For $10.50, THE LIVING AGE and any one of the *four-dollar* monthly magazines (or *Harper's Weekly* or *Bazar*) will be sent for a year, *postpaid;* or, for $9.50, THE LIVING AGE and *Scribner's Magazine*, or *Lippincott's Magazine*, or the *St. Nicholas.*

ADDRESS **LITTELL & CO., 31 Bedford St., Boston.**

C.D. WALCOTT.

THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. I.—*Measurement of the Peruvian Arc;* by E. D. PRESTON.*

ONE hundred and fifty years have passed since Bouguer was making his observations in the measurement of the Peruvian arc. The geodetic science of to-day is so much occupied with the slight deviations of the surface of the earth from a strictly elliptical figure, that it is hard to realize that even in the last century it was an unsettled question whether the equatorial or polar axis was the longer.

A clock, having been carried from Paris to the equator, was found to lose two minutes each day. This fact was supposed to strengthen Newton's theory that the earth was an oblate spheroid. On the other hand, Cassini's surveys in France at the beginning of the last century, indicated a prolate spheroid. It was to reconcile these two determinations that the French Academy undertook the measurements of Meridional arcs; one on a frozen river in Lapland, the other above the clouds in Peru.

Parenthetically, it should be stated, however, that the Peruvian arc so-called, is not in Peru as defined by the geography

* Read before the American Association for the Advancement of Science, Toronto meeting, August, 1889. Published by permission of the Superintendent of the U. S. Coast and Geodetic Survey.

of to-day, but more than a hundred miles north of it in Equador. When the results of these two expeditions were made known, the scientific world accepted Newton's theory, and all later measures have only served to confirm it.

Let us pause just for an instant to examine the triangulation by Cassini, and the time determination by Richer. Looking at the data with our present knowledge of the accuracy attainable in the two kinds of measurement, it seems strange that the former could for a moment have cast doubt on the latter. In the first place, Cassini's results do not agree among themselves. He gives the following statement of the length of one degree in toises:

ϕ	τ
49° 56′	56970
49 22	57060
47 57	57098

Even were there no other reason for distrusting the observations, their disagreement would almost condemn them. We now know that the length of one degree in latitude 49° changes about ten toises per degree, so that the change of more than one hundred and thirty toises in a space of as many miles, indicates either some large error or a value for the earth's radii entirely incompatible with even the rudest observations. Besides, if the first difference were accepted, it would require the place of observation to be in a latitude very different from that known to have been the case. Therefore the triangulation in itself is not very trustworthy. Moreover any assumption in regard to the ellipticity of the meridian derived from measures not extending beyond two degrees, is extremely hazardous.

On the other hand, when we consider that Richer's clock lost two minutes daily, and that it must have been a comparatively easy matter, even at that time, to get differential time within a second, it is plain that the only source of error worth examining is that due to the change of the length of the pendulum. Barring accidents, and leaving to one side the effect of temperature, which must have been well understood and taken account of by the observer, the length could not have changed by nearly so much as its one-thousandth part, and as the time varies as the square root of the length of the pendulum, the time of one oscillation could not have been in error more than one-half this amount. Hence no error can be admitted that would materially change the result, and the pendulum work might have been accepted as demonstrating the oblateness of the figure. But the Academy resolved upon an independent determination, and the two expeditions were equipped.

Bouguer set out on May 6th, 1735, and after a journey of more than a year, arrived at his destination. The party was absent about nine years, but the triangulation and base measurements were executed between December, 1736 and August, 1739. Astronomical observations to determine the amplitude of the arc were made between July, 1741 and January, 1743, and the party arrived at the mouth of the Magdalena river on September 30th of the same year. The pendulum was swung at Porto Bello on the outward trip, and at Petit Goave, Hayti, on the return voyage. The results are incorporated in the account of the equatorial work. Three gravity determinations were made in Peru; at the sea-level, at Quito (9,374 feet elevation), and on the summit of Pichincha (15,564 feet). Magnetic observations were also carried on, and a general study made of the natural history and physical features of the country.

We must not lose sight of the fact that the work was undertaken to decide between the relative lengths of the earth's axes. Several methods of arriving at this result were therefore considered. It was once thought to supply sufficient data to decide the whole question by the equatorial observations alone: measuring for this purpose a degree of latitude and one of longitude in the same locality. But recognizing the fact that with the means at hand, the former would be subject to an error of 1/1500th part while the latter would be uncertain by about six times as much, the preference was given to the degree of the meridian. Measures had already been made in France, and from the nature of the involute curve, formed by the intersection of the earth's radii for any given meridian, it was admitted that combining the equatorial measures with those of a middle latitude, the error to be expected in the ratio of the two axes was only 1/1440th part; and that a combination with arctic measures would reduce the error to about two-thirds as much (1/2030). The errors attributed to accidental causes rest on the assumption that in each astronomical observation the observer is liable to be mistaken by three or four seconds of arc; and that in noting signals for longitude one second of time would be the error expected.

After the arc had been measured it became a matter of some difficulty to combine it with the French and arctic work. Every supposition made in regard to the meridian, supposing that it could be represented by an elliptical curve, seemed to do violence to the results of observation.

A combination was first made, using the arctic and equatorial arcs, the law being that of the square of the sines. This led to a ratio of 214 to 215 for the axes. Then when the middle arc was re-measured, and to the three meridian arcs a longitudinal one was added this ratio was changed, and 222 to 223 given. The formula was still that of the sines squared. Later, an error was discovered in this remeasurement. Picard had used a toise for his base measures, which was too short by its one-thousandth part. The introduction of this new value modified the result so essentially that the law previously adopted no longer satisfied the observations within admissible errors. The formula was changed to one where the increments of the length of the degree varied as the fourth power of the sines of the latitude, and a ratio of 178 to 179 was given for the length of the axes.

The introduction of a power of the sines higher than the square was done reluctantly. But it was found, that in order to represent the curve by the second power of the function, supposing the three arcs subject to the same error, it was necessary to increase the degree in France by sixty-nine toises, and diminish the other two by an equal amount. This would have re-established the ratio 214 to 215 and would have been nearer the truth, as we now know. But such large errors were not thought possible. In fact, reasoning from their accidental errors of observation, only an error of seventeen toises could be admitted for the middle degree, and forty-four for the equatorial one. This would necessitate subtracting one hundred and forty toises from the northern one, which seemed beyond all reason. The procedure, however, would make the meridian a perfect ellipse and give a ratio of 250 to 251.

When compared with Newton's theoretical value of the ellipticity, it was remarked that this erred in defect about as much as the previous conclusion had erred in excess. Therefore the observations left the choice of only two suppositions: either that of the fourth power of the sines, or that of some function of the latitude itself. The arc of longitude which had been measured was brought to bear on the decision, and it was found that the measure would, by the first solution, be in error by one hundred and fifty toises, whereas by the second the error would be reduced to eighteen. This decided the question and the law of the fourth powers, and the ratio 178 to 179 was adopted.

This is the result as given by Bouguer in his discussion of the Peruvian work. Of course it is far from being the truth; but the recapitulation shows to what extent the measures of one hundred and fifty years ago were defective, and gives an idea of the influence of this equatorial arc on the elements of the ellipsoid that are used in all geodetic computations of the present day. A later discussion improved this result, and now there are so many middle arcs entering with great weight on account of their increased accuracy, that the Peruvian arc has not the importance it once had. Notwithstanding, it is believed that a remeasurement would so modify it as to materially change the earth's ellipticity.

We now turn to examine the work more in detail. The first base was measured on the plain of Yarouqui, about fifteen miles east of Quito. Eight days were devoted to clearing the line. Its true direction was N. 19° 26′ W. Three wooden rods, each twenty feet long, with copper contact plates, projecting one and one-half inches at each end were used in making the measurement. The plates were so arranged as to make contact at right angles to each other. A rope was stretched for alignment, and the inclination of each rod was determined by means of a level. Twenty-five days were consumed in the work, which was exceedingly laborious because the rods were laid on the ground. This course was pursued on account of the violent wind. Two rods were always in position. The rear one, carried forward by Indians, was brought into contact with as little shock as possible; but with a heavy rod and in the hands of several untrained persons, it is difficult to see how shocks were avoided. An iron toise was carried along, kept in the shade, and comparisons were made always daily and sometimes oftener. The temperature and humidity of the air affected the wooden rods considerably. The work was begun from both ends and the parties compared their rods when they met in the middle. The south party, however, used tressels, and it was noticed that the effect of wind on the plumb-line, and the consequent error in the length of the base, would be in opposite directions for the two measures. In spite of this fact, and with the exceedingly rough method of making the contact, the two independent measures only differed by about three inches for a distance of more than six thousand toises, which is about $\frac{1}{150000}$th part. This is a degree of accuracy far beyond what we can reasonably expect in work of this kind, and there must certainly have been large compensating errors.

Base measures of the present time, with all our improved methods of dealing with the temperature, perfected contact slides, better ways of alignment, and more skillful manipulation of the bars by persons trained to the work, do not give much better results.

The actual measures gave somewhat less than 6273 toises for the length. It was estimated that the necessary corrections would increase this quantity, and in order to have their base an exact number of toises, one of the end marks was moved three inches and eight lines. It is hard to see what was to be gained by this. Of course the round number would be broken by the solution of the first triangle. Their own measures showed an uncertainty of several inches. Therefore, asserting that the base contained an exact number of toises within the thickness of a line, goes for nothing. Moreover the subsequent reduction gave a correction, different from what they had applied, so that the finally adopted length of the base was not 6274 toises, as they wished it to be, but four inches and one and one-half lines more than this.

The length of the straight line connecting the two extremities of the base was found by first comparing the actual measure with the line as traced on the ground, and then deducing the quantity sought from this last line. An approximate value for the base line substituted in the formula*

$$Z = \int \frac{c\,dx}{\sqrt{c^2 + (b + x)^2}}$$

gives the correction to reduce the actual measures to the ground line, considering it sensibly straight for each of the seven parts into which the whole base was divided. The absolute and relative heights of the extremities and the intermediate points were determined, which furnished the data for referring the ground line to the air line connecting the extremities. The result of the entire work was:

Ground line longer than actual measure	1·52101
Ground line longer than air line	0·23100
Air line longer than actual measure	1·29301

The correction for temperature applied to the Tarqui base would indicate a coefficient of expansion of ·000015 for the wooden rods, which is between that of glass and brass but somewhat nearer the latter. But then not very much reliance can be put on the temperatures. That of the base of verification was only estimated,† and could not certainly have been known within several degrees. But the accordance of the results, errors of compensation being disregarded, would indicate that the temperatures were correct to within one-fourth of a degree. An examination of the record shows conclusively that this could not have been the case. On the other hand the Spanish officers correct the second base by about eight feet which would require a coefficient of expansion, based on the same difference of temperature, at least twice that given above.‡

* The earth's radius is c: x is the length of the line, and b an auxiliary constant.

† Mesure des trois premiers degrés du Méridien, par M. de la Condamine, Paris, 1751, p. 83; see also in this connection "Zeitschrift für Instrumentenkunde," August, 1885, p. 271, and "Resultate über die peruanische Gradmessung." Monat. Corresp., 1887, p. 240.

‡ Observaciones astronómicas y physicas hechas de órden de S. M. en los regnos del Perú. Por Juan y Ulloa, Madrid, 1748, p. 166.

It then appears that the temperature factor alone would give rise to uncertainties far greater than the difference between the two results.

The angles of the triangulation were measured with quadrants whose radii varied from two to three feet. Two telescopes were provided, a fixed and movable one, the whole instrument being universally mounted by means of two right-angled cylindrical elbows. Micrometers were here applied to instruments of this kind for the first time, and it is believed that Bouguer was the first who called attention to errors of eccentricity. As the limb of the instrument only included ninety degrees these errors could not be studied by the method now employed of comparing diametric readings throughout the entire circle. Independent measures of two known angles gave two equations, in which the known quantities were the errors, and a function of the angle itself, and the unknown quantities were the rectangular coördinates of the center of rotation, referred to the center of graduation as the origin. These coördinates being known from the solution of the equations, corrections applicable to any part of the limb could be calculated. Besides this, six or seven angles, which together closed the horizon, were measured. These were corrected for inclination and their sum compared with 360°. The error of closing was on the average about two minutes. Measures of equilateral triangles gave an additive correction of 20″ for an angle of 60°. Other combinations showed a correction of 40″ for 90°. The separate spaces of five degrees were examined by comparing with a known angle of this magnitude. A month was devoted to the study of the errors of the instrument.

With instruments capable of this degree of accuracy we cannot expect a close agreement between the measured and calculated base. They differ by about two feet. The triangulation is two hundred miles long and contains thirty-two principal triangles. But the result of the side computations from this principal network was twice modified. Once at the eighth triangle where some auxiliary figures gave a result different by two and one-half toises from the regular work, and again at the sixteenth, where results having a range of seven-tenths of a toise were obtained, from three different methods of deriving the same line. In both these cases the auxiliary work was combined with the regular triangulation, and the resulting line upon which the succeeding work depended, was changed by one and one-tenth toises in the first instance, and by three-tenths of a toise in the second; so that we should not be surprised at a much greater discrepancy between calculation and observation at the end of the chain of triangles. Bouguer shows that admitting an error of 15″ in each angle the accumulation of these throughout the entire work would produce an error in the second base of about twenty-five toises but adds that a certain compensation must be expected among so many errors.

After having finished the triangulation, astronomical observations were undertaken to determine the amplitude of the arc. They were made with a sector having a radius of twelve feet and a graduated arc of about three degrees. Although this is confessedly the weakest part of all the equatorial work, the methods employed show a keen appreciation of many sources of error. The limb was graduated by laying off an aliquot part of the radius as a chord. This was chosen with reference to the particular star to be observed, and the true zenith distance was found by applying to this known arc, a small micrometer correction. The modern work with the zenith telescope is but a repetition of this same principle; for here the absolute zenith distance of the two stars is for the moment disregarded, but the excess of one over the other is measured, and applied to a function of their declinations, which are quantities determined by other investigations.

The precaution was taken in the Peruvian work to make part of the measures on the same star, and at the same time, at both extremities of the arc. This would eliminate any effect of uncertainty in the constants for precession, aberration and nutation, which were not, at that time, very well determined. But Zach has re-reduced the observations of 1742 and 1743,* ana finds a difference of less than 1″ between the results for the simultaneous observations and that deduced from all the work during these two years. The instrument was reversed several times, thus giving values under different conditions, and it is said that no discordant observations were rejected.† The method of reversal is referred to as having been invented by Picard, and it is probable that this principle, now so often applied, and so essential in all instrumental work was here systematically used for the first time. Its effect in this case was to eliminate the eccentricity of the zero point of the micrometer.

The value of the micrometer was found from terrestrial measures, using the known length of portions of the base, and lines erected perpendicular thereto. The meridian was found by observing, at the moment of culmination, the direction of a beam of sunlight, admitted through a hole in the roof of the observatory. The method was supposed to give the true direction with an error not larger than one minute of arc.

* Ueber die Gradmessung am Aequator; Monat. Corres. vol. xxvi, page 39.
† Figure de la Terre par Bouguer, Paris, 1749, p. 262.

The accuracy of the measurement of a star's zenith distance appears to depend principally on the stability of the limb of the instrument, and the ability of the observer to set the initial point of the arc in exact coincidence with the plumb-line. There seems to be nothing said as to how this was accomplished, but it is easily seen that it must have been a work requiring much care. The measures of the star's zenith distance are given to the nearest second. Indeed the three results for the arc's amplitude have a range of only three seconds. The following were the results from the three stars:

ε Orion	3° 7′ 1″
θ Aquilæ	6 59
α Aquarius	6 58

These are the results considered by the observers to be the best. They do not represent all the observations, but were selected on account of the favorable conditions obtaining at the time they were made. The sector had also undergone some improvement. But a mean value from all the results obtained at both stations gives 58″ which agrees more closely than one would expect from the range of the individual values. Zach estimates that the total error in the equatorial degree will not exceed fifty toises, thirty-eight being for the astronomical and twelve for the geodetic part of the work (Monat. Corres. 1807). This is based, however, on Bouguer's, and La Condamine's estimates of the accuracy of the astronomical work (page 251). Since the radius of the sector was twelve feet, one second on the limb would be about 1/1400th of an inch. To make a plumb-line, suspended freely, coincide with a mark on a scale at its side, to within less than this quantity, must have been a matter of difficulty. In this operation we have in all probability the source of the largest discrepancies.

The flexure of the sector was also studied. Experiments were made on an iron bar, from which it was concluded that the flexure varied as the fourth power of the length. It was found moreover that when the radius of the sector was placed horizontally its flexure amounted to one-twelfth of an inch. This was shown to be inappreciable when the inclination was only a few degrees, and when the objective of the telescope was attached to the center of the sector.

Azimuth observations were made at both bases and at three intermediate points. The agreement between the observed directions and those determined by triangulation is always within less than one minute; the discrepancy at the last base being forty seconds. The sun was invariably used, and the angle between it and a signal was measured with a quadrant. The errors in orientation, estimated liberally, will not change the total length of the arc more than a fraction of a second at each end. Therefore the question of azimuth is not one of vital importance.

We now come to perhaps the most interesting part of Bouguer's work. Not satisfied with investigating the exterior shape of the earth, he determined to study also its interior condition. It had been known for more than fifty years, that a pendulum oscillated more slowly at the equator than near the pole, and finding himself not only in a latitude where the force of gravity was the least, but also in a country where there were exceptional facilities for the study of this force at great elevations, he deemed it his duty to devote some time to the investigation of the subject. Of the two methods, either comparing the times of oscillation by the same pendulum, or comparing the lengths of two different pendulums, vibrating in the same time, he chose the former. In this he has been followed by all later observers. Of course his results cannot now be regarded as of very great value, both on account of the unsuitable methods and inferior instruments employed. But the work pointed in a certain direction, which has been confirmed in a general way by some more recent and accurate determinations. His method of getting time would not now be used in gravity observations, although modern instruments would increase the accuracy of the result several fold. It is doubtful whether, with his instruments, and often using single altitudes of stars, the time was correct within several seconds. About one and one-half hours may be taken as the duration of a swing, so that with the uncertain clock correction, and the short duration of the experiment, great discrepancies in the individual swings were unavoidable The pendulum was of an inaccurate type and its length was found by simply holding an iron bar by the side of a thread stretched by an ounce weight. Contact with the clamp above and the bob below was examined either by means of a magnifying glass or by the naked eye.

The individual results, for the length of the seconds pendulum at Quito, where the conditions were favorable, have a range of about 1/6000 part. This would correspond to discrepancies in the times of one oscillation of less than one unit in the fourth place of decimals. Under the circumstances the accordance is good.

The result was corrected for buoyancy and temperature. The former was here applied for the first time in pendulum observations. It was estimated that the density of the air on the top of Pichincha, was one eleventh thousandth of that of the metal composing the pendulum bob, and since gravity varies inversely as the length of the seconds pendulum, the length found was increased in this same ratio. No correction seems to have been made for the amplitude of oscillation.

When the necessary reductions were made it was found that gravity at the sea level, was diminished by 1/1331 part at Quito, and by 1/845 part on the summit of Pichincha. Since the distance from the earth's center had been increased in the first instance by its 1/2237 part and in the second by its 1/1348 part the results indicated a law, not very different from that of the inverse square of the distance. But gravity had not changed enough, in either case, to satisfy the law. The conclusion therefore was, that some influence, not exactly understood, increased the force of gravity in both cases. Naturally, attention was drawn to the high table land lying between the stations and the sea. It was estimated that the effect of this would be one-half of that of a shell of matter of the same density and thickness encircling the whole earth. Granting this, the diminution of gravity in passing from the sea to the summit would be

$$\frac{2h}{r}\left(1-\frac{3\delta}{4\varDelta}\right)$$

where h is the height of the station above the sea, r is the radius of the earth and δ and $\varDelta$ are the respective mean densities of the table land and earth.

Now this diminution was found by the pendulum to be 1/1331, which, compared with the above expression, leads to the conclusion that the matter composing the table-land has only about one-fifth the density of the earth. The result was something of a surprise at the time, and doubts began to arise as to whether the interior of the earth could be, as some supposed, a fluid mass surrounded by a thin shell. It could not be denied that the density of the surface was less than that of the interior, because it was shown that, in order that their densities be at least equal, the length of the second's pendulum must be in error by about one-thirtieth of an inch, which even with the rough method employed was too great an error to be admitted.

If the land lying between the upper station and the sea be regarded as a plain of infinite extent the same result ensues, and the formula deduced from this point of view is of somewhat simpler derivation. Clarke arrives at the same result by regarding the intervening matter as either a cone, cylinder, or segment of a sphere, where the horizontal dimensions are great compared with the vertical ones. In calculating some attractions in the Hawaiian Islands, the matter was treated rigorously as a cone, and the resultant attraction at the foot of the mountain, based on this value, agreed closely with that derived independently by the latitude observations and triangulation.

The value of the radius of the earth employed in the Peruvian investigation was about 12,000 meters too large. Introducing the value now accepted we get a density for the Andes somewhat greater. The change is in the right direction but it is not enough. The rocks in Peru probably have a density of about 2, or possibly less, and if the sea level is in error by one hundred toises, the pendulum work would give about this density for the underlying mass.

The method used in finding the absolute height of the base line, to which all the elevations were referred, was by triangulation. The results were roughly checked by the barometer. From Niguas, a point between Quito and the mouth of the Inca river, angles of elevation were taken to several mountain peaks, of which Pichincha was one. Niguas was also visible from a point near the sea level. The distances being approximately calculated, with some of the angles concluded, the elevations could be determined with some degree of accuracy. The last station was estimated from barometer readings to be about thirty toises above the sea. But that not much confidence could be placed in the instrument is plain from the fact, afterward stated, that weighing all circumstances it was concluded to fix the difference at forty or forty-two toises. The result was checked by a very rough estimate of the inclination of the river bed and the velocity of the current. Knowing the relation between the velocity and inclination at a point near the station, and determining the velocity farther down the stream, the inclination was calculated. Then from the measured horizontal distance and the inclination the vertical height resulted. It is evident that not much reliance is to be put in such a determination, but perhaps the error is considerably inside some others entering into the deduced height of Pichincha.

The angles of elevation were measured with a quadrant which might give results as much as 30″ from the truth. Then, as there were mountains back of the station, twelve thousand feet high in one case, and fifteen thousand in the other, the angles of elevation may have been in error in either case by the greater part of a minute. And errors from attraction would be accumulative, since Niguas is on the mountain flank. The distance from the sea to Ilinissa, with which Pichincha was connected, was found from the known difference of latitude and the azimuth. It seems therefore probable that the total elevation may have been in error by as much as fifty toises. This is not enough to bring the mean density of the Andes into tolerable accord with that of the surface rock.

It is difficult to accurately estimate the probable error of the distance between the two extremities of the arc, because sufficient data are not available. Take one-eighth of a foot, which is one-half the difference between the results, as the probable error of one measure of the base line. This is composed of errors in the lengths of the rods and errors of measures properly so called. The error in the entire base, as depending on the former, varies as the length, and as depending on the latter, as the square root of the length. Assume these to be equal. This would give for the uncertainty of one of the rods (twenty feet) 0·0004 inches or less than 1/500000th part, and for the uncertainty of making contact about 1/500 of an inch.

Either of these errors is not only much smaller than we can expect from work done under the circumstances, but they are actually less than are generally realized in modern measures. Therefore when we consider the means of comparison with the standard and the method of placing the bars on the ground, the close agreement must be considered entirely accidental, and in no wise to be taken as a criterion of the accuracy of the work.

Any error in the linear measure is transmitted through the triangulation and the probable error in the last side will depend on the average correction to a direction as determined from the shape of the triangles and their number. To this is to be added the error in the base, which transmits itself independently, and its effect depends on the relation between the base and the last side. The average direction error, resulting from joining points in a triangulation, is about twice as much as the average direction error arising from closing the horizon at any one point. Regarding the probable errors of the base and angles as differentials of those quantities, the uncertainty of any side may be computed by a formula involving these differentials and known functions of the angles.

Taking eight seconds as the probable error of an angle which is less than that estimated by the observer, we calculate the uncertainty of the last side, as depending on the angle equations alone to be slightly more than ten feet. This result is based on the formula,

$$r_0 = ar \sin 1'' \sqrt{\cot^2 A + \cot^2 B},$$

which assumes that one of the angles in each triangle is a concluded one. The true probable error, where all the angles are measured, would be somewhat less than that given. Nevertheless, all the circumstances being considered we may assume the uncertainty of the last line to be not far from twelve feet. The chances are that this is an under-estimate. This error, as we have seen, is about that discovered near the middle of the chain, and which influenced all subsequent work by one-half its amount. The error in the base is now disregarded because, although it is much larger than the results of the measures would indicate, its effect on the last side would still be small in comparison with that resulting from the angle equations.

The astronomical observations agree among themselves, but it was not suspected at the time, that the mountains might affect the plumb-line by at least thirty times as much as the results were supposed to be in error. When the work was done instruments and methods had not been brought to that degree of perfection necessary to detect these small influences. Since then many striking cases have been brought to light, 22″ deviation having been noticed in India, 16″ in Russia, and 29″ in the Hawaiian Islands. In the example near Moscow there are no mountains to account for the phenomena, and the supposition is that the density of the underlying strata may be subject to great variations, or that large subterranean caverns may exist. Archdeacon Pratt has shown that small changes of density, if extended over a considerable area, may produce very perceptible deflections of the vertical. The Indian example is produced by the Himalayas. The Hawaiian is the result of the attraction of Haleakala, an extinct volcano ten thousand feet high.

When we consider that between the extremities of the Peruvian arc there is a continuous range of mountains, varying in height from nine thousand feet on the plateau of Cochesqui, to nineteen thousand at the summit of Chimborazo, and remember that the arc was terminated at a point where the elevation dropped suddenly several thousand feet, it is evident there must have been enormous differences between the astronomical and geodetic latitudes.

Judging from analogy with other cases, similar, either in the volume of the mountains or the density of the matter, it seems not unlikely that the amplitude of the arc may be in error by many seconds. Indeed if we take the data used in La Place's first discussion, the Peruvian latitudes should be changed by about 10″ in order to give an ellipticity conforming reasonably with our present value. And the required change shows that the plumb-line was drawn toward the mountains.

The errors in the measures of the two bases, in the triangulation, in the altitudes, or in the azimuths, could not have an influence at all comparable to this, so that a simple redetermination of the latitudes would very much improve the result. In fixing the figure of the earth an equatorial arc enters with great weight, and we find that in a combination by least squares of nine arcs used by La Place, an error of one minute in the amplitude of the equatorial arc would reduce the ellipticity to one-half its original value. This seems to be a great change for the supposed error, but it must be remembered that not only is the arc at the equator and therefore has great influence in the determination of the elliptic figure, but also that it is a comparatively short arc and hence any error in the amplitude has a proportionately greater effect on the length of a degree deduced therefrom.

The individual influence of arcs where many enter into the determination should not, however, be overestimated. If we suppose arcs of one degree to be measured from the pole to the equator, say 10° apart, their weights in fixing the polar axis are approximately as the numbers 39, 43, 54, 70, 89, 111, 131, 146, 157, 161 and in the determination of the equatorial axis these same numbers apply in an inverse order. A curve plotted on rectangular coördinates, with the earth's radii and the above weights as arguments, has a point of inflection in middle latitudes, and since the ellipticity is unity minus the ratio of the two axes, middle arcs have very little influence on the ellipticity.

The pendulum observations indicate that the density of the mountains is about one-fifth the mean density of the earth. We may therefore assume that the Andes in the neighborhood of Quito are one-half as dense as the general surface of the earth; and if we take 15″ for the deflection at each end of the arc the ellipticity of the figure is changed by about one-fourth part of itself.

The effect of any change in an equatorial arc, on the figure of the earth, as deduced from the nine arcs above mentioned is easily found. The conditional equations are combined by least squares in order to find the values of M and N in the equation,

$$d = \mathrm{M} + \mathrm{N} \sin^2 l$$

where d is the length of one degree in latitude l, M is the length of one degree at the equator, and N is the difference in length between the equatorial and polar degree. The change in length of the equatorial degree will be given by differentiating an expression of the form

$$\frac{\Sigma\, b^2\, (\Sigma\, a - \Sigma\, ab)}{9\, \Sigma\, b^2 - (\Sigma\, b)^2}$$

where a is the independent variable. The degree being at the equator, the differential of $\Sigma\, ab$ is zero, and the change in the length of the equatorial degree from the solution of the normal equations would be about two-thirds the assumed linear error in the individual arc. Knowing the differentials of M and N the changes produced in the eccentricity and ellipticity are obtained without difficulty.

It is a singular fact that the first combination of the Lapland and Peruvian arcs gave a value for the ellipticity quite as near the truth as was deduced by La Place fifty years later, using the accumulated data furnished by improved instruments and methods. This is partly owing to the fact that the two arcs, having the greatest influence from their position and length, remained unaltered.

La Place's combination gives a value in excess, and the supposition of the plumb-line being deflected toward the center of the arc changes the value in the right direction. How much attraction should be allowed for it it is difficult to say as the configuration of the land is not known with sufficient accuracy. The indications are, that even admitting the small density of the mountains, the deflections are much larger than would be necessary to bring this arc into accord with the others, and give a value for the ellipticity called for by modern observations in middle latitudes. If we accept the data in La Place's first combination a deflection of eleven seconds at each end of the arc would be required for this purpose.

There seems to have been some compensation of errors, which has given the Peruvian arc a value conforming closely with our present spheroid. But its agreement in this respect is no excuse for not remeasuring it. The measures of the base line agree within a few inches, but no one who has examined the case believes that this is anything but an accident. The combination of this arc with some other recent ones in the determination of the figure of the earth, gives corrections for the equatorial latitudes even smaller than those required by points whose positions were determined with greater precision, and where the direction of the plumb-line is much less disturbed by attraction. These small corrections would probably not be confirmed by a new measure.

Notwithstanding, this work was well done considering the circumstances and the state of science at the time. Bouguer and his associates were scientific men who thoroughly understood the requirements of the case, and executed the work with the utmost fidelity. The necessity for a greater or less degree of accuracy, according to the kind of observations, and the bearing of each partial result on the final one was the source of constant study. Many principles of work here practiced for the first time have been adhered to by all later observers. But the advantage of repeating this work would come from the great improvements in instruments, and the consequent bringing to light of influences that were then unknown. Nothing at the time was known of spherical excess in geodesy. The theory of least squares was undiscovered, and the method of equal zenith distances had never been applied to the determinations of latitude. We now have also the compensating base apparatus and many perfected forms of the pendulum for the measurement of the force of gravity. In fact in every class of work the errors at present range from one-tenth to one-hundredth of what was then considered admissible.

Add to this that there is no check on the astronomical latitudes, which are doubly important on account of the shortness of the arc; that the elevation above sea is very uncertain; that their own observations show an uncertainty of seven or eight feet in the sides of the triangles, and that the arc enters into the determination of the ellipse with great effect owing to its geographical position, and it must be conceded that the geodetic science of to-day demands the re-measurement of the Peruvian arc. It is high time that the equatorial work be put on the same footing as the other data entering into this important problem.

U. S. Coast and Geodetic Survey, Washington, D. C.

ART. II.—*Neutralization of Induction;** by JOHN TROWBRIDGE and SAMUEL SHELDON.

THE invention of the telephone drew attention to the extraordinary sensitiveness of Faraday's electrotonic state, and immediate attempts were made to construct induction balances, so called, which might serve for quantitative measurements. Thus we have Hughes's induction balance, which had its prototype in the balance described in Maxwell's "Electricity and Magnetism," vol. II, § 636, due to Felici,† and which differs from Hughes's balance merely in the employment of a galvanometer instead of a telephone. By substituting the latter instrument Hughes showed that great sensitiveness could be obtained, and even proposed to adopt an instrument for measuring minute amounts of impurities in coins arising from alloys.

The great difficulty, however, in the employment of Hughes's induction balance in quantitative work arises from the difficulty of getting a good minimum of tone in the telephone. The method that Hughes employed was, briefly, to employ four coils—two in a circuit through which an alternating current or an interrupted current was passed, and two other coils placed contiguous to the coils which were in the interrupted circuit, but in another circuit. By interposing a telephone in the last mentioned circuit, and

* From the Proceedings of the American Academy of Arts and Sciences.
† Nuovo Cimento, vol. ix, p. 345, 1859.

by properly placing the coils in this circuit with reference to those in the circuit through which the interrupted current was passed, a balance could be obtained, or an imperfect minimum of sound in the telephone, when the induction between the sets of coils was neutralized In order to obtain a standard, Hughes employed a wedge of zinc, which was thrust between one of the coils in the interrupted circuit and one of the coils in the telephone circuit, in order that the mutual induction between these coils might balance that arising between the other two similarly placed coils when a coin or sheet of metal was placed between these last mentioned coils. Other devices have also been employed by various investigators who have endeavored to use the apparatus for quantitative measurement. Alexander Graham Bell employed a modification of Hughes's induction balance for the detection of the presence of a bullet in the human body. In the form employed by him, one coil, which was a closely wound flat copper band, was made to slide over a similar one by means of a screw, one coil being placed in the telephone circuit and the other in a circuit containing a current-breaker. The induction arising from a similar pair of coils moved over a mass of metal like a bullet could thus be neutralized by this sliding coil arrangement. In no form, however, of Hughes's induction apparatus can one obtain a satisfactory minimum of tone in the telephone. There is never absolute silence, and no two observers can obtain the same point at which the sound seems to be a minimum. The failure to obtain this minimum is thus a radical defect in the instrument. It is doubtless very sensitive, but it cannot be called a quantitative instrument.

To remedy this defect, A. Overbeck and J. Bergmann* substituted an electro-dynamometer for the telephone, and worked out a method of obtaining the resistances of metals when they are in the form of thin circular plates. The standard of comparison they employed was a thin layer of mercury between disks of glass in a cylindrical reservoir. Preliminary investigations had shown the authors that a certain relation existed between the thickness and specific resistance and coefficient of induction of metals in the form of thin disks, which were placed between the coils of the induction balance. In a subsequent paper,† A. Overbeck gives the mathematical theory of the induction balance, which in the main is Maxwell's theory of current sheets applied to Arago's disk.‡ In employing the instrument to measure the effect of change of temperature on induction in copper plates, or, in other words, temperature coefficients, in which we found that Messrs. Overbeck and

* Annalen der Physik, xxxi, 1887, p. 792. † Ibid., p. 812.

‡ Maxwell's Electricity and Magnetism, vol. ii, § 668, *et seq.*

Bergmann had anticipated us,* we were led to adopt the following form of the instrument, which differed entirely from that of these authors. Four coils were employed, as in the Hughes form of instrument. One of the coils in the telephone circuit was fixed upon a horizontal axis which was at right angles to the axis of the coil. The coil could therefore be moved through all positions, from perfect parallelism to its neighboring coil in the interrupted circuit to a position at right angles to this coil. The horizontal axis was provided with an index arm which moved over a graduated circle. Calling θ the angle of inclination of the axis of the movable coil with the axis of the fixed coil in the interrupted circuit, and N the strength of the induction current in the movable coil, we have evidently, on the supposition that the strength of the alternating current remains constant,

$$N = \text{constant} \times \text{cosine } \theta.$$

When the axes of the coils are at right angles, cosine $\theta = 0$, and we should have silence in the telephone. Since adopting this arrangement we have discovered that Dr. Bowditch, of the Harvard Medical School,† has employed this arrangement of a movable coil placed in front of a fixed coil as a modification of Du Bois Reymond's apparatus for controlling induction currents so that they may be administered by known amounts for physiological purposes. In Du Bois Reymond's apparatus one induction coil was simply moved away from a fixed coil through which an interrupted current was passed, much in the same manner as the coils in Wiedemann's form of galvanometer are moved. Here no minimum could be obtained. In Dr. Bowditch's form of this apparatus, theoretically a minimum should be obtained, that is, when cosine $\theta = 0$, or when the axes of the coils were at right angles. An indication of an electrical current is obtained even when the axes of the coils are at right angles, on account of the windings of the coil not being perfectly at right angles to those of the stationary coil.

That no minimum should be obtained when the axes of the coils are at right angles, and when the induction arises from all parts of the circuit, is evident upon an elementary consideration of the subject. We have to deal in this form of instrument with the mutual induction which arises between the fixed coil and the movable one, and also with the self-induction which arises between the spires of the movable coil in the telephone circuit. The mutual induction can be reduced theoretically to zero by placing the movable coil of the telephone circuit at right angles to the fixed coil. The self-induction can

* Annalen der Physik, xxxvi, 1889, p. 783.
† Proc. Am. Acad., vol. xi, p. 281.

be estimated as follows. Taking Maxwell's discussion for the induction between parallel circuits of radii A and a, we have the coefficient of mutual induction,

$$M = \int\int \frac{\cos e\, ds\, ds'}{r}.$$

Projecting one circle upon the plane of the circle of greater radius, A, we have

$$M = \int_0^{2\pi}\int_0^{2\pi} \frac{Aa \cos(\varphi - \varphi')\, d\varphi d\varphi'}{\sqrt{A^2 + a^2 + b^2 - 2\, Aa \cos(\varphi - \varphi')}}.$$

Making b the distance between the planes of the circles $= 0$, we pass from the case of mutual induction to that of self-induction between two spires of a coil which may be considered approximately circular. The form of M adapted for calculation is then

$$M = 4\pi \sqrt{Aa} \left\{ \left(c - \frac{2}{c} \right) F + \frac{2}{c} E \right\},$$

where $c = \dfrac{2\sqrt{Aa}}{(A+a)}$, and F and E are complete elliptic integrals to modulus c.

If we make $A - a = D$, or $A = D + a$, in which D is the distance between the spires at which the self-induction becomes insensible, the most perfect minimum can be attained. We have found that copper wire of 2 mm. diameter, wound in a flat loose spiral, the spires of which from center to center of the wire are 4 mm. apart, gives no sensible self-induction for spirals of eight to ten spires. On turning a movable coil of this form so that its axis may be perpendicular to the axis of the fixed coil, a perfect minimum can be obtained. A slight movement to the right or left of this position is quickly made evident by the note of the interrupted circuit which is heard in the telephone. It is evident that, if four coils are employed, as in Hughes's form of induction balance, the two coils in the telephone circuit should be wound in the manner we have indicated, to avoid self-induction. On placing a plate of metal between one set of the coils of this balance, the movable coil no longer gives a minimum at the position where its axis is at right angles to that of the fixed coil, but at some point removed a few degrees from this. By placing a mirror upon the movable coil, and by observing its deflection with a telescope, a greater refinement of reading is possible.

This instrument in its modified form suggests the possibility of neutralizing induction upon telephone circuits. The extension of the various systems for transmitting power by electricity, especially the electric car system, has led to great disturbances in the telephone circuits. These disturbances are due both to leakage from the power circuit into the telephone circuit, since the earth is used partially by the electric power companies in their return circuits, and to actual induction. The best remedy for these disturbances is doubtless the adoption by either the power companies or the telephone companies of entire metallic circuits, in which the earth plays no part. If this is not possible, a system of neutralization for the inductive disturbances might be adopted as follows. Let a shunt circuit from the electric light wire or the wire carrying the current for motors be led into a station through which also passes the telephone wire. The resistance of this shunt or derived circuit can be made suitable for the purpose. In all cases it reduces the resistance of the main line, and is therefore not prejudicial. On this shunt can be arranged a fixed coil, and on a neighboring telephone wire a movable coil of no self-induction. Let this movable coil be placed in front of the fixed coil in the motor circuit, and let it be turned until the mutual induction between it and the fixed coil neutralizes the induction produced at all points along the telephone circuit. Each telephone wire would need its movable coil, and to every movable coil would correspond a fixed coil in the shunt of the motor circuit. The operator at the central station could adjust the movable coils until the disturbances arising from induction at various points along the line are neutralized.

Art. III.—*Divergent Evolution and the Darwinian Theory;* by Rev. John T. Gulick, Ph.D.

In a paper on *Divergent Evolution through Cumulative Segregation* (Linnean Soc. Journal. Zoology, vol xx, pp. 189–274), I have endeavored to show that selection, whether natural or artificial, is a process that has no tendency to produce divergent evolution, unless different sections of one original stock are subjected to different forms of selection, while at the same time some cause prevents free crossing between the different sections. We now inquire whether Darwin has made us acquainted with any cause or combination of causes that, without the aid of man, produces diversity of selection and at the same time the independent generation of the different classes of variations thus preserved.

Darwin discusses the causes of natural selection more fully than the causes of diversity of natural selection. He does not speak of uniformity and diversity of natural selection, but of the individuals of the same species living under the same external conditions as being modified in the same way, and of those living under dissimilar external conditions as being modified in different ways. Again, he speaks of "the divergent tendency of natural selection," resulting from "the principle of benefit being derived from divergence of character," as explaining divergence of character in the members of one species competing with each other on a common area. How the contradictions in the two statements are to be reconciled, and how, in the second case, the unifying influence of free-crossing is prevented, he does not show, so far as I can discover. As the subject is of the highest importance in the explanation of divergent evolution, and as it is specially desirable to get as clear an understanding as possible of Darwin's method of explanation, I shall consider his reasoning somewhat fully.

Some degree of Local Separation under Different Environments.

Darwin often speaks of the influence of crossing in retarding or preventing the formation of new races and species; but, from the following extracts from his Origin of Species, it will be seen that it is not quite so clear what combination of causes he considered necessary for the production of two or more species from one original species. The obscurity in his statements results, I think, from the fact that "a new species" may be one that has been formed by monotypic transformation, the old form disappearing with the production of the new, or it may be one that has arisen through polytypic transformation which is the modification of one branch of the species, while other branches remain either unmodified or modified in other ways. For the formation of a new species, in the former meaning of the word, he evidently did not consider it necessary that the species or any part of it should enter a new environment, or that crossing should be prevented. But did he not consider both these conditions necessary for the formation of two or more species from one original species?

He says "Intercrossing will affect those animals most which unite for each birth and wander much, and which do not breed at a very quick rate. Hence with animals of this nature, for instance birds, varieties will generally be confined to different countries; and this I find to be the case. With hermaphrodite organisms which cross only occasionally, and likewise with animals which unite for each birth, but which wander little and can increase at a very rapid rate, *a new and improved variety might be quickly formed on any one spot*, and might there maintain itself in a body and afterward spread, so that the crossing would be chiefly between *the individuals of the new variety living together in the same place.* . . .

"Even in the case of animals which breed slowly and unite for each birth, we must not assume that *the effects of natural selection* will always be immediately overpowered by free intercrossing; for I can bring a considerable body of facts showing that within the same area, varieties of the same animal *may long remain distinct*, from haunting different stations, from breeding at slightly different seasons, or from varieties of the same kind preferring to pair together. . . .

"Isolation, also, is an important element in the changes effected through natural selection. *In a confined or isolated area, if not very large, the organic and inorganic conditions of life will be almost uniform: so that natural selection will tend to modify all the varying individuals of the same species in the same manner.* Intercrossing with the inhabitants of the surrounding districts will, also, be prevented. Moritz Wagner has lately published an interesting essay on this subject, and has shown that the service rendered by isolation in preventing crosses between newly formed varieties is probably greater even than I have supposed. But from reasons already assigned, I can by no means agree with this naturalist that migration and isolation are necessary for the formation of new species." [Origin of Species, fifth edition,* Chapter IV, Section on "Circumstances favorable for the production of new forms through Natural Selection."]

Again in the same chapter, in the section on "Various Objections," in answer to the question, "How, on the principle of natural selection, can a variety live side by side with the parent-species?" he replies, "If both have become fitted for slightly different habits of life or conditions, they might live together, though in the case of animals which freely cross and wander much about, *varieties seem to be almost always confined to distinct localities.* But if we put on one side polymorphic species, in which the variability seems to be of a peculiar nature, and all mere temporary variations, such as size, albinism, etc., the more permanent varieties are generally found, as far as I can judge, *inhabiting distinct stations, high land or low land, dry or moist districts, or distinct regions.*"†

In the portions of these passages which I have distinguished by italics, Darwin seems clearly to maintain that for the formation of coexistent permanent varieties some degree of local separation is necessary. I therefore conclude that when he says, he cannot regard migration and isolation as necessary for

* The same passages occur in the sixth edition, pp. 80, 81.

† In the sixth edition this passage will be found, slightly modified, in Chapter VII, p. 169.

the formation of new species he intends to express, in opposition to Moritz Wagner, the opinion that a species may be transformed into a new species without leaving its original locality, but that he does not intend to say, that two or more divergent species can arise in the same locality from the same stock. If I interpret him rightly he considers the partial separation described in the first of the paragraphs just quoted as sufficient to allow of the formation of divergent species, when the external conditions of the separate districts are sufficiently different and sufficiently permanent to secure long continued divergent natural selection. That the second paragraph is to be interpreted in accord with this meaning I judge from the fact that natural selection is mentioned here as the cause of the divergence which crossing tends to overpower, and in the third paragraph, uniformity in the environment is represented as ensuring uniform natural selection. The varieties that are restrained from crossing with each other by diverse times and habits of breeding, he must regard, sometimes as slightly divergent forms tending to disappear under the pressure of uniform natural selection, and therefore never becoming separate species though one of them may prevail and be established as a new species; and sometimes as forms that are becoming more and more divergent, because they have found their way into districts or stations where they are somewhat separated from each other, and where the conditions are somewhat different, and the natural selection, therefore, somewhat diversive.

If this is not his meaning, if he intends to teach that forms arising in one place and not locally separated from each other can continue to diverge till they become separate species, how can he say on the next page that forms isolated in a small area, being exposed to uniform conditions, would be modified by natural selection in a uniform manner. He evidently does not intend to be understood as teaching that in these cases mentioned in the second paragraph there is a cause of divergent evolution which produces separate varieties and species in spite of the unifying influence of natural selection resulting from uniform conditions.

Darwin's Theory of Natural Selection through the Advantage of Divergence of Character.

There is however, one passage in the "Origin of Species" which may be interpreted as assigning a cause for divergence of character in representatives of the same species that are surrounded by the same environment. These are the words; "Only those variations which are in some way profitable will be preserved, or naturally selected. And here the importance of the principle of benefit being derived from divergence of character comes in; for this will generally lead to the most different or divergent variations being preserved and accumulated by natural selection." (Origin of Species, Chap. IV, first page of the section on the "Probable Results of the Action of Natural Selection, through Divergence of Character and Extinction in the Descendants of a Common Ancestor." In the sixth edition, this passage occurs on pp. 90–1). The connection in which this passage stands seems to indicate that "the benefit derived from the divergence of character" is considered the cause of "the most different or divergent variations being preserved and accumulated by natural selection," even in the case of the representatives of the same species that are competing with each other on the same area, and are in no way prevented from intercrossing. It is therefore necessary to show the difficulties that beset such a theory, especially if we adhere to the more general theory, that diversity in the kinds of natural selection affecting a species must be due to differences in the environments by which it is surrounded.

In the first place, natural selection, which is the superior propagation of those best adapted to the environment, prevents the interbreeding of the adapted forms that propagate with the unadapted that fail of propagating; but it can never prevent the interbreeding of those forms which through different kinds of adaptation to the environment survive and propagate, and, therefore, it can have no influence in producing accumulated divergence, unless it is supplemented by some segregative principle that prevents the different kinds of adaptations from being interfused. In the second place, as long as we follow Darwin's explanation of the causes of natural selection, we must hold that the representatives of one species while surrounded by the same environment, whether prevented from intercrossing or not, will, through the uniform action of natural selection, be modified in the same way, if at all, and, while surrounded by distinct and dissimilar environments, will be modified in divergent ways; but, in this latter case, as they will be prevented from competing with each other by occupying different areas, they can derive no advantage from divergence of character through its preventing competition, therefore the divergence that follows must be attributed to some other cause. In other words, the advantage attributed by Darwin to divergence of character is freedom from competition, through diversity of adaptation, and, as some degree of prevention of crossing is necessary for permanent difference in adaptations, the advantage cannot be secured unless there is some cause preventing the crossing of the divergent forms. Now, the prevention of crossing, if it ever arises, will be secured either while the individuals that are prevented from interbreeding are occupying the same limited area and exposed to the same environment, or while occupying distinct areas and exposed to either the same or different environments. In the first case, we are told by Darwin, that exposure to uniform conditions "will tend to modify all the varying individuals of the same species in the same manner." In the second case, as the sections of the species that are prevented from crossing occupy separate areas, the advantage of freedom from competition is already secured without divergent adaptation, and there can be no further advantage of that kind.

Again, it is not difficult to show that divergence is in itself no benefit, for multitudes of more divergent forms fail, leaving the field to less divergent ones. This is generally true of monstrosities, and frequently true of other kinds of variations. Neither can it be claimed that freedom from competition is an advantage unless it results in freer access to unappropriated resources, and this advantage is most frequently gained by migrating into a locality presenting the same environment but not previously occupied by the species. In this last case, the access to unappropriated resources does not depend on new adaptations; and, as any new adaptations that might bring advantage to the representatives of the species in one district would be of equal advantage in the other district, no divergence of character could be advantageous. It is this impossibility of advantage in divergence of character in portions of a species exposed to the same environment which leads many naturalists to maintain that isolation does not tend to produce divergence unless accompanied by exposure to different environments. But their reasoning is inconclusive inasmuch as they have never shown that divergence depends on its being advantageous. In my study of Sandwich Island molluscs I have found very strong reasons for believing that divergence may arise in the representatives of one species during exposure to the same environment, producing not only non-adaptive, but also adaptive differences. But whether adaptive or non-adaptive, whether due to natural selection or to some other principle, differences that arise under the same environment cannot be advantageous differences, and the divergence through which the differences are reached is not advantageous divergence. It seems to me evident that, neither is divergence always advantageous, nor is the advantage of access to unappropriated resources necessarily dependent on divergence; that, neither does the accumulation of divergence depend on its being advantageous, nor is advantageous divergence always accumulated.

Darwin's Theory that Exposure to Different Environments is Essential to diversity of Natural Selection.

Diversity of natural selection in different portions of the same species depends upon diversity in the relations of the different portions to the environment. Now, observation shows that cumulative diversity in the relations of the species to the environment may be introduced, (1) by dissimilar changes in the environment presented by the different areas occupied by the different portions; (2) by different portions of the species entering different environments; or (3) by dissimilar changes in the habits of the different portions of the species in using the same environment. Certainly in this third class of cases, if not in the other classes, without prevention of free crossing between the different portions, there can be no cumulative diversity in relations to the environment, and therefore no cumulative diversity in the natural selection; and without the same condition, there can be no accumulation of divergent effects of natural selection, in any case. Darwin, however, forgetting the possibility of divergent changes in the habits of isolated portions of a species exposed to the same environment, maintains that exposure to different environments is essential to diversity of natural selection and to divergence. Without change in the climate, soil, or organic forms lying outside of the species there is, according to him, nothing to produce modification.

"If a number of species after having long competed with each other in their old home were to migrate in a body into a new and afterwards isolated country, they would be little liable to modification; for neither migration nor isolation in themselves effect any thing. These principles come into play only by bringing organisms into new relations with each other, and in a lesser degree with the surrounding physical conditions."—[Origin of Species. On the 4th and 5th pages of the first chapter on Geographical Distribution.]* "Each separate island of the Galapagos Archipelago is tenanted, and the fact is a marvelous one, by many distinct species; but these species are related to each other in a very much closer manner than to the inhabitants of the American continent, or of any other quarter of the world. This is what might have been expected, for islands situated so near each other would almost necessarily receive immigrants from the same original source, and from each other. But how is it that many of the immigrants have been differently modified, though only in a small degree, in islands situated within sight of each other, having the same geological nature, the same height, climate, etc.? This long

* See ed. 6, p. 319.

appeared to me a great difficulty; but it arises in chief part from the deeply seated error of considering the physical conditions of a country as the most important; whereas it cannot be disputed that the nature of the other species with which each has to compete, is at least as important, and generally a far more important element of success. Now if we look to the species which inhabit the Galapagos Archipelago, and are likewise found in other parts of the world, we find that they differ considerably in the several islands."—[Origin of Species, near the middle of the second chapter on Geographical Distribution.]*

The implication in both these passages is that if the representatives of the same species are surrounded by the same organic forms as well as by the same physical conditions in isolated countries, they will not undergo divergent modification. This is in complete accord with the third paragraph quoted near the beginning of this paper from the 4th chapter of the "Origin of Species."

Divergent Forms of Sexual Selection.

In the passages last quoted there is no mention of any exception to the principle that difference in external conditions is necessary to divergent evolution. No suggestion is given that through the action of sexual selection divergent species may be produced that are not at all dependent on differences in the environments, still there can be no doubt that this was Darwin's view. Though he does not directly discuss this problem in any passage I have been able to discover, he clearly expresses the opinion that the differences between the different races of man, and between man and the lower animals, are in no small degree due to sexual selection, and he never speaks of difference in sexual selection as depending on difference in the environment, though, at the close of the twentieth chapter of "The Descent of Man," he speaks of sexual selection in man as having probably "exaggerated" the "characteristic qualities" "which are of no service to" the tribes and races that possess them. The differences, however, in the races of man are attributed to sexual selection, not because of any lack of difference in their environments, but because the characters in which they differ do not seem to him to be related to the environment. The color of the skin, hair, and eyes, and the different forms of the head and face do not seem to be adapted to different conditions in the environment, while they are undoubtedly occasions of attraction or aversion for those seeking partners. He has not, however,

* See ed. 6, p. 355.

shown whether the change of taste precedes the change of form and color, or the reverse. Differences between the sexes of the same species in secondary sexual characters, are for weighty reasons attributed to sexual selection; but he does not show how this divergence between the sexes leads to the production of new species. This production of difference of character between the sexes, being in no way dependent on the prevention of crossing between the divergent sexes, must be a wholly different process from the production of races and species, which is absolutely dependent on prevention of crossing between the divergent races and species. There is, nevertheless, every reason to believe that when the representatives of a species capable of sexual selection are for many generations separated into groups that never cross, diversity of tastes is one of the forms of diversity that inevitably arises; but that the psychological divergence is the cause of the other correlated divergences is not so certain. The theory of divergence in races because of divergence in the forms of sexual selection seems to rest on the assumption that a psychological divergence may be accumulated and rendered permanent in a new and definite form without being subjected to selection; but if this is true of a psychological divergence, why may it not be true of any form of divergence? The difference in the ideals of beauty in different races is as important as difference in the skin and hair; and in accounting for the origin of races, it is quite as important to account for the former as for the latter; any theory that simply attributes the difference in the color of the skin to difference in the ideal of beauty, will be met by the suspicion that the difference in the ideal was preceded by the difference in the color. My own strong conviction is that the true explanation is equally applicable to either set of phenomena.

Darwin's reference to the Causes which Check the Crossing of Varieties.

In the second paragraph quoted from Darwin at the beginning of this chapter we find mention of three causes that may for a long time prevent the members of the same species from freely intercrossing while occupying the same area; but subsequent statements, in the same and the three succeeding sections, show that he regarded geographical and local separation as the forms of separate breeding that are most favorable to the production of new species. Moreover, in the two sections relating to "Divergence of Character," he seems to maintain that the prevention of intercrossing is not a necessary condition for divergence of character in members of the same species that are competing with each other.* In chapter XVI, of his "Variation under Domestication" several causes that interfere with the free crossing of varieties are enumerated; but they are nowhere recognized as essential factors in the evolution of divergent varieties and species, without which diversity of natural selection would be of no avail, and with which divergence will take place though there is no change in the environment. They are looked upon as characteristics in which many varieties more or less resemble species; but they are regarded as the results rather than the causes of divergent evolution.

Conclusion.

We, therefore, find that though Darwin has not recognized segregation, which is the independent propagation of different variations, as a necessary condition for the production of divergent races and species, he has pointed out one process by which segregation is produced in nature. This one process is geographical or local separation under different environments. It may be the result of migration, or of geological and other changes in the environment; but, in either case, there is the preservation of different variations through diversity of natural selection due to the difference in the environments, and the independent propagation of the same variations due to their geographical or local separation. We have in this process an important cause of segregation resulting in divergent evolution; but no one can maintain that this is the only cause producing segregation and divergence, unless he ignores the fact that, in some cases, the isolated portions of a species, while exposed to the same environment, acquire divergent habits in the use of the environment, producing diversity of natural selection; and that, in other cases, without exposure to different environments, the very process producing the isolation, brings together those of one kind preventing them from crossing with those of other kinds, as when individuals of a special color prefer to pair together. In the former cases, indiscriminate separation is transformed into Segregation; and, in the latter cases, the isolation is segregative from the first; while, in both classes of cases, the divergence is without exposure to different environments.

Osaka, Japan.

*In "Nature," vol. xxxiv, page 407, Mr. Francis Darwin states that in his copy of Belt's "Naturalist in Nicaragua" the words "No, No," are penciled in his father's handwriting on the margin, opposite the sentence: "All the individuals might vary in some one direction, but they could not split up into distinct species whilst they occupied the same area and interbred without difficulty." This seems to give a decisive answer concerning Darwin's opinion on this subject.

Art. IV.—*The Devonian System of North and South Devonshire;* by H. S. Williams.

[Read at Toronto, Aug. 30, 1889, before Section E, American Association for Advancement of Science.]

Last fall I had the pleasure of examining the typical sections of Devonian rocks in Devonshire, England. I went over the southern sections at Torquay, Saltern Cove and Newton Abbot and neighborhood under the guidance of Mr. Ussher of the Geological Survey, who has recently made careful study of the localities for the survey map, and in North Devonshire I had the guidance of Mr. T. M. Hall, a local geologist at Pilton, who has an admirable collection of the fossils and is personally familiar with the ground. I went across the section from Barnstaple to Ilfracombe collecting fossils myself at the fossiliferous zones of Ilfracombe, Sloly and Pilton, Toporchard, Strand and Barnstaple. In Pilton, also, I saw the admirable collection of Mr. Hall In London I examined the collections in the Jermyn Street and South Kensington Museums, at the former place Mr. Newton kindly showing me survey material not yet reported upon, and at South Kensington Mr. Etheridge showing me his original maps and pointing out the peculiarities of the sections. I also had opportunity, through the kindness of Mr. Whidborne, of examining the collection of fossils from the limestone of Lummaton. This collection, which was reported upon by Mr. Davidson in his Monograph on the British Devonian fossils is, perhaps, the finest collection in England of the fossils of that zone. In this study of the English Devonian that which impressed me most vividly was, 1st, that the fossils are very closely allied to the species in the New York Devonian, although in the great majority of cases passing under different names, and, 2d, that the rocks in their appearance, composition and order are as different as two distinct systems well can be. Not only do they differ from those of New York, but the South Devonshire section is utterly unlike that of North Devonshire, quite as unlike as the Old Red sandstone farther north is from either.

In North Devonshire, the whole series, from the Foreland grits and Lynton slates up to the Pilton beds, is made up of siliceous slates, grits and occasional argillaceous slates, and here and there intercalated beds of impure limestone. The colors are grays and purples with light browns and yellows for the grits. Slaty structure prevails throughout and obliterates or makes difficult of detection the true bedding of the rocks. Fossils are rare except in the limestone layers of the middle part and in the slates and shales of the upper part. The rocks are regarded as having a general dip a little west of south, and the outcrops lie in belts obliquely across the county from northwest to southeast and are in order, from below upward, the Lynton, Hangman, Combe Martin, Haggington, Ilfracombe, Mortehoe, Pickwell Down, Baggy, Croyde, Pilton and Barnstaple beds. The last are conformably overlaid by shales and limestones and grits of the Carboniferous age which occupy the interval separating them from the Devonian of South Devonshire. Some faults are recognized but they are few and simple.

In South Devonshire the rocks are greatly disturbed, broken by faults, standing at various angles, folded and distorted; eruptive rocks frequently cut through them and beds of volcanic ash are interstratified with them. Hence has arisen great dispute and uncertainty as to the true order of succession of the deposits although their fossils were referred to the Devonian age nearly fifty years ago.

The most conspicuous member of the Southern Devonian is the great Devon limestone. This is seen at Torquay, at Newton Abbot and farther south at Plymouth. It is blue or white in color, and sometimes red and shaly near its base. There are also great masses of argillaceous red shales which are considered as belonging above it. The character of the succession is generally interpreted to be a series of red slates and shales and grits followed by the limestone, which is again followed by a red shale. At Torquay the shore for a mile south of the town is made up of Triassic conglomerate with pebbles of Devonian limestone, fine red argillaceous slates, not only laminated but so twisted and contorted that neither lamination nor original bedding can be followed continuously for more than a few feet. With this are associated other red slates and limestones and dikes of eruptive rock. These are all so confused that except for the fossils found in them their order of sequence could hardly be determined.

One peculiar feature of the sections as seen about Ogwell and Newton Abbott is the presence of beds regularly interstratified with the limestones and shales, composed of volcanic ash. These "Schalsteins," Mr. Ussher tells me, sometimes contain fossils, and in places they are ten or twenty feet thick.

It will be seen, without comment, that the South Devonshire sections, from which most of the middle and lower Devonian fossils have been obtained, are valueless for determining the order of sequence of the faunas. There are many places (I saw such near Newton Abbott) where limestones, appearing very similar in color and structure, and within a stone's throw of each other, hold distinct faunas. In fact the interpretation of the order of the beds is a matter of the greatest difficulty even when occasional fossils appear.

In North Devonshire the difficulty is not so great, but even there the fossils are rare, and the contorted and slaty structure of the beds, even without the occasional faults, has caused grave dispute as to the true relation of the beds. As classified by Mr. Robert Etheridge, the North Devonshire section is divided into Lower, Middle and Upper Devonian, as follows:

Lower.—The *Foreland grits* and the *Lynton* and *Woodsbay slates*, with fossils in the Lynton slates and in limestone beds intercalated in the higher part of the series.

Middle.—Shales and slates with occasional thin beds of impure limestone, from the *Hangman* and *Trentishoe grits* inclusive of all the coast rocks of the north shore as far as to Morthoe. The Lower beds of Combe Martin and Haggington in their calcareous layers holding the *Stringocephalus*, or Middle Devonian fauna, and the beds about Ilfracombe hold a somewhat higher fauna.

Upper.—From the *Pickwell Down Sandstones* all the slates, shales and grits with occasional calcareous streaks across to the south line of North Devonshire at Barnstaple Bay (called *Marwood*, *Baggy*, *Croyde*, *Pilton*, *Barnstaple*, etc., beds).

It is with this section more particularly that the classification of the New York system was compared in the first surveys. And when we notice that the fauna we now consider as Lower Devonian (i. e., that of the Corniferous limestones), is little represented there and that the Hamilton fauna is largely made up of species quite distinct from those of North or South Devonshire, it is not surprising that T. A. Conrad in the preliminary reports of the State survey drew the line between the Silurian and Devonian of the New York system at the top of the Hamilton formation. Before becoming acquainted with them I expected the original Devonshire sections and fossils to throw some light upon the problem of proper classifications of the Devonian system, but I came away convinced that for internal evidence as to the order of sequence or even the precise composition of the faunas the Devonshire sections are extremely unsatisfactory. It is probable that the fossils of the Plymouth and Newton Bushel limestone formed the basis for the notion of a Middle Devonian. These limestones furnished the fossils which were recognized by Lonsdale, in 1839, as constituting a fauna intermediate between the Silurian and Carboniferous, a determination which resulted in the establishment of a new system, the Devonian. It is, however, quite uncertain what fauna followed or what preceded this limestone in South Devonshire. The rocks about Pilton and Barnstaple, Marwood and Sloly in North Devonshire furnished the originals of the Upper Devonian fauna. The Ilfracombe fauna was identified as in general equivalent to that of the South Devonshire limestones and thus became Middle Devonian, while the Lynton fauna and the faunas of the shales of South Devonshire were assigned to the Lower Devonian because they were below the Middle limestone fauna.

There appears to be no well defined Lower Devonian fauna for England nor any uniform character of deposits to represent it. What occurs below the Middle Devonian limestone is in all cases fragmental; arenaceous slates, grits, or what the Germans call "*schists*," prevail. In North Devonshire the limestone occurs in lenticular masses in the Ilfracombe slates. In South Devonshire the limestones of Plymouth, Torquay and Newton are more or less massive. In Belgium and North France they are represented by the Givetienne limestone. In the German area it is the Eifelien Kalk and the Stringocephalus limestone. In Russia, the Urals, and in Siberia a limestone holding a similar fauna is seen. Below these limestones are slates, conglomerates, sandstones, called by various names: Lynton, Spiriferen sandstein, Gédinnien, Coblenzien, etc., in many sections not recognized at all; in the more northern and western districts called "lower old red."

In North Russia, also in Wales, reaching into Somersetshire (the county bordering North Devonshire on the east) are seen the "old red sandstones." These are more typically represented in Scotland and across the Channel in Ireland.

During the same geological interval, while the estuary, or as Professor Geikie calls them, fresh-water lake deposits of the Old Red Sandstone were being deposited in the north and as far south as the borders of Somersetshire, sands and muds with occasional layers of limestone and marine fossils were deposited in North Devonshire and, still farther, in the Southern Devonshire district, and in the northern parts of Europe a limestone was forming continuously for all the central part of the period and a rich coral and purely marine fauna occupied the region. M. Charles Barrois advances the opinion that the different Devonian limestones of Europe ought to be referred to different Devonian stages, viz: the coral reefs of Erbray to the Gedinnien, those of Brittany and Spain to the Coblenzien, those of Cabrieres to the Eifelien, and those of the Ardenne to the Givetienne and Frasnienne.—*Fauna du Calcaire d'Erbray*, p. 335, Lille, 1889.

Much of the difficulty and confusion seen in attempts to correlate the various sections comes, I am, convinced, from a commonly accepted assumption that formations must be correlated entire, whereas, as in the above example, the lenticular limestones of Ilfracombe undoubtedly represent the massive limestone formation of the south, while the shales and fragmental layers represent the condition of a more northern area, and doubtless when fossils are obtainable will be found to represent distinct (at least local) faunas.

It must be evident that the marine invertebrate faunas of the whole Devonian are but the equivalents of the vertebrate fauna and the flora of the Old Red Sandstone. This striking law is easier to accept and practically understand than the other, viz: that marine invertebrate faunas of very different species with few and possibly in many cases no common forms actually co-existed in the same ocean at the same time. With this second law in mind it is clear to see that the shifting of currents in the ocean—the oscillation upward and downward of the land in relation to the sea-level, the many changes in the relations of land and sea, of which there are unmistakable evidence—all these events must have produced mixing and changing of the faunas over any particular spot, not only constantly but to an extent we can scarcely conjecture from the very slight evidences preserved.

As the off-shore and deeper sea faunas of to-day differ from those living between tides on the coast, so we must believe they differed in the Devonian age. As the fauna off the Florida coast differs from that of Labrador now, so we must believe there were striking differences between the faunas of the warm ocean of the equatorial regions and the faunas of the colder polar regions of the same sea for a time as far back as such differences in climate existed.

When, therefore, we attempt to draw parallel lines to connect the stratigraphical series of New York or other parts of America, with those of England or the continent of Europe, the mere identity of species in their numerical relations is an unsatisfactory guide.

The species that are found identical both sides the sea are likely to be species whose vertical range is as long as a whole system, and the closely related forms may be either (*a*), one the successor of the other, or (*b*), one the modified migrant of the other. As to the relationship between two separate faunas, the one following the other, the difference in species and genera is often greater than that between either of the faunas and the one next below it in a like kind of deposit. As an example, we may cite our Genesee shale and Marcellus shale whose respective faunas more closely resemble each other than either of them does that of the Hamilton fauna between. To eliminate errors of this kind we should compare faunas of like deposits with each other, not because the terrane of the one region has in its beginning and ending any necessary relationship with the corresponding one of the other region, but because conditions of life are likely to have been more nearly uniform where the deposits are alike.

If we examine the Devonian limestone fauna of Devonshire we find its generic combinations very similar to those of the Corniferous limestone of our Appalachian basin, but the same genera are also seen in the calcareous strata of the Hamilton formation, and the specific types of the genera running through the whole system are more closely allied with those of our Hamilton, and even Chemung horizons than with those of our Lower Devonian. The great prominence of corals reminds us of the Corniferous, but when we compare the Brachiopods we find numerous forms, the representatives of which do not appear in our Appalachian sections till after the Hamilton terrane is passed. Such are *Spirifera disjuncta*, *Rhynchonella pugnus* and *acuminata*, *Spirifera curvata*, *Orthis striatula*, *Rhynchonella cuboides*, etc.

Some of these are not in the main limestone on the continent, and there are some indications of a separation of the fauna, in the sections of the Hartz and of Russia, more nearly corresponding to our division into Middle and Upper Devonian. And even in the more western sections of Europe the Frasnienne, as distinguished from the Givetienne limestone contains a decidedly later fauna than the latter. It appears probable that the limestones of South Devonshire represent the general interval between the close of our Corniferous and the early part of our Chemung formation.

Another problem is here suggested, viz: was there any migration of the faunas? For the determination of this point I have made a study of the Cuboides fauna, tracing it from New York to England, Belgium, France, Germany, Russia, Siberia, Persia and China. There seems to be good evidence that this fauna whose place is at the top of the Devonian limestone periods of these regions had a center of distribution nearer north France than either eastern America on the one hand or China on the other. If we take this as a uniform horizon, homotaxially, it may be said that a considerable number of species (including forms, under different names, which are very closely allied modifications of the same races) appeared before the "Cuboides" stage in the English, European and Russian sections, but not till after that stage in the New York sections.

In the sections of the interior of North America this particular fauna has not been recognized. *Rhynchonella castanea* Meek, of the MacKenzie River basin and Nevada, although in some respects resembling *R. cuboides* Sow., appears to be specifically extinct. The few species which occur in the "Cuboides zone" of Europe and range across the continent of America, in their generic history appear to represent a Carboniferous stage of development, and while abundant in the European sections are not common with us. The *acuminata* and *pugnus* types of *Rhynchonella* are known to us at the base of the eastern Chemung terrane, in Iowa at a doubtfully determined horizon, and in other western localities in association with Carboniferous faunas. In England and Europe they are conspicuous in association with what are called "Middle Devonian" faunas. *Spirifera disjuncta* is with them a Middle, as well as Upper, Devonian form. With us it is characteristic of the final Upper Devonian fauna alone.

A comparison of the fauna of the Upper Devonian of North Devonshire with our Devonian fossils shows that it is represented by our Chemung fauna, and although there are indications that it is a later fauna, as in its *Productus* with a row of strong spines along the center ("*Prod. curtinotus*" T. M. Hall), the ordinary forms are "*Productus* (or *Strophalosia*) *productoides*" and "*Chonetes Hardrensis*." The Carboniferous aspect of this Pilton fauna is not more marked than the Upper Devonian aspect of the fauna of the limestones of Ilfracombe and Newton.

Comparison of these European Devonian sections and their fossils with the corresponding ones of the Appalachian basin leads me to the hypothesis that the marine faunas of the Devonian had different histories in the two areas. There is a continuity in the succession from the lowest to the highest faunas of the system in Europe which we do not find in the American series. The explanation which seems to me most probable is that the Middle and Upper Devonian faunas of Europe (probably also down to the Lower Devonian fauna) were merely successive stages of the life inhabitants of a common and more or less continuous basin. That during this period the Appalachian basin was bounded on the east by a considerable barrier and was partially separated from the central continental basin by the Cincinnati uplift.

Up to the close of the Hamilton the Devonian faunas in the Appalachian and in the Central North American basin were extensions of the same general fauna, but they differed markedly from the corresponding European faunas.

With the Tully limestone an incursion of species of the European fauna began, and the following Chemung fauna shows a resemblance to the Upper Devonian of Europe, especially in those species which were present, themselves or in their ancestral representatives, in the European Middle Devonian. In the sections along the central part of the Appalachian basin where the Tully limestone appears holding the European "Cuboides" fauna. the Hamilton fauna is abruptly stopped, but on the eastern side of the basin the Hamilton appears to continue on, even mingling with the few

Chemung species which appear on that side, while on the western side of the basin a distinct fauna, the Waverly, succeeds the Hamilton with no trace of the Chemung or "Cuboides" faunas between.

This American Carboniferous (which we call "Sub-carboniferous"), marine fauna offers as strong contrast with the homotaxial fauna of Europe as do the respective Middle Devonian faunas of the two regions.

It seems to me not unreasonable to assume that the opening of some channel to the north or east allowed migrants of the Devonshire "Cuboides" and Upper Devonian faunas to enter the Appalachian basin, but that they did not advance far enough southward to appear west of the Cincinnati axis. While the general rise of temperature with the approach of the Carboniferous conditions caused the northward shifting of the rich "Sub carboniferous" faunas to occupy the Appalachian basin and, at the same time, the elevation of land to the northeast cut off communications from that direction and prevented any marine forms from thriving north of Pennsylvania during the period extending from the cessation of the Chemung fauna onward. From this stage on, all along the eastern and northern part of the Appalachian basin, there was no pure marine life, the sediments pass from fine red and gray muds to micaceous shales and sandstones and conglomerates, and finally, elevation of the continent into dry land is clearly indicated by the presence of coal deposits from Pennsylvania to Kansas.

Ithaca, N. Y., Aug., 1889.

ART. V.—*The Zinciferous Clays of Southwest Missouri and a Theory as to the growth of the Calamine of that section;* by W. H. SEAMON.

IN connection with the deposits of calamine in Southwest Missouri, there occur quite abundantly certain clays of peculiar physical properties and remarkable chemical composition. Their probable commercial value has been up to this time wholly unsuspected and they are thrown into the dump. The Geological Report of Missouri for 1873–74 states that 33·94 per cent zinc oxide was found in a single specimen of a reddish yellow clay found at the Fraizier diggings, Granby. With this exception the writer has been unable to learn of any previous examination of these clays and therefore hopes that this article, aside from interesting mineralogists, will lead practical miners and metallurgists to give them a trial as possible ores of zinc.

The miners distinguish between "tallow clays" and "joint clays," both of which occur associated and sometimes intermixed in every calamine digging in southwest Missouri, as has been verified by personal examination and the reports of mining men. The "joint clays" are always red in color and are also tougher and harsher in feel than the "tallow clays."

The "tallow clays" are found in layers of from several inches thickness up to two and three feet, or in lumps weighing from 50 to 500 lbs. above, below and intermixed with the crystallized and massive calamine. When taken from the ground they are generally flesh-colored, or light red and brown. On drying in air the light-colored varieties usually darken becoming various shades of brown, while the dark-colored varieties lighten becoming yellowish and sometimes ash gray. Thin streaks of a pure white variety unchanged in color on air-drying are also found in small amounts, which are characterized by a high content of zinc oxide as shown by analyses 1, 2, 3 and 4, appended.

The "tallow clays" have a peculiar greasy feel; are very fine grained and perfectly plastic; on air-drying they shrink and crumble into small fragments having a hardness of 1·25 to 1·5, which the miners call slacking. On moistening the air-dried specimens they regain their original plasticity and in a measure their original color. The air-dried specimens give off water in the closed tube; fuse on charcoal at about 3, always lightening up in color, becoming white or ash gray; give the zinc coatings when heated with soda; and are completely decomposed with gelatinization when gently heated with moderately concentrated hydrochloric acid. Their average composition is shown by analyses Nos. 5–20. In addition to these complete analyses, we have made determinations of zinc oxide in 20–25 other specimens in which the least amount of zinc oxide obtained was 21·93 per cent and the highest 39·31 per cent. The "joint clays" are usually found nearer the surface than the "tallow clays," though sometimes in close proximity to the massive calamine, filling up the crevices in the latter. While they are plastic they are tougher and not so fine grained as the "tallow clays." They are red in color, darken and shrink but little on drying. They contain zinc oxide in amounts varying from 1½ to 14 per cent., the complete analyses 20,21 and 22 appended are believed to represent their average composition. They resemble the "tallow clays" in their behavior before the blowpipe, but are not always completely decomposed with hydrochloric acid.

Analyses of "Tallow" and "Joint" Clays.

(Specimens thoroughly air-dried.)

No.	Locality.	Color as taken from the ground.	Color after drying in the air.	S. G.	H_2O at 100° C.	Loss at low red heat, H_2O mainly.	ZnO	SiO_2	Al_2O_3	Fe_2O_3	CaO	Na_2O+K_2O		Totals.
1.	Aurora, Mo.	White	White	2·91	4·03	3·92	54·06	35 29	1·64	none	1·80	none	....	100·74
2.	" "	"	"	2·92	4·14	4·00	54·92	35·31	1·71	"	0·12	"	....	100·20
3.	Near Peirce City, Mo.	"	"	2·95	3·63	3·52	56·12	34·82	1·52	"	0·32	undet.	....	99 92
4.	Granby, Mo.	Gray	"	2·89	4·37	4·13	50·35	36·82	1·85	0·01	1·93	traces	....	99·46
5.	Aurora Mo.	Flesh colored	Light drab	2·77	6·33	8·93	35·63	38 26	6 17	4·67	tr.	undet.	No P_2O_5	99·99
6.	" "	" "	" "	2·78	6·53	8·73	36·16	36·90	6 29	4·22	1·02	"	"	99 84
7.	Near Peirce City, Mo.	Cream	Yellowish	---	18·06		35·64	33·36	11·03	0·80	und.	"	trace P_2O_5	99 89
8.	Aurora, Mo.	Light brown	Ash gray	2·47	9·38	9 22	36·38	36·59	4·92	1·89	1·77	none	CO_2 trace NoP_2O_5	100·14
9.	" "	Yellowish brown	" "	---	10·50	8·49	42·93	33·86	2·14	0·78	1·07	"	NoCO_2	99·77
10.	" "	" "	" "	2·57	9·62	8·36	30·03	37·34	10·62	2·06	1·36	"	"	99 40
11.	" "	Brown	Chocolate	2·99	7·00	10·38	28·56	43·49	5·16	4 38	1·21	"	"	100·17
12.	Granby, Mo.		Reddish brown	---	12·50	8·02	36·98	31·94	3·05	4·46	2·31	0·810	"	100·07
13.	Near Peirce City, Mo.	Brown	Pinkish yellow	---	10·44	8·19	34 33	34·21	7·91	4·89	0·02	none	"	99·99
14.	Aurora, Mo.		Chocolate	2·41	9·50	10.02	31 72	39·45	6·44	2·08	1·48	"	"	100·69
15.	" "		Reddish brown	2·72	6·76	9·70	32·35	37·11	3·44	9·54	1·06	traces	"	99·95
16.	" "		Brown	2·69	10 49	8·93	32·72	36·11	6·26	4·21	1·61	"	P_2O_5 . 020	100·34
17.	Near Peirce City, Mo.	Reddish brown	Yellow	2·25	10.78	9·93	34 40	37·66	3·88	3·36	0·01	none	No P_2O_5	100·02
18.	Granby, Mo.	Red	Reddish brown	---	21·58		34·78	30·27	8 78	3·98	0·08	traces	traces of CO_2 & P_2O_5	99·47
19.	Near Peirce City, Mo.	"	Pinkish	---	20·15		25·96	34·94	9 92	8 53	tr.	"	P_2O_5 . 23	99·73
20.	Aurora, Mo.	Dark red	Dark brown	---	2·48	13·64	4·30	66 22	4·91	8·44	none	none	none	99·99
21.	Phelps Co., Mo.	" "	" "	---	3·49	12·72	5·17	64 97	3·81	10·11	tr.	"	"	100·27
22.	Near Peirce City, Mo.	" "	" "	2·64	9·26	10·10	12·52	61 78	2·15	5 51	none	.....	....	101·31

Tests for lead and cadmium were made but none found.

Thin sections of the tallow clays were examined with the microscope without yielding any results worthy of note, beyond that they appeared to be perfectly homogeneous, though no general chemical formulæ can be assigned them. They are no doubt mixtures of zinc silicate with clay, formed by precipitation from the reaction of zinc sulphide with hot siliceous waters.

The distribution of blende and calamine in Southwest Missouri shows some interesting points for study. At Cartersville, Webb City and Joplin, blende is the only ore of zinc mined. No "tallow clays" nor calamine is found. It is however true that at Webb City some of the miners call a grayish clay by the name "tallow clay," but it is wholly unlike the other and is improperly named. At Granby, calamine is the principal ore, while at Aurora, a new mining camp, both blende and calamine are found; blende being mined in one shaft, while not far distant there will be other shafts from which calamine is the only output. Lead sulphide is generally found associated with the calamine here. At Aurora, as well as elsewhere in southwest Missouri, "tallow" and "joint" clays are never found in connection with blende deposits.

The following partial section copied from the Missouri Geological Reports for '73 and '74, shows the general relations of the "tallow" and "joint" clays to the calamine.

3 feet red plastic clay.
4 inches calamine with tallow clay.
8 inches black sand and rotten dolomite.
18 inches calamine with much dolomite.
5 inches solid calamine.
6 inches red clay.

Many other sections might be quoted, which, while differing in details only, would show the same general relations of the clays with the calamine. The red clay in the above represents "joint clay." These clays frequently contain crystals of galena, and in the interior of several masses of "tallow clay" I have found in very small pockets crystals of calamine. From the relations in position of the clays and calamines it seems very probable that all the massive calamine once existed in Southwest Missouri as "tallow clays," precipitated from solutions. By filtration of waters the zinc silicate has been and is still gradually being removed from the "tallow clays" and crystallized as calamine. As the zinc silicate is removed from the "tallow clays" they pass to the stage called "joint clays," which differ from the former only in composition.

In conclusion, I desire to call attention to the fact that a clay similar in composition to the "tallow clays" has been reported from Spain (see Dana's Syst. of Min., p. 408), and that Professor Dunnington, of the University of Virginia, discovered a similar clay with an ore of zinc from the Bertha Zinc Mines, Virginia, of which the following analysis was published in No. 1144 of the Chemical News (1881).

SiO_2	37·38
Al_2O_3	24·67
Fe_2O_3	6·34
ZnO	12·10
MgO	·27
K_2O	·47
Na_2O	·27
H_2O at 100°	6·69
H_2O at red heat	10·35
	98·54

Missouri School of Mines, Rolla, Mo., Oct. 15, 1889.

Art. VI.—*On Minium from Leadville*; by J. Dawson Hawkins.

In 1885, Mr. A. Chanute, while in Leadville, collected some specimens of minium from the "Rock Mine." The specimens lay untouched in his collection until some weeks ago, when he gave me some of the mineral for examination.

The mineral was found between two ledges of outcropping rock, one of porphyry and the other of limestone, the ore of the mine being carbonate of lead, with occasional occurrences of galenite. The minium does not occur as a solid mass, but is interspersed with cerussite, and close examination also showed small particles of galenite occurring with the cerussite. The galenite found in the analysis, however, is not this. The sample taken for analysis was a very carefully picked one, a lump of the mineral being broken up, and the red particles of minium alone being taken. This sample was again carefully picked over in order to insure the absence of anything else than the pure mineral. The analysis gave the following results:

		Insoluble.	
Insoluble in HCl	7·51	SiO_2	2·00
Pb calculated as Pb_3O_4	91·39	$Al_2O_3Fe_2O_3$	·41
Fe_2O_3	·80	CaO	·28
V_2O_5	·52	Pb 4·42 PbS	5·08
	100·22		7·77

Physical characters.—Specific gravity (in powder), 4·55, 4·59; hardness, 2·5; fusibility, 1·; luster, dull; color, bright red; streak, orange-red; fracture, cubical.

From the cubical fracture of the minium, resembling that of galenite, and the occurrence of galenite in the red minium, it would appear that the minium here is a pseudomorph after galenite The vanadic oxide which was found in the mineral, no doubt existed as vanadinite, which has been frequently found in Leadville.

The occurrence of sulphide of lead in the pure mineral is rather remarkable and also suggestive. Externally the particles of minium showed no evidence of the presence of any other mineral; it was not until the powdered mineral had been treated with hydrochloric acid and all Pb_3O_4 dissolved, that the galenite could be observed. This seems to be conclusive evidence that the minium in this case, was a direct alteration from galenite. A like deduction is forced, as regards the plattnerite lately found in the Cœur d'Alene Mts., Idaho, where all the lead ore is sulphide.

Laboratory of the Globe Smelting and Refining Co.

ART. VII.—*Mineralogical Notes*; by WILLIAM P. BLAKE.

1. *Thenardite, Mirabilite, Glauberite, Halite and associates, of the Verde Valley, Arizona Territory.*

THE deposits of sulphate of soda of the valley of the Verde river near the military post of Camp Verde have long been known, and extensively quarried, by the rancheros of the region as a substitute for salt for cattle and horses. The occurrence of thenardite in Arizona was first made known to science by the late Prof. B. Silliman, in 1881,* but he had not visited the locality and it has not been described. A recent visit to the place, and a somewhat hurried and superficial examination, enabled me, however, to collect and identify other allied species in association with the thenardite, and a peculiar pseudomorph of carbonate of lime after glauberite.

The deposits of the thenardite and the associated minerals are of considerable magnitude, covering several acres in extent, and reach a thickness of some fifty or sixty feet or more. They appear as a series of rounded hills with sides covered with a snow-white efflorescence and a greenish-colored and yellow clay at the bottom and top, partially covering the saline beds from view.

* This Jour., xxii, 204, 1881.

These beds are doubtless remnants of a much more extended deposit which occupied a local lake-like depression, or basin, probably at the close of the great volcanic era during which most of the mountain valleys of central Arizona were filled up by sediments and then overlaid by successive streams of lava. Sedimentary beds of volcanic origin remain throughout the Verde valley and its chief tributaries, and in the region of Camp Verde are deeply eroded, but rest on the uneven floor of ancient pre-Silurian slates standing on edge. High above the deposits of the valley, vertical cliffs of hard lava mark the edges of extended mesas of *malpais*, under which all the other formations are hidden and protected. But the excavations in the banks of the sulphate of soda are insignificant in comparison with the magnitude of the beds, and have failed to show, conclusively, any bottom or top, or to reveal the true relations of the beds to the surrounding formations. Whether or not they are members of the volcanic series or of a later and more local origin is yet uncertain.

Thenardite.—This salt constitutes the bulk of the deposits. It is a coarsely crystalline mass, so compact and firm that it can be broken out only by drilling and blasting with powder. It varies in its purity. Some portions are more or less contaminated with a greenish colored clay, but it is obtained also in large masses nearly colorless and transparent, with a slight yellowish tint, but seldom showing crystalline forms.

Mirabilite.—The hydrous sulphate of soda occurs in close association with the thenardite and appears to penetrate its mass in veins, but may prove to be an overlying bed. It is this species which, by its rapid efflorescence when exposed to the air, covers the whole deposit with a white powder and a thick crust through which the quarrymen must cut before they reach the solid banks of the anhydrous sulphate.

Halite.—Rock salt in beautifully transparent masses is sparingly disseminated in portions of the great beds. These crystalline masses, so far as observed, do not exceed an inch or two in thickness and no evidence of the existence of any separate workable beds could be seen. It is irregularly disseminated in the sulphate. Some masses exhibit beautiful blue tints of color, like those seen in the salt of the Tyrol and of Stassfurt. Good fragments for optical and thermal experiments could be obtained here.

Glauberite.—This anhydrous sulphate of lime and soda is an interesting associate of the other species. It occurs chiefly near what appears to be the base of the deposits, in a compact green clay. It is in clear, transparent, colorless crystals, generally in thin rhombs, lozenge shaped, with the plane angles of 80° and 100°, and from half an inch to an inch or more broad and one-eighth to one-quarter of an inch in thickness. The prismatic planes *I*, *I*, are generally nearly obliterated, or are absent, through the great development of the hemi-octahedral planes -1, replacing the obtuse terminal edges. The terminal plane, *O*, is chiefly developed and this with the broad planes replacing the obtuse edges gives to some of the crystals the appearance of rhombohedrons of the minus series. The general habit of the crystals is similar to those from Westeregeln near Stassfurt described by Zepharovich;* with the predominating pyramid -1, occur also the pyramids $-\frac{1}{3}$, $-\frac{1}{2}$ and either $-\frac{3}{4}$ or $-\frac{4}{5}$; traces of a pyramid on the acute edges have also been noted. There is evidence that the crystals vary greatly in size and in their habit in different parts of the deposits. They occur also in the midst of portions of the solid thenardite as inclusions, and in one instance a small crystal was found in the midst of a transparent mass of halite. Close inspection of the transparent tabular crystals from the green clay reveals the presence of crystalline cavities with fluid inclusions made evident by the movement of small bubbles. When heated the decrepitation is violent.

Carbonate of lime pseudomorphs.—Where the lower bed containing the bulk of the glauberite crops out at the surface and has become oxidized and dried, the glauberite disappears and is replaced by carbonate of lime in an amorphous condition but having the exact form of the glauberite crystals, whose matrix they have filled. These pseudomorphs are firm, compact and dense, but are without cleavage or interior crystalline structure. Color, cream-yellow. They weather out in great numbers and show that the glauberite must occur in a great variety of sizes and forms of aggregation, in some places in rosettes and in others in crystals two or three inches long.

2. *Bournonite in Arizona.*

Bournonite occurs sparingly at the Boggs Mine, Big Bug District, Yavapai County, Arizona Territory, associated with pyrite, zinc blende, galenite and copper pyrites. The crystals are brilliant and characteristic, with interesting modifications not yet studied and compared. This is believed to be the first announcement of the occurrence of this species in the United States. I am indebted to Fred. E. Murray, Esq., superintendent of the mine, for specimens.

* Sitzungsber. Akad. Wien, vol. lxix, 1874.

ART. VIII.—*On the Spectrum of ζ Ursæ Majoris;** by EDWARD C. PICKERING.

IN the Third Annual Report of the Henry Draper Memorial, attention is called to the fact that the K line in the spectrum of ζ Ursæ Majoris occasionally appears double. The spectrum of this star has been photographed at the Harvard College Observatory on seventy nights and a careful study of the results has been made by Miss A. C. Maury, a niece of Dr. Draper. The K line is clearly seen to be double in the photographs taken on March 29, 1887, on May 17, 1889 and on August 27 and 28, 1889. On many other dates the line appeared hazy, as if the components were slightly separated, while at other times the line appears to be well defined and single. An examination of all the plates leads to the belief that the line is double at intervals of 52 days, beginning March 27, 1887, and that for several days before and after these dates it presents a hazy appearance. The doubling of the line was predicted for October 18, 1889, but only partially verified. The line appeared hazy or slightly widened on several plates but was not certainly doubled. The star was however low and only three prisms could be used, while the usual number was four. The predicted times at which the line should be again double are on December 9, 1889 and on January 30, 1890. The hydrogen lines of ζ Ursæ Majoris are so broad that it is difficult to decide whether they are also separated into two or not. They appear, however, to be broader when the K line is double than when it is single. The other lines in the spectrum are much fainter, and although well shown when the K line is clearly defined, are seen with difficulty when it is hazy. Several of them are certainly double when the K line is double. Measures of these plates gave a mean separation of 0·246 millionths of a millimeter for a line whose wave-length is 448·1, when the separation of the K line, whose wave-length is 393·7, was 0·199. The only satisfactory explanation of this phenomenon as yet proposed is that the brighter component of this star is itself a double star having components nearly equal in brightness and too close to have been separated as yet visually. Also that the time of revolution of the system is 104 days. When one component is approaching the earth all the lines in its spectrum will be moved toward the blue end, while all the lines in the spectrum of the other component will be moved by an equal amount in the opposite direction if their masses are equal. Each line will thus be separated into two. When the motion

* Read at the Philadelphia meeting of the Nat. Acad. of Sciences, Nov. 13, 1889.

becomes perpendicular to the line of sight the spectral lines recover their true wave-length and become single. An idea of the actual dimensions of the system may be derived from the measures given above. The relative velocity as derived from the K line will be 0·199 divided by its wave-length 393·7 and multiplied by the velocity of light 186,000, which is equal to 94 miles a second. A similar calculation for the line whose wave-length is 448·1 gives 102 miles per second. Since the plates were probably not taken at the exact time of maximum velocity these values should be somewhat increased. We may however assume this velocity to be about one hundred miles per second. If the orbit is circular and its plane passes through the sun, the distance traveled by one component of the star regarding the other as fixed would be 900 million miles, and the distance apart of the two components would be 143 million miles, or about that of Mars and the sun. The combined mass would be about forty times that of the sun to give the required period. In other words, if two stars each having a mass twenty times that of the sun revolved around each other at a distance equal to that of the sun and Mars, the observed phenomenon of the periodic doubling of the lines would occur. If the orbit was inclined to the line of sight its dimensions and the corresponding masses would be increased. An ellipticity of the orbit would be indicated by variations in the amount of the separation of the lines, which will be considered hereafter. The angular distance between the components is probably too small to be detected by direct observation. The greatest separation may be about 1·5 times the annual parallax. Some other stars indicate a similar peculiarity of spectrum, but in no case is this as yet established.

ADDENDUM, Dec. 17.—The predicted doubling of the lines of ζ Ursæ Majoris on December 8th was confirmed on that day by each of three photographs. Two more stars have been found showing a similar periodicity : β Aurigæ and b Ophiuchi (H. P. 1100 and 2909).

Harvard College Observatory, Cambridge, U. S., Nov. 12, 1889.

ART. IX—*Contributions to Mineralogy, No.* 46; by F. A. GENTH.

On a new occurrence of Corundum, in Patrick Co., Va.

IN the fall of 1888, Mr. W. B. Rucker, of Stuart, Patrick County, Va., discovered a highly interesting occurrence of corundum, and kindly communicated the following details of his find and the locality, and presented me with a box of specimens for examination, consisting of corundum with its associated rocks and minerals, andalusite, cyanite, chloritoid, mica, etc., all of which were collected on the surface of not over six acres of ground on the side of a hill, 1,800 to 1,900 feet above the level of the sea. Its continuation leads to a mountain about 3,000 feet in height and is the outlying knob of Bull Mountain, being connected with the latter by a high ridge. Bull Mountain runs parallel with the Blue Ridge and is about as high. The knob mentioned above is between 1½ to 2 miles from Stuart.

The rocks of Bull Mountain are mostly mica schists, so-called talco-mica schists, chloritic schists and slates, resembling roofing slate (not over two miles from Stuart). Some of the talco-mica schists near the corundum resemble gneiss and are highly garnetiferous and in places contain crystals of magnetite; then again, on a ridge near by, they are full of crystals of staurolite. *No serpentine or chrysolite rocks* have been observed in connection with the corundum. These rocks are intersected by several granite dikes and the corundum and its associated minerals are found on the surface, generally between the outcrops of the dikes, and probably belong to them.

Corundum.—Only a small quantity of corundum has been found; the largest piece which I have seen is 25^{mm} in diameter. All the crystals and crystalline masses appear to be *remnants* of the alteration of larger masses, into other minerals. Some of the crystals are hexagonal prisms, or, tapering at the ends, perhaps very acute pyramids with the basal plane; mostly they cluster together and form rounded masses, much intermixed with mica; on breaking they show the characteristic striation and, occasionally, are asteriated. Their color is mostly deep blue, sometimes intermixed with white, grayish and brownish white. Sometimes only microscopic grains are left, disseminated in the materials, resulting from the alteration of the corundum, viz: andalusite, cyanite, mica and chloritoid.

Andalusite.—The alteration of corundum into andalusite has never been observed before. Only a very small portion of the andalusite still exists unaltered. The andalusite crystals very closely resemble those from Lisenz in Tyrol, but only a few pieces show the common prism and basal plane. Color grayish and reddish white to flesh-red. The best crystal is nearly 40^{mm} long and 20^{mm} thick and is coated with a thin film of muscovite; other masses, the largest about 80^{mm} in length, are largely mixed with muscovite and cyanite, and, occasionally, enclose some quartz.

The analyses of the purest, carefully picked out with the aid of a good lens have been made, of the grayish white variety by me (1) and of the reddish white by Mr. James S. de Benneville (2 and 3):

	1.	2.	3.
Spec. Grav.	3·154		3·151
Loss by ignition	1·80	1·97	2·42
SiO_2	36·98	36·36	36·22
Al_2O_3	60·50	61·00	60·76
Fe_2O_3		0·72	0·88
MgO	0·10		
Corundum	1·12	trace	trace
	100·50	100·05	100·28

Cyanite and Rhœtizite.—Both the typical blue, bladed cyanite and the so-called rhætizite occur pseudomorphous after andalusite, some of the specimens indicating that the latter has occurred in stout crystals, the largest from 70 to 80^{mm} in size.

The blades of the cyanite are of a bluish white to sky-blue color and often from 10 to 25^{mm} broad, in many specimens, however, much smaller, sometimes radiating and gradually becoming masses of interwoven fibers. Associated are small quantities of quartz and muscovite which latter especially lines the cavities. Blue corundum in small grains is disseminated through the mass.

The rhætizite of a grayish brown color and a more or less fibrous structure is the more frequent form of alteration of the andalusite, and, in breaking the masses, many show in the interior the prismatic forms of the original andalusite. It is often intermixed with a large quantity of grains of blue corundum, muscovite and rarely of chloritoid.

Muscovite.—There is hardly a specimen of the andalusite, rhætizite and cyanite in which muscovite could not be observed as a direct alteration of these minerals. In the rhætizite it is frequently found in somewhat larger quantity and, together with chloritoid, often with a nucleus of blue corundum. This muscovite has a brownish white color. A partial analysis of it gave:

Loss by ignition	6·49
Na_2O	0·87
K_2O	9·23

Margarite (in part).—No crystallized variety of margarite has been found, but some of the andalusite, still retaining the original form, has been altered into a soft, fine-grained, or compact mineral, in some portions discolored by ferric hydrate, and mixed with some fine scales which are probably muscovite. After purification with dilute hydrochloric acid, it was analyzed by Mr. Jas. S. de Benneville (*a*) and me (*b*) with the following results:

	a.	b.
Loss by ignition	5·56	5.40
SiO_2	33·38	35.79
Al_2O_3	46·49	45.95
Fe_2O_3	1·43	1·03
CaO	6·02	5·49
Na_2O	2·47	2.27
K_2O	2·33	2·82
Corundum	1.70	2·07
	99·38	100·82

The analyses indicate a mixture of several micas, margarite predominating.

Chloritoid.—This mineral which has been so frequently observed with corundum, as at Mramorskoi in the Ural, at Gumugh Dagh in Asia Minor and elsewhere, is also found with the corundum of Bull Mountain. In the bladed cyanite it is found in small quantity, but in the rhætizite, associated with muscovite it surrounds a nucleus of blue corundum, from which it originated.

The foliated masses have a blackish green color, the largest is 30^{mm} in diameter. The sp. gr. I found = 3·614. My analyses gave:

	1.	2.
Loss by ignition	6·64	6·58
SiO_2	25·03	25·53
Al_2O_3	39·75	39·23
FeO	22·92	----
MnO	1·30	1·14
MgO	3·32	3·32
CaO	0·21	----
Na_2O	0.07	----
K_2O	0·07	
	99·31	

The pure mineral contains no ferric oxide.

A short distance from the locality where these minerals have been found, indications of the occurrence of the same species have been observed in several places.

This occurrence of corundum is entirely different from any previously described.

Some specimens of blue corundum in grayish brown rhætizite, discovered several years ago by Mr. J. A. D. Stephenson, of Statesville, N. C., at Hunting Creek, north of Statesville are very similar; there was also a mass, consisting of crystals of andalusite, altered into a micaceous mineral which, however, was not further investigated.

Chemical Laboratory,
111 S. 10th St., Philadelphia, November 16, 1889.

Art. X.—*Origin of Normal Faults;* by T. Mellard Reade, C.E., F.G.S., etc.

In the October number of this Journal, Professor LeConte gives an explanation of the origin of normal faults marked by his well known lucidity and graphic power.

The conception is however not a new one, as may be seen on referring to Geikie's Text book of Geology (page 315, first ed.), Beete Jukes' Manual of Geology, and a paper by I. M. Wilson and correspondence thereon in the Geological Magazine for 1868.

As I happen to have devoted a good deal of time and study to a consideration of the same subject, I may perhaps be allowed a little criticism. In the first place I would point out that Professor LeConte has left out of consideration the expansion of the strata above by the heat of the intumescent, molten mass required to produce anticlinal tension and which would completely neutralize such tension excepting at or near the surface. As an illustration, I may point to the fact that normal faulting was not produced by the intumescent masses or laccolites which gave birth to the Henry Mountains. What occurred was radial splitting, not parallel faulting and the slipping down or lifting up of several blocks. It may be urged that this is not a parallel case as the basin faults resulted from an intumescence on a much grander scale with less proportional arching or doming up. It is demonstrable that the heat of such an enormous molten mass would, by expansion, put the superincumbent strata into compression, excepting near the surface, for the lengthening of the strata by increase of temperature would far exceed the lengthening by arching. Any tension would be confined to the surface layers and the rifting would be radial.

Again there is another difficulty connected with the "flotation theory." It is not yet explained how, if the underlying molten matter is of greater specific gravity than the material of the crust, it can ever well over the surface in sheets of lava. I do not say this objection cannot be surmounted, but it leaves the theory very incomplete until an explanation has been given.

A complete or satisfactory theory of normal faulting should account for the phenomena all over the world, and not merely in the basin region. I venture to affirm that there is no evidence other than the requirements of certain theories of the earth, of such a universal, or nearly universal sheet or zone of molten matter as is assumed by Professor LeConte. It is also reasonable to ask if the crust of the earth be an extremely thin shell, floating upon a sub-crust liquid, whence comes the lateral pressure required for the formation of mountains by folding?

It has been shown by myself * and by Davison, Darwin and Fisher, that the secular cooling of the earth cannot, on the most favorable assumptions, bring the outer shell of the globe into compression below a depth variously estimated at from two to five miles, the compression being greatest at the surface and diminishing to zero within these figures of depth or to what has been termed the "level of no strain." The introduction of a molten zone between a thin upper crust and a solid nucleus will not help matters in any way.

Normal faults, as the name implies, are not confined to the Basin region; they are world wide. They frequently occur in extensive areas where there are no volcanic rocks, dikes, sheets, ash beds or other signs of "relief of tension by outpouring of lava or by escape of stream." As associated with strata of mountain ranges, they are more frequent in the surrounding plains than in the folded portions exhibiting signs of great compression.

The theory of normal faulting favored by Professor LeConte is inapplicable outside of the Basin region, and local explanations not in harmony with general phenomena are to be suspected.

In my view, normal faulting is not the result of tension through intumescent upheaval, *but of decrease of bulk of the underlying matter of the crust itself.* This decrease may result from the cooling and consolidation of injected igneous sheets, or from the cooling of portions of the solid heated matter of the crust, or from both combined. In whatever way a diminution of bulk occurs, the overlying strata will by gravity follow up the shrinkage and preserve the solidity of the crust.

This, I have attempted to show, must, through mechanical necessity, take place by shearing and wedging up of the sheared blocks. It has frequently been observed by geologists that in faulted regions the strata seem as if they had been drawn apart, and that if replaced in their original positions they would not fill the void. Contraction of the strata explains this fact, but tension by arching does not.

It would take up too much of the space of this Journal to go into further details; but any one who may desire to pursue the subject, will find the theory fully set out in Chapter VIII of the Origin of Mountain Ranges, and further discussed in my paper on slickensides and normal faults in the Proceedings of the Liverpool Geological Society 1888–9; also in a series of articles entitled Theories of Mountain Formation in "Research" for 1888.

Park Corners, Blundellsands, in Liverpool, England.

* Origin of Mountain Ranges, Chap. XI, and various papers in the Philosophical Magazine and Philosophical Transactions by the authors named.

ART. XI.—*On the Estimation of the Optical Angle by Observations in Parallel Light*;* by ALFRED C. LANE.

§ 1. WHENEVER in a rock section we are lucky enough to find a mineral showing a bisectrix squarely in convergent light, and large enough to give a definite image with Bertrand's lens, we can employ his method as given by Rosenbusch, Lévy et Lacroix, etc.† Occasionally the method developed by Michel-Lévy,‡—of noting the angle that must be turned to bring the image from that of a cross to that of two hyperbolas tangent to a given circle,—may be used here. Supplemental to these methods or in sections in which they cannot be used, nearly or quite as good values of 2V (*not* 2E or H) may be obtained without finding β, by comparing the order of colors in different sections between × nicols. These colors are dependent on the different retardations of the wave fronts in passing through the crystal, and in petrographical textbooks (Rosenbusch–Iddings, Michel-Lévy et Lacroix) are tables giving the relative retardation of one wave front, corresponding to different Newton's colors, for a unit thickness. This difference is proportional to the double refraction.

$$\text{i. e. (the order of color)} \sim o - e \sim \delta\left(\frac{1}{u_o} - \frac{1}{u_e}\right) \qquad (1)$$

Where o and e are the thickness of air that would be traversed by the wave fronts in the time that they actually take to traverse the crystal plate, u_o and u_e are the two wave fronts (or beam) velocities, and $\frac{1}{u_o}$ and $\frac{1}{u_e}$ the indices of refraction for the given section. δ is the section thickness.

But for the optical angle we have§

$$u_e^2 - u_o^2 = a^2 - c^2 \sin\theta \sin\theta' \qquad (2)$$

Where a b c are proportional to the three principal velocities and inversely to α, β and γ, least, middle and greatest indices of refraction, (by a slip of the pen in Dana's Textbook, p. 147, both a and α are called maximum,) θ and θ' are the angles to the principal optical axes from the normal to the wave fronts. Hence they involve 2V.

* From the unpublished report of the Michigan Geological Survey, published by permission of M. E. Wadsworth, State Geologist.

† See also E. Mallard, Cristallographie Physique, vol. ii, p. 416.

‡ Lévy et Lacroix, p. 94.

§ Lloyd, Wave theory of Light, §§ 231, 232, 216.

Then if we let $\frac{a+c}{u_e+u_o} \cdot \frac{u_e u_o}{a c}=1$ (see Mallard, p. 116) which will make less than 1 per cent error we have from 1 and 2,

$$o-e=\delta(\gamma-\alpha) \sin\theta \sin\theta' \qquad (3)$$

§ 2. In the rhombic system we must search for pinacoidal sections. The brightest of these is parallel to γ and α. Which of the other two is ∥ to α and β the determination of axial plane and sign will settle. Then we may derive from (3),

$$(o-e)_{\gamma\alpha}=\delta(\gamma-\alpha) \qquad (4)$$

$$(o-e)_{\alpha\beta}=\delta(\gamma-\alpha)\sin^2 V \qquad (5)$$

$$(o-e)_{\beta\gamma}=\delta(\gamma-\alpha)\cos^2 V \qquad (6)$$

$$\tan^2 V=\frac{(o-e)_{\alpha\beta}}{(o-e)_{\beta\gamma}} \qquad (7)$$

$$(o-e)_{\alpha\beta}+(o-e)_{\beta\gamma}=(o-e)_{\gamma\alpha} \qquad (8)$$

Equation (7) is the best to find V, but if the observations are adjusted to satisfy (8), which serves as a check upon our accuracy, either (5) or (6) may be used.

For example we may pick out the required sections in hypersthene by some of the following marks: 1) $\|\gamma\alpha$ one cleavage direction, ext. $+o$, brightest polarization colors, pleochroism green to red brown, prismatic form with flat dome, no axial image. 2) $\|\gamma\beta$ only one cleavage direction, ext. $+o$, lowest polarization colors of any such section, pleochroism yellowish-brown to green, direct emergence of bisectrix. 3) $\|\alpha\beta$, two cleavages nearly at right angles, diagonal ext., quadratic forms, pleochroism yellowish-brown to reddish-brown. If we meet, in a mineral of any crystallographic system, sections which prove by use of convergent light to be principal sections, we may of course use them. This often happens in mica.

§ 3. In monoclinic minerals we handle but two cases: (a) the elongation is parallel to $\beta{:}b$. Then *if a large enough number of cases be taken,*

$$\frac{\text{No. of cases in which the elongation is } +}{\text{No. of cases in which the elongation is } -}=\frac{-2V}{+2V}$$

But practically in applying this to the commonest case, epidote, we find that in many rocks the elongation is almost always—. This is because the crystals are really tabular through large sized (100). I note in passing, that contrary to Rosenbusch's experience, I find the orthopinacoid (100) the most important face of epidote, one easily recognized too, by the yellow color of c nearly perpendicular to it, and frequently by the twinning.

b). The elongation lies in the axial plane $\alpha\gamma$ (hornblende augite, etc.) In this case sections directly across or parallel to the elongation must be used.

Let two sections, both perpendicular to the plane of symmetry, and respectively parallel and perpendicular to the elongation, have indices of refraction $(\gamma'\beta)$ and $(\alpha'\beta)$ respectively. Let φ be the angle from c to the prismatic axis and let V also be measured from c. Then θ and θ' will become $(\varphi+90°-V)$, and $(\varphi+90°+V)$ or $(\varphi-V)$ and $(\varphi+V)$ respectively. Then substituting in (3) we may transform it into the following forms: $2V'$ is the value of 2V that would be obtained by treating $\alpha'\beta$ and $\gamma'\beta$ as principal sections.

$$\cos 2V = 2.\frac{\delta(\alpha'-\beta)}{\delta(\gamma-\alpha)}+\cos 2\varphi \qquad (10)$$

$$= 2.\frac{\delta(\gamma'-\beta)}{\delta(\gamma-\alpha)}-\cos 2\varphi \qquad (11)$$

$$= \frac{\delta(\gamma'-\beta)+\delta(\alpha'-\beta)}{\delta(\gamma'-\beta)-\delta(\alpha'-\beta)}\cos 2\varphi = \cos 2V' \cos 2\varphi \qquad (12)$$

$$\delta(\gamma-\alpha)\cos 2\varphi = +\delta(\gamma'-\beta)-\delta(\alpha'-\beta) \qquad (13)$$

In a slide of even thickness δ is constant and cancels out. $(\gamma-\alpha)$ and φ will be determined in the same slide. Eq. (13) being an equation of condition controls the observations.

The character of $(\gamma'-\beta)$ and $(\alpha'-\beta)$ whether + or − must be determined by mica plate or otherwise. Eq. (12) is the best one to use. It is easy to make a diagram for its graphical solution. See figure. Throwing (12) into the $\left(\frac{\gamma'-\beta}{\alpha'-\beta}-1\right)\left(\frac{\cos 2V}{\cos 2\varphi}-1\right)=2$, we see that we may consider $\frac{\gamma'-\beta}{\alpha'-\beta}$ the ordinate y. $\frac{\cos 2V}{\cos 2\varphi}$ the abscissa x of a rectangular hyperbola whose asymptotes are $x=+1$ and $y=+1$ and intercepts on ox and oy are $(\bar{1},o)$ and $(o,\bar{1})$. This hyperbola once constructed we can find $\frac{\cos 2V}{\cos 2\varphi}$ for any value of $\gamma'-\beta$ and $\alpha'-\beta$ at once. Then will any point on the line through (o,o) and $\left(\frac{\cos 2V}{\cos 2\varphi}-1\right)$ have its abscissa proportional to 2V if its ordinates is proportional to $-\cos 2\varphi$. Hence by drawing a set of lines diverging from O and by marking the values of φ against the corresponding lengths of $-\cos 2\varphi$ on ON and the values of v against the lengths of cos 2V on the same scale (i. e. to the same radius) on NP we can read off V for a given φ. (See example below). We need only to construct the hyperbola for one quadrant if we remember that x for y is equal to $-x$ for $\frac{1}{y}$, but we must be careful about the signs.

§ 4. Formula (12) etc. may be applied to the hornblendes by seeking out three kinds of sections: 1) Prismatic, with only one cleavage direction, with maximum extinction of the prism zone, *with highest polarization* colors, and often with characteristic pleochroism. (These give $\delta(\gamma-\alpha)$). 2) Prismatic, with one cleavage direction, extinction *o* with lowest colors of the prism zone, and characteristic pleochroism (gives $\delta(\gamma'-\beta)$. 3) Across the prism, with two *equally developed* cleavages at an angle of about 56°, + extinction bisecting the acute angle, and characteristic pleochroism. These give $\delta(\alpha'-\beta)$. When twinning exists it also helps in selection.

In estimating the order of an interference color between × nicols, if the natural color interferes, it often is better to raise and lower the color a wave length or so and take the mean of the orders thus obtained. This may be done with a mica or gypsum plate, for it is hardly worth while to use the compensator.

To illustrate the application of equation 12. In 11670,* a hornblende schist, we have a hornblende with pleochroism, *c* sea-green, *b* brownish-green, *a* yellow and sections whose colors indicate the following double refractions:

$\delta(\alpha'-\beta$,	$\gamma'-\beta$,	$\gamma-\alpha)$	$c:c$		Remarks.
−300	+125	+400	16—		Twin, $\delta(\gamma-\alpha)$ for epidote runs up to 1400
300	175		13		" " orthoclase " 275
350	150		13		
300	175	350	16		Twin, " " apatite " 125
260					
		420	19	tr	Twin, varying shades, the lighter color the greater $\gamma-\alpha$
		to 520	15		
		420	15		Twin, " "
		680	19		
———	———	———	———		applying eq. 13.
−303	155				
mean	−303	+420+ maximum	170		420(cos 34°=0·829)=348 < 458
	———				By eq. 12
	458				$\cos 2V = -\frac{155}{458} \cdot 829 = -0{\cdot}28 = \cos 106°$
					$\therefore -2V = 74°$

Of course the required sections are never exactly found; we use the nearest approach to them we have. In the example above the unsymmetrical extinction shows that there is an error in $\gamma-\alpha$. Now while any error in the $\alpha'\beta$ and $\gamma'\beta$ sections is about as likely to give us higher colors as lower, so that the mean of different observations should be taken (if δ is constant), errors in determining $\gamma-\alpha$ will make it too small. Thus the largest value should be chosen and even then it will be too small. Eq. 13 will show the discrepancy, which serves to measure our error. As we have the equation of condition (13), a connection between $\gamma-\alpha$ and 2φ, different degrees of liability to error in finding the given

* The numbers refer to sections of rocks belonging to the collection of the Michigan Geological Survey.

sections, and a varying angle to measure, it would be hard to say what weight would attach to the probable error as generally computed. I have, however, picked out a number of slides containing the common hornblende of the amphibolites for which 2V has been determined. In five slides I have noted the number of sections used in determining 2V and weighted the results accordingly. Twelve other slides have been combined without weighting. Each set gives $-2V=79°$ with probable error in one case of $0°{\cdot}11$, in the other of $1°{\cdot}08'$. The possible error is certainly much larger.

Deducing $\gamma-\alpha$ by comparison, and from that and 2V, $\gamma-\beta$ and $\beta-\alpha$ (this may also be done graphically by the figure), we find by these methods in the epidiorites and hornblende schists a series often intergrown, thus:

	$\parallel c$	$\parallel b$	$\parallel a$	$\gamma-\alpha$	$\alpha-\beta$	$\gamma-\beta$	$-2V$
1. Actinolite	slightly bluish	colorless	colorless	0·026 decreases always	0·013 increases sometimes	0·013 decreases always	88°
to	to dull	to	to	to		to	to
2. Common hornblende and on toward glaucophane	bluish-green to !	olive green to :	yellow :	0.019	0·012	0·007 and keeps on?	79° and lower

The relations of increase and decrease may be seen very clearly in cases of intergrowth. The series is not a linear one, but we leave the full discussion* for the report of the Michigan Geological Survey.

EXPLANATION OF THE FIGURE.

This figure is to illustrate the graphical determination of 2V from the double refractions—or vice versa—as above referred to. It is founded on the formulæ

$$\left(\frac{\cos 2V}{\cos 2\phi}-1\right)\left(\frac{\alpha'-\beta}{\gamma'-\beta}-1\right)=2=(x-1)(y-1)$$

$$\cos 2V-2\left(\frac{\alpha'-\beta}{\gamma-\alpha}\right)=1-\overline{1-\cos 2\phi}=x-2y$$

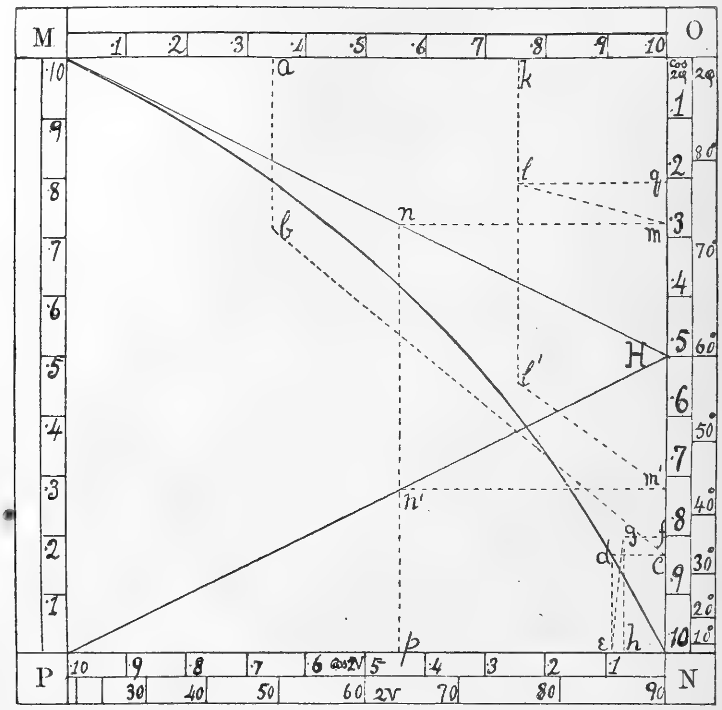
$$-\cos 2V-2\left(-\frac{\gamma'-\beta}{\gamma-\alpha}\right)=1-1-\cos 2\phi=x-2y$$

where $2V=$optical angle about $c=\frac{1}{\gamma}$, α' and γ' are at right angles to each other and to β, and $\phi=\llcorner^{\gamma'}{}_{\gamma}$.

* The change seems mainly due to imbibition of $Na_2Al_2Si_4O_8$, but this requires chemical proof. If this is so, however, in view of this rapid falling off in γ, continued in glaucophane, which contains about 65 per cent $Na_2Al_2Si_4O_8$, and of the—extinction of the undetermined glaucophane mineral, described by Rosenbusch (Mikr. Phys. ii, 319), it seems likely that the pure $Na_2Al_2Si_4O_8$ amphibole has $c=\alpha$. [Between writing this and reading proof, the description of it as Riebeckite, essentially $Na_2Al_2Si_4O_8$, has been given.] We have analogous relations in acmite and ægirine.

It may be shown that by exchanging $\alpha'-\beta$ and $-(\gamma'-\beta)$ we shall only exchange cos 2V and −cos 2V. So that we need consider but the following cases:

1. In the rhombic system $\phi=o$ to find 2V, (a) given $\delta(\alpha-\beta)$ and $\delta(\gamma-\beta)$ with $\gamma-\beta>\beta-\alpha$. Lay off along MO proportional to $\delta(\gamma-\beta)$ the abscissa M*a*, and the ordinate *ab* in the same proportion to $\delta(\alpha-\beta)$. From the point *b* proceed in the direction *mb* till you strike ON at *c*. From *c* proceed ∥ to NP, meeting the hyperbole at *d*, then turn at right angles and go ∥ON till we meet NP at *e*. Then *e*N = + cos 2V and 2V corresponding may be read from the outer scale. If $\gamma-\beta<\beta-\alpha$ we must interchange and 2V will be −.



(b) Given $\delta(\gamma-\alpha)$ and $\delta(\alpha-\beta)$ to find 2V. Lay off from M an abscissa M*k* proportional to $\delta(\gamma-\alpha)$ and as an ordinate *kl* in the same proportion to $\delta(\alpha-\beta)$. From *l* proceed in the direction M*l* till you strike ON, at *m*. Thence go ∥ to OM till we strike the zigzag MHP, at *n*. Turning at right angles go ∥ to ON till we strike NP, at *p*. *p*N (positive) is + cos 2V if *n* is on MH, − cos 2V if *n* is on HP. Interchange for $\delta(\gamma-\alpha)$ and $\delta(\gamma-\beta)$.

2. In the monoclinic system, ϕ being given, and $\delta(\alpha'-\beta)$ (a) and also $\delta(\gamma'-\beta)$ greater than it. Proceed as in 1[a] till we get *e*. Thence go toward O till we meet a line ∥ to OM, and at a distance *f*O = cos 2ϕ from it, at *g*. From *g* drop upon NP again, at *h*. *hn* is + cos 2V if cos 2ϕ is +, otherwise −. Interchange as usual.

(b) And also $\delta(\gamma-\alpha)$. Find *pn* as in 1[b] and subtract 1 − cos 2ϕ, which may be read off from ON from it.

3. Given 2V and one of the three $(\gamma-\alpha)$ $(\gamma-\beta)$ $(\gamma-\alpha)$; to find the other two work backward; e. g. (a) given $\gamma-\alpha$. If *p*N = cos 2V erect a perpendicular cutting PHM at *n'* and *n*. Draw lines through *n* and *n'* ∥ to MO, cutting ON at *m* and *m'*. Draw *m*M and *m'*M. Lay off M*k* = $\gamma-\alpha$ and construct an ordinate, cutting *m*M and *m'*M at *l* and *l'*. Then *kl* and *kl'* are $\alpha-\beta$ and $-(\gamma-\beta)$ [if cos 2V is +].

(b) $(\alpha-\beta)$ given. Proceed as before 3[a] till we get *m* and *m'*. Then lay off on ON O*q* = $\alpha-\beta$. Erect a perpendicular *ql* to ON, cutting *m*M at *l*. Then draw the line *kll'* at right angles to *gl*, M*k* is $\gamma-\alpha$ and *l'k* = $\gamma-\beta$. Of course these various coördinate lines should be drawn once for all in complete sets.

Michigan Mining School, Houghton, Mich., Sept. 14, 1889.

ART. XII.—*A new Stone Meteorite;* by L. G. EAKINS.

THE meteorite which forms the subject of this paper was brought to notice by Prof. R. T. Hill, of the University of Texas, who presented the piece first obtained by him to the National Museum. This piece, of an irregular shape, and weighing about two and a half kilograms, is supposed to be but a fragment of a much larger mass, which Prof. Hill expects to obtain.

It has a superficial coating of a yellowish brown color where it has been subject to weathering, but on a fractured, unaltered surface it is dull black with a slight grayish tinge. It is hard, compact, and very tough; to the unaided eye the stony mass is very uniform in structure, and none of the composing silicates can be distinguished, but troilite can be plainly seen scattered throughout it, and on a ground and polished surface the metallic particles are also visible. Under the microscope, (for which information I am indebted to Mr. Whitman Cross,) the stony portion seems to consist chiefly of olivine and enstatite, with a small quantity of a colorless mineral which is probably a feldspar; as will be seen later, the analytical results also indicate the presence of a feldspar, while chromite also was found unmistakably.

The mass has a specific gravity of 3·543 at 30°, and its analysis as a whole is as follows:

SiO_2	44·75
Al_2O_3	2·72
Cr_2O_3	·52
Cu	tr.
FeO	16·04
Fe	1·83
NiO	·52
Ni	·22
Co	·01
MnO	tr.
CaO	2·23
MgO	27·93
K_2O	·13
Na_2O	1·13
P_2O_5	·41
S	1·83
H_2O	·84
	101·11
Less O for S	·92
	100·19

From some of the finely powdered material the metallic portion was extracted by the aid of an electromagnet, and as slight amounts of troilite and the silicates remained attached, this was then treated with a neutral solution of copper sulphate and the solution analyzed. This gave the metallic part as constituting 2·23 per cent of the mass, with the following composition, calculated to 100 per cent:

Fe	88·74
Ni	10·68
Co	·58
	100·00

The residue from which the metallic portion had been removed was then digested with dilute hydrochloric acid; this dissolved the troilite and olivine, and the soluble and insoluble portions were then separated and analyzed in the usual manner. The sulphur present was calculated as troilite, with the formula FeS, and has been deducted in stating the analysis of the soluble portion:

	Soluble in HCl. (Troilite deducted.)			Insoluble in HCl.		
	Analysis.	Calculated to 100%.	Molecular ratios.	Analysis.	Calculated to 100%.	Molecular ratios.
SiO_2	15·67	38·13	·636	30·36	56·14	·936
Al_2O_3	1·06	2·58	·025	2·02	3·73	·036
Cr_2O_3				·54	1·00	·007
FeO	8·12	19·76	·274	4·95	9·15	·127
NiO	·49	1·19	·016			
CaO	·42	1·02	·018	1·94	3·59	·064
MgO	15·34	37·32	·933	13·22	24·44	·611
K_2O	undet.			·10	·19	·002
Na_2O	undet.			·95	1·76	·028
	41·10	100·00		54·08	100·00	

In the soluble portion the ratio of the RO group to the SiO_2 is as close to that of olivine as could be expected in work of this kind. The insoluble portion, after removing the Cr_2O_3 and a proportional amount of FeO to form chromite, gives these ratios:

$$RO : Al_2O_3 : SiO_2$$
$$\cdot825 : \cdot036 : \cdot936,$$

which seem to bear no definite relations to each other. It is noticeable, however, that the Al_2O_3 and alkalies present are nearly in the proportion required for a feldspar, and if one of the oligoclase type were present in proportion to this Al_2O_3, it would have these molecular values:

$$\begin{array}{ccccc} RO & : & Al_2O_3 & : & 4\tfrac{1}{2}\,SiO_2 \\ \cdot036 & : & \cdot036 & : & \cdot162; \end{array}$$

assuming this to be the case, and deducting this amount of feldspar it would leave

$$\begin{array}{ccc} RO & : & SiO_2 \\ \cdot789 & : & \cdot774, \end{array}$$

which corresponds closely to enstatite.

By calculating the soluble and insoluble parts as having been determined on the original material minus the metallic portion and water, and taking all the sulphur as representing troilite (FeS), the general composition of the meteorite is shown to be

Metallic	2·23
Troilite	5·03
Soluble in acids	39·84
Insoluble in acids	52·42
	99·52

Laboratory U. S. Geological Survey, Washington, D. C., October, 1889.

ART. XIII.—*On the Barium Sulphate from Perkins' Mill, Templeton, Province of Quebec;* by EDWARD S. DANA.

SOME six months since M. A. Lacroix* described, under the name of *Michel-levyte*, a mineral having the same composition as barite, $BaSO_4$, but as he believed crystallizing in the monoclinic system. The discovery of the dimorphism of barium sulphate is a point of so great mineralogical and chemical interest that it seems necessary to scrutinize closely the grounds upon which the conclusion rests.

The mineral from Perkins' Mill is described as occurring in masses showing three cleavages, two of them inclined to one another at angles of 78° and 102°, and a third at right angles to these—the geometrical form then, so far as known, is that of normal barite. The cleavages, however, differ in kind: one of those first named was found to be highly perfect, the surfaces having a marked pearly luster; this is taken by Lacroix as the orthopinacoid, h^1 (100). The cleavage corresponding in position to the other prismatic face of barite was difficult; this is taken as the base, *p* (001). The remaining cleavage, corresponding to the base of barite, was intermediate between the other two in character and gave surfaces having a vitreous lus-

* Comptes Rendus, cviii, 1126.

ter; this is made the clinopinacoid, g^1 (010). The measured angles were $ph^1 = 102°$ to $103°$, $pg^1 = h^1g^1 = 90°$. Further a polysynthetic twinning is described, resembling the triclinic feldspars, the face h^1 being the twinning plane and composition face; "macles par interpénétration" are also mentioned, but not minutely described.

Optically, one axis of elasticity is normal to g^1, this is taken as probably the bisectrix, while the axial plane makes angles of 134° and 124° with h^1 and p respectively in their obtuse angle; in other words the axes of elasticity in g^1 make angles of 5° with the diagonals of the section formed by h^1 and p. The refractive indices are given, but their values are very nearly identical with those accepted for barite. The specific gravity (4·39) and composition are those of barite.

In conclusion, therefore, we find that the monoclinic nature of the Perkins' Mill barium sulphate rests upon the following grounds: the difference in character between the two cleavages, h^1 and p; the presence of enclosed twinning lamellæ seen in sections parallel to g^1; and the deviation of the axes of elasticity of about 5° from the diagonals of the rhombic section formed by the two cleavages h^1 and p.

Through the kindness of Mr. G. Christian Hoffmann, of the Canadian Geological Survey, to whom we are indebted for many important contributions to our knowledge of Canadian minerals, the writer has received a considerable supply of specimens (upwards of fifty) of the barium sulphate from Perkins' Mill. The spot from which these were obtained corresponds in position with that described by Lacroix, and the individual, who furnished Mr. Hoffmann with the specimens, remembered having given others from the same place to a French gentleman (whose name he did not recall) in the summer of 1888.

Upon the first examination of the specimens the observer is struck with the beautiful pearly luster of one of the cleavage surfaces, corresponding to the face called h^1 (100) by Lacroix. The mineral occurs in cleavable forms only, and varies all the way from those which show cleavage surfaces of several square inches to those which are coarsely granular only. Portions of the enclosing granular crystalline limestone are often seen.

Attention was directed first to the most important variation from the requirements of the orthorhombic system reported, viz: the position of the axes of elasticity in the cleavage section, which is normal to the two oblique cleavages (prism of barite), and parallel to the face g^1 of Lacroix (base of barite). A large number of carefully selected cleavage fragments were taken, upwards of thirty from a dozen or more different specimens. These failed, however, to confirm the measurements of Lacroix.

On the contrary, the extinction-direction was found to bisect the obtuse and acute angles as exactly as it could be determined; the individual measurements rarely varied more than from 30′ to 1° from this position. So far as the specimens under examination go, then, there is no variation in the position of the axes of elasticity from that required by normal barite. The relative values of the axes of elasticity were also found to conform to those of barite, and in a section cut normal to the line bisecting the interior obtuse angle (102°) of the cleavages h^1 and p the optic axes were visible, the axial plane being parallel to the shorter diagonal of the rhombic section. Optically, therefore, the specimens examined conform to normal barite.

In the nature of the cleavages the supposed monoclinic character seems to gain more support. The pearly luster of one cleavage surface (h^1 of Lacroix), parallel to which the specimens readily separate into thin plates or scales, is, as has been remarked, a striking feature of the mineral. Parallel to the cleavage which is obliquely inclined to this pearly face (p of Lacroix), the fracture takes place usually with difficulty, and the surface exposed then shows a multitude of fine lines, which are the edges of the plates parallel to h The remaining cleavage is usually, as noted by Lacroix, less difficult than that of p and the surface is generally vitreous in luster.

An examination of a large number of specimens, however, shows that these characters are not constant. Occasionally a mass is found in which there is no surface of pearly luster at all, and in which the character of the cleavage faces could not be distinguished from ordinary barite—such specimens are rare. On the other hand, we find specimens in which the pearly luster and the tendency to separate into thin plates belongs to *both* surfaces of oblique cleavage (prismatic faces of barite) so that it is impossible to distinguish between them. The pearly luster is also sometimes present over a portion of one of the surfaces and absent over the remainder; again, in some specimens this character belongs also to the third cleavage direction (g^1). Moreover, a close examination of the pearly surface shows an iridescence between the plates due obviously to their slight separation, while scales of a foreign substance can often be detected between them.

In short, the writer regards it as clear that the apparent easy cleavage (laminated structure) and the accompanying pearly luster of one of the prismatic faces are secondary in origin and have been called out by pressure—a force the action of which can easily be understood in the case of masses enclosed as these are in crystalline limestone.

Several thin sections have been examined, cut parallel to each of the three cleavages. The sections parallel to what would be the base of barite (g^1) show a nearly uniform development of the cleavage cracks parallel to the two oblique directions. Between these lines, and in *both* directions, (h^1 and p, Lacroix), though somewhat more marked in one of these, are a series of inclusions of the same mineral, having nearly uniform extinction and so orientated that one of the prismatic cleavages is very nearly parallel to the line bisecting the obtuse angle of the cleavage faces of the specimen as a whole. These parallel lines of inclusions vary much in width and on the whole are irregular in outline, though showing a tendency to take a crystalline form. They stand out sharply when the section is examined in polarized light and suggest at once something of the nature of polysynthetic twinning. A careful measurement gave the angle between the similar cleavages in adjacent portions as 56°, and, if the two are actually in twinning position, the twinning plane (referred to the barite form) might then be the macroprism 210, which would require 54° 21′, or the brachyprism 130, requiring 54° 29′. It is to be noted, however, that the extinction-directions vary a few degrees among themselves, and further, besides these inclusions with nearly regular orientation, there are many others which are totally irregular in position. Moreover, a macroscopic examination of such a cleavage surface shows long parallel lines of inclusions with cleavages in nearly the same position and yet changing a few degrees from one to the next, not only in the direction of the prismatic zone (ph^1) but also at right angles to it. This last fact sufficiently explains why in the included portions the extinction-directions vary as much as the 5° of Lacroix from the diagonals of the rhombic section of 78° and 102°.

It seems, therefore, more probable that there is no definite twinning involved in any of these cases. It should be added that these sections show what look at first like very narrow twinning lines following the cleavages, but examination shows them to be, for the most part, only the open cracks between the plates of the mineral. The section parallel to the other faces show also lines of inclusions chiefly in the direction of the prismatic edge (h^1/p), but while some of these keep the same optical orientation, most of them are irregular and many are made up of a multitude of minute grains.

Another feature of this barium sulphate is the presence upon a prismatic face, especially when it shows the pearly luster, of fine striations closely crowded together and parallel to the basal edge. This seems to be due to the development, probably by pressure, of a steep pyramidal face inclined from 5° to 8° to the prism. Furthermore, another set of similar lines upon the same face, are often seen inclined about 45° to the basal edge as if caused by the partial development of a macrodome; this set is also at times crossed by another at right angles to it, that is, inclined about 45° to the basal edge in the opposite direction. These points merit a closer study than it has been possible to give them thus far. They remind one of the twinning lamellæ parallel to the macrodome 601 described by Bauer,* but they do not seem here to be connected with any variation of optical orientation.

In conclusion, the writer regards it as proved beyond doubt for the specimens which he has had in hand from Perkins' Mill, that they are normal barite; and that the existence of a monoclinic form of barium sulphate among specimens from that locality is extremely doubtful.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Decomposition of Carbon disulphide by Shock.*—On attempting to reduce liquid carbon disulphide by means of a liquid alloy of potassium and sodium, THORPE obtained a yellowish-brown powder encrusting the alloy, which exploded violently when the bottle was shaken; this powder being found subsequently to detonate with more violence than diamine di-iodide. The hand of the operator was coated with a black deposit, consisting apparently of finely divided carbon. Reflection convinced the author that this deposit was far larger than could have come from the decomposition of the brown powder itself, and as carbon disulphide is an endothermic compound, absorbing in its formation according to Thomsen 19610 calories, it appeared not at all improbable that, like acetylene, cyanogen, nitric and nitrous oxides, the oxides of chlorine, etc., it might experience decomposition by a sudden shock; and that in the above case, the carbon disulphide had been resolved into its elements by the violent explosion of the yellowish brown powder. Actual trial showed that mercuric fulminate would produce the same effect; and Thorpe suggests the experiment as an easy and safe method of showing in the classroom the decomposition of an endothermic compound by shock. For this purpose a thick glass tube about 600^{mm} long and 15^{mm} wide is fitted at one end with a rubber stopper carrying two stout wires, on the lower end of one of which is a small cup, like a deflagrating spoon, while the other wire is bent so as to come within 2 or 3^{mm} of the bottom of the cup. In this cup is placed about 0·05 gram of mercuric fulminate. A piece of paper slightly longer than the tube is moistened with carbon disulphide and placed within the tube and the cork is put in. After a minute or so, the tube being inclined at 45°, the vapor of the disulphide will practically fill it and the paper may

* Jahrb. Min., i, 37, 1887.

be withdrawn. On passing now the spark from an induction coil through the fulminate by means of the wires through the stopper, it at once explodes and the walls of the tube are seen to be lined with a deposit of soot mixed with a small quantity of mercuric sulphide and sulphur. If the tube be filled with nitrogen or carbon dioxide the deposited carbon is dense, lustrous and coherent. Other explosives were ineffectual.—*J. Chem. Soc.*, lv, 220–223, May, 1889. G. F. B.

2. *Light and Electricity.*—Professor RIGHI (Riv. Sci. Ind., July–August) shows that ultra violet radiations reduce to the same potential two conductors, a plate and a piece of grating, applied to each other, the rays being thrown on the grating side. He suggests a convenient way of measuring differences of potential of contact. One notes the deflection of an electrometer connected with the plate (the grating being permanently connected with earth); then, having connected the electrometer for an instant with earth, makes the radiations act a sufficient time. He used a zinc electric lamp, and the metals examined were placed in some cases in a bell jar, to which some gas or vapor was admitted. From measurement of different plates with the same metallic net (copper, zinc, or platinum), the differences of potential of pairs of metals could be deduced. Prof. Righi found the differences sensibly the same in dry and moist air and in carbonic anhydride: but with hydrogen, very different values (from those in air) appeared, where one of the metals examined was platinum, palladium, nickel, or iron (doubtless due to absorption). In ammonia all the metals, examined with zinc net, seemed to have become less oxidizable; and in coal gas, carbon and platinum behaved like more oxidizable metals.—*Nature*, Nov. 7, 1889, p. 18. J. T.

3. *Galvanic Polarization.*—E. WARBURG has made a careful and long continued study of this subject and concludes that previous observers have not sufficiently taken into account oxidization of the metallic electrode in electrolytes containing oxygen. The metallic electrodes are surrounded thereby with a weak solution of salt of their own metals, and the electromotive force changes with the concentration of this solution.—*Ann. der Physik und Chemie*, No. 11, 1889, pp. 321–344. J. T.

4. *A Simple modification of the method of Telescope and Scale reading.*—The well known method consists in reading the reflection of a scale placed at a certain distance from a movable mirror, in this mirror, by means of a telescope. Since the telescope must be focussed on a reflection which is as far behind the mirror as the scale is in front, the range of adjustment is limited. H. E. J. G. DUBOIS has modified this method by placing a second fixed mirror in front and inclined to the movable mirror. With a telescope one can then read a division of the scale put at twice the usual distance from the movable mirror. With a telescope magnifying 18 times and with an objective of $3{\cdot}5^{cm}$ one can read to two seconds angular measure.—*Ann. der Physik und Chemie*, No. 11, 1889, p. 494. J. T.

II. Geology and Mineralogy.

1. *North American Geology and Palæontology*, for the use of Amateurs, Students and Scientists; by S. A. Miller. 664 pp. large 8vo. Cincinnati, Ohio.—All geologists and paleontologists who have had occasion to use Mr. Miller's invaluable "American Palæozoic fossils" and who thereby know of the thoroughness and accuracy of his work, will give this new volume a hearty welcome. All but the first 100 pages constitute really a new and enlarged edition of the above mentioned work, increased much in value by the introduction of numerous figures, there being scarcely a page without one or more. All Paleozoic species are included in the tables with their latest names and synonymy, and references also to places of publication.

The first part of the work is a brief review of the geological formations commencing with the oldest, giving descriptions of the rocks, their distribution, their characteristic fossils, and other features.

The author, in this part, uses the term *Taconic* of Emmons, dating, as he states, from 1842, in place of *Cambrian* for beds below the rocks of the New York series or the Postdam sandstone, and says that the word Cambrian was first proposed in England "some years after that of Silurian," 1835 being the date of the latter. He overlooks the fact that Sedgwick proposed the term Cambrian also in 1835. "Silurian" was proposed by Murchison in the Philosophical Magazine for July of that year. Then at the meeting of the British Association the next month, August, a communication on the "Silurian and Cambrian" was presented by "Professor Sedgwick and R. I. Murchison," in which each explained his own system of rocks. Sedgwick's first systematic account of the Cambrian system was published in 1838, in the Proceedings of the Geological Society of London, the same year in which, though later, Murchison's completed monograph, "The Silurian System" appeared. This was four years before Emmons's report of 1842.

Mr. Miller's work will be found of great value to geological and paleontological students and the necessary companion of all investigators of the Paleozoic rocks. J. D. D.

2. *The Geological and Natural History Survey of Minnesota for the year* 1888, the 17th Annual Report; by N. H. Winchell, State Geologist. 273 pp. 8vo, St. Paul, Minn.—This volume contains a report by Prof. Winchell on the lower rocks of Minnesota; a second, by Mr. H. V. Winchell on the work of 1888 in the Iron Regions of the State; and a third, by Mr. U. S. Grant, on work in 1888 in northeastern Minnesota.

Prof. Winchell goes over the questions relating to the Archæan and Cambrian ("Taconic") rocks, and presents his views at length with reference to their characters and arrangement. The Archæan of the state is divided into (1) the Laurentian, gneiss, (2) the Vermilion schists, and (3) the Kewatin schists, the latter two adjoining the gneiss but unconformable to it. Above these there follow: with over-lap unconformity, (1) the "*Taconic*" beds stated to be of the Olenellus horizon, and including the Animike and Huronian; (2), with over-lap unconformity, the "*Potsdam*," including quartzytes (with gabbro and red granite), referred to the Paradoxides horizon, on the ground of fossils reported from the Pipe clay district of southwestern Minnesota at the southwestern extremity of the belt; (3) the "*St. Croix*" beds, "of the Dikelocephalus horizon" with only over-lap unconformity between them and the Potsdam, and graduating above into the Calciferous magnesian limestones.

Prof. Winchell makes the beds of iron ore of the Animike to correspond in age and relation to iron ore-beds in the Taconic formation of western New England. But this formation has no such beds, the only iron ore being limonite, of secondary origin, except some local bodies of iron carbonate. Moreover the Taconic limestone, in which the limonite deposits and iron carbonate occur, has afforded in some places Calciferous or Trenton fossils. The latest discovery of this kind was made in 1889 by W. B. Dwight (this Journal, xxxviii, 150), in the Copake-Millerton-Amenia limestone-belt, in which are several of the great limonite-deposits, and at Amenia the largest body of iron-carbonate yet observed in the Taconic region; and here the fossils of the limestone were species of Ophileta, Orthoceras, Cyrtoceras.

There is a misapprehension on page 9, that should be noticed. It is there stated that a second edition of Dana's Manual of Geology was issued in 1864, two years after the first. The author of the work knows nothing of such a second edition. There was an issue of the work that year from the stereotype plates, and the publishers may have inserted 1864 on the title page; but if so, it was not a new edition. Moreover such a method of moving on the date the author has always protested against. J. D. D.

3. *Geology of the Quicksilver Deposits of the Pacific Slope.* 486 pp. 4to, with a folio atlas of 14 plates, by GEORGE F. BECKER. Vol. xiii, Monograph of the U. S. Geological Survey.—In his report Mr. Becker treats of two subjects of prime geological importance—that of the metamorphic Cretaceous rocks of California, and the related one, the origin of the deposits of quicksilver. The former he had previously presented, but less fully and less strongly; in this new volume the facts are so clearly set forth, and are so well fortified, the gradations from non-metamorphic to metamorphic made so plain, that all doubts should disappear even from those who have been relegating all serious rock-crystallization to Archæan time. The metamorphosed rocks are proved *by fossils* to be for the most part at least Lower Cretaceous or Neocomian in age; and in constitution they were granitic sandstones and shales, containing feldspar, quartz, and more or less mica, with often hornblende. The new minerals made by the metamorphism include muscovite, augite, hornblende,

glaucophane, zoisite, saussurite, feldspars even in the half-altered sandstones, of which oligoclase, labradorite, and orthoclase are occurring kinds, the first of the three most common, the last, rare; also epidote, garnet, chlorites, serpentine, rutile, titanite, zircon, apatite. The rocks include diabase, dioryte, (for which metamorphic kinds the author proposes the term *pseudodiabase*, *pseudodiorite*, overlooking the terms metadiabase, metadioryte, proposed in 1876, and used in this Journal in a paper by Mr. G. W. Hawes); coarsely crystalline forms of the diabase or gabbro, with zoisitic and hornblendic varieties; glaucophane schists, containing quartz, a soda feldspar, usually some zoisite and mica, often garnets, passing into gneiss-like varieties on one side and into thin-schistose on the other, and, at Mt. Diablo exhibiting a distinct passage from shales to the schist, proving, as Mr. Becker says, that "the schistose structure is an original feature, not a result of metamorphism"; phthanyte, or flinty silicified sandstones or shales; serpentine. The serpentine is found to have been produced through an alteration of the sandstones, all the kinds having undergone the change; and the minerals altered to serpentine include augite, hornblende, feldspar, chlorite, garnet, and even quartz and apatite. Mr. Becker discusses the conditions of these and other metamorphic changes, and throws much light upon the question of origin.

From the part of the work on quicksilver deposits much might be here cited which is of prominent geological importance. The discussion of the origin of the deposits leads also to observations on the origin of metallic deposits of other kinds. The author had visited the mines of Europe before writing his report. The atlas contains geological maps of differing mining regions, and also diagrams of mine-workings, mine-sections, and other matters of economical interest.

4. *A new locality of Lower Silurian Fossils in the Limestones of Columbia Co., N. Y.;* by I. P. Bishop. (Communicated by the author).—In October, 1887, I found near Pulver's Station, about 2½ miles north of Philmont, Columbia Co., N. Y., and within territory heretofore considered as Taconic, an outcrop of limestone. A very brief search revealed unmistakable organic remains, among which were several gasteropods, crinoid stems and a cast of a single brachiopod valve. A few days later I visited the spot again and brought away several specimens, only one of which, a *Multiculopora*, could be identified. More urgent duties prevented any further search for fossils that season; but in the spring and summer of 1888, I visited the place several times and made a careful examination of about one-third of the whole outcrop. The organic remains proved to be not only more abundant than in the other fossiliferous localities previously discovered,* but to be in greater variety and in a better state of preservation. As many as six or seven Orthocerata were plainly distinguished; but owing to the massive character of the limestone, I

* Vide this Journal, vol. xxxii, p. 438, 1886.

was not able to get a specimen which could be identified. Gasteropod remains were very abundant, forming almost the whole of certain thick layers. Of corals I obtained seven or eight specimens in a fair state of perservation.

The fossils which I carried away were submitted to Professor C. E. Beecher of Yale College Museum, who identified the species:

Chaetetes compacta Billings.
Monticulopora lycoperdon Say.
Orthis testudinaria(?) Dal.
Murchisonia gracilis.
Orthoceras, Sp.

Professor Beecher says that in his judgment the specimens are from the Trenton group, probably from the lower part. I may add that the color and general appearance of the rock go to strengthen this view.

The outcrop of limestone within which the above mentioned fossils were found lies about a mile southeast of Pulver's Station, and not more than 300 yards from the Harlem railroad track. It has the same northeasterly strike as all the rock in this region, and a dip of about 50° to the southeast. The whole exposure is approximately one-third of a mile long, with an average width of 150 yards. It is especially interesting for the reason that there is no other limestone outcrop nearer than a mile, and no vestiges of fossils in any rock within more than two miles. The whole fossiliferous area is surrounded by highly metamorphic schists and slates which extend to an unknown distance on the south and east. From its fossils, its appearance, and its relation to the rocks lying to the eastward, I judge this limestone to belong to the same geological horizon as the other fossiliferous limestones previously found by me north of Chatham in the same county.

5. *Shallow-water origin of the Cincinnati shale and limestone.*—An interesting paper on this subject by Mr. N. W. Perry, in the December number of the American Naturalist, finely illustrated by phototypes, shows conclusively that, in accordance with the views of Professor Newberry and the later observations of Professor Shaler in Kentucky and Prof. J. F. James in Ohio, the Cincinnati shales and limestone are of shallow-water origin. The phototypes represent rain-marks, ripple-marks, and mud-cracks, of the most characteristic kind. Mr. Perry concludes that the rocks were made over the gradually sinking bottom of a shallow sea.

6. *The Lower Cretaceous of the San Carlos Mountains, Mexico.*—Dr. C. A. White, the author of the paper on this subject in the last volume of this Journal, states in a letter of November 19th to the editors: "I have no doubt that the 4,000 feet of limestone which I found in the San Carlos Mountains of Chihuahua, were accumulated on a subsiding sea-bottom. Deep sea forms seem to be either wanting, or very rare. I did not detect any forms from top to bottom of the series that might not have lived in comparatively shallow waters."

7. *The Sabre-toothed tiger and other Quaternary Mammals of Florida.*—Dr. JOSEPH LEIDY has named the Quaternary tiger, of which remains were received by him from Mr. Joseph Willcox, the *Drepanodon* or *Machairodus Floridanus*. The specimens are from Ocala, Marion Co. It was a somewhat smaller animal than the Brazilian species. The same locality has afforded also a præmolar of *Elephas columbi*, and the tooth of a Llama. On Pease Creek, in Florida, Mr. Willcox obtained other Mammalian remains, among which Dr. Leidy has identified *Tapirus americanus*, a *Hippotherium* or *Hipparion*, a *Glyptodon*, named by Dr. Leidy *G. septentrionalis*, and remains of a turtle, *Emys euglypha* Leidy.—*Proc. Acad. Nat. Sci. Philad.*, 1889, p. 29, 86.

8. *Fossils of the Western Taconic limestone in the eastern part of Dutchess Co., N. Y.*—A letter of October 14th, from Professor WM. B. DWIGHT states that he had found, in limestone near the Clove Valley Station, *Calciferous* fossils, including the common Fucoids, with Ophiletas, probably *O. complanata;* proving that the Fishkill belt of limestone is Lower Silurian, and consequently, in connection with his other discoveries, that all the belts of limestone of Dutchess County are fossiliferous.

9. *Cambrian fossils from the limestone of Nahant, Massachusetts*, northeast of Boston; by A. F. FŒRSTE.—The fossils discovered at this locality and reported upon in the Proceedings of the Boston Society of Natural History for 1889, p. 261, are *Hyolithes* resembling specimens found by Prof. Shaler at North Attleboro, not far from the boundary of Rhode Island. The latter species was referred to *H. princeps* Billings. Mr. Fœrste names it *H. inaequilateralis*, and makes the large Nahant specimens the same. The limestone northeast of Mill Cove, in North Weymouth, 12½ miles from Nahant, is referred to the same horizon, which is made that of the Olenellus group. The nearest Paradoxides beds are at Malden.

10. *The Development of some Silurian Brachiopoda;* by C. E. BEECHER and J. M. CLARKE. 96 pp. 4to, with 8 plates. Memoirs of the New York State Museum, Vol. I. Albany, Oct., 1889.—This memoir is the result of a careful study of a number of Brachiopods with reference to their successive differences in the progress of development. The specimens were all from a single locality in the Niagara limestone at Waldron, Illinois. The variations in the several parts with the increase in size are described in detail, and many general conclusions are reached. One of these conclusions of much interest is that, in confirmation of observations of Brooke and Morse on living Brachiopods, the shell in its early stages approaches a subcircular outline, so that there is uniformity in the embryology of the ancient Silurian types and that of the modern species. The memoir is an important study in evolution.

11. *Devonian Plants from Ohio;* by Dr. J. S. NEWBERRY.—In the Journal of the Cincinnati Society of Natural History for October last (page 48), Dr. Newberry describes and figures of

natural size the *Caulopteris antiqua* Newb., of the Corniferous limestone. The fine specimen was from Sandusky, Ohio. In the same rock occur *C. peregrina* Newb., *Sphenophyllum vetustum* Newb., and *Lepidodendron Gaspianum* Dawson. The *C. peregrina* is also figured and described, together with *Dadoxylon Newberryi* of Dawson, and the Sphenophyllum and Lepidodendron mentioned.

12. *U. S. Geological Survey Bulletins.*—The Survey has recently issued Nos. 48 to 53 of its bulletins, as follows: No. 48. On the Form and Position of the Sea-Level, by R. S. Woodward. 88 pp. 8vo.—No. 49, Latitudes and Longitudes of certain points in Missouri, Kansas and New Mexico, by the same.—No. 50, Formulas and Tables to facilitate the construction of Maps, by the same.—No. 51, On Invertebrate fossils from the Pacific Coast, by C. A. White, 70 pp., with 14 plates.—No. 52, Subaerial decay of rocks and origin of the red color of certain formations, by I. C. Russell, 60 pp. 8vo.—No. 53, The Geology of Nantucket, by Prof. N. S. Shaler, 56 pp. 1889.

13. *Geological Survey of Missouri.*—A letter from Mr. Arthur Winslow, dated Jefferson City, states that he has been appointed geologist of Missouri and has entered on his duties.

14. *Geologie der Münsterthals in Badischen Schwarzwald*, by Dr. Adolph Schmidt, Prof. Univ. Heidelberg. (Carl Winter).—The first part of this work on the geology of the Münsterthal appeared in 1886, the second in 1887, and the third, in 1889. The last extends to 112 pages, and treats of the ore-deposits; first of the associated minerals and their paragenetic combinations, and then of their paragenesis. Dr. Schmidt is one of the best authorities on the subject, and his work sheds light on mining deposits generally.

15. *Contribuzioni alla Flora Fossile dei Terreni Terziarii della Liguria;* by S. Squinabol. I. *Fucoidi ed Elmintoidee*, Roma, 1888; II. *Caracee-Felci*, Genova, 1889.—These two contributions seem to be the beginning of a somewhat extensive work by the author on the fossil flora of Liguria, but as the first was published in the Bolletino of the Italian Geological Society in octavo form and the second by the University of Genoa in quarto form they cannot be brought together into a volume. Judging from the work already done by Gaudin, Massalongo, Sismonda, Sordelli, and others in the beds of this age in Liguria and the adjoining provinces the greater part of the fossil plants met with are dicotyledonous leaf impressions, and it is gratifying to note that the lower forms are receiving attention. The fucoids described in the first paper are problematical organisms referred to Chondrites, Laminarites, Zonarites, Münsteria, Helminthoida, and a new genus Eoclathrus. There are twenty species, twelve of which are new. They appear to represent a formation equivalent to the Flysch of Switzerland. The second paper describes one species of Chara and thirty-two ferns belonging to eighteen genera. The figures are for the most part photo-

graphs of the specimens and too indistinct to form a judgment from. The author seems to have thoroughly ransacked the literature of the subject and his "Elenco Cronologico" which forms the second part is a very full list of papers relating in any way to the fossil botany of Italy, considerably fuller than that of Portis. It embraces 262 titles. L. F. W.

16. *Jarosite from Utah*; by F. A. GENTH. (Communicated).—Messrs. Geo. L. English & Co. have recently brought from the Mammoth Mine, Tintic District, Utah, interesting varieties of *Jarosite* in minute crystals, lining cavities of a siliceous limonite, and sometimes associated with a pulverulent, yellow mineral, probably a basic ferric sulphate. The crystals are of a yellowish brown to dark clove-brown color and a very brilliant vitreous luster; they are very small, from about 0·1 to 1^{mm} in size, and look so much like cubes with tetrahedral planes, that they were mistaken for pharmacosiderite. A closer inspection, however, showed their rhombohedral forms. Prof. Samuel L. Penfield had the kindness to examine them for me, and gives the following information. "The crystals are so rounded that they will not give distinct and satisfactory reflections. From a very small crystal I obtained $R \wedge R$ 88° 27′, while Naumann gives 88° 58′ for jarosite, an agreement as close as I could expect. I also identified the base, and a very small plane $-2R$. I was able to produce basal cleavage."

Even the best specimens placed in my hands by Messrs. English & Co. did not furnish me with absolutely pure material for analysis, owing to the fact that the crusts are very thin and the crystals stick so fast to the siliceous matrix and often enclose the latter that only at the expense of a great deal of time and patience, about one gram of nearly pure fragments of crystals could be obtained (I); analysis (II) was made with somewhat larger and darker crystals. Both show a slight contamination with siliceous limonite —but the analyses leave no doubt that the mineral is *jarosite.* Spec. grav. of I (taken in alcohol) = 3·163. The analyses gave:

	I.	II.
SiO_2	0·08	0·29
Fe_2O_3	50·41	51.16
Na_2O	9·23	0·33
K_2O		9·05
SO_3	29.60	28.93
H_2O	10·68	10·24

Chem. Laboratory, 111 S. 10th st., Philadelphia, October 13, 1889.

17. *Brief notices of some recently described Minerals.*—REDINGTONITE, KNOXVILLITE. Two hydrous chromium sulphates from the Redington mine, Knoxville district, California. They occur at a depth of 150 feet at a point where solfataric gases still issue and are regarded as the result of the solfataric action upon chromic iron. Redingtonite occurs in masses with a fine fibrous structure and of a pale purple color; the extinction is oblique (13° to 38°) and a triclinic form is suggested. A qualitative

analysis showed it to be a hydrous chromium sulphate containing some aluminum and iron.

Upon the redingtonite occurs another chromium sulphate containing less water; it appears in rhombic tables of 78° and 102° with cleavage parallel to the base, macropinacoid and prism. Isomorphism is suggested with copiapite (which, however, is monoclinic according to Linck). It is noted that redingtonite is changed by heating into this second chromium sulphate. These minerals, with also napalite, are described by Becker in Monograph XIII, (U. S G. S.) on the quicksilver deposits of the Pacific slope (see p. 68, of this number.)

NAPALITE. A mineral resin occurring with pyrite and millerite in vesicular quartz in the Phœnix mine, Mayacmas district, Napa Co., California. It has a consistency like that of shoemaker's wax; the color is dark reddish brown and it shows a green fluorescence by reflected light, which, however, disappears upon exposure to the air. The hardness is 2, the specific gravity 1·02. It is brittle, inelastic, with a conchoidal fracture; by the warmth of the hand it can be so softened as to be moulded and drawn into long threads. It becomes liquid at 46° and boils at 300°; at 130° a heavy colorless oil distils over, while a heavy dark red oil is later obtained having a boiling point about 350°. Analysis showed the composition to correspond to C_3H_4.

MESSELITE. A hydrous phosphate of calcium and iron found in a bituminous clay-slate near Messel in Hesse. It occurs in small tabular crystals, often grouped in star-shaped forms. They are colorless or pale brown, with hardness 3 to 3.5. From the optical characters they are referred to the triclinic system. An analysis gave

P_2O_5	FeO	CaO	MgO	MnO	H_2O	insol.
37·72	15·63	31·11	1·45	*tr.*	12·15	1·40=99·46

This leads to the formula $(Ca, Fe)_3P_2O_8+2\frac{1}{2}H_2O$, which brings it near fairfieldite. Described by W. Muthmann in *Zeitschr. Kryst.*, xvii, 93, 1889.

RAPHISIDERITE. A name given by A. Scacchi to minute acicular crystals of iron sesquioxide from Pianura and Fiano, which have been examined by E. Scacchi and found to have a rhombic section with an angle of about 72½°. It is not certain that they are not hematite.—*Att. Accad. Napoli*, Dec. 1, 1888.

COHENITE. A name given by Weinschenk to crystals occurring in the Magura, Arva, meteorite. They are indistinct in form but are probably to be referred to the isometric system; they are very brittle, have a tin-white color, hardness 5·5 to 6, and specific gravity 6·977. An analysis gave

Fe 39·78 Ni(Co) 3 57 C 6·65=100.

This leads to the formula $(Fe, Ni, Co)_3C$.—*Ann. Mus. Wien*, iv, 93, 1889.

WARRENITE. Mr. L. G. Eakins has informed the editors that he has given the name Warrenite, after Mr. E. R. Warren of Crested

Butte, Col., to the sulphantimonite, 3(Pb, Fe)S . $2Sb_2S_3$, described by him in this Journal for Dec. 1888.

18. *Das Reich der Krystalle* für jeden Freund der Natur insbesondere für Mineraliensammler leichtfasslich dargestellt von H. BAUMHAUER. 364 pp. 8vo. Leipzig, 1889 (W. Engelmann).—Dr Baumhauer has succeeded in presenting the subject of crystallography in an unusually attractive form. The general morphological relations are given after the commonly accepted methods, but besides this the growth of crystals and crystal groups is explained and illustrated by a large number of excellent figures which reproduce nature's forms with remarkable success. The physical characters of crystals are also briefly but clearly stated, and particularly the molecular structure as developed by etching, a subject to which the author has himself made important contributions.

III. BOTANY.

1. *Die natürlichen Pflanzenfamilien*, von A. ENGLER UND K. PRANTL. [Engelmann, Leipzig.]—In the earlier numbers of this Journal we have taken occasion to speak in terms of high commendation of this work now in course of publication. Two new parts have just come to hand, and they can be praised as heartily as any of their predecessors. Part 37 is devoted to Clethraceæ, Pirolaceæ, Lennoaceæ, and a portion of Ericacæ proper. Part 38 treats of the reminder of Ericaceæ, together with Epacridaceæ and Diapensiaceæ, all by Professor Drude of Dresden, and the order Myrsinaceæ by Pax, of Breslau.

A short account of the treatment of the orders Clethraceæ and Pyrolaceæ by Professor Drude, will indicate to our readers some of the points of peculiar excellence which this work presents. But such an account will give also an opportunity of stating distinctly, once for all, what seems to us a marked defect in the whole treatise.

The treatment begins with a citation of the more important literature of the subject. Then follows a half-page illustration, giving the leaf and flowers of *Clethra arborea* and *tinifolia*, together with numerous analytical details, all of them possessing great clearness and beauty.

The ordinal characters are well described, and then the author gives a sketch of certain peculiarities presented by the organs of vegetation, considered rather from a biological point of view. Next comes a section to which we think exception must be taken, namely, the statement of the supposed relations of the anomalous genus Clethra. On the strength of a suggestion by Klotsch, the author places the genus Clethra in an order by itself, but he does not give plainly the reasons which have controlled him in this disposition of the group. The evidence which he adduces cannot certainly be all that which proved convincing to his own mind, and he should have given his readers the advantage of all the light which he himself possessed. We should not mention this, were it not for the fact that at many places through the book, the editors of the orders have made very grave changes in the orders and suborders, without giving all the evidence in the case. Many of the changes seem to us desirable, but even in these, the plainest, the statement of the new relationships is not sufficiently full for all readers, and it seldom compares favorably with the fullness in other portions of this excellent work.

Continuing our analysis of the treatment of the order, we come next to a short but clear statement of the geographical and paleontological relations of the order, and the subject closes with a synoptical view of the subgenera.

The same author treats the Pyrolas and associated plants under one order, *Pirolaceæ.* The whole treatment is substantially that just described. After the citation of authorities, and the description of the distinguishing features of the group, the writer presents an interesting account of the economy of these plants, and passes, by the way of *Pyrola aphylla*, a partial saprophyte, or humus-loving plant, to the Monotropas and their associates, all of which are true saprophytes. There is a graphic account of the structure of the roots of these plants and their attached fungi, through the intervention of which it is supposed they obtain their nourishment. The anatomical peculiarities are given with considerable detail. There is one point with reference to the roots, which should be very carefully examined in our species, namely, their extraordinary power of enabling the plant to multiply by adventitious buds formed on them. We do not ordinarily look for buds on roots.

The author speaks particularly of the coloring matter held in the tissues of these saprophytes and the effects of agents, especially alcohol, thereon. In short, here as elsewhere, the editors have left out very few facts which can interest the student, the subject of cross-fertilization and the like, receiving much attention. All the more important features throughout, which require illustration, are clearly and copiously figured. The section on geographical distribution is short and telling. It is followed by a paragraph on the supposed relationships, which to our thinking is less satisfactory even than that referred to under Clethraceæ. The reasons adduced for separating these plants from their old time allies, the other Ericaceæ, appear trivial in the extreme. But, of course, these are questions of judgment. It seems, however, as if the editor ought to have given all his reasons for this separation and presented his case in full. It seems ungracious to allude to this, but since the treatise is likely to occupy a place not filled by any other work on Botany, the most important portion of the subject of classification should have demanded rather more space for its elucidation. The treatment of the order closes with a grouping of the genera into suborders, and a description of the genera themselves. The generic descriptions are almost full enough to warrant us in saying that in most instances, it would be possible to use the work as a handy Genera Plantarum.

The illustrations and typographical execution leave nothing to be desired. G. L. G.

2. *On the effects produced on some tropical plants by a temperature of* 40 *to* 34 *degrees.**—In horticultural language, a stove is a hot-house, specially adapted for the cultivation of tropical plants. The temperature at which it is kept, varies, of course, widely, according to the season, but its range in winter is generally from 55° or 60° Fahr. at night, to 70°, Fahr. in the daytime. In a well regulated establishment, the temperature is not allowed to fall below the minimum just mentioned. If, through accident or neglect, the temperature descends below 45° but is still above freezing, certain plants soon exhibit signs of having sustained injury. In the case of some of the *Crotons*, plants cultivated for their foliage, the injury is shown in the partial withering and subsequent fall of the leaves: in the instance of *Eucharis*, a diminished quantity of flowers is the most obvious result. The temperature at which these injuries are produced may be considerably above that of the freezing point of water, and therefore the question of frost is to be left out of account. If the plants were in the open air, the question of frost might well come in, for if a plant is exposed to the open air, on a clear night, when the sheltered thermometer marks a temperature of say 45°, the radiation may carry the temperature of the plant even below 32°. In a greenhouse, this reduction of temperature by radiation is practically impossible, and can be left out of consideration. Hence we have to study only the effects produced by the temperature which is indicated by a thermometer close by the plant.

In order to approach the question as part of a larger inquiry which I have had for some years under investigation, it was thought best that the tissues of certain tropical plants should be examined microscopically, under varying conditions of heat and cold. In the present communication, the principal results of this examination between the somewhat arbitrary limits of 40° and 34° will be briefly detailed. 39° is said to be the point at which water reaches its greatest density, while 34° was considered by me to be well within the danger limit so far as frost is concerned. First, as regards the effect on the cell-wall in all the cases observed: there was no physical injury apparent. Second, as regards the effect on the protoplasmic contents: there was merely a reduction of rate of circulation. Third, there was no appreciable change in the size of the sap-cavities, (vacuoles). Fourth, there was a notable reduction of the power of plasmolytic agents, such as Potassium nitrate, solution of cane sugar, etc. This pointed plainly to a diminution in the power of absorption.

It is well known that the temperature of the soil has a marked influence on the absorption of liquids by the roots, cold diminishing the rate of absorption. Comparative experiments now in progress indicate that in this respect tropical plants are even more sensitive than subtropical, and much more so than those of temper-

* Read Nov., 1889, before American Academy.

ate climates. In the delicately balanced economy of tropical vegetation, even the slight disturbance resulting from carrying the temperature down below the point most favorable for absorption, and yet still considerably above that of the freezing point of water, the supply of water is so much diminished that the withering of the leaves is the natural result. Fifth, Pfeffer has pointed out the interesting fact that although living protoplasm resists the entrance of colored liquids of even moderate strength of solution, it will permit very dilute coloring agents of some kinds to pass into its substance and even to enter the sap cavities. I find that there are not only differences in regard to the absorption of the same liquid at different temperatures, but also of the same liquid by different plants and especially the plants of different climates at the same temperature. For the purpose of this later study, it has been found convenient to use the apparatus described by me in a communication read before the Academy two years ago, and which has since that time found elsewhere extended application.

There is a curious embarrassment attending the selection of material for these studies which I have felt from the outset: Is it not likely that some of the plants cultivated by us in our hot-houses as tropical, and which came originally from the tropics, have become more or less modified through adaptations to their new surroundings? At any rate, I am not yet prepared to deny that here may be an element of uncertainty when we apply the results of this research to the vegetations of tropical plants in their homes. Again it must not be forgotten that we make little distinction in our hot-houses between those tropical plants which grow in jungles where they may be sheltered more or less from radiation, and those which grow in the moist plains under an open sky. For subjecting the tissues of the plants to varying temperatures a special apparatus has been devised by me which forms the subject of a separate communication. G. L. G.

3. *On an Apparatus for easily controlling temperatures at or below freezing, for experiments on the relations of plants to cold.** —The ingenious device by which, through the intervention of a refrigerating coil, it is possible to make excavations in sandy and treacherous land, gave the writer a hint as to the construction of a simple instrument for subjecting plants to low temperatures. Expressed in its lowest terms, the apparatus consists of a metallic or glass tube running round the inside of a properly arranged box adapted to the reception of a microscope. Through this coil there is made to circulate by means of a pressure bulb, a current of a dense solution of calcium chloride kept at the desired temperature. This solution can be carried down far below the freezing point of water, and it is of course capable of being kept perfectly under control. In this way, the temperature of the interior of the box falls after a short time to the desired degree, and it can be kept at this point for any length of time. It is to

* Read before the American Academy, Nov., 1889.

be said that the changes in temperature take place ordinarily very slowly, and this has been found to be a distinct advantage.

The apparatus can be employed for the examination of living plants or microscopic sections, as in both cases the changes of temperature succeed each other so slowly that one can follow the effects produced by them without any difficulty. G. L. G.

4. *The disintegration of woody tissues.*—A review of all the processes hitherto published has convinced the writer that the method most widely applicable for the separation of the structural elements of hard vegetable tissues, is the following, which has been in use in the Botanical Laboratory of Harvard University for several years. The tissue is soaked for a sufficient length of time in a ten per cent solution of potassium dichromate, then quickly freed from the excess of the salt by once rinsing in pure water, and immediately acted on by concentrated sulphuric acid. After the acid has acted for a short time, the tissue is to be placed in a large quantity of water, when it will be found to have undergone a more or less complete disintegration, which has left the constituents practically uninjured. When this process, which is really a chromic acid method, is correctly used, there is merely a separation of one structural element from its neighbors, with little or no corrosion of the wall. It has been found easier and far more pleasant to employ than the macerating method in which potassium chlorate and nitric acid are heated together. Moreover, one obtains all the excellent results which can be gained from the most cautious employment of the chlorate method.

Mr. Stone, of the Worcester Natural History Society, has shown me that the process is readily applicable to even such tissues as Collenchyma. G. L. G.

5. *Illustrations of West American Oaks, by the late* ALBERT KELLOGG, M.D., the text by Edward L. Greene, San Francisco, 1889. 4to, pp. 47.—By an appeal to James M. McDonald, Esq., of San Francisco, Professor George Davidson secured the funds for the publication of Dr. Albert Kellogg's drawings of the Oaks of California. These excellent illustrations, explained by text by Professor Greene, of the University of California, are now before us, and they justify the forcible and discriminating appeal which met with so prompt a response. The drawings are in outline, with very little shading, and give the chief diagnostic features with much distinctness. That they are truthful in every detail must be believed by all who knew Dr. Kellogg. Of this enthusiast, whose drawings of the Oaks are happily saved to us, his friend Professor Davidson says, in the introduction to this work, p. vi, "It was the unselfish and successful work of Kellogg and his colleages through twenty years that educted the first munificent gift of James Lick, and the second still greater one. It was his devotion that subsequently elicited the noble gift of Charles Crocker for the endowment of original research . . . As Dr. Kellogg's years gradually increased, the field of investigation seemed to expand a hundred fold, and again his singleness of

purpose asserted itself. He forsook his profession to devote his life to botany; he forgot where the raiment, the sustenance and the house-protection were to come from. He faithfully believed that his other self, Harford—just as devoted and needful as himself—would see to it that he was clothed for the benefit of his fellow men. For the rest, his time was no longer his own; he gave it unreservedly for the benefit of his fellow-men. His pencil and his pen were never afterwards out of his hands while daylight lasted." It is sincerely to be hoped that the other illustrations left by Dr. Kellogg may find their way into botanical literature in the unexceptionable form in which these have been given to the world. G. L. G.

IV. Miscellaneous Scientific Intelligence.

Ascent of a Peak in the Cascade Mountains. Dr. Julius Röll, of Darmstadt, in the course of a mission of botanical exploration in the north-west of America, made an ascent in June, 1888, of a summit in the Cascade Mountains, hitherto unnamed on our maps. The peak in question is situated under long. 121° 15′ W., and lat. 47° 22′ N., between two small lakes, and about 20 miles north of Easton on the Northern Pacific Railroad. We take the following from a short account of his excursion contributed by Dr. Röll to the current number of Petermann's 'Mittheilungen.' On the 19th June, in company with Herr Purpus, he made his way through the primeval forest, and over rising ground to the foot of the mountain, pitching his tent at an altitude of 5,500 feet. The next morning the actual summit was ascended. It is composed of melaphyr, and many pieces of agate and rock crystal were found. The steep slopes are overgrown with ceanothus bushes, maples, and pines, between which bloom yellowish-red lilies (*Lilium philadelphicum*), and species of dark-red pentstemons. Three successive summits were climbed, the highest was estimated at 7,500 feet; unfortunately the exact altitude could not be ascertained, as the traveller's barometer had become useless. The rocky crest of the mountain is covered with the *Selaginella rupestris*, pentstemons, phlox, pedicularis, several saxifrages, and some low umbelliferous plants, &c. Traces of bears, moose, and mountain sheep were observed. The following day another ascent was made, and a magnificent view of the snow-covered Mount Tacoma obtained. Some weeks later, finding that the peak he had ascended was unnamed, Dr. Röll designated it "Mount Rigi," from the resemblance to the Swiss mountain of that name.—*Proc. R. Geogr. Soc.*, Oct., 1889.

A Bibliography of Geodesy by J. Howard Gore, B.S., Ph.D. pp. 315–512. U. S. Coast and Geodetic Survey. Appendix No. 16, Report for 1887. Washington, 1889. A very valuable and complete work compiled as the result of a vast amount of labor involving the exploration in person of thirty-four of the principal libraries of America and Europe and many minor libraries by proxy, besides an extensive correspondence.

APPENDIX.

Art. XIV.—*Description of New Dinosaurian Reptiles;* by O. C. Marsh. (With Plate I.)

Recent explorations in the West have resulted in the discovery of many remains of Dinosaurs, some of which are of more than ordinary interest. A few are from the Jurassic, but most of them are from the Cretaceous, especially from the upper portion, in the so-called Laramie formation. Those found in the latter horizon show a high degree of specialization, and present some anatomical features not before observed in this group of reptiles. Several of the new forms are briefly described below, and will be more fully discussed in a later communication.

Triceratops serratus, sp. nov.

First in importance of the new discoveries is a nearly perfect skull of the genus *Triceratops*, a typical example of which (*T. flabellatus*) was described and figured by the writer in the last number of this Journal.* The present skull is more perfect than any hitherto found, and exhibits admirably the strongly marked characters of the genus. It is likewise of gigantic size, being nearly six feet in length ($1{\cdot}8^{m}$), although the animal was not fully adult.

A striking peculiarity of this skull, which has suggested the specific name, is a series of bony projections on the median line of the parietal crest. The latter is elevated along this line to support them, and the sides descend rapidly to their union with the squamosals. There is a second series of elevations along the middle of the squamosal bone as it falls away from the base of the horn-core, but these are much less prominent.

The orbit is nearly circular in form, instead of oval, and is situated above, and forward of its position in the species referred to. The quadrato-jugal meets the anterior process of the squamosal, forming a closer union than in the skull previously figured. In this respect, and in the elevations on the squamosal, it approaches a much smaller specimen at present referred to the genus *Ceratops*.

* This Journal, vol. xxxviii, pp. 501–506, December, 1889.

The nasal horn-core is wanting in the present specimen, as it was not ossified with the nasals. It projected upward and forward. The nasal bones extend outside the superior branch of the premaxillaries, the lateral suture uniting the two being nearly vertical.

The present specimen is from the Ceratops beds of Wyoming, in essentially the same horizon of the Laramie as the skull of *Triceratops flabellatus*, to which reference has been made.

Triceratops prorsus, sp. nov.

A second skull of this genus, fully adult, and of nearly equal dimensions, was secured at the same time as the specimen last described. It is in excellent preservation, although somewhat distorted, and evidently belongs to a distinct species.

The nasal horn-core and the rostral bone are in position, and perfect. The former is very large, and is directed straight forward, its upper surface being nearly on a line with the superior face of the nasals. It is somewhat oval in transverse section, and pointed in front, the apex being directly above the anterior extremity of the rostral bone. It is so firmly coössified with the nasals that no trace of a suture can be observed. Its external surface is rugose from vascular impressions, indicating that it was covered by horn, thus forming a most powerful weapon.

The huge frontal horn-cores are more massive, and less slender, than in the species above described.

The parietal crest is not so broad as in the two species last described, but appears to resemble more strongly that of *Triceratops horridus*, its sides being inclined downward, as if to protect the neck.

The rostral bone, likewise, is very similar to that in the last species, but is somewhat more compressed. The two forms may be readily distinguished by the nasal horn-core, for in *T. horridus*, this is comparatively small, and points directly upward, instead of straight forward, as in the present species.

With this skull were found several cervical vertebræ, and some other portions of the skeleton. The atlas, axis, and third vertebra are firmly anchylosed with each other, and their ribs, also, are coössified in the same mass. This union, unknown hitherto among the *Dinosauria*, was evidently rendered necessary to afford a firm support for the enormous skull. The remaining cervical vertebræ are short and massive, and the articular faces of the centra are concave or nearly flat.

The present specimen is from the Laramie of Wyoming, and was found in the same vicinity as the skull above described.

Ceratops paucidens.

The specimen recently described by the writer under the name *Hadrosaurus paucidens** should probably be referred to the genus *Ceratops*, as a comparison with more perfect specimens indicates a much closer affinity with that genus than at first supposed. In addition to the maxillary described, one of the premaxillaries is in good preservation. This agrees in general features with the corresponding bone in *Triceratops*, but is less specialized. Its inner surface is deeply concave, showing that the two premaxillaries did not meet each other closely, as in *Triceratops*, but apparently only in front. This species, as well as the type of the genus, *Ceratops montanus*, represents smaller, less specialized forms of the family, and may be from a lower geological horizon than the gigantic reptiles which the writer has recently made known.

In addition to the special characters of the *Ceratopsidæ* shown in the skull, as stated by the writer in this Journal (vol. xxxviii, p. 505), the following features seen in other parts of the skeleton may be mentioned:

(1) The atlas and axis, and one or more adjoining cervical vertebræ are coössified with each other.

(2) Their cervical ribs are likewise firmly united with the same vertebræ.

(3) The remaining cervical vertebræ are short, and have the articular faces of the centra nearly flat.

(4) The trunk vertebræ have very short centra, with flat articular ends. Above the centra, they resemble the vertebræ of *Stegosaurus*.

(5) The sacrum was strengthened by union with several adjacent vertebræ.

(6) The caudal vertebræ are short and rugose, and the tail was of moderate length.

(7) The ilium is elongated, especially in front; the ischium slender, and directed backward.

(8) The pubis extended forward, and its posterior branch was wanting.

(9) The limbs were short and massive, and all four were used in locomotion.

(10) The feet were all provided with broad hoofs, as in *Stegosaurus*.

(11) The bones of the skeleton all appear to have been solid.

(12) Dermal ossifications were present, and some species were protected by heavy armor.

* This Journal, vol. xxxvii, p. 336, April, 1889.

Ornithomimus velox, gen. et sp. nov.

The high degree of specialization in the reptiles above described has a partial parallel in a small group of typical *Ornithopoda* from the same horizon. Various specimens of these, recently secured, represent a distinct genus and several species. The most marked characters already determined are manifest in the limbs and feet, and these have been selected for description in the present notice. A typical example is shown on Plate I, figures 1–3, which is the type specimen of the species here described.

On the distal part of the tibia represented in figure 1, the astragalus is seen in place, with a very large ascending process, larger than in any dinosaur hitherto known. The calcaneum is also shown in position, but the slender fibula is absent. This bone was complete, but of little functional value. The tibia and all the larger limb bones were hollow, with thin walls, as indicated in the section, figure 1, C.

In figure 5, the corresponding parts of a young ostrich are shown for comparison. The slender, incomplete fibula is in place beside the tibia. The astragalus with its ascending process, and the distinct calcaneum, are also shown in position. The almost exact correspondence of these different parts in the bird and reptile will be manifest to every anatomist.

The most striking feature of the foot belonging with the reptilian tibia is shown in the metatarsals represented in figure 2, A. These are three in number, and are in the same position as in life. They are the three functional metatarsals of the typical *Ornithopoda* and of Birds. The distal ends of these bones correspond in size and relative position in the two groups, but here, in the present specimen, the reptilian features cease, and those of typical Birds replace them. In all the reptiles known hitherto, and especially in Dinosaurs, the second, third, and fourth metatarsals are prominent in front, at their proximal ends, and the third is usually the largest and strongest. In birds, the place of the third is taken above by the second and fourth, the third being crowded backward, and very much diminished in size.

This character is well shown in figure 6, which represents the second, third, and fourth metatarsals of a young turkey, with the tarsal bones absent. In the reptilian metatarsals seen in figure 2, the same arrangement is shown, with the tarsals in place. The second and fourth metatarsals have increased much in size in the upper portion, and meet each other in front.

The third metatarsal, usually the largest and the most robust throughout, here diminishes in size upward, and takes a subordinate, posterior position, as in birds. The correspondence between the metatarsals of the bird and reptile are here as strongly marked as in the tibiæ and their accompanying elements, above described.

In figure 3, the three phalanges represented belong with the second metatarsal, and were found together in place.

The three metacarpals represented in figure 4 were found together in position, near the remains of the hind limb here described. Their very small size indicates that they may possibly belong to a smaller individual, but, with this exception, there is no reason why they do not pertain to the same specimen as the hind foot.

The remains of the present species here described were found in the Ceratops beds of Colorado.

Two other species, apparently of the same genus, are represented by various specimens from the same horizon, in Montana. One of these, which may be called *Ornithomimus tenuis*, was about twice the bulk of the present form. The third metatarsal was much more compressed transversely, both in the shaft and distal end. The bone was also much more slender medially than in the above species. The transverse diameter of this metatarsal at its distal end was 30^{mm}., and the antero-posterior diameter, 35^{mm}.

A third species, much larger, may be called *Ornithomimus grandis*. The third metatarsal was about 600^{mm}. in length, and its distal end 90^{mm}. in transverse diameter, and 80^{mm}. in antero-posterior diameter.

These various remains represent a distinct family, which may be called the *Ornithomimidæ*.

Barosaurus lentus, gen. et sp. nov.

A new genus of the *Sauropoda* is indicated by various remains of a very large reptile secured by the writer during the past season. The most characteristic portions examined are the caudal vertebræ, which in general form resemble those of *Diplodocus*. They are concave below, as in the caudals of that genus, but the sides of the centra are also deeply excavated.

In the anterior caudals, this excavation extends nearly or quite through the centra, a thin septum usually remaining. In the median caudals, a deep cavity on each side exists, as shown in figures 1 and 2, on page 86.

On the distal caudals, the lateral cavity has nearly or quite disappeared. All the caudal vertebræ are proportionally shorter than in *Diplodocus*, and their chevrons have no anterior projection, as in that genus.

FIG. 1. FIG. 2.

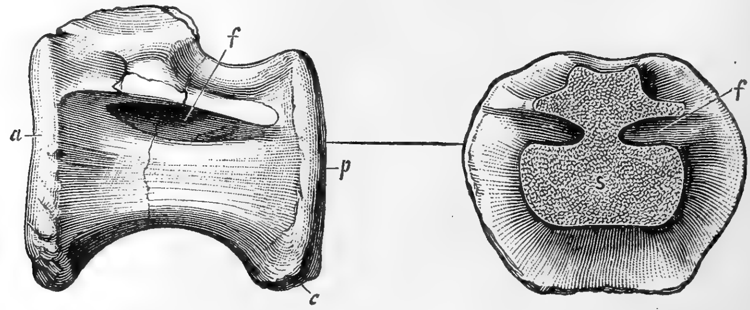


FIGURE 1.—Caudal vertebra of *Barosaurus lentus*, Marsh; side view.

FIGURE 2.—The same vertebra, in section; front view.
a, anterior end; *c*, face for chevron; *f*, lateral cavity; *p*, posterior end; *s*, section.

Both figures are one-eighth natural size.

The remains on which the present description is based are from the Atlantosaurus beds of Dakota, about two hundred miles further north than this well-marked horizon has hitherto been recognized.

For important aid in securing the fossils above noticed, the thanks of the writer are due to Mr. J. B. Hatcher, Dr. C. E. Beecher, and Mr. G. L. Cannon, Jr. The type specimens will be more fully described and figured by the writer under the auspices of the U. S. Geological Survey.

New Haven, Conn., December 21, 1889.

EXPLANATION OF PLATE I.

FIGURE 1.—Left tibia of *Ornithomimus velox*, Marsh; A, front view; B, distal end; C, transverse section.

FIGURE 2.—Left metatarsals of same specimen; A, front view; B, proximal ends; C, transverse section; D, distal ends.

FIGURE 3.—Phalanges of second digit of same foot; front view. A. first phalange; B, second phalange; C, third, or terminal phalange.

FIGURE 4.—Left metacarpals of same species, perhaps of smaller individual; front view.

FIGURE 5.—Left tibia of young Ostrich (*Struthio camelus*, Linn.); A, front view; B, distal end. The separate calcaneum was first observed by the writer's assistant, Dr. G. Baur, who prepared the specimen.

FIGURE 6.—Left metatarsals of young turkey (*Meleagris gallipavo*, Linn.); A, front view; B, proximal ends.

a, astragalus; *as*, ascending process of astragalus; *c*, calcaneum; *f*, fibula; *f′*, face for fibula; II, second metatarsal; III, third metatarsal; IV, fourth metatarsal.

Figures 1–4 are one-third natural size, and figures 5 and 6, one-half natural size.

CONTENTS.

SCIENTIFIC INTELLIGENCE.

VOL. XXXIX. FEBRUARY, 1890.

Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

EDITORS

JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS JOSIAH P. COOKE, GEORGE L. GOODALE AND JOHN TROWBRIDGE, OF CAMBRIDGE.

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

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XXXIX.—[WHOLE NUMBER, CXXXIX.]

No. 230.—FEBRUARY, 1890.

WITH PLATES II–IV.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1890.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. XV.—*The Magnetic Field in the Jefferson Physical Laboratory*; by R. W. Willson, Ph.D.

The Jefferson Physical Laboratory of Harvard University consists of two wings each 60 ft. square, connected by a central portion 80 ft. in length. The western wing is allotted exclusively to original work and special research, and is constructed wholly without iron. It is of course impracticable entirely to exclude magnetic material from the rooms of a building devoted to these objects, but the absence of all iron from the materials of the building itself, making it certain that no disturbing cause lies hidden from view in the walls, that the gas and steam pipes are of harmless material, and that a sensitive instrument may be even set upon the floor without possible risk of disturbance from the nails, is an advantage which will be appreciated by those who are familiar with magnetic measurements.

As the entire avoidance of iron adds largely to the cost of construction of a building 60 ft. square, with three full stories above a high basement, heated by steam pipes in each room and well piped for gas, it is desirable to know how far the end sought has been attained, and as the experiment has rarely, perhaps never, been tried elsewhere upon so extensive a scale, the incomplete series of observations of which I here give the results have a general interest. That a complete survey of the whole wing was out of the question is evident, for while these observations were in progress much other work was being done, some of which required the use of dynamo currents, while in one of the rooms a considerable magnetic disturbance arose from the presence on the floor above, of an iron stove in constant use for other investigations. With one exception this stove was the only mass of iron casually present whose effect it was not easy to eliminate by reversal or removal at the time of the observations.

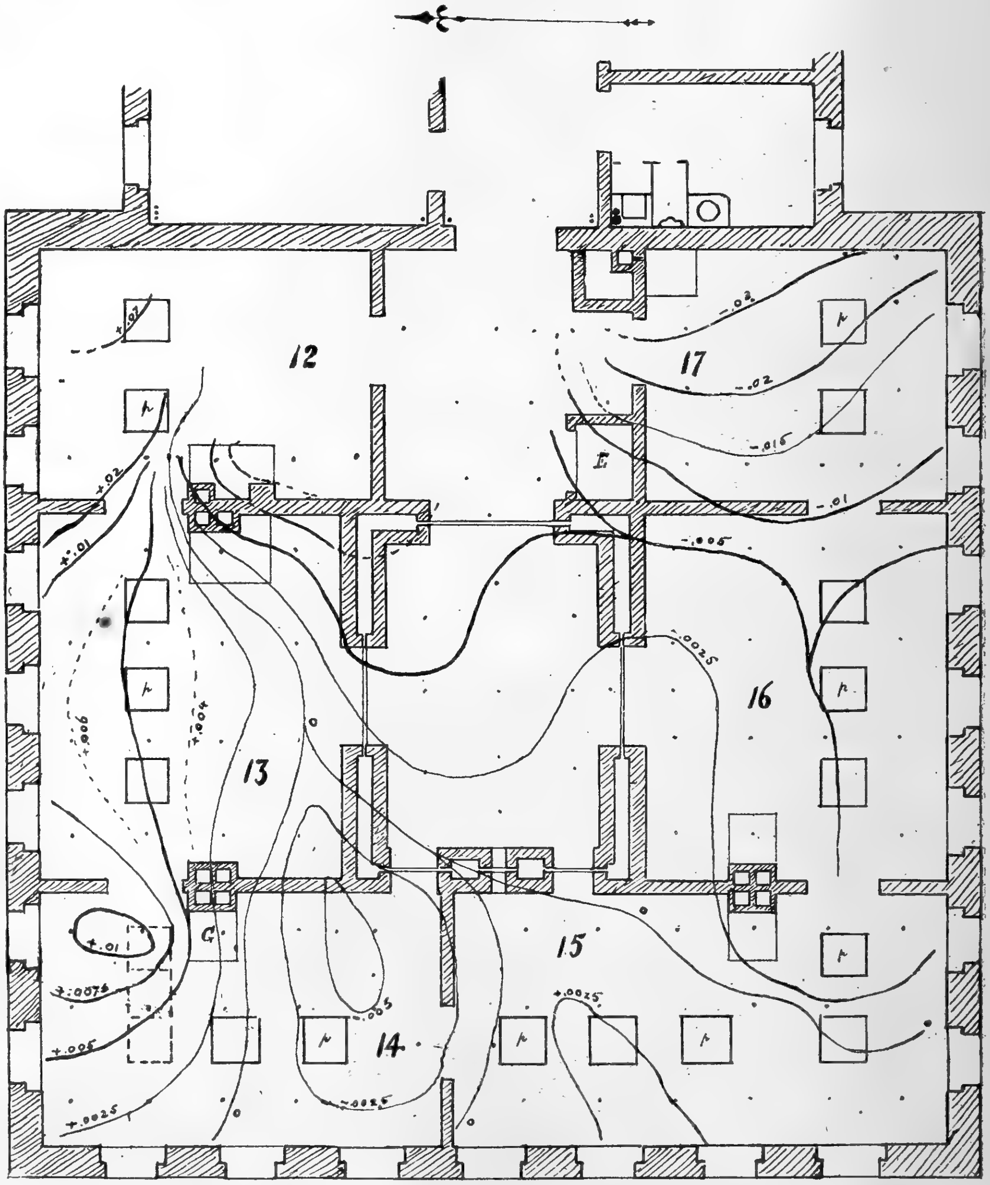


Fig. 1. Plan of west wing of the Jefferson Physical Laboratory, with lines of equal directive force in planes 5 ft. above first floor.

E, elevator.

G, point below iron stove on second floor.

p p p, piers.

When by the courtesy of Prof. Trowbridge and the Director of the Laboratory, Prof. Lovering, I obtained for a special research the use of one of the rooms of the non-magnetic wing (No. 17 on the plan fig. 1), it became necessary for me to investigate the variations of the magnetic field in different parts of the room. For this purpose I made use of the very convenient local variometer devised by Prof. F. Kohlrausch.*

A very few observations showed that the Horizontal Intensity H, acting upon a free magnet was quite variable as will be seen by reference to fig. 1 which shows a system of lines upon each of which the directive force is the same. The general form of the disturbance of the earth's uniform field pointed to a source of free north magnetism in the neighborhood of the N. E. corner of the room, and the stack of iron soil pipe shown at S, fig. 2 was examined and found to be inadequate to produce so great an effect as was observed. This is not surprising since, though of large size, it is made up of short lengths with leaded joints and acts as a series of separate magnets end to end. The neighboring iron steam pipes at C showed a far greater amount of free magnetism, enough indeed to account for the greater part of the disturbance noted.

Feeling desirous to know more of the extent of this effect I made a series of observations on each of the piers *p*, *p*, on the first floor establishing the fact that in the rooms 13, 14, 15 and 16 the greatest deviation of the Horizontal Intensity from its mean value was one half of one per cent. The differences were so large, however, that I determined to make a more extended set of observations, including about twenty-five points on the third floor and several in the basement. The result showed that besides the effect of the stove temporarily used in the room on the second floor over room No. 14, a considerable disturbance was perceptible even in those rooms farthest removed from all iron.

Further observations on the third floor were discontinued on account of the establishment there before the series was complete of the long iron beam which was at this time put in place for the work of Prof. Trowbridge on the spectra of metals.† The frequent changes of position of this beam gave rise to a variable disturbance which was of some magnitude on the third floor though fortunately very small below.

I then determined to make a careful survey of the first floor; the only part of the building in fact where measures are likely to be made which require great uniformity of field over large spaces. The results of this campaign are given in fig. 1; observations were made at the points indicated by dots, the plane of the instrument being five feet above the floor and two feet and three inches above the tops of the piers, this being assumed a sufficient distance to prevent any disturbance from the brickwork of the piers. The lines connect points at which the directive force is the same; at points on adjacent lines the force differs by one quarter of one per cent. of its whole amount,

* Wied. Ann., xix, p. 130, 1883.

† Proc. Am. Acad., 1888, p. 1.

the positive sign indicating excess over the normal value which is assumed to be that at the southwest corner of the building, being nearly the mean value for rooms 13–16 and differing by one fifth of one per cent from that in the tower sixty feet from the ground. The season of the year made it impracticable to make a satisfactory comparison with points out of doors.

It is obvious that, as was inferred from the first observations on the piers in rooms 13–16, over much more than nine tenths of these four rooms the greatest variation from the value assumed as normal did not exceed one half of one per cent. In room 12, however, the variations were so great that a complete survey was not attempted; the difference between the two piers for instance being four per cent. The disturbance in room 14 is such as would be produced by the iron stove on the second floor above the point G, if magnetized in the direction of the dip, about 60°. The symmetry of the disturbance in rooms 12 and 17 led to a closer examination of the steam pipes against the east side of the eastern wall forming the boundary of the non-magnetic wing of the building. Of these there are three groups. At A, B and C, fig. 2 are pairs of pipes reaching from the basement to the second floor, and at A is a third pipe reaching from the basement to the third floor.

The strength of the free north magnetism at a point five feet above the first floor was found to be such as to give at a distance of 10 feet a field of .025 H for C and .04 H each for A and B. To compute the effect of these pipes upon the directive force over the whole ground to be covered, seemed at first sight an undertaking of considerable magnitude, involving the determination of the distribution of magnetism not only throughout their whole extent, but also in that of the whole system of iron steam pipes in the basement and of a large radiator connected with A upon the third floor, and consisting of five parallel horizontal pipes each fifty feet in length. As a matter of curiosity, however, the following investigation was made.

Upon the platform of the elevator at E was placed a simple magnetometer read with mirror and scale, the readings of which as the elevator car was raised or lowered served directly to determine the difference of the magnetic declination at different points in the vertical line above E. These differences referred to a point 10 ft. above the first floor were as follows:

4 ft.	above	basement	floor,	3°·32 W.
9 "	"	"	"	3·00 W.
4 "	"	first	"	1·75 W.
10 "	"	"	"	0·00
4 "	"	second	"	1·18 E.
10 "	"	"	"	1·21 E.
4 "	"	third	"	1·81 E.

The distance between the floors is 12 feet, from the basement to the first floor 10 feet.

As it appeared therefore that the distribution of the free magnetism in the pipes,—if the sole cause of the differences of declination observed,—was such that its variation was not far from symmetrical above and below the plane of observation of

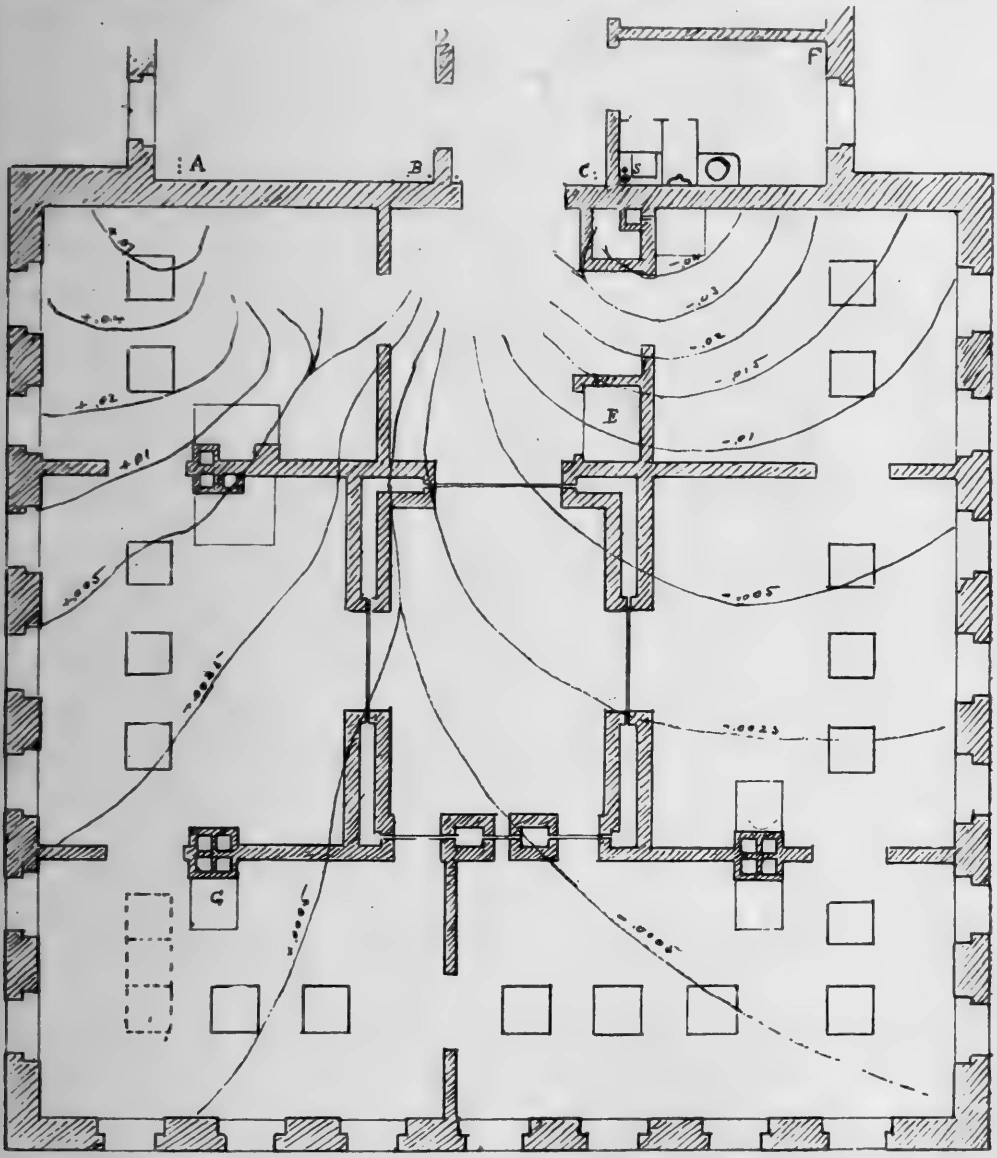


Fig. 2. Plan of west wing of Jefferson Physical Laboratory with lines showing disturbance of the earth's directive force, produced by steam pipes at A, B, C and F.

the Horizontal Intensity, I determined as a first approximation to compute the alteration which would be produced in the uniform field H throughout that plane by the free magnetism indicated by the direct observations upon the pipes, i. e. of three north poles five feet above A, B and C and of the strengths above determined.

Fig. 2 gives the results of this computation, the lines connecting points at which the effect of the pipes as computed on the above assumption is to increase the Horizontal Intensity by equal amounts. From this plotting the value of the disturbance at each of the various points of observation due to the

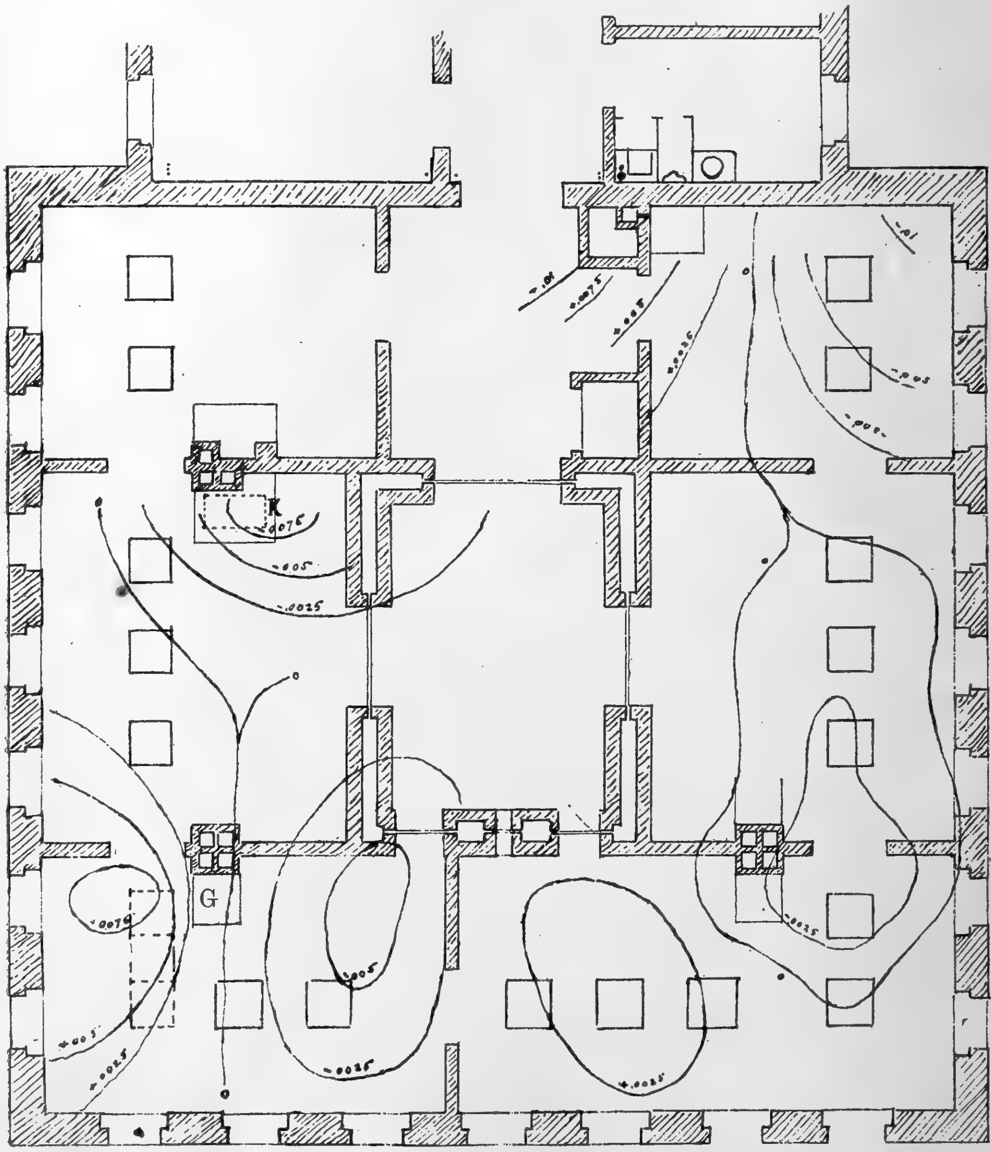


Fig. 3. Plan of west wing of Jefferson Physical Laboratory with lines showing disturbances of the earth's directive force, due to causes other than presence of steam pipes shown on Fig. 2.

G, point below iron stove on second floor.

K, point below iron base plate on second floor.

presence of the pipes was determined and subtracted from the corresponding observed values as shown on fig. 1. By the use of the numbers thus obtained a new system of lines of equal directive force was found which probably fairly represents the field as it would be but for the presence of the pipes; these lines are shown in fig. 3.

Here are clearly shown four distinct disturbances:—(1) That in the S. E. corner of the wing which was at once attributed to a pair of steam pipes at F, nine feet from the eastern wall of the wing and reaching from the basement to the third floor, which had been overlooked until pointed out by this system of lines. (2) That in the N. W. corner due to the stove above G as before described. (3) That in room 13, which might be produced by a horizontal magnet above or below the point K with its north pole directed toward the north. Search showed the probable cause in the presence on the second floor of a heavy iron table top four feet long, two feet wide and an inch thick, whose position is indicated in fig. 3. (4) A disturbance in rooms 15 and 16 which has not been traced to its source.

The foregoing account contains the substance of a paper read before the Mathematical Physical Club of Boston and Cambridge, May, 1887. I had hoped to extend the observations and especially to investigate the last mentioned disturbance in rooms 15 and 16. It is only within the last month, however, that I have again taken up the subject and have been able to show that the brick piers have a sufficient amount of free magnetism to produce the observed effect. These results I shall make the subject of a future paper; meanwhile the present writing will serve to show the magnitude of the disturbance which may arise in practice from such common objects as stoves and iron pipes.

Jefferson Physical Laboratory, Nov. 1889.

ART. XVI.—*On Cretaceous Plants from Martha's Vineyard;* by DAVID WHITE.*—With Plate II.

IT is remarkable that, although the existence of fossil vegetable remains on Martha's Vineyard has been on scientific record for nearly one hundred years, and the announcement, accompanied by several figures, of the occurrence of dicotyledonous leaves at Gay Head was made in the report of the State Geologist of Massachusetts over sixty years ago, no one has ever made a systematic study of the entombed plants, nor attempted to draw any evidence therefrom as to the age of the containing strata. No one seems ever to have searched there for plants with that object in view. The probable reason for this is the lack of importance which they had in the eyes of the State geologist, as well as the crude and indeterminate

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

illustrations of the six specimens that were figured. Certainly nothing has been added meanwhile to the knowledge of the matter gained a half century ago, and which may be summarized in the fact that fossil dicotyledonous plants existed at Gay Head.

As a result of a visit paid to Martha's Vineyard last summer, in company with Professor Lester F. Ward of the U. S. Geological Survey, by whose courtesy the material was referred to me for examination, I was so fortunate as to find a large number of specimens of plants, which, though generally rather poorly preserved, will perhaps furnish important aid in solving the vexed question as to the age of the underlying clays, lignites and sands of Martha's Vineyard. In order, however, that the facts about to be brought forward may take their true position and color in the perspective of evidence and previous opinions as to geological age, it will be well to make a brief review of preëxisting data and opinions.

As early as October, 1786, Samuel West, in "A Letter Concerning Gay Head,"* described the striking color effect and the disturbance of the strata, and noted the occurrence of fossil wood and bones; and Dr. William Baylies, who aided him, and whose letter follows† the other, agreed with Mr. West in regarding the upheaval of the cliffs as due to volcanic action. He found what he considered to be five or six craters, and observed the presence of whales' bones, sharks' teeth and petrified shell-fish. The island is not colored on Maclure's map, nor mentioned in his explanation.‡ In 1824, John Finch§ expressed the belief that the Gay Head clays, in common with the clays at Sand's Point on Long Island, Amboy in New Jersey, and those of Cape Sable, Florida, Alabama and Mississippi, were of the same age as the Alum Bay clays in the Isle of Wight. The same year, Edward Hitchcock, in some "Notices of the geology of Martha's Vineyard and the Elizabeth Islands,"‖ seemed inclined to consider the clays of Gay Head and the Chilmark Cliffs (he visited the latter only) as equivalent to the European Plastic Clay formation, and they were so colored on the accompanying map. The same volume¶ contains a review of Conybeare and Phillips' "Outlines of the Geology of England and Wales," in which the reviewer asserts the identity of the Plastic clays of Europe with those of Gay Head.

* Samuel West: dated Oct. 9, 1786, Mem. Am. Acad. Arts, Sci., vol. ii, 1793, p. 147–150.

† l. c., pp. 150–155.

‡ William Maclure: Observations on the geology of the United States, explanatory of a Geological Map, Trans. Am. Phil. Soc., vol. vi, pt. 2, 1809, pp. 411–428.

§ John Finch: Geological Essay on the Tertiary Formations in America, this Journal, vol. vii, 1825, pp. 31–43.

‖ l. c., pp. 240–248, pl. iv.

¶ l. c., pp. 203–240.

The report of the State geologist, published in 1832,* contains a map on which this region is colored and described as Tertiary. In the Report published in 1833,† which was accompanied by a map and atlas, the organic remains are discussed and figured, and a short description of the Gay Head cliffs is given. The same material, so far as it concerns Martha's Vineyard, is repeated in the "Final Report," of 1841,‡ with a more extended stratigraphical description, and a section of the cliffs. This is the most important contribution to the subject that appeared prior to Professor Shaler's work in 1889. From the similarity of the lithologic characters, and the evidence of the organic remains, the conclusion is reiterated and confirmed that the clays are Eocene, and equivalent to those of Europe. Dr. Hitchcock regarded many of the fossils, especially the bones, as having been rolled and broken, probably from re-deposition. A description of the strata, mammals, fishes, crustacea and mollusca was given in 1844 by Lyell,§ who saw no indications of the occurrence of Cretaceous strata in any fossils appearing to have been washed out from the Cretaceous to form the clays, which were judged by him to be Miocene. Save Professor H. D. Rogers' assent‖ to Sir Charles' conclusions, and Desor and Cabot's correlation of the clay at the base of Sankoty Head in Nantucket with those of Gay Head, which they regarded as representing the opposite side of a Miocene basin,¶ there seems to have been no further discussion of the subject till 1860, when Dr. William Stimpson announced the discovery, without giving descriptions, of new fossils, bones, mollusca, etc., which persuaded him that the strata were Cretaceous, rather than Eocene.** Three years later†† he added a description of *Archæoplax signifera*, a new genus and species of fossil crab, which,

* Edward Hitchcock: Report on the Geology of Massachusetts; examined . . . during . . 1830 and 1831, this Journal, vol. xxii, 1832, pp. 1–70. The same was published that year as the regular Report of the Survey, "pt. 1, Economic," and comprises pt. 1 of the Report for 1833.

† Report on the Geology, Mineralogy, Botany and Zoölogy of Massachusetts, etc., 1833, with map and atlas. (See pp. 172–204, pl. xi.)

‡ Final Report on the Geology of Massachusetts, vol. ii, 1841. (See pp. 422–434, pl. xix, liv.) The clays are mentioned in nearly every report which touches upon the economic geology of the State; only those in which their age is considered are here included.

§ Sir Charles Lyell: On the Tertiary Strata of the Island of Martha's Vineyard in Massachusetts, Proc. Geol. Soc. London, vol. iv, No. 92; this Journal, vol. xlvi, 1844, pp. 318–320.

‖ H. D. Rogers: Address before the American Assoc. Geol. and Nat., May, 1844, l. c. vol. xlvii, 1844, pp. 247–278.

¶ E. Desor and E. C. Cabot: On the Tertiary and more recent Deposits in the Island of Nantucket, Quart. Jour. Geol. Soc., London, vol. v, 1849, pp. 340–344, 2 figs.

** William Stimpson: Cretaceous Strata at Gay Head, this Journal, II, vol. xxix, 1860, p. 145.

†† On the Fossil Crab of Gay Head, Boston Jour. Nat. Hist., vol. vii, 1863, pp. 583–589, pl. xii.

from its distant relation to other fossil crabs, afforded but little aid in determining the geologic age of the terrane. However, for some reason not given he withdraws his statement as to their Cretaceous age. Dana, in his "Manual of Geology,"* adopts the view generally accepted that the beds were of the Yorktown (Miocene) Period.

Except the map prepared for the Centennial Commission,† in which the western end of the island is colored Miocene, and a notice of the opinion expressed before the New York Academy of Sciences by Professor Merrill,‡ in which he referred the Gay Head strata to the Post-Pliocene or Quaternary, nothing further seems to have appeared until the publication (1889) of Professor N. S. Shaler's excellent "Report on the Geology of Martha's Vineyard,"§ in which the stratigraphy of Gay Head is treated at length with full illustrations (p. 328–332, pl. xxvi–xxviii). There the series exposed at Gay Head received the name of "Vineyard Series." His conclusion (pp. 332, 333) is that this series "must be considered as belonging to one great division of the Tertiary deposits;" and when speaking of its outcrop at Indian Hill he says: "This part of the Tertiary series is certainly of later Miocene or Pliocene age." Professor Shaler makes no enumeration or discussion of the fossils, all paleontological data being left to a future report. More recently, in a short paper on some Cretaceous fossils,‖ which were obtained at several points in the drift on the more eastern portion of the island, and which seem to indicate a lower Cretaceous age, he points out the distinctions between their probable source and the Vineyard Series, reiterating his conclusion as to the Miocene or early Pliocene age of the latter, and adding that "a careful study of all the exposures on Martha's Vineyard containing Tertiary clays has failed to show any distinct fragment of Cretaceous rock."

It is obvious from the foregoing review that the prevailing opinion favors a Tertiary, probably Miocene, age for the "Vineyard Series," and the re-deposition of the Cretaceous invertebrates in the younger formation.

The material collected last summer was found at several localities and horizons in the Vineyard Series. The former include the Kaolin clays at Peaked Hill in the western part of the town of Chilmark, the carbonaceous clays at Nashaquitsa

* J. D. Dana: Manual of Geology, ed. 1864, pp. 510, 511; ed. 1875, pp. 494, 495; ed. 1880, p. 495.

† W. O. Crosby: Report on the Geological Map of Massachusetts, Boston, 1876.

‡ F. J. H. Merrill: Geological Structure and Age of the deposits at Gay Head, Mass., Trans. N. Y. Acad. Sci., vol. iv, 1885, p. 79.

§ Seventh Ann. Rept. U. S. Geol. Survey, pp. 297–363, pl. xix–xxix.

‖ On the occurrence of fossils of the Cretaceous Age on the Island of Martha's Vineyard, Mass., Bull. Mus. Comp. Zoöl. Harvard Coll, vol. xvi, No. 5, 1889, pp. 89–97, pl. i, ii.

Cliffs on the south shore of the same town, and various points in the promontory of Gay Head. Fossil wood, more or less lignitized, is found wherever the series is met with. This promontory, about one hundred and forty feet in height, and five eighths of a mile in length, is the typical section of the Vineyard Series. Here remains of dicotyledons were found in the lignitic clays and sands of the south face, the gray and reddish clays and the limonite and the lignites on the west, and the carbonaceous clays on the northwest face of the cliffs.

The greater part and the best of the specimens were obtained (1) from argillaceous concretions in the lignites and carbonaceous clays, (2) from the clay and clay-ironstone concretions in the reddish and gray clays, and (3) rarely from the concretions and the limonite matrix of the ferruginous conglomerates on the western escarpment. Some fine specimens were procured from concretions in an arenaceous lignitic clay at Nashaquitsa. Those plants found in the soft clay matrix on the northwest and south shores of Gay Head, at Peaked Hill, and at Nashaquitsa, though in rare instances determinable, soon became worthless upon exposure to the air.

The plant collection embraces Cryptogams, Conifers, Monocotyledons and Dicotyledons. Numerous fruits were obtained. The aspect of the flora, as a whole, seems pre-Tertiary. Many of the dicotyledons appear to represent archaic types, and the greater part are unlike any that have yet been described.

It is my purpose in this preliminary paper to select from those specimens thus far identified a few which are the most characteristic, and which have probably been described from other localities or formations. They are as follows:

Sphenopteris grevillioides Hr.
Sequoia ambigua Hr.
Andromeda Parlatorii Hr.
Myrsine borealis Hr.
Liriodendron simplex Newb.
(*L. Meekii* Hr., in part.)
Eucalyptus Geinitzi Hr.
Sapindus cf. *Morrisoni* Lx.

Of these species, *Sphenopteris grevillioides* Hr. was found in the Kome beds (Lower Cretaceous) of Greenland. The specimen figured, Pl. II, fig. 1, agrees well with Heer's description, while other fragments in the collection, probably from lower pinnæ, show the entire margins figured by Heer.

Sequoia ambigua Hr., Pl. II, fig. 2, 3, has been found in the Kome beds, and in the lower Atane beds (Middle Cretaceous) of Greenland.

Andromeda Parlatorii Hr., Pl. II, fig. 4, has been reported from the Dakota group (Middle Cretaceous) of Kansas and Nebraska; from the Lower Atane beds of Greenland; and from strata of unsettled age, but probably Cretaceous, from Las Animas, Colorado, and the Bozeman mines of Montana. Though the specimen figured is only the lower half of the leaf, it corresponds precisely with Heer's original description, including the transverse striations of the midrib, while the areolation is like that given by Lesquereux in his Cretaceous Flora, pl. xxiii, fig. 6.

Myrsine borealis Hr., Pl. II, fig. 5, was described by Heer from the Liriodendron bed (Lower Atane) of Greenland.

Liriodendron simplex, Pl. II, fig. 7, was described by Newberry (Bull. Torrey Bot. Club, vol. xiv, 1887, p. 6, pl. lxii, fig. 2–4) from the Amboy clays (Middle Cretaceous) of New Jersey and Long Island. Dr. Newberry considers the forms from Greenland identified by Heer as *L. Meekii*, *Leguminosites Marcouanus* and *Phyllites obcordatus*, as the Amboy species. But whether the Greenland forms of *L. Meekii* are identical with *L. simplex*, or whether the latter is a Liriodendron at all, are questions which cannot be discussed here, nor do they greatly affect the geological relations of our flora. The Amboy clay *L. simplex* is identical with the form which is by far most abundant in the Gay Head flora. The leaf represented in fig. 6 agrees with the Greenland *L. Meekii* Hr., which is so abundant and characteristic of a horizon in the Lower Atane strata that that part is commonly known as the "Liriodendron bed." Fig. 6 coincides most nearly with Heer's specimen from the Patoot beds (Upper Cretaceous) of Greenland. It is somewhat doubtful whether Heer's original specimens or his synonyms from the Dakota group of Nebraska are the same species as his Greenland specimens. It is notable that Lesquereux regarded *L. Meekii*, *Leguminosites Marcouanus* and *Phyllites obcordatus* from Greenland as belonging to *L. primævum* of Newberry, from the Dakota group. Either relation is quite possible, especially in view of the known variation in the leaves of a single species, or even tree, of Liriodendron.

Next to the preceding species, the most numerous of the plants from Gay Head is *Eucalyptus Geinitzi* Hr., fig. 8–11, two of whose fruits, "resembling unopened flowers of syngenesian plants," were figured as "scales of vegetable remains" in Hitchcock's Final Report. This species, first described from the Liriodendron beds (Middle Cretaceous) of Greenland, is abundant in and most characteristic of the Middle Cretaceous of Bohemia, and is also present in the same stage (Cenomanian) in Moravia. The specimen, fig. 11, is included here on account of its coincidence with one figured by Velenovsky (Foss. Fl. böhm. Kreide., iv, pl. xxv, fig. 7), which he supposed represented a flower of this species. It may belong to a conifer.

The remains of the nuts show longitudinal furrows (white in the figures) filled with a resin which is "indistinguishable by ordinary tests from Amber," and which was observed and pronounced amber by Hitchcock in 1841. These doubtless are the remains of gum or oil vessels, such as exist in the nuts of recent Eucalypts; and the granules of "amber" can hardly be else than Eucalyptus gum.

The explanation is at once suggested that the fragments of amber observed by various writers, during the last hundred years, about Gay Head, and in the New Jersey Cretaceous, where also Eucalypts are found, are the product of the contemporaneous "gum-trees," rather than of some conifer. None of this American amber has, I believe, been tested for succinic acid, or to show its relation to true amber.

Although the tertiary nervation of the figured specimen of *Sapindus*, fig. 12, is wanting, I have little doubt, after comparing it with the figures by Lesquereux and Heer, that it is referable to *S. Morrisoni* Lx., from the Dakota group of Nebraska, Lower Atane beds (Middle Cretaceous), and from the Patoot beds (Upper Cretaceous) of Greenland.

As was remarked above, a large part of the Gay Head species seems to be as yet undescribed. Of the remainder, all the identified species are found in the Cretaceous, and all but *Sphenopteris grevillioides* Hr. were present in the Middle Cretaceous. The relation of the Gay Head flora with that of the Middle Cretaceous (Cenomanian) of Greenland seems nearer than that with the flora of the Dakota group. There is, however, every reason for believing that it will be found to be very largely identical with the flora of the Amboy clays, from which, unfortunately, only six species have as yet been published. It is hoped that Dr Newberry's forthcoming monograph of that rich flora will soon appear.

The evidence, then, of the fossil plants bespeaks an age that is decidedly Cretaceous, and probably Middle Cretaceous, for the terrane in which they were deposited.

The question which was raised in the case of the Cretaceous invertebrates will doubtless be repeated as to the plants, viz: whether the immediate matrix in which the plants are found is not either transported and re-imbedded rock, rather than of the nature of true concretions; or whether, supposing the concretions to be genuine, they may not have existed as such in the older formations whence that part of the Gay Head sediment was derived. The circumstances which unite to prove that the plants lie in their original matrix and terrane are as follows: The plant-bearing concretions, which are generally more or less lenticular or oblong-lenticular, sometimes geodic or columnar within, show, often clearly, the concentricity of their structure. In many cases they are formed about a stem-fragment of quite large size. Some are concreted about balls of clay or sand. The leaves, which are often thickly matted, may occur in any zone, and are usually parallel to the longer axes of the concretions. Those found in the thicker lignites seldo . anything determinable, a large portion of the material consisting of woody debris more or less pyritized. They do not show such erosion or abrasion as would be expected had they been transported. Pyritic nodules are still forming in many of the strata. Both at Gay Head and at Nashaquitsa, in the carbonaceous clays, nodules were observed by Professor Ward, who made a review of the ground with me, and myself apparently in process of formation, the margins and outer layers presenting all the stages of transition from the center of the concretion to the general matrix of somewhat sandy carbonaceous clay, which composed the strata. The planes of the nodules are parallel to those of the stratification. We also observed, especially at the latter locality, some cases in which the leaves lay partly within the hard part of the concretion, extending through the intermediate transition material. The plants found in the clays themselves were most difficult to handle and extremely perishable so that none could be preserved; but such comparisons of those that were determinable as could be made on the spot pointed to the identity of the species. Many of the nuts of the Eucalyptus and other fruits, with fragments of stems of various plants were found in the limonitic matrix of the ferruginous conglomerate. This matrix can hardly be regarded as transported.

Similar plant-bearing nodules have been reported by Professor N. L. Britton from the Amboy Clays on Staten Island, and along the Raritan River in New Jersey.* The extension of these New Jersey Cretaceous Clays to the eastward, first pointed out by Mather, is now generally accepted,† Glen Cove on the northern shore being the farthest point yet determined.

If the Vineyard Series does not represent a farther continuation of this Cretaceous, I anticipate that it will be found to have been derived in part from such an extension to the southward of New England.

Against the evidence of the Tertiary elements in the fauna at Gay Head, as that evidence is understood, the presence of a Cretaceous flora cannot be said to furnish conclusive proof as to the age of the Vineyard Series. The present paper is but preliminary. There is need of further and more thorough work in all branches of the paleontology of this series before we shall be able to know its age, whether a large part of the

* Trans. N. Y. Acad. Sci., vol. viii, No. 7, 8, 1889, pp. 177–181.

† W. W. Mather: Rept. 1st Dist. N. Y., 1838, pp. 136, 137; Rept. 1843, pp. 272–742. Hitchcock and Blake: Geol. Map U. S., in the 9th Census, vol. iii. J. D. Dana: this Journal, III, vol. vi, pp. 64–66, 305. C. H. Hitchcock: Proc. A. A. A. S., vol. xxii, pp. 131, 132. Britton: Ann. N. Y. Acad. Sci., vol. ii, pp. 161–182. Trans. N. Y. Acad. Sci., vol. i, pp. 56–58; Trans. vol. iii, pp. 30, 31. F. J. H. Merrill: Ann. N. Y. Acad. Sci., vol. iii, pp. 341–364, pl. xxvii, xxviii.

organic remains have been transported since their first deposition, and, if they have, whence this portion was derived.

U. S. Geol. Survey, November, 1889.

EXPLANATION OF PLATE II.

(Specimens from Gay Head.)

Fig. 1. *Sphenopteris grevillioides* Hr.
Fig. 2, 3. *Sequoia ambigua* Hr.
Fig. 4. *Andromeda Parlatorii* Hr.
Fig. 5. *Myrsine borealis* Hr.
Fig. 6, 7. *Liriodendron simplex* Newb.
Fig. 8. *Eucalyptus Geinitzi* Hr.
Fig. 9. *Eucalyptus Geinitzi*, nut.
Fig. 10. *Eucalyptus Geinitzi*, nut with operculum.
Fig. 11. *Eucalyptus Geinitzi*, flower?
Fig. 12. *Sapindus* cf. *Morrisoni* Lx.

ART. XVII.—*A Review of Dr. R. W. Ells's Second Report on the Geology of a Portion of the Province of Quebec;* with Additional Notes on the "Quebec Group";* by CHARLES D. WALCOTT.

To the geologist interested in the problems presented by the study of the Lower Paleozoic rocks any new data bearing on the geology of the area embraced in the eastern townships of Canada is welcome. It is the region in which Sir William E. Logan worked so long and arduously when building up the "Quebec Group;" also, at a later date, when endeavoring to obtain evidence to sustain his view, that the crystalline rocks were the altered equivalents of the strata referred to the Sillery division of the "Quebec Group." It is the battle ground, where Logan and his adherents have been gradually driven from position to position until, now, there is little left to defend of what seemed in 1863 a well supported position.

The student will find in Dr. Ells's report a careful and detailed description of the geology of the area surveyed and a valuable discussion of the perplexing problem of the "Quebec Group." Not a theoretic discussion, but a discussion based on a careful consideration of the work of those who preceded him in the field, and a thorough study of the typical area in which the "Quebec Group" was first established by Sir William E. Logan and his assistants.

The report, taken in connection with that issued in 1887, sums up the work of the resurvey of the region with the exception of certain areas in the vicinity of Lake Memphrema-

* Geol. and Nat. Hist. Survey Canada, Report for 1887, pt. K, pp. 1–114, Printed in 1889.

gog, and on the western slopes of the Sutton Mountain range, or the northward extension of the Green Mountains of Vermont.

The description of the asbestus mines is continued from the first report,* and a map of the asbestus-producing area accompanies it. A large map of the area surveyed has been prepared and will be published on the completion of the survey of the Laurentian rocks occurring on the north end of the area covered by the N.E. quarter-sheet map of the Province of Quebec.

The area reported upon includes the counties of Megantic, Dorchester, Bellechasse, Levis, Montmagny, and l'Islet and the south line of Quebec or the country to the south and southeast of the city of Quebec and along the St Lawrence river from the Jacques Cartier river, above the city, to Cape Tourmente, below. The group of islands between Quebec and a point opposite St. Thomas were also surveyed, from Orleans Island to Cranes Island, inclusive. The several geologic systems, recognized in this area, include the Devonian, Silurian, Cambro-Silurian (Ordovician), Cambrian, and pre-Cambrian.

Devonian.—The Devonian rocks occur in an outcrop of fossiliferous limestone, which is found on the north bank of the Chaudière river, about midway between the Famine river and the village of St. George. Farther to the northeast, on the road leading to Ste. Justine, a very limited exposure of similar fossiliferous limestone occurs. The breadth of this outcrop is not more than twelve to sixteen feet, and is about the same in length. The outcrop on the Chaudiere river is also of very limited extent. These are the only areas of rock which may be said to belong to the Devonian system that are known to occur anywhere in the area under consideration. Dr. Ells states that the exposures resemble patches of strata which have escaped denudation. A list of thirty species of fossils is given from the Chaudiere locality. (pp. 10K, 11K.)

No rocks that could definitely be pronounced of Silurian age were seen in the area. Some red shales were assumed to represent some portion of the Silurian system. Owing to the character and variety of the exposures, the extent of the areas occupied by these rocks was largely conjectural.†

Cambro-Silurian (Ordovician).—The formations pertaining

* Loc. cit.; Ann. Rep. for 1886, pt. J, pp. 15J–70J. Printed in 1887.

† The Silurian rocks, described in the First Report, pp. 7J–14J, includes a small area at the narrows of Lake St. Francis, a large area stretching southwest from Lake Aylmer to Stoke mountain, and a small area in the township of Stoke, west of Stoke mountain. Silurian fossils occur at a number of localities in the limestones. A comparison of these areas, as shown on the map accompanying the report, with the areas colored Silurian, in Logan's Geological Map of Canada, 1864, shows that the latter included large areas of strata referred to the Lower Silurian or Ordovician by Dr. Ells.

to this system, found south of the St. Lawrence river, range from the Hudson, downward, to the Cambrian. The region in which they occur is divided into an eastern and western area; the former including the rocks that occur between the central Archæan anticlinal, or the northward extension of the Green mountains, and the United States boundary, and the latter, the strata situated between the Archæan anticlinal and the St. Lawrence river. The eastern area is the prolongation to the northeast of the great area of Cambro-Silurian rocks, which lies between the Stoke Mountain range and the Cambrian rocks of Lake Megantic and vicinity.* They consist largely of dark gray and blackish, sometimes plumbaginous slates, with grayish sandstones; the former sometimes ochre-spotted and displaying, on weathered surfaces, a characteristic striped or banded aspect. Calcareous rocks are, as a rule, absent, although they have been seen on the upper Chaudiere river.

The western area of the Cambro-Silurian rocks, or those in the vicinity of the St. Lawrence river, present, at several places, many features differing from those of the eastern area. Dr. Ells considers that the formations are, for the most part, presumably of a later age, as indicated by the fossils. At St. Nicholas, fourteen miles above Levis, the contact between the shales and sandstones of the Hudson, and the red, green, and black shales of the Cambrian Sillery terrane is shown on the river beach, near the cliff. The Hudson sandstones contain graptolites and mollusks characteristic of that zone.

The Utica-Trenton outcrop extends nearly three miles and a half, where it is cut off by a line of fault. At Pointe au Platon highly bituminous, brownish gray shales represent the only typical Utica rocks seen on the south side of the river, in this direction The Levis rocks, occurring about Levis, will be spoken of in describing the "Quebec Group."

The strata on the north shore of the St. Lawrence have already been described in the Geology of Canada, 1863. Dr. Ells has added many details and, also, given lists of the fossils occurring in the Trenton, Utica and Hudson terranes.

Dr. Ells made a careful study of the rocks of the Montmorenci Falls, eight miles below Quebec. He decides, from the evidence of the fossils and from the character of the sediments that the conclusions stated by Sir William Logan, in 1863 (Geology of Canada), as to the structure at this place, and subsequently, by Dr. Selwyn, in sundry papers, are clearly maintained. In company with Drs. Selwyn and Ells I carefully studied the geology of Montmorenci Falls and vicinity, in August, 1889, and I fully concur with them in the view that

* See First Report, 14J–23J.

the Trenton limestone rests unconformably upon the Archæan gneiss that forms the bed of the river, at the Falls; and that a fault has carried the Trenton limestone and superjacent Utica shale downward on the east, a short distance northeast of the Falls. The upturned Trenton limestone and Utica shale, forming the bluff between the Falls and the St. Lawrence river, contain characteristic Trenton and Utica fossils. For further details the reader is referred to Dr. Ells's report, pp. 22K–25K.

Cambrian.—The rocks which are regarded as constituting the Cambrian system of eastern Quebec are the extension, to the northeast, of those described by Dr. Selwyn, in the reports of the Geological Survey of Canada for 1886 and 1887. They consist for the most part of hard quartzites interstratified with purple, greenish, and black slates. Limited outcrops of grayish subcrystalline limestone are found occasionally in the townships of Mailloux, Buckland and West Broughton. They are associated with black slates and quartzites. Dr. Ells has also referred the trappean rocks of Broughton and Moose mountains, also certain associated serpentines, to the Cambrian. North of Chaudiere river, the western boundary of the "Lower Cambrian" is said to be unconformably overlapped by the Sillery red slates, conglomerates, and sandstones, the contact of the two sets of rocks being near the village of St. Claire. It is not improbable that some of the strata referred to the Lower Cambrian by Dr. Ells may prove to belong to that system of rocks; but in the absence of fossils it is very difficult to say whether the strata under consideration should be referred to the Cambrian or to some pre-Cambrian series of rocks. From the occurrence of Lower Cambrian fossils (Olenellus fauna), in grayish limestone, interbedded with purple, green and black slates, in Washington County, N. Y., where the rocks containing them occupy a similar stratigraphic position to those under consideration, it is not improbable that a similar fauna will be discovered in the Canadian section. Dr. Ells thinks that a part of the strata referred to the older Cambrian resembles, in many respects, those of the coast series of Nova Scotia, while in part they resemble the lower portion of the Cambrian of New Brunswick. Stratigraphically they occupy a position between the chloritic and micaceous schists of the Archæan and the superjacent strata of the Sillery (page 87K). (See First Report, pp. 23J–29J, for an excellent description of the character of the rocks referred to the Cambrian.)

The Cambrian strata of the Sillery terrane will be noticed under the description of the "Quebec Group."

Quebec Group.—An excellent historical review is given of the literature pertaining to the "Quebec Group," from the first notice of the rocks in the vicinity of Quebec, in 1827, by Dr. J. Bigsby, to Professor Jules Marcou's essay in 1888. From the study of the literature and of all the original area of the "Quebec Group," including the mapping of the entire area, Dr. Ells concludes that:

"The name 'Quebec Group,' which has for so many years been applied to much of the rocks of this portion of the province of Quebec, has become so misleading and unintelligible in view of the many new facts brought to light concerning its composition and structure, by the study of the past fifteen years and the many changes rendered necessary in consequence, that its further use appears not only undesirable but to a certain extent objectionable. It was applied by Sir W. Logan to a great series of sediments which were deemed to lie somewhere about the horizon of the Calciferous and Chazy formations. Dr. Selwyn and others have, however, since 1876, pointed out that it has been found to embrace rocks ranging from the Pre-Cambrian to the Hudson River or Lorraine, both inclusive. An almost entirely new arrangement of the different formations which make up the group is therefore imperative. In the case of such portions of the original group, the horizon of which has been definitely determined, the proper name of the formation can be readily applied, while in the case of such portions, either distinctly fossiliferous, or closely related areas the exact position of which in the Geological scale may be doubtful, the terms Levis or Sillery, with their system classification, may be retained" (p. 6K).

The author then proceeds to give, after the brief historical sketch, a description of the rocks referred to the "Quebec Group" by Sir Wm. E. Logan.

In the historical review it is stated that the first notice of the rocks of the "Quebec Group" by Sir William Logan, was published in 1845. He then expressed the view that "the rocks on Point Levis come out from beneath the limestone of the St. Lawrence, and belong to an apparently older horizon;" but in a foot note it is stated: "The bulk of evidence points to their superior position, which would make them the equivalents of the Hudson River and Lorraine shale formation."

In the report of progress for 1849, it is stated "that another formation, contemporaneous with the Hudson River of New York, superior to the Trenton limestone, but also far beneath the same Carboniferous deposits, extended from Point Levis to Cape Rosier."

In the Esquisse Géologique of 1855, by Logan and Hunt, the rocks which form the cliffs of Quebec and Point Levis are referred to the Hudson River group, and the series of sandstones and shales, named the Sillery group, are considered equivalent to the Shawangunk or Oneida conglomerate of the New York section.

Mr. Billings's study of the fossils collected from the Point Levis beds proved that the rocks at Point Levis were far below the Hudson River group, and Pre-Trenton in age. These conclusions were first announced by Logan in 1860, and, subsequently, in March, 1861, when the opinion was expressed that "this series of rocks, to which the name 'Quebec Group' is now applied for the first time, represents a great development of strata about tne horizon of the Chazy and Calciferous." With the paleontologic proof of the age of the rocks the history of the "Quebec Group" assumed a new aspect. The five divisions of the grauwacke series of 1849 were divided into two portions, the first four of which were united to form the "Levis" formation, while the last was called the "Sillery." The former was subdivided into seventeen parts, having a total supposed thickness of 5,025 feet, at the summit of which was placed the series of greenish sandstones and red and green shales of the "Sillery," which was given a total thickness of 2,000 feet.

In the Geology of Canada, for 1863, pp. 225–297, Logan gives with great detail his views of the structure and stratigraphical position of the several rock formations, which he referred to the "Quebec Group." The group was then divided into the "Levis" and "Sillery" formations, and referred to about the age of the Chazy and Calciferous formations. (Geol. Canada, 1863, p. 233.)

Subsequently (Rep. Prog. 1866, p. 4) Logan divided the "Quebec Group" into three parts—the "Levis" or lower, "Lauzon" or middle, and "Sillery" or upper.

The "Levis" or lower division was distinguished by its general dark and black color and the presence of numerous graptolites and Calciferous-Chazy fossils. The "Lauzon" or middle division embraced the red, green and purple shales of the section above and below Quebec and on the Island of Orleans. The only fossils known were *Obolella pretiosa* and fragments of Lingula. To the "Sillery" or upper division he referred the sandstones and accompanying shales of the original Sillery, with the exception of those separated to form the Lauzon. The strata were unfossiliferous, as far as known. The dark shales, upon which the city of Quebec is built, were referred to the "Levis" and the series of strata referred to the "Levis," "Lauzon" and "Sillery" formed the typical "Quebec Group," in the vicinity of the city of Quebec.

As far back as 1848, Logan held the view that the metamorphic rocks of the eastern townships of Quebec, or the rocks of the Green Mountains of Vermont, in their prolongation into Canada, were altered Hudson River Group strata, with the possible addition of the Shawangunk comglomerates.

In the Report of Progress for 1849, the entire Quebec series of strata were described, and these rocks, in a highly metamorphic condition, were also stated to constitute the mountain belt; and the entire mass of supposed altered and unaltered rocks were referred to the Lower Silurian System.

When the Quebec Group was established in 1861, the great area of crystalline schists and associated rocks of the mountain portion of Quebec were regarded as the metamorphic equivalents of the fossiliferous rocks of the vicinity of Quebec, and hence a portion of the Quebec Group. The Sutton Mountain range, or the Canadian extension of the Green Mountains, was supposed to represent a portion, if not the whole, of the Sillery formation. To the southwest, the Quebec Group was made to include the Phillipsburgh limestones and certain supposed superjacent conglomerates. To the east, in Newfoundland, a great thicknesss of fossiliferous strata were correlated with the Point Levis and Sillery sections.

From the comparison of the fossils occurring in the Point Levis series with those from the Phillipsburgh limestones, Billings concluded that limestone No. 2, of the Point Levis series, was the equivalent of limestone No. 2, of the Phillipsburgh section. Dr. Ells calls attention to the fact that limestone No. 2, of the Levis section, was formed of beds of conglomerate, and could not be relied upon for the determination of the exact stratigraphic position of the zone in the Phillipsburgh section. In summing up all the evidence in relation to the position of the Levis rocks, Dr. Ells says: "It will be seen from all the evidence adduced from so many sources that the true position of the Levis was very conclusively established, both on paleontological and stratigraphical grounds, as distinctly newer than the Calciferous, and this conclusion has been sustained by the most recent examination."

Such is a brief outline sketch of Dr. Ells's historical review of the "Quebec Group" to the year 1868. It is the history of the theoretic evolution of a group of strata based largely upon lithologic resemblances and structural geology.

We have next to consider the breaking down of this elaborately constructed geologic group, built up by the labors of Sir Wm. E. Logan and his associates, Mr. E. Billings, Dr. T. S. Hunt and Mr. James Richardson.

Dr. A. R. C. Selwyn began the work of disintegration in the Report of Progress, 1877–'78, pp. 3A–9A, where he shows that the rocks of the Canadian extension of the Green Mountain range, or the Sutton Mountain range and its northeasterly extension, were arranged in an anticlinal, instead of a synclinal form, as supposed by Logan. This removed the keystone upon which the stratigraphic structure of the altered portions of the Quebec Group was based and with it went the Crystalline Schist Group and the Volcanic Group. The former was referred to a pre-Cambrian Group, probably the Huronian; and the latter, to the Lower Cambrian. "Another source of error, and possibly the most considerable," says Dr. Ells, p. 43K, "was the assumption that the metamorphic rocks of that area must of necessity be the equivalent of the unaltered sediments of the St. Lawrence region, a theory which once suggested, seems to have been unhesitatingly maintained, although for its support, unnecessary inversions of strata, and profound chemical changes were requisite." Dr. Selwyn also pointed out the fact that sandstones, widely differing in age, had been grouped under the Sillery series, and that the rocks of the city of Quebec were cut off from the Lauzon red and green slates by a fault and were not a portion of the Point Levis series.

Dr. Selwyn followed up his first paper with descriptive notes, in 1882,* and a more popular article later in 1882.† A still more recent paper sums up the results of the study of the fossiliferous portion of the original Quebec Group.‡ He here states that no less than four distinct horizons can be recognized, each of which is marked by a coarse band of conglomerate. Three of these bands, numbers 2, 3 and 4, are fossiliferous limestone conglomerate, while one, number 1, is chiefly feldspathic and dioritic, is non-fossiliferous and generally presents the appearance of a volcanic agglomerate or breccia, which he considers pre Cambrian. Number 2 is in the Sillery shales and is of Cambrian age, and contains exclusively a fauna of Cambrian type. Number 3 is the celebrated Point Levis conglomerate, and contains a pre-Cambriam and Lower Cambro-Silurian fauna, while the fauna of the associated shaly bed is exclusively Lower Cambro-Silurian (Ordovician). Number 4 is the Citadel Hill conglomerate of the city of Quebec; the fauna is mixed, but it is chiefly of Trenton-Hudson age, as is that of the associated shales. The mineralogical and lithological characters of the four groups are markedly different, as are the paleontological features.

Dr. Selwyn describes the structural geology, recognizing the great fault and its branches, which have broken up the formations in the vicinity of Quebec, and, also, the folds on the Point Levis side which Sir William Logan mapped so carefully in his study of the geology of this region.

Dr. Ells's careful survey and mapping of the area embracing the typical strata of the "Quebec Group," has demonstrated

* Rep. Prog. Geol. Survey Canada, 1880–'81–'82.
† The Quebec Group Geology, Trans. Roy. Soc. Canada.
‡ Science, vol. ix, p. 267, 1887.

the correctness of the views advanced by Dr. Selwyn and has also added materially to our own knowledge of the geologic structure and stratigraphic succession of the beds forming the unaltered series of the "Quebec Group." He has shown that the order of succession of the strata was inverted by Logan, and that the Levis series is conformably superjacent to the Upper Sillery (Lauzon of Logan), and that the Lower Sillery forms the base of the section in the vicinity of Quebec.

The study of the relations of the Levis to the Sillery, at Levis, is a beautiful piece of stratigraphic geology and a most careful and conscientious work. I accompanied Dr. Ells over the area, in August, 1889, and fully concurred with him in his views of the structure. The surface outcrops are essentially as mapped by Sir Wm. E. Logan, in 1863. The radical difference between the interpretation of the latter and Dr. Ells is that Dr. Ells places the red Sillery strata below the Levis and not above, as was done by Logan. Dr. Ells recognizes four anticlinal axes, two of which, at least, are completely overturned. One of these is so well shown that I obtained a very good photograph of it, on the road leading up the cliff, 300 yards south of the lower ferry at Levis. Beneath the Levis strata the red shales of the Sillery are shown, and the synclinals of Levis strata rest in the red shales of the Sillery. The tracing of the anticlinals and synclinals was by means of the stratification and the occurrence of the sub-faunas in the graptolitic shales of the Levis terrane. On the eastern margin of the Levis beds an overturned synclinal has placed the red shales of the Upper Sillery upon the graptolitic shales of the Levis. In the upper beds of the Sillery a few graptolites and brachiopods indicate the intimate paleontologic relations of the upper portion of the red Sillery shales with the dark graptolitic shales of the Levis terrane. A list of the graptolites at each locality is given by Dr. Ells, with a discussion of the stratigraphic relations of the several fossiliferous zones.

The strata of the city of Quebec were referred to the Levis series by Logan and to the pre-Potsdam Taconic by Jules Marcou. Dr. Ells gives a list of forty species of fossils, obtained from the shales and interbedded dark limestone, that were collected by Messrs. Giroux and Ami, and determined by Mr. H. M. Ami. The fauna is essentially Middle Ordovician or Trenton-Utica, and proves conclusively that the Quebec city strata are neither Levis, nor pre-Potsdam. Prof. Lapworth thinks that the graptolites indicate the Lower Trenton, and Mr. Ami considers the *Monticuliporoids* to be of Lower Trenton age.

The limestone conglomerates of the "Quebec Group" have been a fruitful source of confusion since they were described by Logan in 1863, in connection with the lists of fossils determined from them by Mr. Billings. According to Logan, the conglomerate in the Sillery series was the highest of the conglomerate beds; the fossils in its bowlders were not described. The Levis conglomerates were interbedded with the graptolitic shales, and contained fossils in the matrix and also in the bowlders imbedded in the matrix or paste. Mr. Billings identified the fossils, but did not distinguish between those found in the paste and those obtained from the bowlders. This led to a mixing up of the Upper Cambrian and Lower Ordovician faunas, such as is unknown elsewhere. Mr. Billings never felt assured that the fossils occurred *in situ* in the paste or matrix of the conglomerate, and hence he correlated the Levis beds with the upper or Chazy zone of the Phillipsburgh section, under the name of Upper Calciferous, instead of with the central or true Calciferous strata of the Phillipsburgh section. The conglomerates of the Quebec city rocks were not known to contain fossils when described by Logan.

Dr. Ells describes three zones of limestone conglomerates (p. 83K). 1st. Those of the Upper Sillery interbedded in the green, black and reddish or purple shales; 2d, those of the Levis series, and 3d, those of the city of Quebec. The first or lower zone contains the Olenellus or Lower Cambrian fauna; the second, Potsdam and Calciferous fauna, and the third, the Lower? Trenton fauna. In the first no fossils have been found in the paste or matrix. In the second Dr. Ells quotes Mr. Billings as follows: "All the specimens described in this article were found in the conglomerate limestones near Point Levis, opposite Quebec. It is not yet decided whether the fossils occur in the bowlders of the conglomerate or in the matrix." In the succeeding paragraph Sir Wm. E. Logan is quoted as saying: "I am satisfied, notwithstanding the conglomerate aspect of the bands of rock which contain our new fossils, that the fossils are of the age of the strata."

Page 39K. "It follows from a consideration of the facts just presented . . . that the rocks of Point Levis, viz: the Point Levis conglomerate limestone and graptolitic shales, are at least 2000 feet above the true Calciferous formation." It is stated in the next paragraph that from the known data the Levis conglomerates and associated graptolitic shales are superior at least to the Upper Calciferous of the Phillipsburgh series.

Of the collections made from the Levis conglomerates, during Dr. Ells's survey, he says (p. 56K): "Other collections were made from the interstratified beds of conglomerates, but as these were in all cases from the limestone pebbles, and not from the matrix, their value in determining exact horizons from these rocks is doubtful." This statement is repeated on page 81K.

When first reading the description of the Point Levis rocks in 1874, I was puzzled by the mixing of the faunas in the lists published by Mr. Billings and the statement made by Sir Wm. E. Logan, that the fossils were from the matrix. On reaching Quebec, in August, 1889, I took the first opportunity to examine the lowest bed of limestone conglomerate back of St. Joseph de Levis and northwest of the Catholic cemetery. Dr. Ells accompanied me. As we crossed the ridge I picked up a loose bowlder full of Potsdam or Upper Cambrian fossils. A second bowlder was found embedded in the matrix and then several more, some of which were three feet in diameter. The matrix is a hard, gray, impure limestone that occurs at this point in a solid band, that we traced 500 feet or more. In the matrix I found the Calciferous fauna was represented by *Obolella* sp.? *Orthis* sp.? *Camerella calcifera* Billings, *Ecculiomphalus canadensis* Billings, *Ecculiomphalus intortus* Billings, *Ophileta complanata* Vanuxem, *Pleurotomaria canadensis* Billings, *Pleurotomaria* sp.? *Orthoceras*, 4 sp. undet., *Ceraurus? apollo* Billings, *Ceraurus eryx* Billings, *Bathyurus bituberculatus* Billings, *Bathyurus quadratus* Billings.

In a bed of limestone, fifty feet higher in the section, I found, in addition to the preceding, the following: *Bathyurus cordia* Billings, *Bathyurus oblongus* Billings, *Amphion Caleyi* Billings. In the succeeding band of limestone conglomerate *Orthis porambonites* Pander occurs.

A large number of specimens were obtained from the bowlders embedded in the limestone containing the fossils of Calciferous age, among which I have identified *Camerella calcifera* Billings (?), *Agnostus americanus* Billings, *Dicelocephalus magnificus* Billings, *D. Oweni* Billings, *D. Belli* Billings, *Arionellus subclavatus* Billings, *Menocephalus? Sedgwicki* Billings, and *Illænurus illænoides* Billings (sp.). Other species occur, but the preceding list is sufficient to indicate the fauna of the Upper Cambrian or Potsdam zone.

Dr. Ells accepted the view that the Calciferous fauna occurred *in situ* in the matrix of the conglomerate, and that the bowlders containing the Potsdam fauna were derived from preëxisting strata.* In the next band of conglomerate, above that which forms the ridge on the north side of the cemetery, the matrix also carries Calciferous fossils, and they are also abundant in the bowlders. In a search of two days I failed to find a Potsdam fossil at this horizon. From Dr. Ells I learned that nearly all the fossils described by Mr. Billings came from

* This view was added in a foot note at the close of Mr. Ami's list of the species on Dr. Ells's return to Ottawa in October.

the lower zone, and we found traces of extensive collecting. With this exact data I was enabled, at once, to correlate the lower belt of limestone and conglomerate with the central band of the Phillipsburgh section, where an identical fauna occurs 1000 to 1110 feet above the recognized Potsdam sandstone.*

This zone is 600 feet beneath the zone of "*Maclurea ponderosa*," where Mr. Billings placed the Levis conglomerates. The long period of uncertainty regarding the true mode of occurrence of the faunas in the Levis calcareous rocks is now terminated, and a fixed datum point secured for comparison with the known section on the shores of Lake Champlain.

Dr. Ells quotes the greater part of the conclusions contained in Professor Charles Lapworth's instructive paper on the graptolites of the "Quebec Group."† In this the graptolitic zone of the Levis shales is correlated with the typical Arenig of Great Britain and the Phyllograptus beds of Scandinavia. The graptolites of the Citadel Hill or Quebec City strata are correlated with the middle Llandeilo zone of Great Britain.

The stratigraphic succession, as determined by Dr. Ells, is as follows (p. 64K):

1. Black, green and gray shales, with thick bands of grayish and sometimes yellowish-white quartzose sandstone and occasional thin bands of limestone conglomerate.

2. Greenish, grayish and blackish, and occasional bands of reddish or purple shales, with thin layers of gray sandstone. Annelid trails (fucoidal markings of Ells) are numerous on the greenish shales. On the south shore of the St. Lawrence, below Levis and also on the south shore of the Island of Orleans, beds of conglomerate occur at about this horizon, in which the Lower Cambrian fauna occurs (p. 65K).

3. Bright-red shales, with thin bands of greenish and gray shale.

4. Red, greenish-gray and black shales, with interstratified Sillery sandstones.

Obolella pretiosa in the upper part, near Sillery, and on the south side of the river, *Obolella pretiosa*, *Protospongia fenestrata*, *Phyllograptus typus*, *Tetragraptus serra* and *Lingula quebecensis*.

5. Levis shales and conglomerates of Point Levis.

6. Black and grayish-striped or banded shales, with the black and graphitic shales and limestone of the Arthabaska and Somerset synclinal, the latter not appearing in the Quebec and Point Levis sections.

7. The black or brownish bituminous shales and limestones of

* During the summer of 1888 I discovered the Potsdam sandstone beneath the limestones of the Phillipsburgh terrane, on the shore of Missisquoi Bay, one mile south of the wharf at Phillipsburgh. The section was measured from this horizon to the Chazy-fauna zone, and then to the Trenton limestone.

† Trans. Roy. Soc. Canada, 1886, section iv, pp. 167–184.

the city of Quebec and northwest side of the Island of Orleans. The contained fauna is of Trenton-Utica age.

From the Cape Rouge section and the strata on the south side of the St. Lawrence, Dr. Ells concludes that the evidence afforded by the stratigraphy and the graptolites, determined by Professor Lapworth, is sufficient to refer the Sillery rocks of 1, 2, 3 and 4 of the section, to the Cambrian system, and the Levis beds (5) to the Lower Ordovician.

The thickness of the Sillery and Levis rocks are not given; but Dr. Ells told me that the measurements given by Logan were as nearly correct as could be determined. These were 2000 feet for the Levis shales and 5000 to 6000 feet for the Sillery series as now known.*

The *Obolella pretiosa* ranges through from 1500 to 2000 feet of the Upper Sillery, and the lower conglomerate, of 2, occurs in the lower portion of this series. The Cape Rosier *Dictyonema sociale* zone is regarded as the lowest of the graptolitic zones, and to indicate the horizon of the Tremadoc terrane of Great Britain. The Cape Rosier beds are referred to the Upper Cambrian by Professor Lapworth and Dr. Ells, but with our present knowledge of the Cambrian in America, I would refer them to the Lower Ordovician or to the Lower Calciferous. The occurrence of the typical Calciferous fauna within one hundred (100) feet of the base of the Levis series, at St. Joseph de Levis, points very strongly to considering the graptolitic fauna of the Upper Sillery to be of Calciferous age, if a comparison is made with the Phillipsburgh section.

Dr. Ells refers the Sillery series to the Cambrian and in this I mainly agree with him, except that the upper portion is evidently a passage series between the Cambrian and Ordovician. On lithologic and stratigraphic evidence the line would be drawn at the summit of the red shales. On paleontologic evidence, as furnished by the graptolites, I would include the upper portion of the Sillery red, and green beds in the Ordovician, as I think they are above the typical Potsdam zone of America.

It will be recalled that Dr. Ells stated that the Sillery beds rested unconformably upon the slates, quartzites, etc., which he refers to the Lower Cambrian. He mentions that, in this lower series, beds of gray subcrystalline limestone occur. It may be that we here have the source from which the limestone conglomerate of the Sillery was derived, which contains the Olenellus fauna. This would be in accordance with the mode of occurrence of the Olenellus or Lower Cambrian fauna to the southward, in Vermont and eastern New York.

Dr. Ells's conclusion as to the value of the term "Quebec

* This transfers a considerable portion of the strata originally referred to the Levis to the Sillery.

Group" in geologic nomenclature has already been quoted, *ante* p. 105. After an examination of the typical area, in company with Drs. Selwyn and Ells, and with the latter, the Sutton Mountain anticlinal and superjacent volcanic rocks and so-called Lower Cambrian rocks, I agree with the conclusions given, and think that the term "Quebec Group" had best be dropped from geologic nomenclature. To the one who would use the term I will ask, to *which* of the following groups would you apply it?

1. The Trenton-Utica strata of the Citadel Hill of the city of Quebec?
2. The Lower Ordovician strata of the Levis Terrane?
3. The Upper and Middle (?) Cambrian strata of the Sillery Terrane?
4. The Lower Cambrian strata flanking the Sutton Mountain range? or,
5. The pre-Cambrian post-Laurentian strata of the Sutton Mountain anticlinal?

Until it is determined which of the above shall receive the name, it appears best not to use it indiscriminately.

Dr. Ells's suggestion to use the name "Levis" for the local development of the Calciferous terrane about Quebec, and the name "Sillery" for the passage beds and Cambrian strata of the St. Lawrence valley, in the viciinity of Quebec, is an admirable one and worthy of imitation by those geologists interested in the advance of geology in America.

Pre-Cambrian.—The crystalline schists of the Sutton Mountain anticlinal and its northeasterly extension are unconformably subjacent to the overlapping slates and quartzites of the supposed Lower Cambrian, and form the oldest known rock series in the district. Dr. Ells describes their geologic distribution, and the character of the micaceous, chloritic and talcose schists, as found in several sections crossing the anticlinal.

Under the head of "Crystalline and Igneous Rocks," p. 93K, intrusive granite and diorite are described. The diorite forms a chain of hills that extend from the Vermont boundary, near Lake Memphremagog, to north of the Chaudiere river. The diorites are closely associated with the serpentines and all are referred to the Cambrian system. The areas of serpentine are quite large and of great economic importance, owing to the numerous veins of asbestus found in them, especially in the townships of Thetford, Coleraine and Ireland. A short description of the mines is given, with the product of several of the larger ones (pp. 106K–112K). A short description of the economic minerals notes the presence of gold on the Chaudiere river and the exploration for it; also the indications and mining of copper, and the occurrence of iron ores, soapstone, limestone and building stones.

Surface Geology.—The features of the surface geology to which special attention was directed had reference to the course of the ice-flow and the distribution of bowlders and other drift. The conclusion is reached that the St. Lawrence river extended, in pre-glacial times, from 25 to 40 miles east of its present valley, and that its channel, as well as that of many tributary streams, Etchemin, Chaudiere, etc., was pre-glacial and of considerable antiquity. Large areas of sand and clay occur, and rock exposures are infrequent in the broad, flat country east of the St. Lawrence. The pre-Cambrian ridges abruptly rise from 1400 to 1600 feet, and then the surface slopes gradually to the St. John river basin near to the Maine boundary.

Dr. Ells thinks that the theory of local glaciers instead of a great ice cap appears to be supported by the direction of the striæ following the river valleys and the prevailing slopes from the central highlands. This may be true, but if considered as the closing phenomena of the glacial period after the great ice sheet had retreated, the local glaciation is readily explained; and the theory of the cap still remains to explain the great glaciation observed to the south, in New England, New York, etc.

The distribution of the bowlders of Laurentian rocks over the surface is explained by submergence and floating ice carrying the bowlders from the Laurentian hills south. Elevated terraces are cited to show submergence.

A systematic list of the fossils referred to in the report is given by Mr. Henry M. Ami at the close of the report.

ART. XVIII.—*Measurement by Light-waves;** by ALBERT A. MICHELSON. With Plate III.

ALMOST every accurate measurement of any physical quantity involves and usually depends upon a measurement of length or of angle. In linear measurements the microscope is usually employed, and in angular measurements the telescope.

The use of these instruments depends entirely on the properties of the optical media in their relation to *light-waves;* so that in fact light-waves are now the most convenient means we have for making accurate measurements; and it can readily be shown that it is the very minuteness of the waves which permits the extraordinary degree of accuracy already attained in the use of optical instruments.

* A lecture delivered at the Jefferson Physical Laboratory of Harvard University.

It is especially with a view of testing whether it is not possible to utilize these light-waves to even greater advantage that I desire to institute a comparison between the telescope and microscope on the one hand, and the refractometer on the other; to point out some remarkable analogies in their fundamental properties; and to illustrate a few cases in which the last-named instrument appears to possess a very important advantage over the others.

In the microscope (and the same remarks can be modified to apply equally well to the telescope) the performance depends largely on the quality of the objective. Let this be supposed a single perfect lens. Very elementary considerations will show that the magnifying power of the lens is $\frac{\sin \alpha}{\sin \beta}$, where α and β are the apparent semi-diameters of the lens viewed from the object and image respectively; and this is greatest when $\alpha = 90°$ and then $\overline{M} = \frac{1}{\sin \beta}$. But it is well known that the image of a luminous point consists of a series of small concentric rings of light; and it is easy to show that the radius of the first ring is the wave-length divided by 2 sin β, or $\frac{1}{2}\lambda\overline{M}$. This means that the indistinctness of the image grows in exactly the same proportion as the magnifying power.

Now a microscope is commonly used: 1st, to separate into their elements closely packed groups of minute objects; 2d, to recognize the forms of minute objects; 3d, to locate the positions of minute objects. In the first case and also the second, it is manifestly useless to increase the magnification beyond the limit where interference fringes are just perceptible. In the third case, however—were it not for the attendant decrease in the illumination—it would be advantageous to go beyond this point—so far in fact that the apparent width of the fringes is about a hundred times that of the cross-hairs in the eye piece. But long before this stage is reached the illumination is much too feeble for distinct vision. (If the lens is in any way imperfect, the imperfections are of course much magnified.)

With the first-named requisites of telescopes and microscopes, namely, "resolution" and "definition," we have no further concern. It is especially with regard to the third requisite—which may be termed "accuracy"—that I wish to institute a comparison between these instruments and the refractometer.

As there appears to be a slight confusion in regard to these terms, it may not be amiss to propose the following:

Confining the attention to the objective alone,

Let B = diameter of objective.

F = focal length of objective.

α = apparent semi-diameter of objective viewed from the object.

β = " " " " " image.

d = smallest distance between lines which can be clearly "resolved."
λ = wave-length of the light employed.
b = breadth of the diffraction fringes with this kind of light.
M = Magnification.
R = Resolution.
D = Definition.
A = Accuracy.

Then if M is the ratio of size of image to object,

$$M=\frac{\sin \alpha}{\sin \beta}$$

The *resolution* is measured by the closeness of two lines which can be clearly distinguished or "resolved." Let us therefore put

$$R=\frac{1}{d}$$

Now two lines are clearly distinguishable when the central fringes of their images are separated by the width of one fringe. The actual limit at which the resolution disappears may be anywhere between b and $\frac{b}{2}$. (See "Wave Theory," Lord Rayleigh, Enc. Brit.) But it can readily be shown that $b=\frac{\lambda}{2 \sin \beta}$ and $d=b/M$, hence,

$$R=\frac{2}{\lambda} \sin \beta.$$

The *definition* of an objective is measured by the ease with which the forms of minute objects may be recognized. Thus, were it not for diffraction, D would be simply proportional to M. But for a given magnification the form of the image is clearer, or the definition greater as the fringes are narrower; hence, we may put

$$D=\frac{M}{b}=R$$

Definition is not capable of being so precisely formulated as Resolution, and would undoubtedly vary with the form of the object, its nearness to other objects, etc. In view of these uncertainties it would scarcely be worth while to introduce a constant coefficient in the last equation.

The error of setting of the cross-hairs of an eye-piece on the middle of a diffraction band of sufficient width will be b/e where e is a constant not far from 100, and the corresponding error in distance would be $b/e \div M$. This smallest *measurable* distance is therefore e times as small as the smallest *resolvable* distance; hence,

$$A=eR.$$

These formulæ may be applied to the microscope (in which case the maximum values correspond to $\alpha=90°$), or to the telescope (in which α is nearly zero, and angular measurements alone are of importance). Accordingly we obtain the following:

	Microscope.	Telescope.
M	$= 1/\sin \beta$	F
R	$= 2/\lambda$	B/λ
D	$= 2/\lambda$	B/λ
A	$= e2/\lambda$	eB/λ

The formulæ for microscopes apply when the object is very near the lens. They show, first, that with a microscope of given length the magnifying power depends on the smallness of the objective and on nothing else; second, that the resolution, definition and accuracy (upon which the usefulness of a microscope chiefly depends) are the same for all microscopes, no matter how large the objective may be, or how great the magnifying power, provided the latter be sufficient to show diffraction fringes; third, that these qualities vary inversely with the wave-length of the light employed.

There seems to be a prevailing impression that a microscope may have a high resolving power with but moderate definition and *vice versa*. This may be due to the difficulty in giving an exact signification to the terms. If those here employed be admitted it is evident that the two qualities must go together.

In the telescope the size of the image and hence the magnification depends entirely on the focal length. The resolution is in this case the reciprocal of the smallest angular distance which can be clearly distinguished. It increases with the diameter of the objective and inversely with the wave-length. These formulæ may also be applied to the revolving mirror as used in galvanometers, etc., except that in this case the accuracy is doubled, so that

$$A=2eB/\lambda.$$

The foregoing statements must be understood to refer to theoretically perfect lenses. If the lenses be imperfect the ratio of their performance to that of a perfect lens may be expressed by a constant depending on the accuracy of the surfaces and the nature of the glass.

The first named qualifications depend on the accuracy with which all parts of the lens contribute to make the elementary waves reach the focus in exactly the same phase. But this is not at all necessary for "accuracy." For this purpose it would be as well to entirely annul the central portions of the lens (or mirror) leaving only an external annular ring; or better still only *two small portions* at opposite ends of a diameter need be used; and this too without any sacrifice of accuracy but on the contrary a very considerable gain. For it is now possible to increase the size of the interference fringes up to any limit without affecting the light; and the result is exactly the same as could be obtained with a perfect microscope of infinite magnifying power with an infinitely bright source of light.

These two small portions to which the lens is thus reduced need not be curved, but may be either plane mirrors or prisms. *Thus the telescope or microscope will have been converted into a refractometer.*

The details of the various forms which the instrument may take, their classification, and their older and better known analogues, are shown in the diagrams, Plate III.

Description of Plate.

In the first four groups the paths of the two pencils are equal.

Group I.—Waves emanate at a point and converge at another. Nos. 1 and 3 are the types; 2, represents Fresnel's mirrors; 4, Billet's half-lenses; and 5, Fresnel's bi-prism. In this group the diminution in intensity is the same as in the microscope.

Group II.—In this and the succeeding groups a pencil of rays divides at a plane surface and reunites at another. No. 1 is the type (a simple microscope objective). Nos. 2 and 3 are forms appropriate for linear measurements; 4, 5, 6 and 7, for differential measurements. 4 and 5 show the essential part of the refractometer of Jamin and of Fresnel respectively. (The latter does not belong to the group, but serves as a type for 6 and 7.)

Group III.—In this group the pencils retrace their path, and reunite at the same surface, *o*, where they separate. Fig. 1 is the type for 2 and 3. These figures represent the original form from which the others have been derived.* They may be used for absolute or differential linear measurements.

Fig. 4 is the type for 5 and 6 which are appropriate forms for angular measurements; in fact just as the angular motion of the mirror *mm* of 4 is detected by the motion of the image at *o*, so that of the mirrors *mm* of 5 and 6 is detected by the motion of the interference fringes at *o*.

* See "Interference phenomena in a new form of refractometer," A. A. Michelson, this Journal, Art. xlvi, p. 395, 1882.

These forms may also be used for differential measurements with the advantage that the displacement is double that of the corresponding instruments of Group II.

Group IV.—This group is useful only in cases where the velocity of light varies with the direction according as this is positive or negative. The only application thus far made is in the problem of the speed of light in moving media. For this purpose it is very essential that no accidental variations in the two paths should have any effect. Accordingly each pencil is made to return by the *other's* path. Of this group fig. 1 is the type; 3 is the form used by Fizeau in his celebrated experiment; and 2 that employed in a recent repetition of the same work.*

Group V.—In this case the paths of the two pencils are unequal. Figs 1, 2 and 3 represent various forms of grating spectroscope, of which the last is a concave grating in which the spectral image coincides with the slit. The transition to the corresponding refractometer forms, 4 and 5, is apparent.

Linear Measurements.

It may be assumed from experiments made by Professors Rogers and Morley that with the most accurate and powerful microscope at their command, and with the very best conditions as regards the object observed and its illumination, the utmost attainable limit of accuracy of a setting of the cross-hair of the microscope on a fine ruled line was about two millionths of an inch or about a tenth of a light-wave. Now it is usually granted that the cross-hair of an eye piece can be set upon the middle of an interference fringe, if this is sufficiently broad and clear, with an error of about one thirtieth of a fringe. In the refractometer this would mean an error in distance of only one-sixtieth of a light-wave.

The following is a record of the results of three direct measurements of the length of a wave of green light emitted under the proper conditions by incandescent mercury vapor. I have been fortunate in obtaining the first series from observations by Professor Morley, whose results with the microscope have just been quoted. The second series was taken by myself; and the third, by an observer who had no previous practice in this kind of measurement. In all cases the scale readings were unknown to the observer.

	(1)	Δ	(2)	Δ	(3)	Δ
	119·0	2·0	118·5	0·0	117·0	−2·0
	117·5	0·5	119·0	0·5	118·5	−0·5
	117·0	0·0	119·5	1·0	118·5	−0·5
	116·0	−1·0	118·0	−0·5	122·5	3·5
	115·5	−1·5	119·5	1·0	120·5	1·5
	117·5	0·5	119·0	0·5	120·5	1·5
	117·0	0·0	118·5	0·0	119·0	0·0
	117·0	0·0	119·0	0·5	118·0	−1·0
	117·5	0·5	117·5	−1·0	117·5	−1·5
	117·5	0·5	116·5	−2·0	118·5	−1·0
Means:	117·15	0·65	118·50	0·70	119·05	1·30
Error in waves:		0·0056		0·0059		0·0110

* "Influence of Motion of the Medium on the Velocity of Light:" Michelson and Morley, this Journal, xxxi, May, 1886.

It is evident therefore that one-thirtieth of a wave is much too large an estimate of the average error in a setting, and that it is in fact less than a hundredth of a wave, corresponding to an error in distance of one two-hundredth of a wave, or about one ten-millionth of an inch.*

Angular Measurements.

In the measurement of angles the microscope is replaced by the telescope. From considerations quite analogous to those employed in the former case, it can be shown that the limit of accuracy attainable in the estimation of angles involves an error of about one tenth of a second for a ten-inch glass. Let this be compared with the performance of the refractometer, 5, Group III, the distance *mm* being also ten inches. If the line joining *mm* be rotated in the plane of the figure, there will be a corresponding difference in path. Taking one hundredth of a fringe as the smallest perceptible displacement, this would correspond to a distance of one two-hundredth of a wave, or in ten inches, to an angle of one five-hundredth of a second.

In the use of the revolving mirror—as in galvanometers, gravity and torsion balances, etc.—the accuracy can be increased only by making the surface, and therefore also the moment of inertia, of the mirror larger; but here we may make the mirrors insignificantly small and yet—with the same distance between the outer edges—increase the accuracy at least twenty-fold. It is important to note that any motion of the line joining the two mirrors as a whole, or even a tilting of the mirrors in a plane at right angles to this line, has absolutely no effect on the central part of the fringes. Fig. 3, plate III, shows the application of this method of angular measurement to the testing of the ways of a dividing engine, comparator, etc.

Spectrometer Measurements.

It is not at first evident that there is any resemblance between the spectroscope and the refractometer. A consideration of the figures under Group V will show that there is a close analogy. Exactly as in the case of mirrors and lenses, we may here too sacrifice resolution and definition by using only the extreme portions of the surface, with an actual gain in accuracy. To compare numbers, it appears that the probable error in the measurement of a wave by a grating with an ex-

* It may be possible with the aid of photography to increase this degree of accuracy many times. Thus, the curve representing the brightness of the fringes is a simple sine function, fig. 1, plate III. Now if the intensity at the minima is really zero, and a photographic plate be very much over-exposed to the image of such interference fringes, the resulting curve would be represented by fig. 2, plate III, and it is evident that the error in setting on the darkest points (the brightest on the negative) must be far less than by direct observation.

treme difference in path of about 250,000 waves is about one part in half a million.

It is believed that in some experiments recently published* this degree of accuracy has been attained with a difference of path only one-tenth as large, and exceeded with twice this number. But there is no reason to think that (in some cases at least) the limit of visible interferences will be reached even with two or three hundred thousand waves. This means ultimately an error of something like *one part in twenty millions* in the estimate of a single wave-length.

Thus it appears that it is possible to construct a single instrument of a few pieces of plane glass which can combine the functions of a microscope, a telescope and a spectroscope; and that *for purposes of measurement* may be made to far surpass these instruments in accuracy.

ART. XIX.—*On Lansfordite, Nesquehonite, a new Mineral, and Pseudomorphs of Nesquehonite after Lansfordite;* by F. A. GENTH and S. L. PENFIELD. With Plate IV.

UNDER the name lansfordite one of us † described a new mineral which had been discovered in October, 1887, by Messrs. D. M. Stackhouse and F. J. Keeley in one of the anthracite mines in the neighborhood of Lansford, near Tamaqua, Schuylkill Co., Pa. The specimens collected at that time, which were entirely uniform in appearance, occurred as incrustations and in the form of stalactites showing some crystalline faces. They had throughout their whole mass the appearance of paraffine, a distinct cleavage, probably basal as will be shown later on, and a vitreous luster. The specific gravity was found to be 1·692 (Keeley) and 1·54 (Stackhouse), the former being probably too high owing to a slight decomposition caused by boiling the specimen in water. An analysis by Mr. Keeley gave the following formula: $3MgCO_3 . Mg(OH)_2 . 21H_2O$, corresponding to

	Found.	Calculated.
CO_2	18·90	19·19
MgO	23·18	23·25
H_2O	57·79	57·56
	99·87	100·00

In the month of June, 1888, Mr. Keeley paid a second visit to the locality in order to secure the balance of the lansfordite,

* "On the feasibility of establishing a light-wave as the ultimate standard of length:" Michelson and Morley, this Journal, xxxviii, Sept., 1889.

† Dr. Genth: Zeitschr. Kryst., xiv, 255.

and after a great deal of trouble found the locality and collected every available fragment. Altogether there may have been fifty pieces, the total weight of which did not exceed half a pound. The exact locality is in No. 1 Tunnell at Nesquehoning, four miles from Lansford. All the specimens of the second lot showed a remarkable change. They were not like the first, uniform in appearance, but had suffered partial decomposition, showing at the base of the stalactites and incrustations, where they were attached to the carbonaceous shales, groups of transparent, radiating, prismatic crystals, individuals of which penetrated or were wholly covered by the material of the still unaltered lansfordite. During the period of a few months after collecting the second lot at summer temperature, when the thermometer ranged about 90° F., almost all of the lansfordite specimens suffered a still further decomposition, being converted into an opaque white cryptocrystalline or chalk-like mineral, and this change has been continually going on, so that at the time of writing this article there is not a single specimen of wholly unaltered lansfordite in our possession.

The clear crystals, which we have just mentioned, proved on examination to be a new mineral, having the composition $MgCO_3 . 3H_2O$, to which we have given the name Nesquehonite, after the locality where the mineral was found, the Nesquehoning Mine being one of the best known in Pennsylvania.

In the following pages in addition to the nesquehonite we shall describe a crystallized artificial salt of the same composition. It will also be shown that the altered stalactites are pseudomorphs of nesquehonite after lansfordite and from the crystal faces on the stalactites we have been able to make out the crystallization of the original lansfordite which is at present only known as pseudomorphs. In making the investigation the chemical work was all done by Dr. F. A. Genth in Philadelphia, Pa., and the crystallographic work by S. L. Penfield in New Haven, Ct.

Nesquehonite.

The crystallization of nesquehonite is orthorhombic. The prismatic crystals occur occasionally isolated but usually in radiating groups, showing only one free end which sometimes projects into a cavity but more often penetrates and is covered with the material of the lansfordite. Individual crystals are frequently over 10^{mm} long and 2^{mm} thick, and show at the free end either a basal plane alone or the base in combination with a brachydome. The faces in the prismatic zone are always deeply striated parallel to the vertical axis and consequently the crystals have their vertical edges rounded and are frequently much distorted owing to the prominence of one or more of the vertical faces. On the reflecting goniometer the faces in the prismatic zone frequently yield an unbroken band of reflections of the signal with more prominent parts indicating the position of a unit prism *m*, 110 and a brachypinacoid *b*, 010. No reflections were ever obtained from a macropinacoid and what appears to be that face on many of the crystals is probably a rounding off of the obtuse edge of the prism owing to oscillatory combination of the prismatic faces. No sharp reflections were obtained in this zone from either prisms or brachypinacoids, but by measuring from the most prominent reflections approximate values were obtained for the prismatic angle. The faces at the ends of the few crystals at our disposal yielded better results, the dome faces giving fair reflections of the signal so that the angle could be measured with a good deal of accuracy. The basal plane gave in all cases a double reflection of the signal, the two reflections being just about 1° apart, while the reflection from a simple basal plane, just truncating the brachydome, should be midway between them This vicinal development of the basal plane can be detected on all of the crystals. The cleavage of the mineral is quite perfect parallel to the prism and less perfect parallel to the base. Parallel to the prism the mineral breaks with a splintery, almost fibrous fracture and no success was obtained in developing large flat prismatic surfaces by cleavage; with larger crystals and more material one might obtain cleavage prisms which on the goniometer would give a very correct measurement of the prismatic angle, but in trying to obtain such prisms, splinters were always loosened which were more or less displaced from their proper position and yielded multiple reflections of the signal so that we could not tell from just what reflection to take the reading of the goniometer. The best measurement of the prismatic angle was however obtained from one of these cleavage prisms, and although not as good as one would desire, it is the best that the material at our disposal afforded.

The forms which have been identified on the crystals are:

c, 001, *O*; *b*, 010, *i*-$\breve{i}$; *m*, 110, *I*; and *d*, 011, 1-$\breve{i}$.

The arrangement and development of the faces is shown in fig. 1.

For fundamental angles the following were chosen:

$d \wedge d$, $011 \wedge 0\bar{1}1$	= 49° 6′
$m \wedge m$, $110 \wedge 1\bar{1}0$ (both cleavage)	= 65 36

from which the following axial relation is calculated:

$$\breve{a} : \bar{b} : c = 0{\cdot}645 : 1 : 0{\cdot}4568$$

The following angles were measured independently on six different crystals in addition to the fundamental angles given above:

	$d \wedge d$	$d \wedge b$	$m \wedge m$	$m \wedge m$
Calculated	49° 6′	65° 27′	65° 36′	114° 24′
Measured	49 6	65 28	66 30	113 30
	48 57	65 8	66	115 5
		65 15	66 4	
		65 10		
		65 51		
		66 0		

The prismatic angles vary considerably from the fundamental values, which would be expected from the nature of the crystals, and consequently the value of the $\breve{a}$ axis 0·645 can only be regarded as approximate.

The optical properties indicate decidedly orthorhombic symmetry. The plane of the optical axes is the base, the brachy-axis being the acute bisectrix and axis of greatest elasticity; the double refraction is therefore negative and is rather strong. From a small plate $1\frac{1}{2}\times 4^{mm}$ cut parallel to the macropinacoid the divergence of the optical axes was measured on a large Fuess axial angle apparatus and found to be:

2E = 83° 55′ for red Li flame.
2E = 84 15 for yellow Na flame.
2E = 84 22 for green Th flame.

Five reading for yellow varied between 83° 56′ and 84° 37′. As the green and red lights were not so brilliant it was harder to bring the hyperbolæ on the cross-hairs of the instrument and the values can not be regarded as very accurate; they serve, however, to show the small dispersion of the optical axes, which is $\rho < v$. Small cleavage chips of the mineral show under the polarizing microscope with crossed nicols very little change in color on revolving the stage, but in convergent polarized light an optical axis is seen almost in the center of the field. The optical axes are therefore almost at right angles to the prismatic faces. Indices of refraction were not determined. The hardness of the mineral is about 2·5. The crystals readily scratch gypsum but cannot be made to scratch calcite. The specific gravity was determined by just floating the crystals in the Thoulet solution and found to be 1·83. The solution had a slight solvent action on the mineral, carbon dioxide being liberated, bubbles of which attached themselves to the crystals and buoyed them up. The specific gravity had to be taken therefore very carefully after washing the crystals and taking the observation before any appreciable chemical action had set in. A specific gravity determination made in alcohol gave 1·852, agreeing closely with the above.

For the chemical analysis only the best crystals were used, which after drying for three days over sulphuric acid lost only 0·10 per cent and showed a few opaque spots resulting probably from a slight contamination of lansfordite. The analysis yielded:

	I.	II.	III.	IV.	Average.	Ratio.	
CO_2		30·18		30·25	30·22	·687	1·
H_2O and CO_2	70·56		70·52				
MgO	29·44	29·24	29·18	29·04	29·22	·731	1·06
H_2O					40·32	2·240	3·26
					99·76		

The ratio of CO_2 : MgO : H_2O is about 1 : 1 : 3, agreeing with the formula $MgCO_3 . 3H_2O$. The calculated percentage composition of a mineral with the above formula being:

CO_2	31·38
MgO	28·99
H_2O	39·13

which also agrees closely with chemical analysis.

Artificial nesquehonite.

A salt of the composition $MgCO_3 . 3H_2O$ is most readily obtained by dissolving magnesium carbonate in water containing carbon dioxide and allowing the solution to stand till it deposits crystals. The preparation of this salt we find mentioned in Klaproth's Chemisches Wörterbuch, edition of 1808, where it is stated that it crystallizes in transparent six-sided prisms, terminated by a six-sided basal plane, but the water of crystallization is not mentioned. In Berzelius' Chemie, edition of 1835, the same method of preparation and description of the salt are given with mention of the three molecules of water of crystallization. In 1855, Marignac* published his results of the crystallographic measurement of the crystals, which he describes as brilliant but deeply striated orthorhombic prisms. He observed *c*, 001, *O*; *b*, 010, *i-ĭ*; *m*, 110, *I* and *d*, 011, 1-*ĭ*, the same forms which occur on the natural mineral. His measurements are:

	Marignac.	Nesquehonite, Penfield.
$m \wedge m$ 110 ∧ 1$\bar{1}$0	64°	65° 36′
$d \wedge d$ 011 ∧ 0$\bar{1}$1	47	49 6

We prepared a quantity of the salt, which crystallized in radiating tufts of prismatic crystals. Individual crystals were scarcely over 0·2^{mm} in diameter and about 2·0^{mm} long. Most of them were terminated by a simple basal plane and showed either a rhombic or hexagonal cross section according as *b*, 010, was wanting or present. Sixteen of these little crystals were measured on the reflecting goniometer in hopes of finding one which would give sharp reflections of the signal, but owing to the small size of the crystals and some physical unevenness of the faces the angles admitted of only approximate measurement and showed considerable variation. The prismatic angle varied from 64° 30′ to 68° 45′, most of the

* Mém. de la Soc. de Phys. and D'Hist. Nat. de Genève, xiv, p. 252.

crystals, and among these the best, giving an angle of nearly 66°, which is about that obtained from the natural mineral. One of the largest of the crystals served as a prism for measuring the indices of refraction. The prismatic angle measured 68° 20′; the minimum deviation for yellow light, soda flame, was found to be 46° 40′ for rays vibrating parallel to the vertical axis of the prism and 49° 40′ for rays vibrating parallel to the macro axis. Two of the indices of refraction are therefore $\beta=1{\cdot}501$ and $\gamma=1{\cdot}526$. The relation of the axes of elasticity to the crystallographic is therefore the following $\overline{\breve{a}=\mathfrak{a}, \bar{b}}=\mathfrak{c}$ and $c=\mathfrak{b}$. The brachy-axis being the acute bisectrix the double refraction is negative the same as in the natural mineral. As a further proof of the identity of the natural and artificial salts we find that the two show exactly the same behavior in convergent polarized light; one of the little crystals lying on a prismatic face shows in convergent polarized light one optical axis almost in the center of the field, the base as the plane of the optical axes and a strong double refraction. Making use of $\beta=1{\cdot}501$ for yellow in the determination of the divergence of the optical axes in the natural mineral 2E=84° 15′, we find 2V=53° 5′, from which we see that the optical axes vary only about 6° from a normal to the prismatic faces. Also having 2V=53° 5′, $\beta=1{\cdot}501$ and $\gamma=1{\cdot}526$ we can calculate $\alpha=1{\cdot}495$.

Owing to the ease with which this simple carbonate of magnesia can be produced artificially in crystals and its stability, for the crystals do not lose water in the warm, dry air of a laboratory nor in a desiccator over sulphuric acid, it would seem to be a very natural compound to find in nature; it is, however, probable that its solubility, especially in water containing carbon dioxide, would account for its absence in localities which would seem favorable for its formation. The hydrated carbonates of magnesia which up to this time have been found in nature are basic and are:

Hydromagnesite ----	$3MgCO_3, Mg(OH)_2, 3H_2O$
Lansfordite --------	$3MgCO_3\ Mg(OH)_2\ 21H_2O$
Hydrogiobertite ----	$MgCO_3\ Mg(OH)_2\ 2HO_2$ or $Mg_2CO_4.3H_2O$

The last of these is a mineral which has recently been described by E. Scacchi* as occurring in dense spherulitic masses from 2 to 15^{mm} diameter in a lava at Pollina, Sicily. The formula written $Mg_2CO_43H_2O$ reminds one very much of our mineral but requires 44·94 per cent MgO, while the nesquehonite requires only 28·99 per cent.

* Rendi. della R. Acad. delle. Sci. di Napoli 12, Dic. 1885.

Pseudomorphs of nesquehonite after lansfordite.

Mention has already been made in the first part of this paper and in the original article by Dr. Genth* of the occurrence of lansfordite. On the specimens which were first collected no nesquehonite prisms were visible, but by the time when the second lot was obtained owing to some process a decomposition and recrystallization of the material of the lansfordite had gone on in the mine, resulting in the formation of the nesquehonite crystals. This recrystallization, resulting in the formation of rather large crystals, had in all cases commenced at the base of the stalactites and incrustations, leaving the ends of the stalactites still unaltered lansfordite and no real pseudomorphs were found, while the white cryptocrystalline mineral which was formed afterwards from the lansfordite during a period of warm summer temperature has resulted in the production of perfect pseudomorphs, leaving not only the original stalactite form but also the flat crystal faces at the ends well preserved, the stalactites looking like bits of crayon upon the ends of which flat faces had been worn by writing on a black-board. When the specimens were first sent to New Haven in the spring of 1889, there were among them only two specimens, one a small fragment the other a small stalactite, which still showed the paraffine luster, but when the crystallographic work was commenced in the fall of 1889, these two specimens had also lost their luster and become almost completely changed into the opaque white material. The altered stalactites show on a fractured surface with a strong lens a fine fibrous structure, the fibers either radiating or inter-woven like felt and giving a sort of "schimmer" when held in a strong light. In places it appears dense like chalk or crypto-crystalline. When carefully crushed and mounted in Canada balsam it shows with the microscope throughout a fine fibrous structure, the larger fibers, which happen to lie on a prismatic or cleavage face giving the same optical properties as nesquehonite. This fibrous material has proved on examination to be like nesquehonite in its chemical composition, an analysis giving:

		Ratio.			Calculated. Nesquehonite.	Calculated. Lansfordite.
CO_2	28·85	0·656	0·93	1·	31·88	19·19
MgO	28·23	0·706	1·00	1·	28·99	23·25
H_2O	42·92	2·384	3·37	3·	39·13	57·56
	100·00					

The analysis and ratio indicate the composition $MgCO_3 \cdot 3H_2O$, the variation from the theoretical being too little CO_2 and too much H_2O resulting probably from a slight admixture of

* Loc. cit.

unaltered lansfordite. For more ready comparison we have given the calculated percentage composition of both nesquehonite and lansfordite.

From the above observations we conclude that the lansfordite is very unstable, losing its water and changing into nesquehonite at a very moderate temperature. Under ordinary conditions this change goes on so rapidly that only microscopic crystals are developed and perfect pseudomorphs are formed. In the mine, where we should expect the temperature conditions to be uniform, the change undoubtedly went on slowly and quite large crystals were formed. We should not expect the summer temperature in the mine to be as high as out of doors, and what agency had been at work in bringing about the change other than rise of temperature we do not know. It is probable that the lansfordite was discovered very soon after its formation and we feel that we were very fortunate in obtaining it before its conversion into nesquehonite.

Crystallization of lansfordite.

Lansfordite is at present only known in pseudomorph crystals; these are, however, so unlike anything which we have ever seen before that they have been subjected to very careful crystallographic study. They are exceedingly interesting as they show a curious combination of stalactitic and crystal growth. The stalactites are mostly round and tapering like ordinary stalactites, but on and near the ends they have perfectly flat crystal faces; these have rounded contours where they join the curved surface of the stalactites and frequently two crystal faces, instead of coming together forming a straight edge, are separated by a curved stalactitic surface. On looking over the material, at first all hopes of measuring the crystals on a reflecting goniometer by direct reflection of light was given up as the faces seemed too dull for that purpose. Two of the crystals were therefore laboriously measured by placing a little Canada balsam on the faces and pressing small bits of thin cover glass upon them before placing them on the goniometer. This method gave rather unsatisfactory results, especially for the smaller faces and was soon abandoned, as it was found that in cleaning up the crystals with alcohol and wiping them with cloth a slight polish was developed on the faces, causing them to give a slight reflection of light, sufficient for an approximate measurement of the angles by using a strong illumination and the low ocular (δ of Websky) on the Fuess reflecting goniometer. It was also soon found that most of the crystal faces were so smooth and perfect that without any polishing they gave, with strong illumination and a low ocular, a fair reflection of light. Altogether there were sent to New Haven thirteen crystals or parts of stalactites which seemed suitable for measurement and these have been conveniently designated in the following pages by numbers.

No. 1. The best crystal of all was a small one about 5^{mm} in its greatest diameter, which was attached to one of the larger stalactites and readily separated from it leaving an angular cavity, marked with regular lines which are so often seen in breaking apart two crystals which have accidentally grown together. This small crystal gave distinct reflections of the signal and values which can probably be relied on within half a degree. The crystal is triclinic and is shown in fig. 2. The observed forms have been taken as follows: *c*, 001, *O*; *b*, 010, $i\text{-}\breve{i}$; M, $1\bar{1}0$, *I*; *m*, 110, *I'*; *d*, 021, $2\text{-}\breve{i}'$; *p*, $1\bar{1}1$, −1 and *r*, $1\bar{3}2$, $-\frac{3}{2}\text{-}\breve{3}$. The following measurements were chosen as fundamental.

$c \wedge b$, $001 \wedge 010 = 84°\ 6'$	$b \wedge$ M, $010 \wedge \bar{1}10 = 64°\ 13'$
$c \wedge$ M, $001 \wedge \bar{1}10 = 96\ \ 35$	$m \wedge$ M, $\bar{1}\bar{1}0 \wedge \bar{1}10 = 56\ \ 57$

$b \wedge d$, $010 \wedge 021 = 39°\ 16'$

from which the following relations are calculated.

$\alpha = 95°\ 22'$
$\beta = 100\ \ 15$ $\qquad \breve{a} : \bar{b} : \acute{c} = 0{\cdot}5493 : 1 : 0{\cdot}5655$
$\gamma = 92\ \ 28$

In addition to the fundamental measurements given above the following were made for the identification of the pyramids.

	Measured	Calculated.
$m \wedge p$, $110 \wedge 1\bar{1}1$	$= 59°\ 36'$	$58°\ 56'$
$p \wedge r$, $1\bar{1}1 \wedge 1\bar{3}2$	$= 21\ \ 17$	$21\ \ 41$
$c \wedge p$, $001 \wedge 1\bar{1}1$	$= 44\ \ \ 1$	$44\ \ 59$

This crystal, which was attached at its lower end, in reality showed none of the M face and only a little of *m* in front, but on top and behind it was quite perfect except for a slight rounding off of the vertical edges between 010, $\bar{1}10$ and $\bar{1}\bar{1}0$ by a stalactitic surface.

The position which we have adopted for our crystal is probably as good as any which could have been chosen for showing the relation of the faces. On the thirteen stalactites which we have examined twenty-four separate forms have been identified whose relations and zones can be well understood from the spherical projection, fig. 3, and which are distributed as follows:

Pinacoids.	Prisms.	Domes.
c, 001, *O*	*m*, 110, *I'*	*d*, 021, $2\text{-}\breve{i}'$
b, 010, $i\text{-}\breve{i}$	M, $1\bar{1}0$, *I*	*e*, $0\bar{2}1$, $2\text{-}\breve{i}$
	h, 150, $i\text{-}\breve{5}'$	*f*, $\bar{2}01$, $2\text{-}\bar{i}$
	k, $3\bar{1}0$, $i\text{-}\bar{3}$	
	l, $1\bar{7}0$, $i\text{-}\breve{7}$	

Pyramids in the four upper octants.

Front right.	Front left.	Back right.	Back left.
P, 111, $-1'$	p, $1\bar{1}1$, -1	y, $\bar{1}11$, $1'$	n, $\bar{1}\bar{1}1$, 1
	q, $3\bar{1}2$, $-\frac{3}{2}\text{-}\bar{3}$	x, $\bar{1}32$, $\frac{3}{2}\text{-}\breve{3}'$	o, $\bar{1}\bar{1}2$, $\frac{1}{2}$
	r, $1\bar{3}2$, $-\frac{3}{2}\text{-}\breve{3}$	z, $\bar{3}12$, $\frac{3}{2}\text{-}\bar{3}'$	ρ, $\bar{1}\bar{3}1$, $3\text{-}\breve{3}$
	s, $1\bar{7}2$, $-\frac{7}{2}\text{-}\breve{7}$	w, $\bar{5}\,15\,1$, $15\text{-}\breve{3}'$	π, $\bar{1}\bar{5}2$, $\frac{5}{2}\text{-}\breve{5}$
	τ, $12\,\bar{1}\bar{2}\,21$, $-\frac{12}{11}\text{-}\breve{\frac{6}{5}}$		

As the thirteen crystals which were sent to New Haven offered a great diversity of habit it was found necessary to study and discuss each one separately. In the figures which have been drawn, a mere outline of the stalactite has been given with no attempt at artistic shading. In all of the drawings the flat crystal faces have been lettered and can thus be distinguished from the rounded stalactitic surfaces which are unlettered and show throughout curved contours. After establishing the triclinic character and axial relation of the mineral from the fundamental measurements considerable difficulty was found in orientating some of the more complicated crystals; this was rendered all the more difficult as none of the crystals gave very exact measurements and cleavage, luster or any decided crystalline habit failed entirely, but after becoming familiar with some of the principal zones in a few of the more complicated crystals this difficulty disappeared. It should also be stated here that during the investigation no uncertain reflections were seen which were neglected, all of the reflections were recorded and in every case they could be referred to faces having rational indices and in only two cases τ and w were these indices unusual numbers: The zonal relations were throughout very satisfactory.

No. 2. This is a very simple stalactite about 22^{mm} long and 9 in diameter, terminated at the end by only two crystal faces and with one large prominent face on the side, fig. 4. Reflections were obtained from the faces by sticking glass plates to them and the measured angles, which are not very exact, indicate that the faces are probably c 001, p $1\bar{1}1$ and m 110. The angles are as follows:

	Measured	Calculated.
$c \wedge p$, $001 \wedge 1\bar{1}1$	$= 42°\ 30'$	$44°\ 59'$
$c \wedge m$, $001 \wedge 110$	$= 77\ \ 40$	$78\ \ 12$
$p \wedge m$, $1\bar{1}1 \wedge 110$	$= 61$	$58\ \ 56$

No. 3 is a stalactite, which is very similar to the previous one, and is terminated by only two faces which are probably c 001 and d 021, giving the measurement $c \wedge d = 44°\ 56'$ calculated $44°\ 50'$.

No. 4 is a stalactite about 15^{mm} long and 8 in diameter attached at the base to a mass of radiating prismatic crystals of nesquehonite. At the end it is terminated mostly by a brachypinacoid *b* $0\bar{1}0$ and shows in addition M $1\bar{1}0$, *m* $\bar{1}\bar{1}0$, *p* $1\bar{1}1$ and *c* 001. A measurement of the two zones M, *b*, *m* and M, *p*, *c* was sufficient for a determination of the faces, which when drawn in proper position represent the stalactite as laying on its side. The crystal is represented in fig. 5, where *b* and *m* being to the left and behind are not shown. The measured angles are:

		Calculated.			Calculated.
M ∧ *b*,	$1\bar{1}0 \wedge 0\bar{1}0$ = 65° 30′	64° 13′	M ∧ *p*,	$1\bar{1}0 \wedge 1\bar{1}1$ = 39° 25′	38° 26′
b ∧ *m*,	$0\bar{1}0 \wedge \bar{1}\bar{1}0$ = 57 9	′58 50	*p* ∧ *c*,	$1\bar{1}1 \wedge 001$ = 44 30	44 59
c ∧ *b*,	$001 \wedge 0\bar{1}0$ = 96 30	95 54			

The *b* face not being very perfect accounts for a rather large variation from the theoretical for the first three angles. It was from this crystal that the smaller one was taken, No. 1, which was used for obtaining the fundamental measurements. It was attached at the end of the stalactite, separated readily from it and had no definite crystallographic relation to the larger crystal.

No. 5, is a short stalactite about 10^{mm} long and broad attached at the base to a mass of nesquehonite crystals. Like the previous stalactite the prominent face at the end is a brachypinacoid *b* $0\bar{1}0$, with which the following forms are associated. M, $1\bar{1}0$; *l*, $1\bar{7}0$; *h*, $\bar{1}\bar{5}0$; *c*, 001; *e*, $0\bar{2}1$; *p*, $1\bar{1}1$; *r*, $1\bar{3}2$; *s*, $1\bar{7}2$; and *o*, $\bar{1}\bar{1}2$, which were identified by measurements made in the following prominent zones M, *l*, *b* and *h*; M, *p* and *c*; *p*, *r* and *e*; *b*, *s* and *r*; *s*, *e* and *o* and *b*, *e* and *c*. As the faces intersect the negative end of the *b* axis the figure, No. 6, has been drawn representing the crystal as turned about the vertical axis so that the negative end of $\bar{b}$ is in front and the positive end of $\breve{a}$ to the right. We are thus looking as it were directly at the end of the stalactite. The face *b* is in two levels separated by a narrow prismatic face *h* $\bar{1}\bar{5}0$. The angular marking at the lower left hand corner of the drawing represents where a small crystal was detached. The important measurements in the zones mentioned above are as follows.

		Calculated.			Calculated.
M ∧ *l*,	$1\bar{1}0 \wedge 1\bar{7}0$ = 49° 15′	49° 16′	*b* ∧ *s*,	$0\bar{1}0 \wedge 1\bar{7}2$ = 33° 34′	33° 24′
M ∧ *b*,	$1\bar{1}0 \wedge 0\bar{1}1$ = 63 30	64 13	*s* ∧ *r*,	$1\bar{7}2 \wedge 1\bar{3}2$ = 26 36	26 14
l ∧ *h*,	$1\bar{7}0 \wedge 1\bar{5}0$ = 33 30	34 16	*s* ∧ *e*,	$1\bar{7}2 \wedge 0\bar{2}1$ = 18 25	19 2
M ∧ *p*,	$1\bar{1}0 \wedge 1\bar{1}1$ = 39	38 26	*e* ∧ *o*,	$0\bar{2}1 \wedge \bar{1}\bar{1}2$ = 42 26	42 14
p ∧ *c*,	$1\bar{1}1 \wedge 001$ = 44 5	44 59	*b* ∧ *e*,	$0\bar{1}0 \wedge 0\bar{2}1$ = 45	44 32
p ∧ *r*,	$1\bar{1}0 \wedge 1\bar{3}2$ = 21 30	21 41	*e* ∧ *c*,	$0\bar{2}1 \wedge 001$ = 51 30	51 22
r ∧ *e*,	$1\bar{3}2 \wedge 0\bar{2}1$ = 23 52	24 36			

On this crystal we find for the first and only time *l* and *s*. *l* gives a faint but distinct reflection and gives a measurement on M very close to the calculated; *s* is very surely determined both by its zones and the angles which do not vary much from the calculated. The prism *h* $\bar{1}\bar{5}0$ gave a poor reflection, as *b*,

$0\bar{1}0$ also reflected poorly the angle of *h* on *l* was taken for the identification of *h*. The angle varies 46′ from the theoretical but considering the poor reflection of the signal and that this same form was identified on two other crystals we feel very sure that we have given to *h* the proper indices. A second faint reflection was obtained from a face 3° from *h* and corresponding nearly to $\bar{1}60$ but the measurement is not very exact and the form does not occur on any other crystals, so that we do not feel warranted in numbering this among our list of planes.

No. 6 is like an incrustation or very short stalactite covering the ends of a cluster of radiating nesquehonite crystals. The incrustation is terminated by a very prominent brachypinacoid *b*, 010, measuring 9 by 7^{mm} with which the following forms are associated, *m*, 110; M, $\bar{1}10$; *h*, 150; *d*, 021; *e*, $02\bar{1}$; *c*, 001; *p*, $1\bar{1}1$ and $\bar{1}1\bar{1}$ and *r*, $\bar{1}3\bar{2}$; figure 7 represents the arrangement of the faces on this crystal. The large *b* face is in three levels separated by narrow *m*, *p* and *d* faces. At the back of the crystal we find a zone of three small faces *p*, *r* and *e* indicated by dotted lines, as *e* is reduced almost to a line, in one projection it does not show on any of the figures except the basal projections. As we usually have on these stalactites only the faces corresponding to one end or corner of a crystal it is seldom that we have two parallel faces as the pyramid *p* $1\bar{1}1$ and $\bar{1}1\bar{1}$ in this example. In the following table will be found the angles which were measured in the prominent zones for the identification of the faces.

	Measured	Calculated.		Measured	Calculated.
b ∧ M, $010 \wedge \bar{1}10$	=64°	64° 13′	*p* ∧ *c*, $1\bar{1}1 \wedge 001$	=44° 15′	44° 59′
b ∧ *m*, $010 \wedge 110$	=59 30′	58 50	M ∧ *p*, $\bar{1}10 \wedge \bar{1}1\bar{1}$	=39 4	38 26
m ∧ *h*, $110 \wedge 150$	=38 15	39 31	*p* ∧ *r*, $\bar{1}1\bar{1} \wedge \bar{1}3\bar{2}$	=21 43	21 41
b ∧ *d*, $010 \wedge 021$	=39 30	39 16	*r* ∧ *e*, $\bar{1}3\bar{2} \wedge 02\bar{1}$	=24	24 35
d ∧ *c*, $021 \wedge 001$	=44 30	44 50			

No. 7 is a small fragment of a stalactite about 11^{mm} in its greatest diameter. The faces which are present are represented in about their natural development in fig. 8. Crystal faces are present only in the front, lower and right hand part of the crystal. The following forms were present: *c*, $00\bar{1}$; *b*, 010; *m*, 110; *k*, $3\bar{1}0$; M, $1\bar{1}0$ and $\bar{1}10$; *g*, $3\bar{1}2$; *z*, $\bar{1}\bar{2}3$; *y*, $1\bar{1}\bar{1}$; *x*, $1\bar{3}\bar{2}$; *n*, $11\bar{1}$; *o*, $11\bar{2}$, *e*, $02\bar{1}$ and *p*, $\bar{1}1\bar{1}$. The prominent zones which were measured for the identified of the faces are as follows: *b*, *m*, *k* and M; *m*, *z*, *y* and *x*; *m*, *n* and *o*; *z*, *k* and M, *q* and *p* and *c*. The measured angles are as follows:

	Measured	Calculated.		Measured	Calculated.
b ∧ *m*, $010 \wedge 110$	=64°	64° 13′	*m* ∧ *n*, $110 \wedge 11\bar{1}$	=45° 27′	44° 37′
m ∧ *k*, $110 \wedge 3\bar{1}0$	=37 32′	38 2	*m* ∧ *o*, $110 \wedge 11\bar{2}$	=68 45	68 5
k ∧ M, $3\bar{1}0 \wedge 1\bar{1}0$	=19 17	18 55	*k* ∧ *z*, $3\bar{1}0 \wedge 3\bar{1}2$	=37	35 29
m ∧ *z*, $110 \wedge 3\bar{1}\bar{2}$	=55 40	53 22	*k* ∧ *q*, $3\bar{1}0 \wedge 3\bar{1}2$	=30 23	29 59
z ∧ *y*, $3\bar{1}\bar{2} \wedge 1\bar{1}\bar{1}$	=19 45	20 8	M ∧ *p*, $\bar{1}10 \wedge \bar{1}1\bar{1}$	=39 15	38 26
y ∧ *x*, $1\bar{1}\bar{1} \wedge 1\bar{3}\bar{2}$	=24	25 6	*p* ∧ *c*, $\bar{1}1\bar{1} \wedge 00\bar{1}$	=44 37	44 59

The zones and the approximate measurement of the angles fully determine the forms on this crystal. The dome *e*, which is relatively quite a large face, is reduced almost to a line in our projection.

No. 8 is one of the most perfect of the stalactites; it is short, 10ᵐᵐ long and 6ᵐᵐ in diameter. At the base the white material of the altered lansfordite spreads out very much and covers a group of nesquehonite prisms which are attached to a piece of carbonaceous shale. The planes which are present are very symmetrically grouped, reminding one of a monoclinic crystal, and are as follows: *b*, 010; *c*, 001; M $1\bar{1}0$ and $\bar{1}10$; *d*, 021; *e*, $0\bar{2}1$; *x*, $\bar{1}23$; *y*, $\bar{1}11$; *p*, $1\bar{1}1$ and *r*, $1\bar{3}2$. The arrangement of the faces in about their natural development is shown in fig. 9, while fig. 10, which is a projection on a plane at right angles to the vertical axis, will give a somewhat better idea of the symmetrical arrangement of the faces. The large basal plane *c* is in two levels, and to the left there is a cleft in the stalactite which is also bounded by crystal faces, not shown in the drawing. The faces of the crystal were quite devoid of luster before rubbing and polishing with a soft cloth, by which treatment the edges were somewhat rounded and the angles of the faces slightly changed; however, the faces can be fully determined by the zones and the approximate measurements. The angles measured in the prominent zones are as follows:

		Calculated.			Calculated.
$b \wedge M$,	$010 \wedge \bar{1}10 = 64°$	64° 13′	$d \wedge x$,	$021 \wedge \bar{1}32 = 21°\ 10′$	20° 20′
$b \wedge d$,	$010 \wedge 021 = 39\ 30$	39 16	$x \wedge y$,	$\bar{1}32 \wedge \bar{1}11 = 24\ 40$	22 50
$d > c$,	$021 \wedge 001 = 45\ 10$	44 50	$r \wedge c$,	$1\bar{3}2 \wedge 001 = 41\ 25$	43 24
$c \wedge e$,	$001 \wedge 0\bar{2}1 = 49$	51 22	$c \wedge x$,	$001 \wedge \bar{1}32 = 44\ 50$	43 52
$p \wedge r$,	$1\bar{1}1 \wedge 1\bar{3}2 = 19\ 54$	21 41	$M \wedge v$,	$.10 \wedge \bar{1}11 = 43\ 30$	44 10
$r \wedge e$,	$1\bar{3}2 \wedge 0\bar{2}1 = 25\ 24$	24 36	$y \wedge c$,	$\bar{1}11 \wedge 001 = 53\ 30$	52 25

Nos. 9 and 10 are two crystals which had grown together into a single stalactite about 25ᵐᵐ long by 8ᵐᵐ diameter, and readily separated lengthwise with the stalactite. At the junction of the two crystals at the lower end there was a deep reentrant angle, reminding one of a twin crystal but there seemed to be no crystallographic relation between the two halves, and we probably have to do simply with the growth of two crystals into one stalactite. This much must be said, however, that the axis of the stalactite corresponds closely to the vertical axis of the crystals, and the faces on the two crystals for the most part intersect the negative end of the vertical axis. One of these crystals is represented in fig. 11. The rounded surface of the stalactite is behind, while in front there is an angular marking indicating the surface by which the two crystals were united and at the lower end a group of crystal faces, which are as follows: *b*, 010; *c*, 001; *h*, 150; *m*, 110; *d*, 021; *e*, $02\bar{1}$; *r*, $\bar{1}2\bar{2}$ and *p*, $\bar{1}1\bar{1}$. The angles were measured in the following zones: *b*, *h* and *m*; *p*, *r*, *e* and *m* and *d*, *b*, *e* and *c*; and are as follows:

		Calculated.			Calculated.
$b \wedge m$, $010 \wedge 110$	=56° 47′	58° 50′	$d \wedge b$, $021 \wedge 010$	=38° 55′	39° 16′
$h \wedge m$, $150 \wedge 110$	=39 11	39 31	$b \wedge e$, $010 \wedge 02\bar{1}$	=45	44 32
$p \wedge r$, $\bar{1}1\bar{1} \wedge \bar{1}3\bar{2}$	=21 31	21 41	$e \wedge c$, $02\bar{1} \wedge 00\bar{1}$	=50 50	51 22
$r \wedge e$, $\bar{1}3\bar{2} \wedge 02\bar{1}$	=24 9	24 36			

The other half of this stalactite is shown in fig. 12, where the rounded stalactitic surface is in front, while the small group of crystal faces, which are mostly in the back, are indicated by dotted lines. The forms which were identified are as follows: M, $1\bar{1}0$; *m*, 110; *c*, $00\bar{1}$; *b*, $0\bar{1}0$; *d*, $0\bar{2}\bar{1}$; *e*, $02\bar{1}$; *p*, $\bar{1}1\bar{1}$; *r*, $\bar{1}3\bar{2}$ and *x*, $1\bar{3}\bar{2}$, and were measured in the following zones: *b*, M and *m*, *p*, *r* and *e*; *b*, *d*, *c* and *e*; and *r*, *c* and *x*, the angles being as follows:

		Calculated.			Calculated.
$b \wedge M$, $0\bar{1}0 \wedge 1\bar{1}0$	=64° 10′	64° 13′	$b \wedge d$, $0\bar{1}0 \wedge 0\bar{2}\bar{1}$	=39° 5′	39° 16′
$M \wedge m$, $1\bar{1}0 \wedge 110$	=57 15	56 57	$d \wedge c$, $0\bar{2}\bar{1} \wedge 00\bar{1}$	=44 50	44 50
$p \wedge r$, $\bar{1}1\bar{1} \wedge \bar{1}3\bar{2}$	=21 30	21 41	$c \wedge e$, $00\bar{1} \wedge 02\bar{1}$	=51 5	51 22
$r \wedge e$, $\bar{1}3\bar{2} \wedge 02\bar{1}$	=24 25	24 36	$r \wedge c$, $\bar{1}2\bar{2} \wedge 00\bar{1}$	=44 5	43 24
			$c \wedge x$, $00\bar{1} \wedge 1\bar{1}\bar{2}$	=42	43 52

No. 11 is a small stalactite 18^{mm} long by 7^{mm} diameter, which when it was first sent to New Haven in the spring of 1889, still showed the paraffine luster of the unaltered lansfordite; when it was measured in the following fall it was only partially altered to nesquehonite, but had become almost completely changed by the first of December. The faces did not give good reflections of light, but as the angles which were measured on this partially altered crystal do not vary widely from the calculated, which were obtained from the measurement of a completely altered crystal, we conclude that in the change of composition the angles of the lansfordite have not been very materially changed. The faces which were identified are as follows: *b*, 010; *c*, $10\bar{1}$; *m*, 100; M, $1\bar{1}0$; *p*, $\bar{1}1\bar{1}$; *d*, $0\bar{2}\bar{1}$; and P, $\bar{1}\bar{1}\bar{1}$, *x*, $1\bar{3}\bar{2}$, and are arranged as shown in fig. 13. The angles were measured in the following zones: *b*, *m* and M; *m*, *c* and P; and *m*, *x* and *d*, and are as follows:

		Calculated.			Calculated.
$b \wedge m$, $010 \wedge 110$	=59° 15′	58° 50′	$m \wedge c$, $110 \wedge 00\bar{1}$	=103° 30′	101° 48′
$m \wedge M$, $110 \wedge 1\bar{1}0$	=58	56 57	$c \wedge P$, $00\bar{1} \wedge \bar{1}\bar{1}$	= 44 30	43 15
$d \wedge x$, $0\bar{2}\bar{1} \wedge 1\bar{3}\bar{2}$	=19	20 20	$c \wedge p$, $00\bar{1} \wedge 1\bar{1}$	= 44 30	44 59

This is the only crystal on which the pyramid P, 111 was identified, and here it occurs only as a very small face which is not represented in the drawing. It is interesting to find on the mineral all of the four possible faces making up the triclinic unit pyramid. On this crystal we notice that the decomposition or change from lansfordite to nesquehonite proceeds along certain planes which are parallel to the base. It is probable that these planes indicate the direction of cleavage of the lansfordite. On breaking across the stalactite near the base where it seemed wholly altered to nesquehonite, it parted with nearly a plane surface parallel to *c*, 001.

No. 12 is a small end of a stalactite about 8^{mm} in diameter. Like the previous one it showed at the time the measurements were made a little of the paraffine luster of the unaltered lansfordite. The crystal is highly modified and shows the following forms: *b*, 010; *c*, 001; *d*, 021; *e*, $0\bar{2}1$; M, $\bar{1}10$; *x*, $\bar{1}32$; *y*, $\bar{1}11$; *n*, $\bar{1}\bar{1}1$; *o*, $\bar{1}\bar{1}2$; *q*, $3\bar{1}2$; *p*, $1\bar{1}1$; *r*, $1\bar{3}2$; *π*, $\bar{1}\bar{5}2$; *ρ*, $\bar{1}\bar{3}1$ and *w*, $\bar{5}151$. These are represented in about their natural size in fig. 14, which is a projection upon a plane at right angles to the vertical axis and which in this case is better than an ordinary projection for showing the relation of the faces. The prominent zones which were measured are: *b*, *d*, *c* and *e*; *d*, *x* and *y*; *c*, *o* and *n*; *c*, *y* and M; *q*, *p*, *r*, *e*, *π* and *ρ*, and *r*, *c*, *x* and *w*, the angles being:

		Calculated.			Calculated.
b ∧ *d*, 010 ∧ 021 =	39° 25′	39° 16′	*q* ∧ *p*, $3\bar{1}2$ ∧ $\bar{1}11$ =	15° 20′	15° 3′
d ∧ *c*, 021 ∧ 001 =	44 57	44 50	*p* ∧ *r*, $1\bar{1}1$ ∧ $1\bar{3}2$ =	21 38	21 41
c ∧ *e*, 001 ∧ $0\bar{2}1$ =	53 35	51 22	*e* ∧ *r*, $0\bar{2}1$ ∧ $1\bar{3}2$ =	23 51	24 36
d ∧ *x*, 021 ∧ $\bar{1}32$ =	35 20	20 20	*e* ∧ *π*, $0\bar{2}1$ ∧ $\bar{1}\bar{5}2$ =	18 21	20 2
x ∧ *y*, $\bar{1}32$ ∧ $\bar{1}11$ =	24 15	22 50	*e* ∧ *ρ*, $0\bar{2}1$ ∧ $\bar{1}\bar{3}1$ =	32 36	33 42
c ∧ *o*, 001 ∧ $\bar{1}\bar{1}2$ =	33 30	33 43	*π* ∧ *ρ*, $\bar{1}\bar{5}2$ ∧ $\bar{1}\bar{3}1$ =	14 15	13 34
c ∧ *n*, 001 ∧ $\bar{1}\bar{1}1$ =	56 38	57 11	*r* ∧ *c*, $1\bar{3}2$ ∧ 001 =	45 44	43 25
c ∧ *y*, 001 ∧ $\bar{1}11$ =	52 40	52 25	*c* ∧ *x*, 001 ∧ $\bar{1}32$ =	44	43 52
y ∧ M, $\bar{1}11$ ∧ $\bar{1}10$ =	44 40	44 10	*x* ∧ *w*, $\bar{1}32$ ∧ $\bar{5}151$ =	35 16	35 22

In this crystal we notice for the first time two new pyramids *π* and *ρ* in the zone *p*, *r*, *e* which has been so prominent in most all of the crystals, we also notice for the first and only time the very steep pyramid *w* in the zone *r*, *c*, *x*.

No. 13 is a fragment about 19^{mm} by 11^{mm} wide, with some rounded surfaces, which was broken from a much larger piece of incrustation; except for the rounded surfaces the incrustation did not have anything of a stalactitic habit. The fragment which was measured separated readily from the rest of the incrustation, leaving angular markings which indicate the juncture of independent and distinct crystals. It was more highly modified than the remaining parts of the incrustation and showed the following forms, *b*, both 010 and $0\bar{1}0$; *c*, 001; M, $\bar{1}10$; *k*, $\bar{3}10$; *m*, $\bar{1}\bar{1}0$; *d*, 021; *e*, $0\bar{2}1$; *o*, $\bar{1}\bar{1}2$; *n*, $\bar{1}\bar{1}1$; *x*, $\bar{1}32$; *y*, $\bar{1}11$; *z*, $\bar{3}12$; *f*, $\bar{2}01$; *p*, $1\bar{1}1$; *τ*, 10 $\overline{12}$ 11, *r*, $1\bar{3}2$, *π* $\bar{1}\bar{5}2$ and *ρ*, $\bar{1}\bar{3}1$. The arrangement of the faces is shown in about their natural size and developement in fig. 15, which is a projection upon a plane at right angles to the vertical axis. The prominent zones which were measured are *b*, M, *k* and *m*; *c*, *o* and *n*; *d*, *x*, *y*, *z*, *f* and *m*; *b*, *d*, *c*, *e* and *b′*; and *p*, *τ*, *r*, *e*, *π* and *ρ* the angles being—

		Calculated.
$b \wedge$ M, $010 \wedge \bar{1}10$	$=63° 50'$	$64° 13'$
M $\wedge k$, $\bar{1}10 \wedge \bar{3}10$	$=20\ \ 20$	$18\ \ 55$
$m \wedge$ M, $\bar{1}10 \wedge 1\bar{1}0$	$=56\ \ 30$	$56\ \ 57$
$d \wedge x$, $021 \wedge \bar{1}32$	$=21\ \ 40$	$20\ \ 20$
$x \wedge y$, $\bar{1}32 \wedge \bar{1}11$	$=24$	$22\ \ 50$
$y \wedge z$, $\bar{1}11 \wedge \bar{3}12$	$=20\ \ \ 0$	$20\ \ \ 8$
$y \wedge f$, $\bar{1}11 \wedge \bar{2}01$	$=33\ \ 10$	$32\ \ 59$
$f \wedge m$, $\bar{2}01 \wedge 1\bar{1}0$	$=41\ \ 15$	$41\ \ 31$
$c \wedge o$, $001 \wedge \bar{1}\bar{1}2$	$=32$	$33\ \ 43$
$c \wedge n$, $001 \wedge \bar{1}\bar{1}1$	$=56\ \ 45$	$57\ \ 11$

		Calculated.
$b \wedge d$, $010 \wedge 021$	$=39° 30'$	$39° 16'$
$d \wedge c$, $021 \wedge 001$	$=44\ \ 45$	$44\ \ 50$
$c \wedge e$, $001 \wedge 0\bar{2}1$	$=51\ \ 25$	$51\ \ 22$
$e \wedge b'$, $0\bar{2}1 \wedge 0\bar{1}0$	$=44\ \ 25$	$44\ \ 32$
$p \wedge e$, $1\bar{1}1 \wedge 0\bar{2}1$	$=46$	$46\ \ 16$
$\tau \wedge e$, $10\,\bar{12}\,11 \wedge 0\bar{2}1$	$=43$	$42\ \ 49$
$r \wedge e$, $1\bar{3}2 \wedge 0\bar{2}1$	$=24\ \ 15$	$24\ \ 36$
$e \wedge \pi$, $0\bar{2}1 \wedge \bar{1}\bar{5}2$	$=20$	$20\ \ \ 8$
$e \wedge \rho$, $0\bar{2}1 \wedge \bar{1}\bar{3}1$	$=32\ \ 30$	$33\ \ 42$

At one edge of our crystal, near the top and middle in fig. 15, we notice a little indentation where three small faces *f*, *z* and *y* form zone, a few millimeters to the right we again find *z* and *y* but separated from the former by a curved stalactitic surface and also by the pyramids *n* and *o*. The small face *f* is very perfect and is here observed for the first time. It has a very simple symbol $\bar{2}01$, 2-$\bar{i}$ and is readily determined by its angles with the faces *m* and *y* in the zone. Another feature of this crystal is the highly developed zone *p*, *r*, *e*, where we notice for a second time the pyramids π and ρ. The pyramid *p* is present only as a very small face but gave a distinct reflection, the pyramid τ however, which is only a few degrees removed it is a face of considerable size. The symbol $10\ \bar{12}\ 11$ is an unnatural one and may be regarded as questionable; it would not have been accepted if it had not been that the reflection from it was followed by a distinct reflection making the proper angle for the pyramid *p*. The pyramid *n* is in two levels separated by the zone of small faces *f*, *z*, *y*; to the right of this zone, see fig. 15, we notice both *o* and *n*, to the left only *n*.

Recapitulation.

The measurements which have thus far been given were obtained from thirteen crystals; from the material which was sent to New Haven a few other fragmentary ones could have been measured but they did not seem to offer anything new or of special interest. Owing to the curious combination of stalactite and crystal there is no decided crystallographic habit which can be mentioned as characteristic of our mineral nor in those specimens which are decidedly stalactitic is there any definite relation between the axis of the stalactite and the crystallographic axes for in figures 11, 12 and 13 the faces which terminate the stalactite mostly intersect the end of the vertical axis and in fig. 4 its positive end; in figs. 5 and 6 they intersect the negative end of the macro axis and in fig. 7 its positive end.

In criticising the crystallographic results it must be borne in mind that none of the crystal were well suited for measurement, as they were without exception pseudomorphs and the faces had lost to a greater or less extent the high polish and luster of ordinary crystal faces. Many of the measurements were therefore made from very indistinct reflections, being mere "schimmer" measurements and in such cases the angles vary at times more than one degree from the calculated. Among all the measurements the agreement between the measured and calculated angles is very satisfactory, considering the nature of the material, while the zonal relation of the faces, as observed on the goniometer, was throughout very perfect. From the following statement a good idea of the frequency of the faces can be obtained: leaving out of consideration two stalactites, No. 2, terminated by only three faces, and No. 3, by only two, we find that the faces, *c*, 001, *b*, 010 and *p*, $1\bar{1}1$ were identified on all of the remaining eleven crystals; M, $1\bar{1}0$ on ten; *m*, 110 on nine; *e*, $0\bar{2}1$ and *r*, $1\bar{3}2$ on eight; *d*, 021 on seven; *x*, $\bar{1}32$ on six; *y*, $\bar{1}11$ and *o*, $\bar{1}\bar{1}2$ on four; *n*, $\bar{1}\bar{1}1$ and *h*, 150 on three; *k*, $3\bar{1}0$, *q*, $3\bar{1}2$, *z*, $\bar{3}12$, *π*, $\bar{1}52$ and *ρ*, $\bar{1}31$ on two and *l*, $1\bar{7}0$, *s*, $1\bar{7}2$, *f*, $\bar{2}01$, P, 111, *τ*, 10, $\bar{1}\bar{2}$, 11 and *w*, $\bar{5}$, 151 on only one crystal. Owing to the pseudomorphous nature of the mineral we cannot give any statement of the optical properties of the lansfordite. The cleavage of the lansfordite, which Dr. Genth mentioned in the original article as being very good is probably basal, which we infer from the fact that the partially altered crystal No. 11 broke near its base, where it was wholy altered, parallel to the basal plane and lower down where the mineral was only partially altered the decomposition seemed to be advancing along planes, probably cleavage, parallel to the base.

Chem. Laboratory, 111 S. 10th St., Philadelphia.
Mineralogical Laboratory, Sheffield Scientific School, Dec. 10th, 1889.

Art. XX.—*Weber's Law of Thermal Radiation*; by William Ferrel.

1. In a previous paper on the Law of Thermal Radiation,* which will be referred to in what follows as paper A, the laws of Dulong and Petit and of Stefan were examined, and it was shown from comparisons with the results of experiment that neither of these laws holds generally for all temperatures of the radiating body, but that either, and especially the latter, holds through a considerable range of the ordinary temperatures of experiment and observation, and that for higher or lower temperatures, a change in the values of the constants is

* This Journal, xxxviii, July, 1889.

required. We come now to a similar examination of Weber's new law.*

2. Putting s for the rate with which energy is emitted in all directions by the rays of wave-length λ from the surface F of the radiating body at the absolute temperature T, he assumes

$$s=c\pi F\frac{1}{\lambda^2}\,.\,e^{aT-\frac{1}{b^2T^2\lambda^2}}, \qquad (1)$$

in which $a=\cdot 0043$ and b and c are constants which vary with different substances. This makes s increase with the increase of T more rapidly for the rays of short than of long wave-lengths, as it should, and is found to represent approximately the experimental results obtained by Langley. But experiments on the radiation of the separate wave-lengths are too few yet to furnish data for an accurate test of this formula.

3. Putting now S for the rate with which heat of all wave-lengths is radiated, he gets from the preceding expression of s by integration,

$$S=\int_0^\infty s d\lambda = CFT\,.\,e^{aT}. \qquad (2)$$

This gives for the rate with which the surface F of a body at absolute temperature T loses heat when placed in an inclosure of absolute temperature T_1, in Weber's notation,

$$\varDelta S_{T,T_1}=CFT_1\,.\,e^{aT_1}\left\{\frac{T}{T_1}\,.\,e^{a(T-T_1)}-1\right\}. \qquad (3)$$

The value of C in these expressions is a function of b and c in (1) above, and therefore is different in different substances.

The values of the first member of this expression being obtained from experiment with an inclosure of absolute temperature T, for a number of values of T extending through a considerable range, the test of the formula is that we must have

$$\frac{\varDelta S_{T,T_1}}{\frac{T}{T_1}\,.\,e^{a(T-T_1)}-1}=CFT_1\,.\,e^{aT_1}=\text{a constant.} \qquad (4)$$

4. In testing the formula Weber used the results of Schleiermacher's experiments,† in which the radiation was determined by the amount of electric energy consumed in maintaining a platinum wire at a given temperature, stretched in vacuo in the interior of a tube. In one of the sets of experiments a bright wire, 0·197^{mm} in diameter, was used, and in the other a wire coated with the black oxide of copper, 0·296^{mm} in diame-

* Sitzungsb. der Kön. Preuss. Ak. der Wissenschaften, 1888 (2), 933.

† Wied. Annalen, xxvi, 287.

ter. With the results of these experiments the first member of (4) was found to be very nearly a constant through a range of temperature of about 700°, which is remarkable for so great a range.

Schleiermacher has himself tested Weber's formula in the same way by using the results of his more recent experiments by the electric method,* and found the formula fairly satisfactory, but these experiments extended through a range of not more than 150°, and less in the one case.

5. The formula, so far, has been compared with the results only of Schleiermacher's experiments, but when we come to test it by means of experimental results in which the absolute rate of losing heat is determined from the observed rate of cooling of heated bodies of known thermal capacity, and the relative rate, from the galvanometer needle of the thermopile, the law is not so satisfactory.

If we take the corrected rates of cooling R obtained in Dulong and Petit's experiments, given in the table of § 4, paper A, and given here in the second column of the following table, in which $T_1=273°$, we get the corresponding values of $CFT_1 . e^{aT_1}$ with $a=\cdot0043$ as given in Weber's formula.

T	$\Delta S_{T, T_1}$	$CFT_1 . e^{aT_1}$ with	
		$a=\cdot0043$	$a=\cdot0064$
353°	1·48°	1·799	1·160
373	1·96	1·782	9·906
393	2·60	1·842	0·922
413	3·38	1·917	0·964
433	4·31	2·000	1·005
453	5·43	2·090	1·062
473	6·64	2·145	1 035
493	7·95	2·178	0·955
513	9·74	2·279	1·003

The values in the second column here are rates of cooling and not the rates of given out heat in absolute measure as the formula requires, but the two are sensibly proportional since the capacity of mercury for heat changes but little with change of temperature. The values of the third column, therefore, should still be a constant. It is seen that this is far from being the case, but that there is an increase with increase of temperature, indicating that a greater value of a is required in the formula to satisfy the condition of (4), which the law requires. But if we increase the value of this constant about one half, or to ·0064, we get the results of the last column of the table,

* Wied. Annalen, xxxiv, 623.

which are much more satisfactory, but not entirely so, since some of the individual values differ as much as $\frac{1}{11}$ part from the mean of all, 1·001, and the first one in the column much more. The law is not nearly as well satisfied as either of the expressions given in the table of § 4, paper A.

6. Again, let us take the relative measures of the loss of heat indicated by the deviations of the galvanometer needle of the thermopile in Rosetti's experiments, given in §10, paper A, and also contained in the second column of the following table, in which $T_1=273+23{\cdot}8=296{\cdot}8°$.

T	$\Delta S_{T,\,T_1}$	$CFT_1 \,.\, e^{aT_1}$ with	
		$a=\cdot0043$	$a=\cdot0059$
329·6°	10·0	36·0	28·8
369·6	29·5	42·7	32·3
389·6	42·8	45 5	33·7
409·6	55·0	45·2	32·6
429·6	72·5	47·4	33·4
449·6	91·5	48·6	33·5
469·6	116·7	51·3	34·5
489·6	141·9	52·3	34·2
509·6	169·5	52·9	33·7
529·6	204·0	54·4	33·7
549·6	239·5	54·9	33·1
569·6	283·5	56·1	33·0

It is seen that with Weber's value of $a=\cdot0043$ the condition of (4) is not even approximately satisfied, but by changing it to ·0059, the results of the last column of the table indicate that it is approximately satisfied, neglecting the first place in the column, through a range of 200°; but Weber's formula, even with this great change in the value of the constant, does not satisfy the results of experiment nearly so well as the expression at the head of the last column of the table of §10, paper A, since some of the numbers of the last column above vary from the mean as much as $\frac{1}{30}$ part and more.

T	$\Delta S_{T,\,T_1}$	$CFT_1 \,.\, e^{aT_1}$ with	
		$a=\cdot0043$	$a=\cdot0070$
321·2	.02049	·0706	·0497
328·5	·02601	·0721	·0501
354·0	·04794	·0754	·0500

7. With the values of the differences of the rates of cooling of a black and a silvered thermometer bulb, as observed by De la Provostaye and Desains we get, as in the preceding cases,

the accompanying table of results, in which the second column contains the differences of the rates of cooling of the two thermometers, and in which $T_1=287{\cdot}7°$.

In this case, also, the value of $a=\cdot0043$ is very much too small and the value of ·007 is required to satisfy the condition of (4), which requires the last member to be a constant.

8. From what precedes it is seen that the value of a in Weber's formula which satisfies (4) with Schleiermacher's experimental results, in which the rate of losing heat in the heated body is determined by the electric method, does not satisfy it where the rate of the loss of heat is ascertained from the observed rate of cooling of a body of known heat capacity, or by the deviations of the galvanometer needle of the thermopile; and that the value of a required in the last two cases is much greater than in the former. It also appears that the value of a required in the last two cases increases with decrease of temperature. For in the case of the table of § 6, in which the range of temperature, neglecting the first two places, is from 389·6° to 569·6°, the mean being 479·6°, and through which the values of the last column of the table are approximately equal, the value of $a=\cdot0059$ is required, while in the case of the table of § 5, in which the range of temperature is from 353° to 513°, the mean being 433°, the value of a required is ·0064. Again, in § 7 where the average temperature is only 337·7, the still greater value of $a=\cdot007$ is required to make the numbers of the last column approximately equal.

That the value of a in Weber's formula must increase with decrease of the temperature in Rosetti's experiments is seen from the values in the last column of the table of § 6, in which the numbers increase for the lower and decrease for the higher temperatures, which indicates that the value of a in the formula must be greater for the lower than for the higher temperatures.

9. It has been shown in § 7, paper A, that if we multiply the rates of cooling in the experiments of Dulong and Petit by 0·4516, we get the rate of losing heat by radiation from each unit of surface. Hence, multiplying the mean value of $CFT_1e^{aT_1}$ in the last column of the table of § 5, which is 1·001, into 0·4516, we get

$$273\ Ce^{273a}=0{\cdot}452$$

the value of F being unity in this case, and the first member of this equation is the expression of the rate of radiating heat from each unit of surface at the temperature of $T_1=273°$ which in §7, paper A, was denoted by m and found to be 0·7188 from Dulong and Petit's formula with $a=1{\cdot}0082$, and 0·3296 from Stefan's law with $e=4{\cdot}2$.

From (3) we get with the value of 273 Ce^{273} above and putting F=1,

$$\Delta S_{373, 273}=0{\cdot}452\left(\frac{373}{273}e^{100a}-1\right) \qquad (5)$$

This expression with $a=\cdot0064$, which was required to satisfy the observations in the table of § 5 and the condition of (4), we get

$$\Delta S_{373, 273}=0{\cdot}7192$$

This was denoted by $H_{100}-H_0$ in § 7, paper A, and was found from the experiments of Dulong and Petit to be 0·9092 by the one formula and 0·8926 by the other. It was also determined by Lehnebach directly from experiment to be 0·912. This quantity, then, must be regarded as being pretty accurately determined, and therefore the law of Weber, which gives only 0·7192 when applied to the same experiments does not hold for the temperatures between 0° and 100°, even with the value of $a=\cdot0064$ instead of ·0043, and indicates that the value of a must be still greater for this range of lower temperatures; and this is in accordance with what we have already shown, namely, that the lower the temperature, the greater must be the value of a.

10. While nearly the same values of a in Weber's formula are required for all temperatures in Schleiermacher's experiments in which the loss of energy by the wire is measured by the electric method, in all other experiments in which it is measured by the observed rates of cooling and by the thermopile, the value of a required seems to be much greater, and to increase with decrease of temperature. This may arise in part from the uncertainty in the temperatures of the wire as determined from the observed resistances at different temperatures, especially for high temperatures, but a more probable explanation is found in the want of a perfect vacuum in the tubes through which the wires, heated by the electric current, are stretched; for the heat conduction from small wires is enormous for all ordinary, and even very low, air pressures, and so it is perhaps impossible to have a vacuum so nearly perfect, and to maintain it during the whole time of the experiments, that the amount of heat lost by conduction is so small in comparison with that lost by radiation that it may be neglected in comparison.

Putting

h=the heat conducted from each unit of surface of the wire,

r_1, r_2=the radii of the wire and the internal part of the tube respectively,

τ_1, τ_2=the corresponding temperatures at r_1 and r_2 from the center,

$\delta=\tau_1-\tau_2$,
K_0=the constant of conductivity of air at $\tau=0°$,
α=the temperature coefficient of the conductivity, we have

$$h=\frac{MK_0}{r_1\log\frac{r_2}{r_1}}\left(1+\alpha\tau_2+\tfrac{1}{2}\alpha\delta\right)\delta \qquad (6)$$

Stefan has used the value of K_0=·000054, where the unit of time is the second, and a=·0027.

11. It is readily seen from this formula that with very small values of r_1 the values of h become very large. For instance, the last experiments of Schleiermacher, referred to in §4, were made with wires 0·405^{mm} in diameter, the internal diameter of the tube being 24·2^{mm}. Putting, therefore, in centimeters r_1=·02 and r_2=1·2, the preceding formula gives for δ=1, and τ_2=0, h=0·00064. But we have found in § 22, paper A, for the heat lost by radiation from a unit of glass surface with δ=1, E=·0056 nearly on the average from all experiments, and by means of several formula, which reduced to the second unit is ·000093, a quantity which differs but little from the values found experimentally by Winkelmann and by Kundt and Warburg. But the radiativity of platinum is only about $\frac{1}{9}$ of that of glass, and hence for platinum we have, for the second unit of time, E=·00001 very nearly. Hence, in these experiments of Schleiermacher the heat of the wire lost by conduction with ordinary, or even with very small air pressure, would have been 64 times that lost by radiation, where the difference between the temperature of the wire and that of the tube is small. It is reasonable to suppose, therefore, that it is necessary for the tension of air in the tube to be reduced to an exceedingly low one, in order that the heat *conducted* may be neglected in comparison with that lost by *radiation*, and this is especially so in the case of a bright wire, in which the radiation is comparatively small. And if the tension is not so reduced, but a part of the heat lost by the wire is due to conduction, it is evident that the rate of increase with increase of temperature is diminished, since the increase in the part due to conduction, as is seen from (6), is but little more than the first power of δ, the difference between the temperature of the heated body and the enclosure, and very uncertain for high temperatures, and since the value of the temperature coefficent has been determined for ordinary temperatures only, while from a mere inspection of the various formulæ which should represent the rate of loss of heat, or from the experimental values of ΔS_{TT_1} in the preceding tables, it is seen that the rate of increase with increase of temperature is much greater. In this case a smaller value of a in Weber's formula would be re-

quired than if the loss of heat in the wire depended upon radiation only.

12. That there is such a decrease of the rate of losing heat with increase of temperature, where there is only an exceedingly small air tension left in the tube, is shown by the asymptotic experiments of Mr. Bottomly.* Taking his values of C^2R/Js for the temperatures of the wire at 408° and 505° C. respectively, the temperature of the inclosure or water jacket being 16°, and coördinating them graphically with the corresponding pressures, and smoothing off a little the irregularities, as usual, in drawing a curve through the different points determined by the coördinates, the values of C^2R/Js in the following table, corresponding to the several tensions in the first column, are found:

Air-tension.	C^2R/Js at		Ratio.
	408°	505°	
0·10^{mm}	0·125	0·172	1·38
·09	·117	·162	1·39
·08	·109	·153	1·40
·07	·102	·144	1·41
·06	·095	·135	1·42
·05	·088	·127	1·44
·04	·080	·118	1·47
·03	·071	·108	1·52
·02	·061	·096	1·57
·01	·050	·084	1·68
·00	·037	·072	1·92

From this table it is seen that with an air-tension of only 0·1^{mm} in the tube the rate of loss of heat in an increase of the temperature of the wire from 408° to 505° is as 1 to 1·38, while for a vacuum, with the numbers here given, it is as 1 to 1·92. Hence in the former case Weber's formula, in order to represent these results, would require a much smaller value of a than in the case of a perfect vacuum. And for an air-tension of only 0·01^{mm} the rate of increase is as 1 to 1·68, which is still much less than in the case of a perfect vacuum, and the value of a in Weber's formula would still have to be much less. It should be here stated that the numbers in the last line of the table, for a perfect vacuum, are uncertain, on account of the uncertainties in the measurements of so low tensions in approximating to a vacuum.

13. The effect of a very small air-tension upon the rate of heating or cooling of a thermometer bulb in a glass globe of 1·5 inches in diameter, is shown by the experiments of Mr. Crookes.† The temperature of the inclosure being kept at 65°,

* Phil. Trans., vol. clxxviii, p. 129, 1888.

† *Nature*, vol. xxiii, 1880–1881, p. 234.

with an air-tension of 5M (·0038^{mm}), the time required for the bulb to be heated from 25° to 50° was 322 seconds; but when the tension was reduced to 2M (·00152^{mm}), the time was 412 seconds. With a perfect vacuum the time, of course, would have been still much greater. The diameter of the bulb is not given, but by the formula of §5, paper A, with a very small bulb, the effect of conduction would have been much greater.

ART. XXI.—*Tracks of organic origin in rocks of the Animikie group;* by A. R. C. SELWYN, Director of the Geological and Natural History Survey of Canada (letter to the Editors, dated Jan. 7, 1890).

THE discovery of even traces of fossils, or what are supposed to be such, in the Animikie rocks of Lake Superior, is an interesting and important fact which I wish to announce through the medium of this Journal. The specimens were collected by Mr. E. D. Ingall of this Survey, and were submitted to Mr. Matthew of St. John, N. B., for examination and comparison. Mr. Matthew has furnished me with the accompanying very interesting statement of his views respecting them. I have long held the view that the black Animikie shales represented the Lower Cambrian of the Atlantic border, and I have little doubt that sooner or later the Paradoxides and Olenellus fauna will be found in them. They are quite distinct from and unconformable on the Huronian.

DEAR SIR: I have examined the pieces of flagstone and shale of the Animikie group, bearing impressions of various kinds, which you were kind enough to send me for comparison with markings on the flags and shales of the St. John group and other Cambrian rocks.

These have greatly interested me, and while some are too indefinite to be of value for such comparison, others are undoubtedly of similar origin with characteristic tracks of the Cambrian rocks here.

I should observe, however, that the vertical range of these peculiar tracks of the oldest Palæozoic rocks is not known, and I can only speak of the Animikie forms in comparison with such markings as they appear in the Cambrian sediment of this region.

I would refer especially to two types of tracks which are present on the pieces sent for examination. One of these recalls objects which have been referred to *Eophyton*, but incorrectly, as there are two resembling types of tracks in the Lower Cambrian rocks which have been classed under Eophyton, of which one only is the true Eophyton of Torell.

Another piece of flag has an impression similar to some which have been referred to *Taonurus*, etc., but which I think are not seaweeds. These as well as Eophyton appear to me to be tracks made in the mud by marine animals.

This Taonurus-like impression exhibits a group of striæ converging from a furrowed margin, and becoming more or less parallel and approximate. The markings are such as would be made by an animal having numerous tentacles or arms, furnished with hooks or horny protuberances at the extremity. If such arms were spread and pressed down upon the muddy bottom, and gradually drawn together as the animal moved onward, they would make such markings as are found on this piece of flagstone.

A radiate animal might make a track like this, and since remains of such creatures (Acalephs and Echinoids) have been reported from a lower horizon in the Cambrian rocks of Sweden, than that which, in this region, carries the resembling impressions, one may conjecture that these tracks have been made by a radiate animal of some kind.

The resembling impressions at St. John are found on the layers of fine sandstone and shale which belong to Bands *a* and *c* of Division 2 of the St. John group. The equivalent of Division 2 in Europe is the Olenus Zone, the Mæntwrog and Ffestiniog groups of Wales.

Our best examples show spindle-shaped furrows, radially arranged near the margin of the track, larger and flatter in the bottom than those of the Animikie example. In ours the furrows narrow into striæ which converge and become nearly parallel. The Animikie form shows markings made by three groups of tentacles, all moving in nearly the same direction, but not applied to the sea-bottom simultaneously.

I propose for such tracks the name *Taonichnites*.

Another piece of flagstone from the Animikie group has markings due to an animal entirely different from that which made the markings above described. These are straight and parallel, and in sets which often cross at a small angle. They look exceedingly like the glacial striæ found on rock surfaces, in which, in a similar manner, the different sets interfere with each other.

I have studied the variations of these markings found in the rocks at St. John, and think they indicate an animal which had arms placed on each side of the body, at least three in each set, and that these arms were beset with small spines or hooks. When moving along the bottom the animal threw its arms backward and outward and then drew them forward, thus making as it advanced the straight parallel striæ so characteristic of the principal part of its track.

The manner in which it spread its arms was therefore the reverse of that pursued by the creature which made the Taonichnite track.

After a consideration of the various forms of this track and the circumstances under which it occurs, I can think of no animal except one related to the Squid or Calamary capable of making it.

These impressions are found near the base of the St. John group and through its Division 2, or in other words, in the Olenellus and Olenus Zones; and I would suggest for them the name *Ctenichnites*. A fuller description of these tracks with figures will be given in a paper now in preparation for the Royal Society of Canada.

Both of the forms of track above described belong to shallow sandy and muddy shores, and must have been comparatively common on the Cambrian coasts, where sand and mud beds alternated. On the sands unless they are muddy sands the tracks were only faintly made, but in the soft fine mud they are most prominent. They are most easily recognized by the mould of the track on the under side of beds of sandstone whose sand has been deposited in and over the impressions the animal made in the mud beneath. These moulds are often strikingly distinct, more so than the tracks themselves.

Eophyton (properly Eoichnites) bears considerable resemblance to Ctenichnites, but in the examples of Eophyton which I have seen, we seldom fail to recognize a depressed groove or broad shallow furrow, which Torell appears to have mistaken for the stem or trunk of a plant.

I should add that in the Ctenichnites of the Acadian Cambrian rocks as known to me the striæ are coarser and more widely spread than those of the Animikie example which you sent me.

I remain, yours, etc.,

G. F. MATTHEW.

St. John, New Brunswick, January 3, 1890.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Periodic Law.*—In his Faraday lecture before the Chemical Society, Mendeléeff took for his subject the periodic law of the chemical elements. In March, 1869, he had enunciated his conclusions as follows: (1) The elements if arranged according to their atomic masses, exhibit an evident *periodicity* of properties; (2) elements which are similar as regards their chemical properties, have atomic masses which are either of nearly the

same value (e. g., platinum, iridium, osmium) or which increase regularly (e. g., potassium, rubidium, cæsium); (3) the arrangement of the elements in the order of their atomic masses corresponds to their so-called *valencies* as well as, to some extent, to their distinctive chemical properties; (4) the elements which are the most widely diffused have *small* atomic masses; (5) the *magnitude* of the atomic mass determines the character of the element just as the magnitude of the molecule determines the character of a compound body; (6) we must expect the discovery of many yet *unknown* elements—for example, elements analogous to aluminum and silicon, whose atomic mass would be between 65 and 75; (7) the atomic mass of an element may sometimes be amended by a knowledge of those of the contiguous elements; i. e., the atomic mass of tellurium must be between 123 and 126 and cannot be 128; and (8) certain characteristic properties of the elements can be foretold from their atomic masses. And in 1889, twenty years afterwards these conclusions may still be considered as expressing the essence of the now well known periodic law. Three sets of data had contributed to make the discovery of this law possible. In the first place the true conception of an atom had been arrived at and real atomic masses had been reached. The relation between K 39 and Ca 20, between Rb 85 and Sr 43·5, between Cs 133 and Ba 68·5 fails entirely to show the consecutiveness in atomic mass, which becomes so apparent when Ca is 40, Sr is 87 and Ba is 137. In the second place it had already become evident that the relations between the atomic masses of analogous elements were governed by some general and simple laws; in proof of which the classifications of Cooke, Dumas, Strecker and others may be mentioned. Among these he includes Newland's "Law of Octaves;" which although suggestive, included elements having no apparent connection with each other in the same octave, and which contained occasionally ten elements in the octave instead of eight. The third circumstance favoring the discovery of the law of periodicity was the accumulation of new information respecting the rarer elements, disclosing their many-sided relations to the other elements and to each other; among specially important researches being those of Marignac on columbium and of Roscoe on vanadium. When the striking analogies between vanadium and phosphorus on the one hand and between vanadium and chromium on the other had become apparent, and when V 51 had been compared with Cr 52, Cb 94 with Mo 96 and Ta 192 with W 194, or P 31 with S 32, As 75 with Se 79 and Sb 120 with Te 125, there remained but a step to the discovery of the law of periodicity. Mendeléeff then passes to an attempt to answer the question wherein lies the secret of the special importance of the periodic law, which has already given to chemistry unexpected aid and which promises to be far more fruitful and to impress upon several branches of chemical research a peculiar and original stamp. As soon as the law appeared, it demanded a revision of many facts supposed to be well established; and the legitimacy of the law, as a deduction from verified facts, has been proved by the completeness with which this requirement has been met. Periodic functions have long been known and have long been used for the purpose of expressing changes which are dependent on variations of time and space. "A like periodic function became evident in the case of the elements, depending on the mass of the atom. The primary conception of the masses of bodies or of the masses of atoms belongs to a category which the present state of science forbids us to discuss because as yet we have no means of dissecting or analyzing the conception. All that was known of functions dependent on masses derived its origin from Galileo and Newton and indicated that such functions either decrease or increase with the increase of mass like the attraction of celestial bodies. The numerical expression of the phenomena was always found to be proportional to the mass and in no case was an increase of mass followed by a recurrence of properties such as is disclosed by the periodic law of the elements. This constituted such a novelty in the study of the phenomena of nature that although it did not lift the evil which conceals the true conception of mass, it nevertheless indicated that the explanation of that conception must be searched for in the masses of the atoms; the more so as all masses are nothing but aggregations or additions of chemical atoms which would be best described as chemical individuals." "The periodic law has shown that our chemical individuals display a harmonic periodicity of properties dependent on their masses." "If we mark on the axis of abscissas a series of lengths proportional to angles and then lay off ordinates proportional to sines or other trigonometrical functions, we get periodic curves of a harmonic character. So it might seem at first sight that with the increase of atomic masses the function of the properties of the elements should also vary in the same harmonic way. But in this case there is no such continuous change as in the curves just referred to because the periods do not contain the infinite number of points constituting a curve, but only a *finite* number of such points. An example will better illustrate this view. The atomic masses—

Ag 108	Cd 112	In 113	Sn 118	Sb 120	Te 125	I 127

steadily increase and their increase is accompanied by a modification of many properties which constitute the essence of the periodic law. Thus for example the densities of the above elements decrease steadily being respectively

10·5	8·6	7·4	7·2	6·7	6·4	4·9

while their oxides contain an increasing quantity of oxygen:—

Ag_2O	Cd_2O_2	In_2O_3	Sn_2O_4	Sb_2O_5	Te_2O_6	I_2O_7

But to connect by a curve the summits of the ordinates expressing any of these properties would involve the rejection of Dalton's law of multiple proportions. Not only are there no intermediate elements between silver which gives AgCl and cadmium which gives $CdCl_2$, but according to the very essence of the periodic law there can be none; in fact a uniform curve would be inapplicable in such a case, as it would lead us to expect elements possessed of special properties at any point of the curve. The periods of the elements have thus a character very different from those which are so simply represented by geometers. They correspond to points, to numbers, to sudden changes of the masses and not to a continuous evolution. In these sudden changes destitute of intermediate steps or positions, in the absence of elements intermediate between say silver and cadmium or aluminum and silicon, we must recognize a problem to which no direct application of the analysis of the infinitely small can be made. Therefore neither the trigonometrical functions proposed by Ridberg and Flavitzky nor the pendulum-oscillations suggested by Crookes, nor the cubical curves of the Rev. Mr. Haughton, which have been proposed for expressing the periodic law, can, from the nature of the case, represent the periods of the chemical elements."

With reference to the bearing of the periodic law on the question of a primary matter, Mendeléeff says: The periodic law based as it is on the solid and wholesome ground of experimental research, has been evolved independently of any conception as to the nature of the elements; it does not in the least originate in the idea of a unique matter; and it has no historical connection with that relic of the torments of classical thought, and therefore it affords no more indication of the unity of matter or of the compound character of our elements than the law of Avogadro or the law of specific heats or even the conclusions of spectrum analysis. None of the advocates of unique matter have ever tried to explain the law from the standpoint of ideas taken from a remote antiquity when it was found convenient to admit the existence of many gods—and of a unique matter."

In concluding, the lecture discusses the enlargement of the range of vision by the periodic law. For the first time it enabled us to perceive undiscovered elements at a distance hitherto unaccessible to chemical vision and to define their properties; as is seen in gallium, scandium, and germanium. A fourth element he now foresees analogous to tellurium, which he calls dui-tellurium, Dt, having an atomic mass of 212 and forming an oxide DtO_3. It is an easily fusible crystalline non-volatile metal of a gray color, having a density of about 9·3, and giving an oxide DtO_2 equally endowed with feeble acid and basic properties. On active oxidation it gives DtO_3 which resembles PbO_2 and Bi_2O_5 and is unstable. The hydride will be less stable than H_2Te. Its compounds will be easily reduced and it will form characteristic alloys. Attention is then called to the way in which the periodic law has compelled a modification of both atomic masses and valencies, as in the cases of indium, cerium, yttrium, beryllium, thorium and uranium, and has detected errors in atomic masses, as in the case of tellurium, titanium and platinum. Moreover the periodic law has detected periodicity in the physical properties of bodies; so that density, elasticity, tenacity, fusing point, heat of formation, magnetic properties and the like are now deducible from it. As to chemical properties, the periodic law shows not only that the increase of the power of combining with oxygen in the elements is accompanied by a corresponding decrease in their power of combining with hydrogen, but also that there is a limit to oxidation just as there is to hydrogenation; so that just as CH_4 and SiH_4 represent the highest hydrides so RuO_4 and OsO_4 represent the highest oxides. Moreover this law has demonstrated that the maximum extent to which different non-metals enter into combination with oxygen is determined by the extent to which they combine with hydrogen, the sum of the number of equivalents of both being always equal to eight. Thus Cl forms ClH and Cl_2O_7; and since O is bivalent each chlorine atom has seven equivalents in the oxide and one in the hydride, making 8. So sulphur which fixes two equivalents of hydrogen cannot combine with more than six equivalents or two atoms, of oxygen. As to the peroxides, they have a character special to themselves. The peroxide form of sulphur (the so-called persulphuric acid) stands in the same relation to sulphuric acid that hydrogen peroxide stands in to water:

$$H(OH) \text{ or } H_2O \text{ is to } (OH)(OH) \text{ or } H_2O_2 \text{ as } H(HSO_4) \text{ or } H_2SO_4 \text{ is to } (HSO_4)(HSO_4) \text{ or } H_2S_2O_8.$$

So that the periodic law is strengthened rather than weakened by the existence of peroxides. In proof that the law extends to compounds, a double list of oxides is given with their densities and specific volumes, ranging from Na_2O and K_2O to S_2O_6 and Cr_2O_6. In a fourth column the differences are given between the volume of the oxygen compound and that of the parent element, divided by the number of oxygen atoms in the compound; and these differences steadily increase with the increase of oxygen.—*J. Chem. Soc.*, lv, 634, October, 1889. G. F. B.

2. *On Sonorous Sand in the Peninsula of Sinai;* by H. Carrington Bolton.—The author describes the results of his personal observations on the sonorous sands of Jebel Nagous, Arabia Petræa. The paper is in continuation of two others on Musical Sand presented jointly with Dr. A. A. Julien at the meetings of the American Association in Minneapolis and Philadelphia.

The isolated mountain of Jebel Nagous is situated about four and one-half hours northwest of Tor on the Gulf of Suez. On the steep slopes of this mountain rest several large banks of sand; one of these, called the Seetzen's Bell Slope, after its discoverer, emits distinct musical sounds whenever the sand slides down the incline either spontaneously or through the agency of man. The mountain consists of massive white sandstone carrying quartz pebbles and veins; it is about three miles long and 1,200 feet high. The Bell Slope measures 260 feet across the base, five or six feet across the top and is 390 feet high; it is bounded by nearly vertical walls of sandstone. The yellowish white sand rests on the rocks at the high angle of 31°, is very fine grained, and composed chiefly of quartz and calcareous sandstone. The grains are well rounded to subangular, and silt is notably absent. As the sand reposes at a high angle it possesses a curious mobility which causes it to flow down the incline like soft pitch or molasses; the sand above the point of disturbance falls into the depression and this depression advances up the slope at the same time. This downward flow takes place spontaneously whenever the sand, forced up the incline by the violent winds, accumulates in such quantity as to exceed the angle of rest. The movement is accompanied by a strong vibration and by a musical tone resembling the lowest bass note of an organ with a tremolo stop. The larger the bulk of sand moved the louder the sound; it is by no means so sensitive as the sand of so-called singing beaches (which the author has described elsewhere), and fails to emit sounds when struck with the hand or clapped together in a bag. The vertical cliffs on either side yield an echo that may magnify and prolong the sounds, which were loud enough to be heard several hundred feet. The peak of Jebel Nagous rises above the slope to the height of 955 feet above the sea level. The Bedouins of the region account for the acoustic phenomenon by attributing it to the *Nagous* or wooden gong of a subterranean monastery in the heart of the mountain, and claim that the sounds can only be heard at the hours of prayers.

Several other sandbanks presenting a similar appearance to the eye were tested but gave out no musical sounds whatever. Microscopical examination of these sands shows that they contain much silt, which prevents the vibrations necessary to yield the sounds. Further, the author after testing many sandbanks on the journey northward to Suez, discovered banks of sonorous sand resting on low cliffs a quarter of a mile long at Wadi Werdân about a day and a half from Suez, by camels, on hillocks called Ojrat Ramadân. The sand blown from the extensive plains to the north, falls over the southern face and rests at two angles, 31° at the top and 21° or less near the base. Wherever it possesses the mobility before described it emits a distinct musical note on being disturbed. The highest bank measures only sixty feet on the incline, and it is not probable that the sounds can occur spontaneously. Dr. Julien finds that at the new locality named by him Bolton's Bell Slope, the sand is chiefly quartz, with a larger proportion of calcareous sandstone than at Jebel Nagous. The size of the grains of quartz varies from 0·11 to $0{\cdot}42^{mm}$ and of sandstone 0·11 to $0{\cdot}34^{mm}$, the average being smaller than that of the sand grains on Jebel Nagous. Like the latter it is very free from silt.

After alluding to the various hypotheses advanced by different authors to explain the phenomena described, the author goes on to mention the explanation arrived at by himself and Dr. Julien. The cause of sonorousness in the sands of singing beaches and of deserts is believed to be connected with thin pellicles or films of air, or of gases thence derived, deposited and condensed upon the surface of the sand-grains during gradual evaporation after wetting by the seas, lakes, or by rains. By virtue of these films the sand-grains become separated by elastic cushions of condensed gases, capable of considerable vibration, and whose thickness has been approximately determined. The extent of the vibration and the volume and pitch of the sound thereby produced, after any quick disturbance of the sand, is also found to be largely dependent upon the forms, structures and surfaces of the sand grains, and especially upon their purity or freedom from fine silt or dust. Though the environment of the sand on beaches and in the desert differs greatly as respects moisture, this above theory is regarded applicable to both. Water is not wholly lacking even in the desert to aid in the chemical cleansing of the sand grains, and the powerful winds accomplish the work of sorting and winnowing done by the waves elsewhere. The fineness of the grains at the Bell Slopes makes the displacement of a very large amount of sand necessary for the production of sound, while the coarser particles on the beaches yield a resonance on a smaller provocation. The pitch of the musical notes produced on sea beaches is directly proportional to the mass of sand moved, the greater the mass the lower the tones; on the Bell Slopes in the desert the large mass moved, yields a very deep note.—*Amer. Assoc. Adv. Science*, vol. xxxviii.

3. *Electromagnetic effect of Convection.* — F. HIMSTEDT has repeated Rowland's experiments upon this subject and concludes that electric convection can produce electromagnetic effects. Rowland's results have been questioned by certain observers, among them, by Lecher (Rep. d. Phys., xx, p. 151, 1884). Himstedt believes that Lecher's apparatus was not sufficiently sensitive to obtain the phenomena. During the progress of his work, Himstedt discovered that ebonite shows traces of magnetism and therefore he used glass discs. The method was the same as that employed by Rowland. Two glass discs, rubbed with graphite, and strongly charged were set in revolution, one on each side of an astatic combination. The speed of the discs was from 60 to 170 revolutions per second. In general Himstedt confirms Rowland's work. He does not however confirm Rowland's observation that a difference is called forth by changing the direction of rotation. No difference could be observed.—*Ann. der Physik und Chemie*, 1889, No. 12, pp. 560–573. J. T.

4. *Mechanical equivalent of Light.* — H. O. TUMLIRZ states his results as follows: A surface of 1 square centimeter placed at a distance of 1 meter from the planes of an Amylacetate lamp—in such a way that the normal to the surface is horizontal and passes through the middle of the plane—receives per second a quantity of light which expressed in units of work is

$$\frac{15{\cdot}15\ (cm^2 g\ \mathrm{sec}^{-2})}{1\ \mathrm{sec}}$$

If the pupil of an eye is placed at the surface its aperture is 3^{mm} it receives in each second,

$$\frac{1\ (cm^2 g\ sec^{-2})}{1\ sec}$$ units of work. This quantity of work would require 1 year 89 days to raise 1 gram of water 1° C. A comparison of the light of the sun and that of stars of various orders of magnitude is appended to the paper.—*Ann. der Physik und Chemie*, 1889, No. 12, pp. 640–662. J. T.

5. *The Bolometer.*—R. VON HELMHOLTZ constructed a bolometer of which all four branches of the Wheatstone's bridge were contained in the cylindrical case of the instrument and two branches of the bridge were exposed to the source of light. The theory indicates that the resistance of the four equal branches of the bolometer balance should be as great as possible (with suitable galvanometer resistance) that this resistance should be in the form of blackened strips: that these strips should receive the light along their entire length.—*Beiblätter Ann. der Physik*, 1889, No. 12, p. 882. J. T.

6. *The Cavendish Experiment.*—C. V. BOYS has greatly reduced the size of the apparatus used by Cavendish to measure the force of attraction between two masses. Mr. Boys shows that an apparatus the size of an ordinary galvanometer can be employed. As a lecture room experiment the attraction of small masses can readily be shown, even though the resolved force causing motion is no more than the $\frac{1}{200,000}$ of a degree (less than $\frac{1}{10,000,000}$ of the weight of a grain), and this is possible with the comparatively short period of 80 seconds. So perfectly does the instrument work, that there can be no difficulty in making a fairly accurate measure of the attraction between a pair of No. 5 or even of dust shot.—*Nature*, Dec. 19, 1889, p. 154. J. T.

7. *Report on the Magnetic Results of the Voyage of H. M. S. Challenger.*—"The voyage of the Challenger has shown that local magnetic disturbance is found in the solitary islands of the seas, although surrounded by apparently normal conditions similar to those on the great continent. It has been suggested that the magnetic portions of these islands causing the disturbance may possibly have been raised to the earth's surface from the magnetized portion of the earth forming the source of magnetism and tending to prove Airy's conclusion that "the source of magnetism lies deep.

"In view, therefore, of past geological changes and those now in progress, it may fairly be conceived, not only that larger changes have likewise occurred in the distribution of the magnetic portions of the earth appearing here and there on the surface and producing local magnetic disturbance, but that there are others of a more progressive character below the earth's surface which are only made manifest by the secular change observed in the magnetic elements. This conception with regard to secular change is not intended to exclude the view that solar influences may have a small share in producing the observed phenomena."—*Nature*, Dec. 5, 1889, p. 165. J. T.

II. Geology and Mineralogy.

1. *Report of the State Geologist, of New York, for the year* 1888.—Forty-second Annual Report New York State Museum Natural History. Albany, 1889, pp. 351–496. This report and those of the Director of the Museum, the State Entomologist, and the State Botanist, included in the same volume, give evidence that the spirit of scientific investigation that was developed during the geological survey of 1836–'40 is still active and producing results of high scientific value. The report under consideration, by Prof. James Hall, should be in the hands of every working geologist and paleontologist in America.

A short sketch of the contents of Vol. VII, of the Paleontology of New York, is given with a synoptical table of the genera and species of Devonian crustaceans, and a list of the types in the possession of the State Museum. An historical statement of the preparation of Vol. VII. of the same work, on the genera of Brachiopoda, is presented, and followed by a most useful list of 207 genera of the Paleozoic Brachiopoda, prepared by Prof. J. M. Clarke.

A list, prepared by Mr. Charles Schuchert, of the fossils occurring in the Oriskany sandstone of Maryland, New York, and Ontario, exhibits 140 species, 14 of which pass from the Lower Helderberg into the Oriskany sandstone and from the latter, 54 species pass upward into the Upper Helderberg, or Corniferous limestone. Of the 371 species of the Lower Helderberg fauna 3.75 per cent. only pass up into the Oriskany sandstone. A list is given of the specimens originally arranged by Prof. E. Emmons, as representatives of the Taconic System.

Another important list is the record of locality numbers used in labelling the specimens collected for the illustration of the paleontology of the State of New York. A record is given to No. 730 and the list will be continued in the next report.

A note, on the genus Bronteus in the Chemung Rocks of New York, by Prof. J. M. Clarke, describes the discovery of a new species, *B. senescens*, represented by a portion of the pygidium. This is probably the latest recorded appearance of the genus Bronteus (pp. 401–405). Professor Clarke also gives a list of the species constituting the known fauna and flora of the Marcellus epoch of New York.

One of the most interesting papers in the report is that of Professor Clarke on "The Hercynian Question."

The Hercynian Fauna of the Northern Hartz in Germany.—A. Roemer (1843) regarded the fauna as Upper Silurian; subsequently the Cephalopod facies of the fauna was considered as Devonian, and the Brachiopod facies as Silurian. Beyrich (1867) believed the two faunas of Roemer to be one, and suggested their equivalence to Barrande's stages F, G, H, and their relation to the Devonian; Kayser (1878) demonstrated their unity and Devonian character; in 1880 he regarded them as Lower Devonian, representing a calcareous facies of the Coblenzian and parallel to the F, G, H fauna, but, in 1884, he appears to have resumed his original position in regard to the age of the Hercynian, modifying his conception of the parallelism of the Bohemian fauna by removing from his equivalent the lower portion of F. Novak (1886) shows that the fauna of F was not divisible except into different facies. Frech (1886) made the Bohemian representative of the Devonian series the top of the middle division, and F the equivalent of the Hercynian, as lowest Devonian; in 1887 he placed the base of the Bohemian Devonian at E (Hercynian). Barrois (1889) made the Hercynian, with Beyrich and Kayser (1878, not 1880), a lowest Devonian fauna, but differed from Kayser (1878, 1880) in regarding it, not as a calcareous facies of the Coblenzian, but as such a facies of the older Gedennian, considering the Bohemian stage G as its eqivalent.

Professor Clarke next discusses the equivalent rocks of North America or the Lower Helderberg, Oriskany and Upper Helderberg, and argues that the fauna of the Lower Helderberg is more closely related to that of the Devonian Oriskany fauna than to the Niagara. In conclusion he says: "What has been here written is intended to be only suggested, and the inquiries to which it should give rise are:

"(*a*) Is the normal Lower Helderberg fauna, by virtue of predominant Devonian characters, to be referred to the Devonian system?

"(*b*) Is it the American equivalent of the European Hercynian, i. e. an earliest Devonian calcareous pelagic fauna?

"(*c*) Is it the pelagic fauna, of which the Oriskany Sandstone includes the arenaceous facies?"

This suggestion comes to me with peculiar force at the present time, and, if the Silurian system was to be re-classified to-day, I should favor the following scheme: lower division, Canadian, Calciferous and Chazy; middle division, Trenton and Hudson, and upper division, Niagara and Salina. The summit of the Silurian would be drawn at the Waterlime formation, and the Lower Helderberg would be considered, with the Oriskany sandstone, as lowest Devonian. This, to my mind, is the more natural classification, and divides the Paleozoic into four subequal groups—Cambrian, Silurian, Devonian, and Carboniferous. C. D. W.

2. *Kadaliosaurus priscus* Credner, *a new Reptile from the Lower Permian of Saxony;* by DR. G. BAUR.—Only a few months ago Professor H. Credner described a very important Reptile from the Permian of Saxony, which he called *Palæohatteria longicaudata.** To-day I have received through the kindness of Professor Credner another paper,† which deals with a new reptile from the same locality entirely different from *Palæohatteria.* It is called *Kadaliosaurus priscus.*

When the animal was discovered by the quarrymen it was complete, but in taking it out it was partially destroyed. In this

* Zeitschr. deutsch. geol. Ges., 1888. This Journal, April, 1889.
† Zeitschr. deutsch. geol. Ges., 1889, pp. 319–342, pl. xv.

condition it was found by Mr. F. Etzold, the assistant of Professor Credner. It consists now of parts of the dorsal and caudal vertebræ with ribs, parts of the anterior and posterior extremities, the pelvis, and the complete set of abdominal ossicles. No parts of the skull and the scapular arch were preserved.

Kadaliosaurus had the shape of a Lizard with relatively very long limbs of equal size. There were about twenty dorsal vertebræ each 9–10^{mm} long. The vertebræ are considered biconcave with persistent notochord and short neural spines. The ribs were hollow and one-headed. The sacrum consisted of two vertebræ, with strong sacral ribs; the tail was probably not very long, but possessed very long ribs on the first four vertebræ.*

The constitution of the abdominal skeleton is very remarkable. It extends from the shoulder-girdle to the pelvis, consisting of about 80 strings of ossicles. Each of these strings is composed in the anterior two-thirds of the "plastron" of a median and 5–6 lateral pieces. The distal end of each piece is forked for the reception of each following one. Median pieces are only developed in the anterior part; the lateral pieces diminish in number from front to behind, there being only two or three at the end. According to Credner, from whom this account is taken, these abdominal ossicles were connected by five or six bands of ossicles with the true ribs, but only in the anterior region of the body. The pelvis was very strong and solid. The ilium showed anterior and posterior processes, very much more developed than in *Palæohatteria*, pubis and ischium were plate-like; all three seemed to take part in the acetabulum. The limb-bones were solid, with well-ossified condyles; humerus with an ectepicondylar foramen; femur strongly curved. Fore- and hind-limbs of about the same length. The first row of the tarsus contained two bones, astragalus and calcaneum. The end phalanges formed curved claws.

The question now is, what is the systematic position of *Kadaliosaurus?* Professor Credner calls it a lizard-like reptile, and seems to be inclined to consider it as an ancestral form of the Lacertilia. He lays much stress on the foramen ectepicondyloideum of the humerus. But it seems to me that it is not quite sure yet, whether this foramen is really ect- or entepicondylar. I do not think it possible to determine the exact systematic position of this interesting fossil until the skull and shoulder girdle are known. It may be the ancestor of Lizards, but it may be just as well the ancestor of the archesaurian branch of Reptiles, containing Crocodilia, Dinosauria, Pterosauria, or that of Birds. We have to wait for more material for the solution of this question.

My opinion on the origin of the abdominal ossicles in the Reptilia is entirely supported by the condition found in *Kadalio-*

* These ribs are very peculiar and quite unique among Reptiles, with the exception of the Mesosauridæ, in which the first caudal ribs are also long. In *Kadaliosaurus* the first caudal rib is the longest, the fourth the shortest, the posterior ends of these four ribs are nearly on a straight line.

saurus. A similar arrangement is seen in *Palæohatteria*, *Hyperadapedon* and *Mesosaurus* (Stereosternum). Each of these three genera forms a distinct family of which the *Palæohatteridæ* is the most generalized; the *Hyperadapedontidæ* is a highly specialized family, which probably, or certainly did not leave any descendants; the same I may say of the Mesosauridæ which I consider as aquatic forms of the Proganosauria. The Proterosauridæ and Rhynchosauridæ are in the line of the Rhynchocephalia.

The chronological order of the different families is probably the following:

Palæohatteriidæ:	"Mittel Rothliegendes" (Lower Permian).
Kadaliosauridæ:	"Mittel Rothliegendes" (Lower Permian) a little higher than the Palæohatteriidæ
Proterosauridæ:	"Kupferschiefer" (Upper Permian).
*Mesosauridæ:**	Karoo-system (position not sure, but probably older than Upper Triassic).
Hyperadapedontidæ:	Upper Triassic.
Rhynchosauridæ:	Upper Triassic.

Prof. Huxley has placed *Rhynchosaurus* together with *Hyperadapedon* in one family Rhynchosauridæ; the structure of the abdominal ossicles, so different in both,† leads to a different opinion. I consider *Hyperadepedon* as the representative of a distinct family Hyperadapedontidæ, related to the Proganosauria, forming a highly specialized branch of this primitive order. The Rynchosauridæ are nearly related to the Sphenodontidæ and form a family of the Rhynchocephalia. The Proterosauridæ seem to connect the Rhynchocephalia with the Proganosauria.

3. *American Geological Society.*—The American Geological Society held its first annual meeting on the 26th to the 28th of December, at the American Museum of Natural History, New York. The meeting was a very large one, and comprised geologists from all parts of the country and from Canada, and in this respect, in the value of the many papers presented and the spirit of the discussions, it was a great success. The number of papers presented was nearly forty, and over a sixth of them were by Canadian geologists. The authors included Sir William Dawson, D. P. Penhallow, R. Bell, A. C. Lawson, R. G. McConnell, J. B. Tyrrell, R. W. Ells, P. McKellar, T. C. Chamberlain, James Hall, J. S. Newberry, S. F. Emmons, J. S. Diller, G. H. Williams, I. C. Russell, E. Orton, Wm. B. Clark, Wm. M. Davis, G. F. Wright, W. J. McGee, C. D. Walcott, E. Brainard, H. M. Seely, R. P. Whitfield, C. D. White, A. S. Bickmore, A. Winchell, C.

* *Stereosternum* Cope, from Brazil, which had been considered as of probable Carboniferous age is not distinguishable from *Mesosaurus* from the Karoo-system of South Africa. The South American strata represent the Karoo-system of South Africa.

† The abdominal ossicles of *Rhynchosaurus* are of the same structure as those in *Sphenodon.* In a specimen in the British Museum I have counted thirty-two abdominal bones.

New Haven, Conn., Dec. 10, 1889.

H. Hitchcock, B. K. Emerson, C. R. Van Hise, F. L. Nason, W. Upham, F. J. H. Merrill, W. O. Crosby, P. Fraser, E. D. Cope.

The next meeting is to be held at Indianapolis, at the time of the meeting of the American Association. Prof. Dana was elected President for the coming year. Prof. J. S. Newberry and Alexander Winchell, Vice-Presidents. An address was delivered by the retiring President, Prof. James Hall, on the earlier American geologists.

4. *New fossils from the Lower Cambrian.*—Mr. C. D. Walcott describes, as new, in the Proceedings of the U. S. National Museum, xii, 33–36, *Kutorgina Labradorica* var. *Swantonensis*, Swanton and Highgate Springs, Vt.; *Obolella Atlantica*, Eastern Newfoundland and North Attleborough, Mass.; *Camerella minor*, Stissingville, Dutchess Co., N. Y.; *Coleoloides* (new genus) *typicalis*, a shell near Hyolithes, Manuel's Brook, Newfoundland; *Hyolithes terranovicus* and *H. similis*, same locality as the preceding; *Helenia* (new genus) *bella* same loc.; *Agnostus desideratus*, Salem, Washington Co., N. Y.; *Microdiscus helena*, Manuel's Brook; *Olenellus Bröggeri*, Eastern Newfoundland, and perhaps Shropshire, England; *Avalonia* (new genus) *Manualensis*, a trilobite, Manuel's Brook; *Zacanthoides Eatoni*, Washington Co., N. Y.; *Solenopleura Harveyi*, Manuel's Brook; *S. Howleyi*, same loc.

5. *A Lingula with a cast of its peduncle* has been described by C. D. Walcott in the Proceedings of the U. S. National Museum for 1888 (p. 480). The species is the *L. æqualis* of Hall; its locality, the upper part of the Lorraine shales near Rome, N. Y. Mr. Walcott refers to Davidson's description of a similar case in the *Eichwaldia subtrigonalis* from the Black River limestone in Canada, and of a similar specimen of *Lingula? Lesueuri.*

6. *Cambrian fossils in the Salt Range, India;* by Dr. A. Warth.—Dr. Warth reports the discovery of a *Conocephalites* resembling *C. formosus* Hartt, of the St. John's group, and probably an *Olenus*, in the "Neobolus beds." It indicates a great unconformity in the Salt Range; the beds above the plane of unconformability are Upper Carboniferous and Permian.

7. *Wulfenite from Sing Sing, N. Y.*—Specimens of wulfenite from Sing Sing, N. Y. have recently been received by the editors from Mr. Ernest Schernikow of New York City. It occurs in small red tetragonal crystals of thick tabular habit; the form and blowpipe characters are both characteristic of the species. The crystals are implanted upon a mammillary variety of green pyromorphite, which forms a thin coating upon a friable crystalline limestone. A reddish mammillary mineral very sparingly associated with the pyromorphite has proved to be vanadinite.

8. *Rutile-Edisonite.*—Mügge has recently described some peculiar forms of rutile from the Ural and from Snarum. They show cleavage parallel to the two square prisms and in addition a parting in a direction nearly parallel to faces of the form $\frac{9}{2}$-i (902); the observed angle between two faces (over 100) was 36° 51′ to 37° 47′, while for rutile we have $902 \wedge 90\bar{2} = 38° 4'$. In con-

nection with this the author calls attention to the form of TiO_2 from North Carolina described as a dimorphous form of rutile by Descloizeaux,* and shows that it is apparently beyond doubt to be explained in this way.—*Jahrb. Min.*, i, 231, 1889.

9. *Native Gold in Calcite;* by J. S. Diller (Communicated).—While at Minersville, Trinity County, Cal., last summer, Mr. Bates of that place showed me several excellent specimens of native gold associated with calcite. They were obtained from a mine on Digger Creek, about a mile above Minersville. I visited the locality in a narrow gulch and found that the mine, although not worked at present, was once vigorously and profitably operated. Two drifts were run into the hillside for nearly 100 feet and considerable gold removed. The calcite occurs in small lenticular masses in a dark carbonaceous shaly rock which is sometimes black and slickensided with a graphitic aspect. The shaly layer is highly inclined and crumpled and varies from one inch to fifteen feet in thickness. The calcite is very irregularly distributed in the dark layer and is not always auriferous, but is occasionally very rich in gold. One of Mr. Bates's specimens is nearly as large as a fist and three-fourths of its volume was estimated to be native gold. Quartz also has been found in the mine but it is less abundant than the calcite and rarely auriferous.

The strata belong to the auriferous slate series and are considerably metamorphosed. In the dark mass containing the calcite as well as beneath it in an impure limestone, there is considerable pyrite which by its decomposition coats portions of the mine with copperas and oxide of iron. It may be that the gold came from the pyrite. Mrs. J. H. Tourtellette of Minersville has presented several specimens to the National Museum of Washington, D. C.

Washington, D. C., Dec. 11, 1889.

10. *Brief Notices of some recently described Minerals.*—Wurtzilite. A kind of bitumen described by W. P. Blake from the Uintah Mts., Wasatch Co., Utah, and named after Dr. Henry Wurtz of New York. It is a firm solid, having a brilliant luster and breaking with a conchoidal fracture; it has a deep black color in reflected light, but translucent and reddish in thin splinters. It is sectile and is more or less elastic in thin shavings, the elasticity increasing when it is slightly warmed. The hardness is between 2 and 3, and the specific gravity 1·030. It becomes soft and plastic in boiling water and in the flame of the candle takes fire and burns with a bright bituminous flame. It resists the usual solvents of bitumen. Wurtzilite is related to elaterite and also resembles in some points the uintahite or gilsonite obtained from the same region.—*Eng. Mining Journal*, Dec. 21, 1889.

Ferrostibian, Pleurasite, Stibiatil, Epigenite. Minerals described by Igelström as occurring at the Sjö mines, Grythytte

* Bull. Soc. Min., ix, 184, 1886; this has later been made a new species by Hidden under the name *Edisonite*, this Journal, xxxvi, 272, 1888.

parish, Sweden. *Ferrostibian* is found imbedded in rhodonite in well developed monoclinic crystals. The color is black to blackish-gray, the streak brown, the luster submetallic, the hardness 4; it is weakly magnetic. An analysis gave

Sb_2O_3	FeO	MnO	H_2O	
14·80	22·60	46·97	10·34	Mg_2CO_3, $CaCO_3$ 2.14, insol. 2·24=99·09

Pleurasite from the same locality is regarded as an arseniate of iron and manganese containing chlorine. It has a blue-black color, submetallic luster, a conchoidal fracture, and hardness of 4. No analysis is given, the assumed composition being based upon some blow-pipe and other qualitative tests. *Stibiatil* is another imperfectly studied mineral, regarded as a hydrous antimoniate of manganese and iron, associated with polyarsenite (sarkinite). It occurs in crystals, referred to the monoclinic system, and is black and opaque with metallic luster and has a hardness of 4.

EPIGENITE.—A hydrous silicate of manganese and magnesium occurring in brownish red bladed masses imbedded in tephroite. An analysis gave

SiO_2	MnO	MgO	FeO	H_2O
29·50	40·60	20·05	*tr.*	9·85=100·

The formula deduced is $R_2SiO_4+H_2O$ which places it near the hydrotephroite of the same author. The same name has been used before for a mineral related to enargite.—*Geol. Förening i Stockholm Förhandl.*, xi, 389, 1889.

11. *Native Arsenic from Colorado.*—Mr. CLARENCE HERSEY has announced the discovery of native arsenic in a mine yielding silver and some gold, five or six miles west of Leadville, Colorado. The mineral occurs in nodular concretionary forms so brittle that they readily break to fragments.

12. *Catalogue of Minerals found in New Jersey*, by F. A. CANFIELD, 23 pp. Trenton, N. J. 1888.—From the final report of the State Geologist, vol. ii. This well prepared list will be useful to all interested in the local mineralogy of New Jersey.

III. BOTANY AND ZOOLOGY.

1. *Hybrids.*—G. DE SAPORTA (Comptes rendus, Oct. 28, 1889) gives an interesting account of certain hybrids observed in Provence. These are (1) *Pinus halepensis-pinaster*, the mother-plant being assumed to be *P. pinaster*, and the father, *P. halepensis.* The hybrid has the port of the mother but with less regularity of branching, and having the grayish bark scaling off in large flakes. The leaves, so far as their size is concerned, are just between the two. (2.) *Quercus pubescente-Mirbeckii.* The hybrid is exactly intermediate between the two parents. The mother, *Q. Mirbeckii*, is from Africa. (3.) *Tilia platyphyllo-argentea* has hybrids of all ages, showing that the fertilization is not, by any means, confined to any particular year.

It is noteworthy that of the species mentioned above, two are monœcious, and one hermaphrodite. G. L. G.

2. *The cause of the ascent of sap.*—Josef Boehm (Berichte der Deutsch. bot. Gesellschaft, Nov. 28, 1889) states the results of certain interesting experiments which he interprets as proving that in plants which are "transpiring," the absorption of water by the roots is caused by capillarity, while the transfer of water to the parenchyma of the leaf is brought about by the pressure of air within the tissues. The experiments appear to the present reviewer to be capable of an entirely different explanation, and a detailed account of some modifications of Boehm's line of work will be shortly published, but it will be well to give briefly at this time an outline of the suggestive method pursued by Boehm. To show that the absorption of liquids by roots is not due to osmosis (since that depends on the activity of the protoplasmic lining of the cells of the root-hairs and adjacent epidermis) he *boils* the roots in water in order to kill the living matter. He finds that after this destructive process, absorption of liquids goes on as before; at any rate, the supply of liquid to the leaves is sufficient to prevent any wilting. To this subject it is proposed to recur at an early day. G. L. G.

3. *Memoirs of the Torrey Botanical Club.*—Vol. I, No. 1, Studies of the Types of various species of the genus *Carex.* By L. H. Bailey. pp. 85. No. 2, Marine Algæ of the New Jersey Coast and adjacent waters of Staten Island. By Isaac C. Martindale. pp. 22. These are in octavo, and are unexceptionable in their typographical execution. From the titles of these first two memoirs it is plain that the Club has determined to appeal at the very outset to a wide range of specialists, and we trust earnestly that this praiseworthy effort will meet with the heartiest response. The Bulletin of the Torrey Club is known to all of our botanical readers, and we hope that this their supplementary publication will soon receive the substantial aid of all our botanists.

It is certainly creditable to botanical science in this country that our two botanical journals, the Bulletin of the Torrey Club, and the Botanical Gazette, should be so well patronized. Both of them are excellent, and deserve, and should receive strong support at the hands of all amateur and professional botanists in this country. G. L. G.

4. *On the nitrification of Ammonia.* — Th. Schlœsing (Comptes rendus, Dec. 9, 1889) has continued his experiments on the behavior in the soil of certain salts of ammonia, and now reaches the conclusion that the process of nitrification is not only accompanied by the formation of nitrites, as has long been known, but that these products distinctly retard the further progress of nitrification. The nitrifying microbes are plainly hindered in their work by these partially oxidized substances. G. L. G.

5. *On the part which Ammonia plays in the nutrition of the higher plants.*—A. Müntz (Comptes rendus, 21 Oct., 1889) first traces the history of the subject, pointing out the successive phases of development of the subject, going as far back as the time in which it was held that only organic compounds of nitro-

gen could be made available to plants, down to the present. His observations are directed chiefly to the demonstration of the thesis that ammonia can be utilized by vegetation without previous nitrification. For this purpose he made use of soil thoroughly sterilized and freed from every trace of nitric or nitrous acids in any combination, and in these soils provided with ammonia, he carried on his cultures. His experiments are not sufficiently extensive to settle the question, but they go very far to show that the nitrification of ammoniacal manures cannot be regarded as indispensably necessary to the utilization of the nitrogen therein contained. G. L. G.

6. *Fixation of Nitrogen by Leguminous plants*, (Comptes rendus, 28 Oct., 1889).—E. Bréal has already communicated to the French Academy the results of his experiments showing that it is possible to inoculate the roots of Leguminous plants from the tubercles of other species, therefrom transferring bacteria which produce tubercles. The same experimenter gives now the chief facts in regard to his cultivation of plants of this order for the purpose of ascertaining the relations of the tubercles to the utilization of the nitrogen of the soil. His experiments can be fairly interpreted as confirmatory of some of the studies of Hellriegel, Wilfarth and Berthelot. G. L. G.

7. *Economic Mollusca of New Brunswick*, by W. F. Ganong.—Bulletin viii, of the Natural History Society of New Brunswick, Saint John, N. B., 1889, contains facts on the distribution of mollusks of the coast which are of much interest in Quaternary geology.

9. *Bibliotheca Zoologica*, II, Verzeichniss der Schriften ueber Zoologie welche in den periodischen werken enthalten und vom Jahn 1861–1880, Selbständig erschienen sind, bearbeitet von Dr. O. Taschenberg (Wm. Engelmann, Leipzig).—The seventh part of this important work (see vols. xxxiii *et seq.*) has recently been issued including signatures 241–280, pp. 1971–2290.

IV. Miscellaneous Scientific Intelligence.

1. *American Metrological Society.*—This society, founded in 1873, has elected the following officers for the year 1890:

President, B. A. Gould, Cambridge, Mass.

Vice-Presidents, T. R. Pynchon, Hartford, Conn.; Sanford Fleming, Ottawa, Canada; T. C. Mendenhall, Washington, D. C.; T. Egleston, New York City; R. B. Fairbairn, Annandale, N. Y.; J. H. Van Amringe, New York City. Treasurer, John K. Rees, New York City. Recording Secretary, John K. Rees, New York City. Corresponding Secretary, O. H. Tittmann, Washington, D. C.

Members of the Council, H. A. Newton, Cleveland Abbe, R. H. Thurston, A. M. Mayer, C. F. Brackett, W. F. Allen, Simon Newcomb, S. P. Langley, E. O. Leech, Geo. Eastburn.

The following is cited from the Constitution of the Society:

Objects of the Society.—(1) To improve existing systems of weights, measures and moneys, and to bring them into relations of simple commensurability with each other.

(2.) To secure universal adoption of common units of measure for quantities in physical observation or investigation, for which ordinary systems of metrology do not provide; such as divisions of barometer, thermometer, and densimeter; amount of work done by machines; amount of mechanical energy, active or potential, of bodies, as dependent on their motion or position; quantities of heat present in bodies of given temperatures, or generated by combustion or otherwise; quantity and intensity of electro-dynamic currents; aggregate and efficient power of prime movers; accelerative force of gravity; pressure of steam and atmosphere; and other matters analogous to these.

(3.) To secure uniform usage as to standard *points of reference*, or physical conditions to which observations must be reduced for purposes of comparison; especially temperature and pressure to which are referred specific gravities of bodies, and the zero of longitude on the earth.

(4.) To secure the use of the decimal system for denominations of weight, measure, and money derived from unit-basis, not necessarily excluding for practical purposes binary or other convenient divisions, but maintained along with such other methods, on account of facilities for calculation, reductions, and comparison of values, afforded by a system conforming to our numerical notation.

Modes of operation.—(1) The society will endeavor to carry out its objects, by appeals to congress, state legislatures, boards of education, higher institutions of learning, and to directors and teachers of schools of every grade throughout the country, urging adoption of measures in their several spheres for diffusing information as to the present state of the world's metrology and recent progress in its reform, and specially for instructing the rising generation in these matters, to the end that our people may be early and fully prepared to act intelligently on the important questions connected with weights and measures.

(2.) By invoking the aid and coöperation of bodies organized to consider questions of scientific or social interest, boards of trade, chambers of commerce, societies of engineers, industrial associations, professions and trades, in this country and elsewhere.

(3.) By specially urging scientific bodies to open communications with similar bodies in other countries, with a view to general agreement on values to be henceforth uniformly given to units of measure and points of reference which particularly concern them: i. e., to the so-called constants of science.

(4.) By memorializing Congress in favor of laws requiring the use, in certain departments of the public service, of metric weights and measures, wherever such legislation may tend to relieve commerce of some of its burdens, to facilitate international communication, to promote international jurisprudence, and to familiarize our own people with the benefits of that system of metrology, with the least interference with their ordinary habits of thought or daily business.

(5.) By direct appeals to the people through the public press, and by circulating so far as means allow, books and documents informing the public of the defects of the common system of weights and measures, the means most proper for its amendment, and the great advantages which the acceptance of a universal system would insure to all mankind.

2. *Royal Society of N. S. Wales*, vol. xxii, Part 2. 1888.—This number of the Journal and Proceedings contains an important illustrated paper by J. E. Tennison Woods on the anatomy and life-history of Mollusca peculiar to Australia; a paper on the desert-sandstone of Australia, making it largely of volcanic origin, by the same; a catalogue with comparative observations of the older Tertiary fossils of Australia, by Prof. R. Tate; notes on N. S. W. minerals, by A. Liversidge; and other papers.

3. *Reports of Examinations of Waters and Water Supply and related subjects during the years* 1886–89, by E. W. HILGARD.—The following note on *the change of saline condition attending concentration* in some California lakes is taken from this valuable report.

The three lakes of the Upper San Joaquin Valley—Kern, Buena Vista and Tulare—were once connected, and the alkali contained in their waters is manifestly of the same origin. Evaporation has for years past gradually concentrated their waters, for want of the natural influx (Kern River) now diverted by irrigation ditches. But analysis showed that apart from concentration, a change in the *ratio* between the soluble salts has been going on as evaporation progressed. The cause of this change was not obvious.

The table below giving the results of the analyses made in 1880 and one lately made of the water of Tulare Lake, which has likewise been seriously diminished by evaporation so as to more than double its solid contents, shows a difference has occurred corresponding to that which in 1880 existed between Kern and Tulare Lakes. That is, the relative proportions between sodic carbonate on one hand and common and Glauber's salts on the other, have changed, and are tending toward the same ratio that then existed in Kern Lake, evidently as the result of concentration. There has been a relative diminution of the sodic carbonate; in conformity with the rule shown in our experiments, above reported, that as the amount of neutral alkali salts is increased, a relatively smaller amount of carbonate is formed under the influence of $CaCO_3$ and CO_2. The calcic carbonate required for the reaction is abundantly present both in the waters and in the deposits of the lake. The following table shows the *increase of alkali carbonates by concentration.*

Locality.	Total Residue.	Carbonate of Soda.	Common and Glauber's Salt.
1880, Tulare Lake, near mouth of Kings River,	38·55	1	1·11
1880, Tulare Lake, middle	81·83	1	1·29
1880, Tulare Lake, south end	81·49	1	1·35
1888, Tulare Lake, middle	204·00	1	1·58
1889, Tulare Lake, north end	303·07	1	1·94
1880, Kern Lake	211·50	1	1·78

Doubtless a host of similar examples can be found within arid regions. We hope before long to communicate additional results.

4. *Arthrolycosa antiqua of Harger*, volume vii, 219, 1874, and xxxviii, 219, 1889.—Justice to Mr. Harger requires it to be stated—what he did not state in his paper—that he was not at liberty to develop any covered parts of the spider on the specimen put in his hands for description. The specimen was regarded as a very valuable one, and the parts of the animal were supposed to be fully exposed. J. D. DANA.

Transactions of the Kansas Academy of Science, vol. x, 1885–86. 154 pp. 8vo.—"A fossil bird-track" from the Dakota sandstone is described by Professor F. H. Snow, on pages 3 to 6, with an accompanying figure; a historical sketch is given of geological work in the State, by Robert Hay and A. H. Thompson, on pages 45 to 52; and besides there are other short papers of value.

A theoretical and practical treatise on the strength of beams and columns, by ROBERT H. COUSINS. 170 pp. 8vo. New York, 1889 (E. & F. N. Spon).

Richtigstellung der in bisheriger Fassung unrichtigen mechanischen Wärmetheorie und Grundzüge einer allgemeinen Theorie der Aetherbewegungen von A. R. von Miller-Hauenfels. 256 pp. 8vo. Vienna, 1889.

Der Einfluss einer Schneedecke auf Boden, Klima und Wetter; von A. Woeikof, Prof. Phys. Geogr. Univ. St. Petersburg. Penck's Geograph. Abhandl. Wien, iii, heft 3. 116 pp. 1889.

OBITUARY.

CHARLES ALBERT ASHBURNER.—The able geologist, of Pennsylvania, Mr. Charles A. Ashburner, died at Pittsburg, on the 24th of December in his 36th year, having been born in Philadelphia in February, 1854. He left the University of Pennsylvania with high honors in 1874, and during the past year received from the University the honorary degree of Doctor of Philosophy. Soon after graduation, on the organization of the Second Geological Survey of the State, he became an assistant in the survey, and in this position the larger part of his geological investigations were carried on. Mifflin, Juniata, McKean, Elk, Forest and Cameron counties were surveyed and reported on by him, and also with great completeness and excellence of maps and sections, the anthracite coal fields which were made his special work in 1880. In 1885, when the director of the survey, Prof. Lesley, commenced the preparation of his final report on the survey, Mr. Ashburner was put in charge of the executive business of the whole State Survey. In 1887 Mr. Ashburner was given the Bituminous Coal-Region for investigation and report. Subsequently he became connected with the Philadelphia Natural Gas Company, as an expert, and made Pittsburg his place of residence. Mr. Ashburner was a man of great energy and executive ability, and of thoroughness in all his work, as his various reports show. The Pennsylvania Survey owes much of the value of its results to his labors.

CONTENTS.

Chas. D. Walcott,
U. S. Geological Survey.

VOL. XXXIX. MARCH, 1890.

Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

EDITORS

JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS JOSIAH P. COOKE, GEORGE L. GOODALE AND JOHN TROWBRIDGE, OF CAMBRIDGE.

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

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XXXIX.—[WHOLE NUMBER, CXXXIX.]

No. 231.—MARCH, 1890.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1890.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

Chas. D. Walcott.

THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXII.—SEDGWICK and MURCHISON: *Cambrian and Silurian*; by JAMES D. DANA.

ERRONEOUS impressions have long existed among American geologists with regard to the relations to one another, and to Cambrian and Silurian geology, of SEDGWICK and MURCHISON. The Taconic controversy in this country served, most unreasonably, to intensify feelings respecting these British fellow-workers in geology, and draw out harsh judgments. Now that right views on the American question have been reached, it is desirable that the facts connected with the British question should be understood and justly appreciated.

Sedgwick and Murchison were literally fellow-workers in their earlier investigations. Professor John Phillips, in a biographical sketch of Sedgwick,* whose intimate friendship through fifty years "he had the happiness of enjoying," speaks thus, in 1873, of their joint work:

"Communications on Arran and the north of Scotland, including Caithness (1828) and the Moray Firth; others on Gosau and the eastern Alps (1829–1831); and still later, in 1837, a great memoir on the Palæozoic strata of Devonshire and Cornwall, and another on the coeval rocks of Belgium and North Germany, show the labors of these intimate friends in the happiest way—the broad generalizations in which the Cambridge professor delighted, well supported by the indefatigable industry of his zealous companion."

* Nature, Feb. 6, 1873, vii, 257.

Professor Phillips then speaks of the Cambrian and Silurian labors "of two of the most truly attached and mutually helpful cultivators of geological science in England."

Of these Cambrian and Silurian labors it is my purpose to give here a brief history derived from the papers they published. They were begun in 1831, without concert—Sedgwick in Wales, Murchison along the Welsh and English borders.

In September of 1831, the summer's excursions ended, Murchison made his first report at the first meeting of the British Association. It was illustrated by a colored geological map representing the distribution of the "Transition rocks," the outlying Old Red Sandstone, and the Carboniferous limestone.*

These "Transition Rocks" (of Werner's system), upturned semi-crystalline schists, slates and other rocks, passing down into uncrystalline, and regarded as mostly non-fossiliferous, the "*agnotozoic*" of the first quarter of the century, were the subject of Sedgwick's and Murchison's investigations—the older of the series, as it turned out, being included in Sedgwick's part.† They were early resolved into their constituent formations by Murchison, and later as completely by Sedgwick in his more difficult field.‡

Already in March and April of 1833, Murchison showed, by his communications to the Geological Society of London, that he had made great progress; for the report says:§ He "separated into distinct formations, by the evidence of fossils and the order of superposition, the upper portion of those vast sedimentary accumulations which had hitherto been known only under the common terms of Transition Rocks and Grauwacke." And these "distinct formations" were: (1) the Upper

* Murchison, Report of the British Association, i, 91, 1831.

† Murchison says, in the introductory chapter of his Silurian System, p. 4, "No one [in Great Britain, before his investigations began] was aware of the existence below the Old Red Sandstone of a regular series of deposits containing peculiar organic remains." "From the days of De Saussure and Werner, to our own, the belief was impressed on the minds of geologists that the great dislocations to which these ancient rocks had been subjected had entirely dissevered them from the fossiliferous strata with which we were acquainted."

‡ The term "Transition" early appeared in American geological writings. Sixty to seventy-five years ago it was applied by Maclure, Dewey and Eaton to the rocks of the Taconic region and their continuation; for these were upturned, apparently unfossiliferous, semi-crystalline to uncrystalline, and extended eastward to a region of gneisses. The study of the rocks was commenced; but in 1842, before careful work for the resolution of them had been done—like that in which Murchison and Sedgwick were engaged—they were, unfortunately, put, as a whole, into a "Taconic system" of assumed pre-Potsdam age; at the same time "Transition" was shoved west of the Hudson, over rocks that were horizontal, and already resolved. Owing to this forestalling of investigation, and partly also to inherent difficulties, the right determination of the several formations comprised in this Taconic or "Transition" region was very long delayed.

§ Murchison, Proceedings of the Geol. Soc. London, i, 470, 474, 1833, in a paper on the Sedimentary deposits of Shropshire and Herefordshire.

Ludlow rocks; (2) the Wenlock limestone; (3) the Lower Ludlow rocks; (4) Shelly sandstones, "which in Shropshire occupy separate ridges on the southeastern flanks of the Wrekin and the Caer Caradoc"; (5) the Black Trilobite flagstone whose "prevailing Trilobite is the large *Asaphus Buchii*, which with the associated species," he observed, "is never seen in any of the overlying groups;" and, below these, (6), Red Conglomerate sandstone and slaty schist several thousand feet in thickness.

By the following January, 1834, Murchison was ready with a further report,* in which he described the "four fossiliferous formations" in detail, and displayed, on a folded table arranged in columns, their stratigraphical order, thickness, subdivisions, localities, and "characteristic organic remains." The subdivisions of the rock-series in the memoir are as follows, commencing above: I, Ludlow rocks, 2,000 feet; II, Wenlock and Dudley rocks, 1,800 feet; III, Horderley and May Hill rocks (afterward named Caradoc), 2,500 feet; IV, Builth and Llandeilo flags, characterized by *Asaphus Buchii*, 1,200 feet; and, below these, V, the Longmynd and Gwastaden rocks, many thousand feet thick, set down as unfossiliferous.

Thus far had Murchison advanced in the development of the Silurian system by the end of his third year. Upper and Lower Silurian strata were comprised in it, but these subdivisions were not yet announced.

During the interval from 1831 to 1834, Sedgwick presented to the British Association in 1832 a verbal communication on the geology of Caernarvonshire, and another brief report of progress in 1833. A few lines for each are all that was published. The difficulties of the region were a reason for slow and cautious work.

In 1834, as first stated in the Journal of the Geological Society for the year 1852, the two geologists took an excursion together over their respective fields. Sedgwick says:† "I then studied for the first time the Silurian types under the guidance of my fellow-laborer and friend; and I was so struck by the clearness of the natural sections and the perfection of his workmanship that I received, I might say, with implicit faith everything which he then taught me." And further, "the whole 'Silurian system' was by its author placed *above* the great undulating slate-rocks of South Wales." The geologists next went together over Sedgwick's region, and the sec-

* Murchison, Proc. Geol. Soc., ii, 13, 1834. The subject was also before the British Association: Report for 1834, p. 652.

† Sedgwick, Quarterly Journal of the Geological Society, viii, 152, 1852.

tions from the top of the Berwyns to Bala. Murchison concluded, after his brief examination, and told Sedgwick, that the Bala group could not be brought within the limits of his system. He says: "I believed it to plunge under the true Llandeilo flags with *Asaphus Buchii* which I had recognized on the east flank of that chain." "Not seeing, on that hurried visit, any of the characteristic Llandeilo Trilobites in the Bala limestone, I did not then identify that rock with the Llandeilo flags, as has since been done by the Government surveyors."*

In 1835, the terms "Silurian" and "Cambrian" first appear in geological literature. Murchison named his system the "Silurian" in an article in the Philosophical Magazine for July of that year, and at the same time defined the two grand subdivisions of the system: I, the *Upper Silurian*, or the Ludlow and Wenlock beds; and II, the *Lower Silurian*, or the Caradoc and Llandeilo beds.†

During the next month, August, the fourth meeting of the British Association was held at Edinburgh, and in the report of the meeting,‡ the two terms, *Silurian* and *Cambrian*, are united in the title of a communication "by Professor Sedgwick and R. I. Murchison," the title reading, "On the Silurian and Cambrian systems, exhibiting the order in which the older sedimentary strata succeed each other in England and Wales." Murchison, after explaining his several subdivisions, said that "in South Wales" he had "traced many distinct passages from the lowest member of the 'Silurian system' into the underlying slaty rocks now named by Professor Sedgwick, the Upper Cambrian." Sedgwick spoke of his "*Upper Cambrian group*" as including the greater part of the chain of the Berwyns, where he said, "it is connected with the Llandeilo flags of the Silurian and expanded through a considerable part of South Wales;" the "*Middle Cambrian group*" as "comprising the higher mountains of Caernarvonshire and Merionethshire;" the "*Lower Cambrian group*" as occupying the southwest coast of Caernarvonshire, and consisting of chlorite and mica schists, and some serpentine and granular limestone; and finally, he "explained the mode of connecting Mr. Murchison's researches with his own so as to form one general system."

Thus, in four years Murchison had developed the true system in the rocks he was studying; and Sedgwick likewise had reached what appeared to be a natural grouping of the rocks of his complicated area. Further, *in a united paper*, or papers presented together, they had announced the names Silurian and Cambrian, and expressed their mutual satisfaction with the

* Murchison, Q. J. G. Soc., viii, 175. † Phil. Mag., vii, 46, July, 1835.
‡ Brit. Assoc., v, August, 1835.

defined limits. Neither was yet aware of the unfortunate mischief-involving fact that the two were overlapping series.

It is well here to note that *the term "Cambrian" antedates "Taconic" of Emmons by seven years;* and also that Emmons did not know—any more than Sedgwick with regard to the Cambrian—that his system of rocks was in part Lower Silurian, and of Llandeilo and Caradoc age.

In May, of 1838, nearly three years later, Sedgwick presented his first detailed memoir on North Wales and the Cambrian rocks to the Geological Society.* Without referring to the characteristic fossils, he divides the rocks below the Old Red Sandstone, beginning below, into (I) the PRIMARY STRATIFIED GROUPS, including gneiss, mica schist and the Skiddaw slates, giving the provisional name of *Protozoic* for the series should it prove to be fossiliferous, and (II) the PALÆOZOIC SERIES; the latter including (1) the Lower Cambrian (answering to Middle Cambrian of the paper of 1835), (2) the Upper Cambrian and (3) the *Silurian*, or the series so called by Murchison. Without a report on the fossils, no comparison was possible at that time with Murchison's Silurian series. Yet Sedgwick goes so far as to say that the "Upper Cambrian," which "commences with the fossiliferous beds of Bala, and includes all the higher portions of the Berwyns and all the slate-rocks of South Wales which are below the Silurian System," "appears to pass by insensible gradation into the lower division of the Upper System (the Caradoc Sandstone);" and that "many of the fossils are identical in species with those of the Silurian System."† Respecting the *Silurian System* he refers to the abstracts of Mr. Murchison's papers and "his forthcoming work."

The *Protozoic* division included the "Highlands of Scotland, the crystalline schists of Anglesea and the Southwest Coast of Caernarvonshire." It is added: "The series is generally without organic remains; but should organic remains appear unequivocally in any part of this class they may be described as the Protozoic System."

In the later part of the same year, 1838, Murchison's "Silurian System" was published‡—a quarto volume of 800

* An abstract appeared in the Proc. Geol. Soc., ii, 675, 1838. A continuation of the paper appeared in 1841, ibid., iii, 541. See also Q. J. Geol. Soc, viii, 1852.

† Of these fossils, he had mentioned "*Bellerophon bilobatus*, *Producta sericea* and several species of *Orthis*" as occurring in the Bala limestone, "all of which are common to the Lower Silurian System," in a Syllabus of his Cambridge lectures, published in 1837.

‡ Murchison's "Silurian System" bears on its title page the date 1839. He states in the Q. J. Geol. Soc., viii, 177, 1852, that the work was really issued in 1838. The fossil fishes of the volume were described by Agassiz, the trilobites, by Murchison, and the rest of the species, by Sowerby.

pages, with twenty-seven plates of fossils, and nine folded plates of stratigraphical sections, besides many plates in the text—the outcome of his eight years of work. Five hundred pages are devoted to the Silurian System.

The dedication is as follows:

"To you, my dear Sedgwick, a large portion of whose life has been devoted to the arduous study of the older British rocks, I dedicate this work.

Having explored with you many a tract, both at home and abroad, I beg you to accept this offering as a memorial of friendship, and of the high sense I entertain of the value of your labours."

Through Murchison's investigations here recorded, as he remarks in his Introduction with reasonable satisfaction, "a complete succession of fossiliferous strata is interpolated between the Old Red Sandstone and the oldest slaty rocks." He observes as follows of Sedgwick: "In speaking of the labours of my friend, I may truly say, that he not only shed an entirely new light on the crystalline arrangement or slaty cleavage of the North Welsh Mountains, but also overcame what to most men would have proved insurmountable difficulties in determining the order and relations of these very ancient strata amid scenes of vast dislocation. He further made several traverses across the region in which I was employed; and, sanctioning the arrangement I had adopted, he not only gave me confidence in its accuracy, but enhanced the value of my work by enabling me to unite it with his own; and thus have our joint exertions led to a general view of the sequence of the older fossiliferous deposits." In accordance with these statements many of the descriptions and the very numerous sections represent the Cambrian rocks lying beneath the Silurian,—though necessarily with incorrect details, since neither Murchison nor Sedgwick had then any appreciation of the actual connection between the so-called Cambrian and Silurian.

The Silurian system, as here set forth, is essentially that of Murchison's earlier paper of 1835; and through the work, as each region is taken up, the rocks of the *Upper* and *Lower* divisions, and their several subdivisions, are described in order, with a mention of the characteristic fossils As to the relations of the two grand divisions, he says that "although two or three species of shells of the Upper Silurian rocks may be detected in the Lower Silurian, *the mass of organic remains in each group is very distinct.*" Later he makes the number of identical species larger; but even the newest results do not increase it so far as to set aside Murchison's general statement of 1838.

Sedgwick, with all the light which the fossils of the "Silurian System" were calculated to throw on his Upper Cambrian series, found in the work no encroachments on his field or on his views. They were still side by side in their labors among the hitherto unfathomed British Paleozoic rocks.

In 1840 and 1841 Murchison was in Russia with M. de Verneuil and Count Keyserling, and also in Scandinavia and Bohemia, seeking to extend his knowledge of the older fossiliferous rocks and verify his conclusions; and in 1845 the great work on the Geology of Russia and the Urals came out, with a further display of Upper and Lower Silurian life. In his Presidential addresses of 1842 and 1843, reviewing the facts in the light of his new observations, he went so far as to say that the Lower Silurian rocks were the oldest of fossiliferous rocks and that the fossiliferous series of North Wales seemed to exhibit no vestiges of animal life different from those of the Lower Silurian group.

Still Sedgwick made no protest. He states definitely on this point in his paper of 1852,* that from 1834, the time of the excursion with Murchison, until 1842, he had accepted Murchison's conclusions, including the reference of the Meifod beds to the Caradoc or Silurian, without questioning; but that from that time, 1842, he began to lose his confidence in the stability of the *base-line* of the "Silurian System." He adds that in 1842, Mr. Salter, the paleontologist, informed him that the Meifod beds were on the same horizon nearly with the Bala beds; and he accepted this conclusion to its full extent, using the words "if the Meifod beds were Caradoc, the Bala beds must also be Caradoc or very nearly on its parallel." Thus the inference of Murchison was adopted and discrepancy between them deferred. And on the following page he acknowledges that all his papers of which there is any notice in the Proceedings or Journal of the Geological Society between 1843 and 1846 admit this view as to the Bala beds and certain consequences of it—"mistakes" as he pronounced them six years later, in 1852.†

In 1843, Sedgwick read before the Geological Society in June, a paper entitled *An Outline of the Geological Structure of North Wales*, which was published in abstract in the Proceedings (iv, 251); and in November of the same year, one *On the Older Palæozoic (Protozoic) Rocks of North Wales* (from observations by himself in company with Mr. Salter), which appeared, with a map, in the Journal of the Geological Society (i, 1). The abstract in the Proceedings was prepared by Mr. Warburton, the President of the Geological Society, and the paper of the following November, makes no allusion to this fact, or any objection to the abstract.

* Q. J. Geol. Soc., viii, 153, 1852. † Ibid., p. 154.

A remarkable feature of the November paper is that it nowhere contains the term *Upper Cambrian or even Cambrian*, although the rocks are Sedgwick's Upper Cambrian, together with Murchison's Upper Silurian.

A second fact of historical interest is the use of the term "Protozoic," not in the sense in which it was introduced by him in 1838, but in that in which introduced in 1838 by Murchison, on page 11 of his Silurian System, where he says:

"But the Silurian, though ancient, are not, as before stated, *the most* ancient fossiliferous strata. They are, in truth, but the upper portion of a succession of early deposits which it may hereafter be found necessary to describe under one comprehensive name. For this purpose I venture to suggest the term *Protozoic Rocks*, thereby to imply the first or lowest formations in which animals or vegetables appear."

These facts are in accordance with Sedgwick's acknowledgment, mentioned on the preceding page.

The map accompanying the paper as originally prepared, had colors corresponding to five sets of areas, those of the "Carboniferous Limestone," "Upper Silurian," "Protozoic" Rocks, "Mica and Chlorite Slate," "Porphyritic Rocks;" and here again Cambrian, Upper or Lower, does not appear, the term Protozoic being substituted. The map, as it stands in the Journal of the Geological Society, has in place of simply *Protozoic*, the words "Lower Silurian (Protozoic)." Sedgwick complains, in his paper of 1852, pages 154, 155, of this change from his manuscript, and attributes it to Mr. Warburton, saying that "the map with its explanations of the colors plainly shows that Mr. Warburton did not comprehend the very drift and object of my paper." "I gave one colour to this whole Protozoic series only because I did not know how to draw a clear continuous line on the map between the upper Protozoic (or lower Silurian) rocks and the lower Protozoic (or lower Cambrian) rocks." "Nor did I ever dream of an incorporation of all the lower Cambrian rocks in the system of Siluria." Sedgwick also says on the same point: "I used the word *Protozoic* to prevent any wrangling about the words Cambrian and Silurian." But this is language he had no disposition to use in 1843, as the paper of 1843 shows.

Page 155 has a foot note. In it the aspect of the facts is greatly changed. He takes back his charges, saying, "I suspect that, in the explanation of the blank portion of the rough map exhibited in illustration of my paper I had written *Lower Silurian and Protozoic*, and that Mr. Warburton, erroneously conceiving the two terms identical, changed the words into Lower Silurian (Protozoic)" "I do not by any means accuse

Mr. Warburton of any *intentional* injustice—quite the contrary; for I know that he gave his best efforts to the abstract. But he had undertaken a task for which he was not prepared, inasmuch as he had never well studied any series of rocks like those described in my papers." Sedgwick here uses Protozoic in the Sedgwick sense, not, as above in the Murchison sense. Sedgwick again in 1854, speaks of "the tampering with the names of my reduced map." But these explanations of his should take the harshness out of the sentence, as it was in 1843 to 1846 out of all his words.

The paper has further interest in its long lists of fossils in two tables: I, "Fossils of the Older Palæozoic (Protozoic) Rocks in North Wales, by J. W. Salter and J. de C. Sowerby," showing their distribution; and II, "Fossils of the Denbigh flagstone and sandstone series."

Thus, until 1846, no serious divergence of views had been noted by Sedgwick. This is manifested in his paper on the Slate rocks of Cumberland, read before the Geological Society on the 7th and 21st of January, 1846,* which says, on the last page but one: "Taking the whole view of the case, therefore, as I know it, I would divide the older Palæozoic rocks of our island into three great groups: 3d, the upper group, *exclusively Upper Silurian;* 2, the middle group, or *Lower Silurian*, including Llandeilo, Caradoc, and perhaps Wenlock; 1, the first group, or *Cambrian;*" differing in this arrangement from Murchison only in the suggestion about the Wenlock. The italics are his own. He adds:

"This arrangement does no violence to the Silurian system of Sir R. Murchison, but takes it up in its true place; and I think it enables us to classify the old rocks in such a way as to satisfy the conditions both of the fossil and physical as well as mineralogical development."

But before the year 1846 closed not only the overlapping of their work was recognized but also the consequences ahead, and divergence of opinion began.

In December a paper was presented by Sedgwick to the Geological Society on "the Fossiliferous Slates of North Wales, Cumberland, Westmoreland and Lancashire,"† which contains a protest against the downward extension of the Silurian so as to include the Cambrian. It is excellent in spirit and fair in argument. Many new facts are given respecting sections of the rocks in South Wales and North Wales, in some of which occur the Lingula flags, and characteristic fossils are mentioned. In describing some South Wales sections, Sedg-

* Q. J. Geol. Soc., ii, 106, 122, 1846.

† Ibid., iii, 133, Dec., 1846.

wick uses the term *Cambro-Silurian* to include, beginning below, (1) "Conglomerates and slates, (2) Lower Llandeilo flags, (3) Slates and grits (Caradoc Sandstone of Noeth Grug, etc., (4) Upper Llandeilo flag passing by insensible gradations into Wenlock shale." The Cambrian series is made to include (1) The Festiniog or Tremadoc group; (2) Roofing slates, etc., the "Snowdonian group," fossiliferous in Snowdon, etc.; (3) the Bala group; and then (4) "the *Cambro-Silurian* group," comprising "the lower fossiliferous rocks east of the Berwyns between the Dee and the Severn—the Caradoc Sandstone of the typical country of Siluria—and the Llandeilo flags of South Wales, along with certain associated slates, flags, and grits." The extension of the term Silurian down to the Lingula flags, or beyond, is opposed because the beds below the Llandeilo are not part of the Silurian system; the term Silurian [derived from the Silures of Southeast Wales and the adjoining part of England] is not geographically applicable to the Cambrian rocks; and because the only beds in North Wales closely comparable "with the Llandeilo flags are at the top of the whole Cambrian series." This last reason later lost its value when it was proved, as Sedgwick recognized years afterward, that Murchison's Llandeilo flags were really older than Sedgwick's Bala rocks.

Sedgwick's paper was followed, on January 6th, with one by Murchison,* objecting to this absorption of the Lower Silurian and reiterating his remark of 1843 that the fossiliferous Cambrian beds were Lower Silurian in their fossils, and arguing, thence, for the absorption of the Cambrian, to this extent, by the Silurian. Having, eight years before, in his great work on the "Silurian System," described the Lower Silurian groups with so much detail, and with limits well defined by sections and by long lists of fossils, over a hundred species in all, many of them figured as well as described, and having thus added a long systematized range of rocks to the lower part of the Paleozoic series, he was naturally unwilling to give up the name of Lower Silurian for that of Upper Cambrian or Cambro-Silurian. Moreover, the term "Silurian," with the two subdivisions of the system, the Upper and Lower, had gone the world over, having been accepted by geologists of all lands as soon as proposed, become affixed to the rocks to which they belonged, and put into use in memoirs, maps and geological treatises.

In 1852, the controversy, begun by encroachments not intended on either part, reached its height. Sedgwick's earnest presentation of the case† and appeal before the Geological

* Q. J. Geol. Soc., iii, 165, Jan., 1847.

† Ibid., viii, 152.

Society in February of that year—making the latter part of a memoir by him on the "Classification and Nomenclature of the Lower Palæozoic Rocks of England and Wales"—argues, like that of 1846, for the extension of the Cambrian from below upward to include the Bala beds, and thereby also the Llandeilo flags, and Caradoc sandstone, although, he says "my friend has published a magnificent series of fossils from the Llandeilo flagstone." Sedgwick also expresses dissatisfaction with Mr. Warburton's abstract of his paper of June, 1843, and with the change made in his map of November, 1843, as indicated on page 174, but, as there shown, he has no blame for Murchison and little for Mr. Warburton. He also points out some errors in the stratigraphical sections of the "Silurian System,"—since the publication of which fourteen years had passed. He closes with the words (p. 168):

"I affirm that the name 'Silurian,' given to the great Cambrian series below the Caradoc Group, is historically unjust. I claim this great series as my own by the undoubted right of conquest; and I continue to give it the name 'Cambrian' on the right of priority, and, moreover, as the only name yet given to the series that does not involve a geographical contradiction. The name 'Silurian' not merely involves a principle of nomenclature that is at war with the rational logic through which every other Palæozoic group of England has gained a permanent name, but it also confers the presumed honor of a conquest over the older rocks of Wales on the part of one who barely touched their outskirts and mistook his way as soon as he had passed within them.

"I claim the right of naming the Cambrian rocks because I flinched not from their difficulties, made out their general structure, collected their fossils, and first comprehended their respective relations to the groups above them and below them, in the great and complicated Palæozoic sections of North Wales. Nor is this all,—I claim the name Cambrian in the sense in which I have used it, as a means of establishing a congruous nomenclature between the Welsh and the Cumbrian Mountains, and bringing their respective groups into a rigid geological comparison; for the system on which I have for many years been laboring is not partial and one-sided, but general and for all England."

Sedgwick does not seem to have recognized the fact that Murchison had the same right to extend the Silurian system to the base of the Llandeilo beds, whatever its horizon, that he had to continue the Cambrian to the top of the Bala beds.*

* One important fact is pointed out in this paper in a letter from M'Coy, on page 143: that the May Hill group, which Murchison had referred to the Caradoc series, really belonged by its fossils to the Upper Silurian. This point was the subject of a paper by Sedgwick in the next volume (vol. ix) of the Journal of the Geological Society.

Murchison's reply was made at the meeting of the Geological Society in June.* He remarked, with regard to Sedgwick's allusion to the excursion of 1834, that "if I lost my way in going downward into the region of my friend, it was under his own guidance; I am answerable only for Silurian and Cambrian rocks described and drawn as such within my own region."

In his closing remarks Murchison says:

"I am now well pleased to find that, with the exception of my old friend, all my geological contemporaries in my own country adhere to the unity of the Silurian System and thus sustain its general adoption."

"No one more regrets than myself that Cambrian should not have proved, what it was formerly supposed to be, more ancient than the Silurian region, and thus have afforded distinct fossils and a separate system; but as things which are synonymous cannot have separate names, there is no doubt that, according to the laws of scientific literature, the term "Silurian" must be sustained as applied to all the *fossiliferous* rocks of North Wales.

"Lastly, let me say to those who do not understand the nature of the social union of the members of the Geological Society, that the controversy which has prevailed between the eloquent Woodwardian Professor and myself has not for a moment interrupted our strong personal friendship. I am indeed confident we shall slide down the hill of life with the same mutual regard which animated us formerly when climbing together many a mountain both at home and abroad."

Murchison was right in saying that all British geologists were then with him, even in the extension of the name Silurian to the lower fossiliferous Cambrian rocks; and this was a chief source of irritation to Sedgwick. It was also, with scarcely an exception, true of geologists elsewhere. This state of opinion was partly a consequence of Murchison's early and wonderfully full description of the Silurian rocks and their fossils, which made his work a key to the Lower Paleozoic of all lands. Sedgwick's Cambrian researches and the paleontology of the region were not published in full before the years 1852–1855, when appeared his "Synopsis of the Classification of the British Palæozoic Rocks," along with M'Coy's "Descriptions of British Palæozoic Fossils."

But this general acceptance was further due to the fact that the discovered fossils of the Cambrian, from the Lingula Flags downward, or the "Primordial," were few, and differed not more from Silurian forms than the Silurian differed among themselves; and also, because the beds were continuous with the Silurian, without a break. Geologists under the weight of

* Q. J. Geol. Soc., viii, 173, 1852.

the evidence, American as well as European, naturally gravitated in the Murchisonian direction, while applauding the work of Sedgwick.

In 1853, Mr. Salter showed, by a study of the fossils,* that the Bala beds from Bala in Merioneth, the original Bala, were included within the period of the Caradoc. Sedgwick subsequently (in the preface to the Catalogue of the Woodwardian Museum by J. W. Salter), divided his Upper Cambrian into (1) The *Lower Bala*, to include the Llandeilo flags (Upper Llandeilo of the Geological Survey, the Arenig being the Lower); (2) the *Middle Bala*, corresponding to the Caradoc sandstone, the Bala rocks, and the Coniston limestone (Geological Survey); and the *Upper Bala* or the Caradoc-shales, Hirnant limestone and the Lower Llandovery."†

In 1854, the Cambrian system not having secured the place claimed for it, Sedgwick brought the subject again before the Geological Society. Besides urging his former arguments, he condemned Murchison's work so far as to imply that none of his sections "give a true notion of the geological place of the groups of Caer Caradoc and Llandeilo"; and to speak of the Llandeilo beds, in a note, as "a remarkable fossiliferous group (about the age of the Bala limestone) of which the geological place was entirely mistaken in the published sections of the Silurian System." There were errors in the sections, and that with regard to the May Hill group was a prominent one; but this was sweeping depreciation without new argument; and, in consequence of it, part of the paper was refused publication by the Geological Society.

The paper appeared in the Philosophical Magazine for 1854.‡ It contains no bitter word, or personal remark against Murchison. Sedgwick was profoundly disappointed on finding, when closing up his long labors, that the Cambrian system had no place in the geology of the day. He did not see this to be the logical consequence of the facts so far as then understood. It was to him the disparagement and rejection of his faithful work; and this deeply moved him, even to estrangement from the author of the successful Silurian system.

Conclusion.

The ground about which there was reasonably a disputed claim was that of the Bala of Sedgwick's region and the Llandeilo and Caradoc of Murchison's. Respecting this common field, long priority in the describing and defining of the

* Q. J. Geol. Soc., x, 62.
† Cited from Etheridge, in Phillips' Geology, ii, 77, 1885.
‡ Fourth series, volume viii, pages 301, 359, 481.

Llandeilo and Caradoc beds, both geologically and paleontologically, leaves no question as to Murchison's title. Below this level lie the rocks studied chiefly by Sedgwick; and if a dividing horizon of sufficient geological value had been found to exist, it should have been made the limit between a Cambrian and a Silurian System.

The claim of a worker to affix a name to a series of rocks first studied and defined by him cannot be disputed. But Science may accept, or not, according as the name is, or is not, needed. In the progress of geology, the time finally was reached, when the name Cambrian was believed to be a necessity, and "Cambrian" and "Silurian" derived thence a right to follow one another in the geological record.

"To follow one another;" that is, directly, without a suppression of "Silurian" from the name of the lower subdivision by intruding the term "Ordovician," or any other term. For this is virtually appropriating what is claimed, (though not so intended), and does marked injustice to one of the greatest of British geologists. Moreover, such an intruded term commemorates, with harsh emphasis, misjudgments and their consequences, which are better forgotten. Rather let the two names, standing together as in 1835, recall the fifteen years of friendly labors in Cambria and Siluria and the other earlier years of united research.

Art. XXIII.—*Notes on the Cretaceous of the British Columbian Region.—The Nanaimo Group;* by George M. Dawson.

In Bulletin No. 51 of the United States Geological Survey, (1889) by Dr. C. A. White, on Invertebrate Fossils from the Pacific Coast, Part III is devoted to the discussion of lower Cretaceous fossils from the Vancouver Island region; and the name 'Vancouver group' is proposed for the formation from which these are derived. Dr. White writes:—"Although this formation is paleontologically equivalent, at least in large part, with the Chico portion of the Chico-Téjon series of California, as has been indicated by Meek, Gabb, Whiteaves and by Professor Whitney, I propose to use the name Vancouver group as a local name for those strata which occur in the Vancouver Island region; and still retain the name Chico group for the California strata, which the geologists of that State applied to them."* On meeting with Dr. White's proposal for the adoption of the term 'Vancouver group,' as above stated, I wrote

* Op. cit., p. 33.

to him pointing out that the name had, unfortunately, already been used by me in the publications of the Geological Survey of Canada, to designate the Triassic rocks of the same coast region,* and ventured to suggest that if a local name for the equivalent of the Chico group in the Vancouver Island region is considered requisite, it might be termed the *Nanaimo group.* No general name had, so far as I am aware, been given to the strata in question, previous writers (and more particularly Mr. Whiteaves, by whom a larger proportion of the fossils have been described) thinking it sufficient to refer to them as an extension of the Chico.

Dr. White promptly and cordially replied to my communication, approving of the proposed change of name, and the present note is written primarily at his suggestion in order to prevent possible confusion in the nomenclature.

To more clearly define the strata to which the name Nanaimo group may at present be applied, it is necessary to state that the whole of the large collections examined by Mr. Whiteaves (and doubtless also those of other writers) have been derived from the lower subdivisions of the local section, which, according to the late Mr. James Richardson, is as follows in the Comox and Nanaimo fields respectively:

Comox.	feet.	Nanaimo.	feet.
G. Upper conglomerates	320		
F. Upper shales	776		
E. Middle conglomerates	1,100	G. to C. sandstones	
D. *Middle shales*	76	Conglomerates and shales	3290
C. *Lower conglomerates*	900		
B. *Lower shales*	1,000	B. *Shales*	660
A. *Productive Coal-measures*	739	A. *Productive Coal-measures*	1360

As stated by Mr. Whiteaves, no characteristic fossils have yet been found in the three higher subdivisions of the Comox section (E., F. and G.) nor in subdivisions C. to G. inclusive of the Nanaimo section,† and while all the subdivisions are conformable, it is thus the lower parts of the sections alone, including about 2,020 feet at Nanaimo and 2,715 feet at Comox, which are known to correspond more or less perfectly with the Chico group. These are printed in italics in the above table. In the publication just alluded to, Mr. Whiteaves further states, that there was, at the time he wrote, no positive evidence to show whether the upper portions of these sections were Cretaceous or Tertiary, and this statement still holds good. It is therefore quite possible that some at least of the higher subdivisions may represent the Téjon group of Califor-

* See particularly Annual Report Geol. Survey, Can., 1886, p. 10 B.
† Mesozoic Fossils, vol. i, pp. 94, 185.

nia, or the recently proposed Puget group of Washington,* both of which Dr. White is inclined to regard as equivalent in a general way to the Laramie.†

While referring to the Puget group, it may be added that a considerable tract of low land about the mouth of the Fraser and extending northward to Burrard Inlet, is underlain by rocks which though as yet only partially examined, appear with little doubt to correspond to that group, with which they are geographically connected and so far as known lithologically identical. Mr. A. Bowman has ascertained that these strata are at least 3000 feet in thickness, and, like those of the typical area of the Puget group, they hold carbonaceous matter and more or less lignite-coal at many different horizons.

I may also take the opportunity to note, in this connection, that throughout the entire Cretaceous period as represented on the littoral of British Columbia, there is evidence of a transgressive extension of the area of sedimentation from north to south, the local base of the Cretaceous being found at successively higher stages in the system to the southward. Thus, of five stages into which the Cretaceous of the Queen Charlotte Islands is divided, the three highest only have been found resting on the pre-Cretaceous rocks of the northern part of Vancouver Island. In the Comox and Nanaimo fields, the local base of the Cretaceous corresponds approximately to the highest observed beds of the first-mentioned locality, and in northern Washington, the still higher Puget group occurs in very great mass and apparently almost to the exclusion of the Cretaceous proper, or marine Cretaceous as distinguished from the Laramie. Though further investigation may disclose small areas of older Cretaceous rocks, occupying the deeper hollows in the much-eroded surface of the pre-Cretaceous land, these can scarcely be such as to invalidate the general features as now understood and above outlined. Coupled with this gradual southward encroachment of the Cretaceous Sea, is no doubt the fact that the principal coal-bearing horizon, beginning at the north in the earlier Cretaceous (about the horizon of the Gault) is found at Comox and Nanaimo near the base of the Nanaimo group (representing the Chico) and in Puget Sound in the Puget group, which as already noted may, according to Prof. Newberry and Dr. White, be equivalent to the Laramie.

We have yet, however, much to learn respecting the physical history of the Cretaceous period in the British Columbian region; and in view of the above facts relating to the littoral of the Province, it remains in particular to explain the occur-

* This Jour., vol. xxxvi, 1888.

† Bulletin of the U. S. Geol. Survey, No. 51, pp. 12, 54.

rence of the earlier Cretaceous rocks which at no great distance inland run parallel to the basin occupied by the Nanaimo and Puget groups.* It appears possible that an elevation of a part of the Cretaceous sea-bed bounded to the westward nearly by the present line of the Coast Ranges of British Columbia, may have occurred after the deposition of the earlier strata. The tract of land thus produced, or added to that previouly in existence, may have served as the chief source of supply of the later sediments and more particularly of the massive estuarine beds of the Puget group, in accounting for which Dr. White finds some difficulty.† Such a supposition would also be in accord with the absence, so far as known, of any rocks referable to the Laramie throughout the entire region eastward to the Rocky Mountains proper, within the limits of British Columbia.

Geological Survey of Canada, Ottawa, Dec. 18, 1889.

Art. XXIV.—*Celestite from Mineral County, West Virginia*; by George H. Williams.

An extensive cutting on the line of the West Virginia Central railroad has recently brought to light a large number of celestite crystals, which, on account of their unusual habit, large size and fine color, merit description. The cutting is nearly a mile in length and had been made into a high bluff of lower Helderberg limestone which forms the western flank of Knobly mountain, between the fourth and fifth milestones south of Cumberland, Md. The crystals thus far discovered occur just outside the limits of the State of Maryland, since the Potomac river here flows so near the base of the mountain that sufficient space for the railroad had to be secured by artificial means between them.

The writer is indebted to the kindness of Mr. F. M. Offutt of Cumberland for first bringing the crystals to his notice; as well as to the efforts of Mr. J. C. Brady (on whose farm the crystals occur) and his sons for aid in securing most of the material that has thus far come to light.

The rock exposed in the cutting is a thickly bedded and nearly horizontal, argillaceous limestone, similar to that used at Cumberland and Hancock, Md., for the manufacture of cement. The crystals occur in flattened lenticular cavities or pockets, which vary from a foot to a yard in diameter and from three to seven inches in height. These are confined to only two or three of the many strata which compose the bluff and apparently

* Cf. this Jour., vol. xxxviii, p. 121.
† Bulletin of the U. S. Geol. Survey, No. 51, p. 57.

represent former concretions. They are now partially empty and partially filled with clay. The celestite crystals adhere to the walls of these cavities or lie unattached in the clay. The latter are the most perfectly developed, being in most cases doubly terminated, and occurring either singly or in groups. With the celestite, minutely crystalline calcite is associated, exhibiting the combination: ∞P $(10\bar{1}0)$ and $-\frac{1}{2}R$ $(01\bar{1}2)$. No other mineral was observed within these ovoid cavities except gypsum, minute crystals of which sometimes incrust the celestite crystals, especially near their acute ends.

The celestite crystals vary in length from less than a millimeter to three inches or more. The largest are two inches in thickness. In color they range from a deep blue to the palest possible tint. Some are even colorless. One specimen shows layers parallel to the macropinacoid which are alternately of a lighter and darker color. Many of the smallest or medium-sized crystals are clear and transparent, but the large majority are more or less opaque from internal impurities. The clay, in which the crystals appear to have grown, is frequently included in them in large amount.

The most striking feature presented by this occurrence of celestite is, however, its crystal-habit. This is pyramidal, which is not common for the species, and is always due to the preponderance of the acute brachy-pyramid χ, $\breve{P}4$ (144). On a large proportion of the crystals, especially the smaller ones, this form occurs alone, when it becomes almost lenticular from a rounding of the faces (fig. 6). On other crystals other forms were observed in combination with the above-named pyramid. These are, in order of their frequency and importance, as follows: a, $\infty \bar{P} \bar{\infty}$ (100); d, $\frac{1}{2}\bar{P}\bar{\infty}$ (102); c, OP (001); o, $\breve{P}\breve{\infty}$ (011); and m, ∞P (110) (figs. 1 and 2). Of these forms, d is the only one whose planes are sufficiently even and bright to yield satisfactory measurements. a is always striated parallel to the vertical axis, probably by oscillatory combination with m. c, the principal cleavage plane, is uneven and drusy, when it occurs at all. o is usually present only as a rounding of the edge: (144):($\bar{1}$44), but in a few cases yielded a tolerably sharp reflex. m is of extremely rare occurrence and even then is so poorly developed as to leave its identification doubtful.

The following angles, obtained with a reflecting goniometer are unsatisfactory, owing to the uneven nature of all the planes except d. They are compared with the calculated angles given by Auerbach in his monograph on celestite,* because none of the data requisite to the calculation of a new axial-ratio could be obtained.

* Sitzungsberichte der Wiener Akad., vol. lix, p. 549. 1869.

		(Observed.)	(Auerbach.)
$o \wedge o$	(011):(0$\bar{1}$1)	103° 33′	104° 8′ 14″
$d \wedge d$	(102):(10$\bar{2}$)	101° 26′	101° 11′
$d \wedge c$	(102):(001)	139° 57′	140° 35′ 30″
$\chi \wedge o$	(144):(011)	166° 50′—165° 12′	165° 47′ 44″
$\chi \wedge \chi$	(144):($\bar{1}$44)	150° 20′—153° 10′	151° 35′ 28″

The variations in the angles measured against the face χ are due to its extremely rounded character and to the flatly convex prominences with which it is invariably covered (figs. 8, 9, 10 and 11). Quite as reliable measurements were made on the largest crystals with a hand goniometer, which gave for the angle (144):($\bar{1}$44) values between 150½° and 152½°, with an average closely approaching 151½°. This is sufficient to fix the symbol of the predominating form, since the corresponding angle for the pyramid $\breve{P}5$ (155) is 157° 7′; and for $\breve{P}3$ (133), 142° 47′.

The irregularities of growth which have interfered with the evenness of the planes on the celestite crystals, do not appear to have materially affected their internal homogeneity. This was shown by an optical examination. A section cut parallel to the macropinacoid, *a*, showed a normal interference figure in converged polarized light, by means of which the optical angle was measured in a Thoulet solution of specific gravity, 2·922.

This gave for lithium light, $2H_a = 49° 04'$,
and for sodium light, $2H_a = 49° 28'$.

From Goldschmidt's curve* the index of refraction for this solution was found to be for lithium light 1·666, and for sodium light 1·675; and, assuming the mean index of refraction of celestite, β, to be for lithium light 1·621, and for sodium light 1·624,† we obtain as the true optical angle:

Li	$2V_a = 49° 18'$
Na	$2V_a = 49° 54'$

The celestite crystals were subjected to a chemical examination by Mr. W. F. Hillebrand of the U. S. Geological Survey, who reports that they are composed of strontian sulphate, in which he was able to detect only a faint (spectroscopic) trace of BaO and 0·12 per cent of CaO. The adjacent limestone was also tested for strontian which was found so abundantly in the form of the sulphate as to indicate that the rock was strongly impregnated with celestite substance for some distance.

Celestite crystals of a pyramidal habit are not common, but they have, nevertheless, been described from several localities.

* Neues Jahrbuch für Min., etc. Beil. Bd. i, Pl. vii. 1881.

† Cf. Arzruni: Zeitschr. für Kryst., vol. i, p. 179. 1877. Babcock: Neues Jahrbuch für Min., etc., 1879, p. 838.

In nearly all cases the predominating form is the brachypyramid, φ, $\breve{P}\breve{3}$ (133). Such, for instance, are the crystals called by Haüy "apotome" from the marl of Montmatre and Bougival near Paris;* and those designated as "dioxynite" from Meudon in the same region.† Similar crystals of celestite are also described by Sucrow‡ and Schmid§ from the Muschelkalk of Dornburg near Jena; by von Lasaulx from Girghenti on Sicily;‖ and by Groth from Hall in the Tyrol.¶

The brachypyramid, χ, $\breve{P}\breve{4}$ (144) was first mentioned by Brooke and Miller.** It has since been recognized by Auerbach on crystals from Dornburg, and Montecchio in Vicentia;†† by Groth on those from Pschow in Silesia;‡‡ and by von Hauer on those from the Banat.§§

This pyramid was, however, first noticed as predominating and giving the habit to celestite crystals by von Lasaulx in 1879.‖‖ This author describes an occurrence of this mineral in the marl of Ville-sur-Saulx, Dept. Haute Marne, France, which must bear a close resemblance to that in Mineral Co., W. Va. At least this would appear to be the case from the published descriptions, since I have had no opportunity to examine specimens from this locality.

In passing, it may also be not without interest to refer to the pyramidal crystals of Hungarian anglesite figured by Krenner.¶¶ These often have a habit closely like that of the above-mentioned celestites, but their predominating pyramid is π, $\breve{P}\breve{5}$ (155).

The West Virginia celestite crystals acquire additional interest from their strong resemblance, in form as well as in their surface markings, to the well-known Sangerhausen pseudomorphs, whose further resemblance to the "thinolite" of the desiccated lake-basins of the west has been pointed out by Clarence King, and E. S. Dana.*** The Sangerhausen pseudomorphs have generally been referred to gaylussite, but Descloizeaux unqualifiedly identifies them with the variety of celestite

* Traité de Minéralogie, 2d ed., 1882, vol. ii, p. 33. Atlas, Pl. xliii, fig. 81.

† Ibid., p. 35. Atlas, pl. xliv, fig. 85. Cf. Schrauf's Atlas der Krystalformen, V Lieferung, 1876.

‡ Pogg. Ann., vol. xxix, p. 504, pl. i, fig. 16, 1833.

§ Ibid., vol. cxx, p. 637, 1863.

‖ Neues Jahrbuch für Min., etc., 1879, p. 509.

¶ Mineraliensammlung der Universität Strassburg, 1878, p. 146.

** Mineralogy, 1852, p. 527.

†† Sitzungb. Wien. Akad., vol. lix, pp. 580 and 588. 1869.

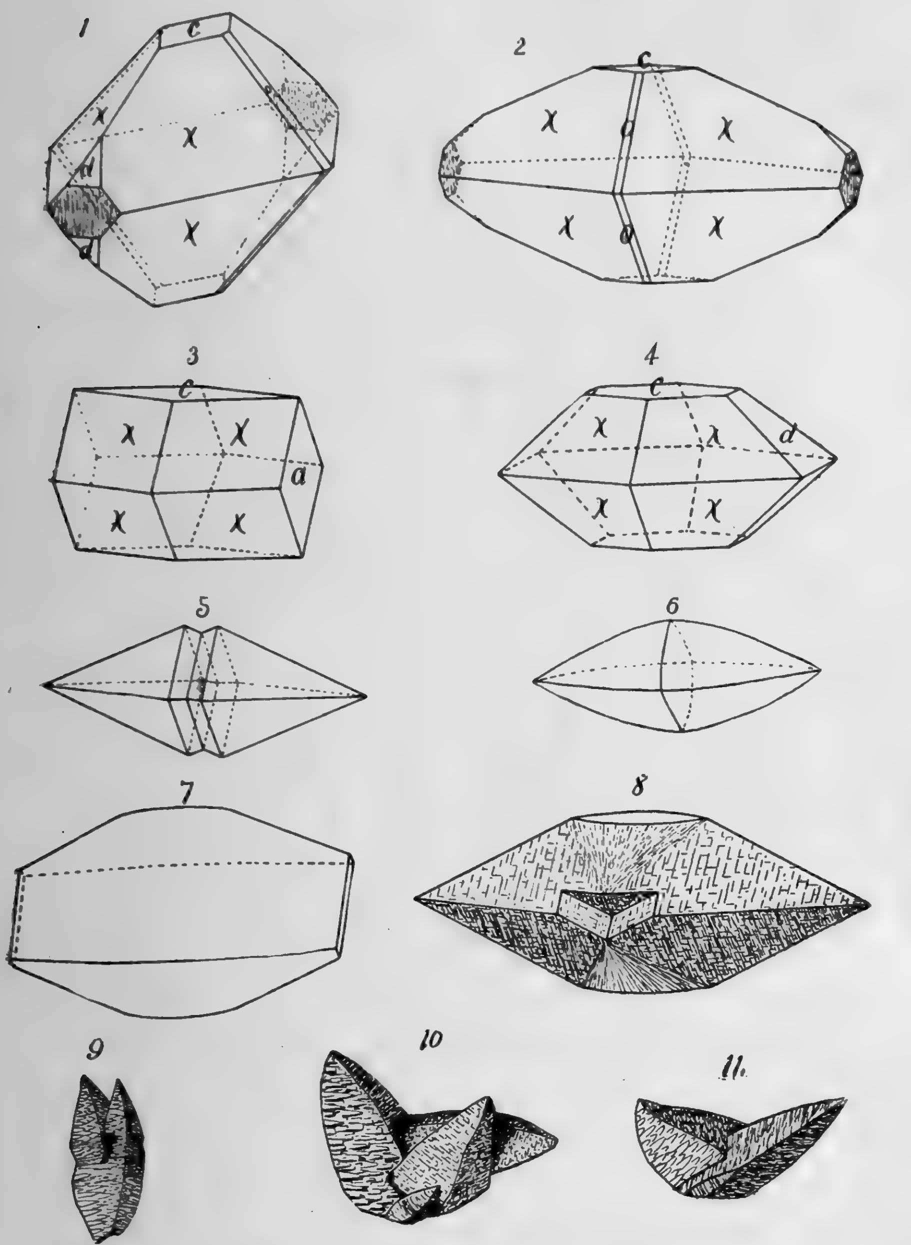
‡‡ Mineraliensammlung der Universität Strassburg, 1878, p. 146.

§§ Verhandl. k.k. geol. Reichsanstalt, 1879, p. 216. Cf. Zeitschr. für Kryst., vol. iv, p. 634.

‖‖ Sitzungsber. der schlesischen Gesellschaft für vaterlandische Cultur, Nov. 19, 1879. Cf. Zeitschr. für Kryst., vol vi, p. 203.

¶¶ Zeitschr. für Kryst., vol. i, pl. xv, 1877.

*** A Crystallographic Study of the Thinolite of Lake Lahontan. Bull. U. S. Geol. Survey, No. 12, 1884.



Celestite Crystals from Mineral Co., West Virginia.

Fig. 1.—Combination showing the forms χ, $P\breve{4}$ (144); a, $\infty P\bar{\infty}$ (100); c, OP (001); d, $\frac{1}{2}P\bar{\infty}$ (102); o, $P\breve{\infty}$ (011). Miller's position.

Fig. 2.—Same, turned 90° about the vertical axis into the position assumed by von Lang for anglesite. This is so much more advantageous for showing the forms of these crystals that it is retained in all the other figures.

Fig. 3.—Exceptional combination of χ, a and c.

Fig. 4.—Ditto of χ, c and d.

Fig. 5.—Parallel growth of two individuals.

Fig. 6.—Crystal showing only the form χ, which is almost lenticular from the curvature of its planes.

Fig. 7.—Distorted form, with χ, a, and a rounded surface corresponding to o.

Fig. 8.—Crystal bounded by χ and c, with a conically rounded surface in place of o.

Figs. 9, 10 and 11.—Crystal groups showing growth forms and surface markings.

called by Haüy "apotome."* The striking likeness between the forms of the West Virginia celestite and the Sangerhausen pseudomorphs may be seen by comparing the last three of the preceding figures with those numbered 26, 31 and 32 in Professor Dana's paper. This will at least serve to show the resemblance which must exist between the products of the locality here described and those mentioned by Haüy near Paris, where, he says, the celestite also occurs in "flattened ovoid masses."†

Art. XXV.—*A Method for the Determination of Iodine in Haloid Salts;* by F. A. Gooch and P. E. Browning.

(Contributions from the Kent Chemical Laboratory of Yale College.—I.)

Few problems of analysis have been more discussed than the estimation of iodine accompanying chlorine and bromine in haloid salts; and yet the constant succession of new processes is sufficiently indicative that the solution of the question is not generally regarded as satisfactorily settled. The method of Fresenius, according to which iodine is liberated by nitrous acid, collected in carbon disulphide and titrated by sodium thiosulphate, finds ready acceptance for the determination of small amounts of iodine; but when the quantity of iodine to be estimated is considerable, the method is unwieldy. Probably the process most generally in use is that based upon the liberation of iodine by means of a ferric salt, and the titration of the distillate by one or other of the well-known iodometric methods. The latter method is fairly accurate, but the requirement of special apparatus for properly condensing the distillate is detrimental to rapidity and ease of execution. In this process the amount of iodine set free should be measured exactly by the reduction of the ferric salt, and were the ferrous salt produced in the course of the action sufficiently stable, the determination of its amount might be substituted for the titration of the iodine, and so the collection and further treatment of the distillate might be dispensed with; but ferrous salts are too sensitive to atmospheric influence to preserve under the conditions of this process their own degree of oxidation, and the amount of iron found in the ferrous condition cannot be made to serve as a trustworthy indication of the reducing action which actually takes place in the separation of the iodine. The advantage of replacing the collection and ex-

* Ann. chim. et phys. III, vol. vii, p. 489, 1843; Manuel de Minéralogie, vol. ii, p. 119, 1874.

† Traité, 2d ed., vol. ii, p. 37, 1822.

amination of the distillate by treatment of the residue is, however, so great as to constrain us to search for some substitute for the ferric salt, which, by virtue of easy reducibility may act as a liberator of iodine from hydriodic acid, and, at the same time, by reason of stability after reduction, shall register accurately the quantity of iodine set free in the reducing process. The results of our experience are contained in the following account.

Strong sulphuric acid, as is well known, acts upon an iodide in a way to liberate iodine at the cost of its own loss of oxygen, though by simple dilution of the mixture thus formed the action is reversed, the iodine going back into the form of hydriodic acid, and the products of the reduction of sulphuric acid again taking back their oxygen and re-forming the acid. In the presence of any substance easily reducible by the deoxidation products of sulphuric acid the liberation of iodine, by the action of that acid upon iodides, should take place without interference, and even more easily and completely than in the absence of such a substance, while the sulphuric acid should remain at the end of the process in its original form. If the products of reduction which appear in such a case in the place of those of the sulphuric acid should be neither readily oxidizable nor easily volatilizable, it ought to be possible to remove by heat the iodine set free in the action without disturbing the record kept of its amount by the reduced substance remaining in the residue.

The qualities of arsenic acid suggest it as a substance likely to possess just these qualities; for, though arsenious acid is converted into arsenic acid by the action of iodine in alkaline solution, in acid solution the reverse is true to at least a limited extent, and arsenic acid liberates iodine according to the equation,

$$H_3AsO_4 + 2HI = H_3AsO_3 + H_2O + I\text{-}I.$$

In company with sulphuric acid of such strength as to liberate the iodine from hydriodic acid, the reduction should fall in the end upon the arsenic, and the arsenious oxide produced should, under proper conditions, preserve the record of the iodine liberated and removed by volatilization. We therefore undertook experimentation upon this line, and the accompanying table shows the results of a preliminary investigation of the mode of action of a mixture of sulphuric and arsenic acids upon an alkaline iodide. In making these tests a standard solution of potassium iodide was put into a test-tube, a solution of potassium arseniate was added, sulphuric acid mixed with its own volume of water was introduced, the volume of the liquid was adjusted, a film of kerosene 3 mm. thick was placed upon the surface of the liquid, and the whole was heated gently and agitated. Kerosene was chosen in preference to other solvents of iodine on account of its lightness, which makes it float upon the mixture, and its high boiling-point, which permits the application of heat to hasten and complete the reaction. Its disadvantage is the persistency with which it adheres to the walls of the test-tube, so that washing with alcohol (or other solvent) after the completion of each test is necessary to prevent the transfer of the iodine of one test to the test next succeeding. The data of these experiments are indicated in the headings.

It will be noted that in Series A, in which the absolute amount of iodine employed, its proportion to the entire volume, and the amount of the arsenic salt remained the same, the proportion of sulphuric acid being the variable element, it is shown that the proportion of sulphuric acid should reach at least twelve parts by volume in one hundred of the solution in order that the maximum distinctness of the test may be developed. An excess of sulphuric acid beyond this proportion is not disadvantageous.

In Series B the proportion and absolute amount of iodine vary as well as the proportion of acid, while the quantity of arsenic remains invariable. The results of this series confirm those of the previous series as to the proper proportion of sulphuric acid to be used, and the sensitiveness of the test is shown to reach (in round numbers) one part by weight of iodine in six hundred thousand parts of the solution.

The tests of Series C indicate plainly that it is the sulphuric acid which is the potent agent in liberating the iodine, the experiment in which acetic acid was substituted for sulphuric acid being particularly noteworthy in this connection. The presence of arsenic acid increases the sensitiveness of the reaction, but its addition beyond a very moderate amount does not appear to be necessary or advantageous. The presence of a chloride or bromide does not impair the delicacy of the test.

The quantities of iodine taken in the experiments just described were necessarily small, and the question arises naturally as to whether the course of action would be similar in the presence of larger amounts of that substance and the correspondingly greater amount of arsenious oxide which is produced with its tendency to reverse the reaction according to which the elimination of iodine proceeds. The solution of this question was reached in the following experiments:

To 50 cm^3 of liquid containing 10 cm^3 of sulphuric acid [1 : 1], and 1 cm^3 of a decinormal solution of iodine in potassium iodide (0·001265 grm. of the former in 0·0018 grm. of the latter) was added 1 cm^3 of a decinormal solution of arsenious oxide (0·00495 grm.), an amount ten times as much as would be necessary to convert the iodine into hydriodic acid were the solution alkaline. The color of the iodine vanished gradually under the action of the arsenious acid, but was restored by the addition of 1 grm. of hydrogen potassium arseniate, and again dispelled by another portion of arsenious acid equal in amount to that introduced at first. Heat was applied at this

SERIES A.

KI.	Grms. of Iodine to cm³ of solution.	H_2KAsO_4	H_2SO_4. [1 : 1]	H_2SO_4 (strong) in 100 parts by volume.	NaCl.	KBr.	Total vol.	Reaction for Iodine.
grm.		grm.	cm³		grm.	grm.	cm³	
0·0001	1 : 132000	1	2	10 : 100	----	----	10	Faint.
0·0001	1 : 132000	1	2	10 : 100	----	----	10	Faint.
0·0001	1 : 132000	1	2·5	12·5 : 100	----	----	10	Faint.
0·0001	1 : 132000	1	2·5	12·5 : 100	----	----	10	Distinct.
0·0001	1 : 132000	1	3	15 : 100	----	----	10	Distinct.
0·0001	1 : 132000	1	4	20 : 100	----	----	10	Distinct.
0·0001	1 : 132000	1	4·5	22·5 : 100	----	----	10	Distinct.
0·0001	1 : 132000	1	5	25 : 100	----	1	10	Distinct.

SERIES B.

0·0005	1 : 26400	1	2·5	12·5 : 100	----	----	10	Distinct.
0·000133	1 : 99000	1	2·5	12·5 : 100	----	----	10	Distinct.
0·0001	1 : 198000	1	3	10 : 100	0·007	----	15	Faint.
0·000067	1 : 198000	1	2·5	12·5 : 100	----	----	10	Faint.
0·000067	1 : 198000	1	2·5	12·5 : 100	----	1	10	Faint.
0·0001	1 : 198000	1	5	16·6 : 100	0·005	----	15	Distinct.
0·0001	1 : 198000	1	5	16·6 : 100	0·005	----	15	Distinct.
0·0001	1 : 264000	1	2 5	6·25 : 100	----	----	20	Invisible.
0·0001	1 : 264000	1	2·5	6·25 : 100	----	----	20	Faint.
0·0001	1 : 264000	1	5	12·5 : 100	----	----	20	Faint.
0·000033	1 : 396000	1	2·5	12·5 : 100	----	----	10	Faint.
0·000033	1 : 396000	1	2·5	12·5 : 100	----	----	10	Faint.
0·000033	1 : 594000	1	5	16·6 : 100	0 005	----	15	Faint.

SERIES C.

0·0020	1 : 8000	1	None. Acetic acid 1·5 grm. (absolute).	----	----	----	12	Invisible.
0·0010	1 : 13200	----	5 cm³	25 : 100	----	----	10	Distinct.
0·0002	1 : 66000	----	5	25 : 100	----	----	10	Faint.
0·0010	1 : 13200	0·2	5	25 : 100	----	----	10	Marked.
0·0001	1 : 132000	0·2	5	25 : 100	----	----	10	Distinct.
0·000033	1 : 198000	0·5	1·25	12·5 : 100	----	----	5	Faint.
0·000033	1 : 198000	0·5	1·25	12 5 : 100	----	----	5	Faint.
0·0001	1 : 264000	2 0	4	10 : 100	----	----	20	Faint.
0·0001	1 : 264000	2·0	6	15 : 100	----	----	20	Faint.

point with the result that the color of iodine showed again faintly, and upon boiling the liquid until its volume decreased to 25 cm³ it became colorless and yielded no iodine when agitated with nitrous acid and chloroform.

An experiment differing from the last in that thirty times as much arsenious oxide and iodine were taken, gave similar results.

It is plain, therefore, that the arsenious acid and arsenic acid exert opposite effects under the conditions of these experiments, and that one or the other prevails according to the proportionate composition of the solution, the degree of dilution, and the temperature.

The experiments detailed in the following statement were intended to determine the conditions best adapted to eliminate the iodine from such quantities of potassium iodide as would ordinarily be dealt with in the course of analysis.

A solution of potassium iodide was placed in an Erlenmeyer beaker of 300 cm^3 capacity, followed by a solution of potassium arseniate and by dilute sulphuric acid [1 : 1], and the volume of the liquid was diluted to about 100 cm^3. A mark was put upon the beaker to indicate the level to which the liquid was to be reduced, a spiral of platinum wire was placed in the solution to prevent explosive ebullition, and the contents of the flask were boiled until the desired degree of condensation was reached. Colorlessness of the liquid at this point, though a fair indication of the absence of free iodine, is no indication that the hydriodic acid has been completely decomposed, and so, in the event of finding the liquid colorless, it was first cooled and shaken with chloroform to prove or disprove the absence of free iodine, and then tested for the presence of hydriodic acid by shaking with nitrous acid and chloroform.

An inspection of these results shows at once that when the larger amounts of iodine are to be eliminated the proportion of sulphuric acid to the final volume after boiling needs to be increased somewhat beyond that which is necessary to set free very small portions such as were dealt with in the experiments of the earlier series.

In Series D it appears that the proportion of sulphuric acid increases from 8·3 per cent to 25 per cent of the whole volume before the liquid is found to be free from iodine as such, and even then there sometimes remain minute, though probably insignificant traces of hydriodic acid.

In the experiment of Series E the liquid was diluted after concentration and the boiling repeated, and the volatilization of the iodine was thus more nearly perfected than in the corresponding experiments of the previous series—a proportion amounting to 16·6 per cent apparently accomplishing the work done by 25 per cent of the same acid in a single concentration. The results of Series F, G, and H, are closely comparable with those of the corresponding experiments of Series D. Throughout these experiments it is again made evident that it is the proportion, and not the absolute amount, of sulphuric acid which is the great factor in the liberation of the iodine. So far as concerns the purposes of good analysis these results indicate the elimination of iodine to a reasonable sufficiency when the reduction of bulk raises the percentage by volume of the strong sulphuric acid to twenty-five, and to perfection, as in the latter deter-

SERIES D.

KI.	H_2SO_4 [1:1].	Per cent of strong H_2SO_4 by volume.	H_2KAsO_4.	Final volume.	Free Iodine.	Combined Iodine.
0·5 grm.	10 cm^3	8·3	1 grm.	60 cm^3	Present	Abundant.
0·5	10	10	1	50	Present	Abundant.
0·5	10	12·5	2	40	Present	Distinct.
0·5	10	12·5	2	40	Trace	Distinct.
0·5	10	12·5	4	40	Trace	Distinct.
0·5	10	16·6	1	30	Trace	....
0·5	10	16·6	2	30	Trace	....
0·5	10	16·6	2	30	Trace	....
0·5	10	16·6	4	30	None	Distinct.
0·5	10	16·6	5	30	Trace	Distinct.
0·5	10	25	1	20	None	Faintest trace.
0·5	10	25	2	20	None	Faintest trace.
0·5	10	25	2	20	None	Faintest trace.
0·5	10	25	2	20	None	Faintest trace.
0·5	10	25	2	20	None	Faintest trace.

SERIES E.

KI.	H_2SO_4 [1:1].	Per cent of strong H_2SO_4 by volume.	H_2KAsO_4.	Final volume.	Free Iodine.	Combined Iodine.
0·5 grm.	10 cm^3	16·6	1 grm.	{ 30 cm^3 / 30 }	None	Faintest trace.
0·5	10	16·6	1	{ 30 / 30 }	None	Faintest trace.
0·5	10	16·6	1	{ 30 / 30 }	None	Faintest trace.
0·5	10	16·6	1	{ 30 / 30 }	None	Faintest trace.

SERIES F.

KI.	H_2SO_4 [1:1].	Per cent of strong H_2SO_4 by volume.	H_2KAsO_4.	Final volume.	Free Iodine.	Combined Iodine.
0·5 grm.	15 cm^3	25	2 grm.	30 cm^3	None	Faintest trace.
0·5	15	25	2	30	None	Faintest trace.
0·5	15	25	4	30	None	Faintest trace.

SERIES G.

KI.	H_2SO_4 [1:1].	Per cent of strong H_2SO_4 by volume.	H_2KAsO_4.	Final volume.	Free Iodine.	Combined Iodine.
0·5 grm.	20 cm^3	25	2 grm.	40 cm^3	None	Faintest trace.
0·5	20	25	2	40	None	Faintest trace.
0·5	20	25	2	40	None	None.
0·5	20	28·6	2	35	None	None.
0·5	20	28·6	2	35	None	None.
0·5	20	33·3	2	30	None	None.

SERIES H.

KI.	H_2SO_4 [1:1].	Per cent of strong H_2SO_4 by volume.	H_2KAsO_4.	Final volume.	Free Iodine.	Combined Iodine.
0·5 grm.	30 cm^3	25	2 grm.	60 cm^3	None	Faintest trace.
0·5	30	25	2	60	None	Faintest trace.

minations of Series G, when the percentage reaches twenty-eight and a half. It remains to be seen whether the arsenious oxide reduced in the separation of the iodine will resist successfully, under the conditions of these experiments, the tendency to volatilize which the presence of chlorides and bromides, and the consequent liberation of hydrochloric and hydrobromic acids, might presumably induce.

The experiments of Series I were directed to the elucidation of this point.

Decinormal solutions of iodine and arsenious acid prepared, standardized, and tested against one another in the usual manner. Definite portions of the solution of arsenious acid were measured from a burette into Erlenmeyer beakers such as were used in the previous experiments, sulphuric acid [1 : 1], and sodium chloride were added, the volume of the liquid was adjusted to 100 cm³, or a little more, and the process of concentration by boiling was carried to the point desired and indicated by a mark upon the flask. After cooling, the acid was neutralized and the titration effected in the usual manner in the presence of an excess of acid potassium carbonate and starch employed as the indicator. These experiments were arranged upon the presumption that the essential conditions determining the degree of volatility of the arsenic when the reduction is effected by hydriodic acid are imitated, though neither hydriodic acid, nor arsenic acid, nor free iodine is present.

SERIES I.

H_2SO_4 [1:1].	NaCl.	Final volume.	Per cent of strong H_2SO_4 by volume.	As_2O_3 taken.	As_2O_3 found.	Loss.
10 cm³	1 grm.	20 cm³	25	0·0495 gr.	0·0485 gr.	0·0010 gr.—
10	1	20	25	0·0495	0·0493	0 0002 —
10	1	20	25	0·0495	0·0488	0·0007 —
10	0·8	20	25	0·0495	0·0488	0·0007 —
10	0·5	20	25	0·0405	0·0495	0·0000
20	1	40	25	0 0495	0·0490	0·0005 —
20	1	40	25	0·0495	0·0490	0·0005 —
20	0·8	40	25	0 0495	0·0490	0·0005 —
20	0·5	40	25	0·0495	0·0490	0.0005 —
20	0·5	40	25	0·1385	0·1380	0·0005 —
20	1	30	33·3	0·0495	0·0476	0·0019 —
20	0·8	30	33·3	0·0495	0·0466	0·0029 —
20	0·5	30	33·3	0·0495	0·0481	0·0014 —
20	0·5	30	33·3	0·0495	0·0485	0 0010 —
20	0·5	30	33·3	0·0595	0·0490	0·0005 —
20	0·5	30	33·3	0 0495	0·0490	0·0005 —
20	0·5	30	33·3	0·0495	0·0490	0·0005 —
30	1	60	25	0·0495	0·0485	0·0010 —
30	0·8	60	25	0·0495	0 0490	0 0005 —
30	0·8	60	25	0·0495	0 0490	0 0005 —
30	0·5	60	25	0·0495	0·0490	0·0005 —

SUMMARY OF SERIES I.

H_2SO_4 [1:1].	Final volume.	Per cent of strong H_2SO_4 by volume.	NaCl.	Mean loss of As_2O_3.	Number of determination.
10 cm³	20 cm³	25	1 grm.	0·0006 gr —	3
20	40			0·0005 —	2
30	60			0·0010 —	1
10	20	25	0·5 and 0·8	0·0003 —	2
20	40			0·0005 —	3
30	60			0·0005 —	3
20	30	33·3	0·5	0 0008 —	5
			0·8	0·0019 —	1
			1·0	0·0029 —	1

It appears in these results that there is some loss of arsenic in nearly every case within the limits of our experimentation, the amount of volatilization increasing with the ratio of sulphuric acid to the entire volume when the quantity of chloride present is constant, and likewise with the amount of chloride when the ratio of the acid to the total liquid is constant.

The effect of increasing the amount of chloride is naturally accounted for by the "mass action" of the hydrochloric acid thus liberated upon the arsenious oxide in solution; that it is the proportion, and not the absolute amount, of sulphuric acid which determines the degree of volatility of the arsenic is explicable upon the assumption that the smallest quantity of sulphuric acid employed is sufficient to liberate all the hydrochloric acid (or, at least, nearly all), and that this, by its action on the arsenious oxide, forms the volatile chloride proportionately to the amount of water removed bodily by concentration or withheld from effective action by the attraction of the sulphuric acid.

In extending this line of experimentation to cases involving the action of hydrobromic acid upon arsenious oxide we found it sufficient for our purpose to employ only the highest degree of concentration recorded in the previous experiments and to use 1 grm. of potassium bromide—an amount corresponding, molecule for molecule, to about 0·5 grm. of sodium chloride. The results, given in Series J, indicate that under these circumstances the loss of arsenic is inappreciable.

SERIES J.

H_2SO_4 [1:1].	KBr.	Final volume.	Per cent of strong Hs_2SO_4 by volume.	As_2O_3 taken.	As_2O_3 found.	Loss.	Mean loss.
	grm.			grm.	grm.	grm.	grm.
20 cm³	1	30 cm³	33·3	0·0495	0·0490	0·0005	0·0001 —
20	1	30	33·3	0·0495	0·0493	0·0002	
20	1	30	33·3	0·0495	0·0495	0·0000	
20	1	30	33·3	0·0495	0·0495	0·0000	
20	1	30	33·3	0 0495	0 0495	0·0000	

It appears, therefore, from the results of Series I, that, when the amount of sodium chloride present is restricted to 0·5 grm., the liquid may be boiled until the sulphuric acid amounts to 33·3 per cent of it, with a loss, on the average, of 0·0008 grm. of arsenious oxide, and to 25 per cent with a loss of 0·0004 grm. With either of these proportions the results are sufficiently favorable to warrant quantitative testing of a method for separating chlorine and iodine based upon the volatility of iodine and the non-volatility of arsenious oxide under the conditions. The case is even more favorable for the similar separation of bromine from iodine—the loss of arsenic amounting on the average to 0·0001 grm., under similar conditions. The experiments of Series D to H indicated that the degree of concentration at which all iodine vanishes from the liquid corresponds to the presence of 28·6 per cent of the acid—a point midway between the points of concentration indicated above. We fixed this proportion, therefore, for the following experiments, as being rather more favorable as regards the fixity of the arsenic and perfect as to the elimination of iodine. The smallest absolute amount of sulphuric acid which we have used—10 cm^3 of the [1 : 1] mixture—demands evaporation of the liquid to a bulk too small to be easily determined with certainty in flasks of the shape and dimensions which we found convenient for this work. The larger amounts of acid are uncomfortably large in the subsequent neutralization. We took, therefore, 20 cm^3 of the [1 : 1] mixture of sulphuric acid and water as the amount best adapted to our purpose and set the limit of concentration at 35 cm^3.

The potassium iodide which we used was prepared with great care, by acting with re-sublimed iodine upon iron wire, three-fourths of the iodine being added to an excess of iron covered with distilled water, decanting the solution from the excess of iron when the color of iodine had vanished, adding the remainder of the iodine, pouring the filtered solution slowly into boiling water, to which the exact amount of acid potassium carbonate necessary to combine with the iodine had been added, and filtering off the magnetic oxide of iron thus precipitated. The solution of potassium iodide thus made, very faintly alkaline and entirely free from chlorine and bromine, was made up to a suitable volume and standardized by precipitating the iodine of aliquot portions by weight as silver iodide, which was heated and weighed upon asbestos. Weighed portions of this solution, containing approximately 0·5 gm. of potassium iodide to 30 cm^3, were taken for the tests in which the larger quantities of iodine were introduced; measured portions of a solution made by diluting the former were employed in the tests involving the smaller amounts.

The sodium chloride and potassium bromide used were shown to be free from iodine, and the hydrogen potassium arseniate contained no arsenious acid.

The mode of proceeding was, in general, like that of the previous experiments. The solution of potassium iodide was put in an Erlenmeyer beaker of 300 cm^3 capacity, two grams of hydrogen potassium arseniate were added in solution and followed by 20 cm^3 of sulphuric acid [1 : 1], the liquid was diluted with water to a little more than 100 cm^3, a platinum spiral was placed in the flask to secure quiet ebullition, a trap made by cutting off a two-bulb drying tube about an inch from the inside bulb was hung, large end downward, in the mouth of the flask to prevent mechanical loss, and the liquid was boiled until the level reached the 35 cm^3 mark put upon the flask. At this point the flask was cooled, the acid nearly neutralized with sodium hydrate in solution, the neutralization completed by acid potassium carbonate, 20 cm^3 of the last being added in excess, a definite portion of starch indicator added, and the contents in arsenious acid determined by titration with a decinormal solution of iodine for the larger amounts, and a centinormal solution for the smaller. Due correction was made for the amount of iodine necessary to develop the test-color in a solution prepared and treated similarly in all respects to the experimental solutions excepting the introduction of the iodide—the correction amounting to a single drop more of the decinormal solution than was required to produce the end reaction in the same volume of pure water containing only the starch indicator.

The decinormal solution of iodine was made by dissolving 12·65 grms. of carefully resublimed iodine in potassium iodide (proved free from iodate) and diluting to a liter. The centinormal solution was made by diluting the stronger solution. The standardizing was effected by comparison with a solution of arsenious oxide containing 4·95 grm. to the liter. This mode of fixing the value of the solution should, and, as the sequel proved, did indicate the correct standard, but for the sake of confirmation the value of the arsenic solution was redetermined by titration against iodine specially purified by subliming off potassium iodide, re-subliming between watch-glasses, and exposing during forty-eight hours over sulphuric acid. Portions of the iodine thus prepared were weighed in a glass-stoppered weighing bottle, dissolved in the same without danger of volatilization by introducing pure solid potassium iodide and a little water, and diluted and treated with the solution of arsenious acid measured from a burette until the color of iodine vanished. The excess of arsenious oxide was determined by titrating against the standard solution of iodine whose value in terms of measured portions of the solution of arsenious oxide was perfectly known.

In Series K are detailed experiments which follow the line marked out for the separation of iodine from chlorine and bromine in the haloid salts, excepting that the iodide was entirely omitted for the purpose of discovering whether hydrochloric and hydrobromic acids possess reducing action upon arsenic acid under the conditions. The evidence is plain that no arsenious oxide is formed by the action of 0·5 grm. of sodium chloride upon 2 grm. of the arseniate under the circumstances as given.

Hydrobromic acid, on the contrary, is slightly decomposed with the evolution of bromine enough to give visible color to the concentrated liquid, but the amount of bromine lost, as indicated by the arsenious acid produced in its evolution, is only 0·0003 grm. for 0·5 grm. of potassium bromide, and 0·0001 grm. for 0·1 grm. of the bromide. Further experiments indicated, however, that concentration cannot go on to a volume less than 35 cm³ without causing serious loss when the maximum amount of bromide is present.

SERIES K.

H_2SO_4 [1:1].	H_2KAsO_4.	NaCl.	KBr.	Final volume.	Iodine correspondi'g to As_2O_3 reduced.	Chlorine corresponding (average).	Bromine corresponding (average).
					grm.	grm.	grm.
20 cm³	2 grm.	0·5 grm.	--	35 cm³	0·0000		
20	2	0·5	--	35	0·0000	0·0000	----
20	2	0·5	--	35	0·0000		
20	2	--	0·1 grm.	35	0·0003		
20	2	--	0·1	35	0·0001	----	0·0001
20	2	--	0·1	35	0·0001		
20	2	--	0·5	35	0·0005		
20	2	--	0·5	35	0·0005	----	0·0003
20	2	--	0·5	35	0·0005		

In Series L are given the results of twenty-six determinations of iodine by the method outlined.

Upon inspection of these results it appears that the method is good and reliable under all the conditions tested.

When neither chloride nor bromide is present, the iodine is determinable with a mean error of 0·0002 grm.

When sodium chloride accompanies the iodide, the results show a loss of arsenious oxide and a consequent apparent deficiency of iodine—as we should expect in accordance with the indications of Series I. This deficiency proves to be proportional to the amount of iodide broken up, or the arsenious oxide thus produced. For 0·56 grm., approximately, of potassium iodide and 0·5 grm. of sodium chloride the deficiency measured in iodine amounted to 0·0011 grm. When the potassium iodide is decreased ten-fold (or more) the deficiency falls to

0·0002 grm. It should be recalled, too, in this connection that the results of Series J pointed to increasing volatility of the arsenic with the increase of the sodium chloride present.

SERIES L.

No.	H_2SO_4 [1:1].	H_2KAsO_4.	NaCl.	KBr.	Final vol.	KI taken.	Theory for Iodine.	Iodine found.	Error.	Average error.
		grm.				grm.	grm.	grm.	grm.	grm.
(1)	20 cm³	2	----	----	35 cm³	0·5616	0·4080	0·4079	0·0001 −	
(2)	20	2	----	----	35	0·5630	0·4091	0·4086	0·0005 −	
(3)	20	2	----	----	35	0·5622	0·4083	0·4086	0·0003 +	
(4)	20	2	----	----	35	0·0506	0·0400	0·0396	0·0004 −	
(5)	20	2	----	----	35	0·0506	0·0400	0·0391	0·0009 −	0·0002 −
(6)	20	2	----	----	35	0·0506	0·0400	0·0400	0·0000	
(7)	20	2	----	----	35	0·0506	0·0400	0·0401	0·0001 +	
(8)	20	2	----	----	35	0·0051	0·0040	0·0037	0·0003 −	
(9)	20	2	----	----	35	0·0051	0·0040	0·0038	0·0002 −	
(10)	20	2	0·5	----	35	0·5611	0·4077	0·4066	0·0011 −	
(11)	20	2	0·5	----	35	0·5619	0·4082	0·4073	0·0009 −	0·0011 −
(12)	20	2	0·5	----	35	0·5624	0·4086	0·4073	0·0013 −	
(13)	20	2	0·5	----	35	0·0506	0·0400	0·0402	0·0002 +	
(14)	20	2	0·5	----	35	0·0506	0·0400	0·0395	0·0005 −	
(15)	20	2	0·5	----	35	0·0051	0·0040	0·0037	0·0003 −	0·0002 −
(16)	20	2	0·5	----	35	0·0051	0·0040	0·0037	0·0003 −	
(17)	20	2	----	0·5	35	0·5619	0·4082	0·4092	0·0010 +	
(18)	20	2	----	0·5	35	0·5697	0·4138	0·4136	0·0002 −	0·0008 +
(19)	20	2	----	0·5	35	0·5622	0·4083	0·4099	0·0016 +	
(20)	20	2	----	0·5	35	0·0506	0·0400	0·0410	0·0010 +	
(21)	20	2	----	0·5	35	0·0506	0·0400	0·0404	0·0004 +	
(22)	20	2	----	0·5	35	0·0051	0·0040	0·0048	0·0008 +	0·0008 +
(23)	20	2	----	0·5	35	0·0051	0·0040	0·0049	0·0009 +	
(24)	20	2	0·5	0·5	35	0·5626	0·4087	0·4083	0·0004 −	
(25)	20	2	0·5	0·5	35	0·5660	0·4112	0·4111	0·0001 −	0·0003 −
(26)	20	2	0·5	0·5	35	0·5622	0·4083	0·4079	0·0004 −	

The presence of potassium bromide results in the liberation of minute amounts of bromine and a consequent increase in the arsenious oxide and apparent excess of iodine. The mean error due to this cause is 0·0008 grm. for 0·5 grm. of the bromide, and the variation in the quantity of iodide present is without effect upon it.

The simultaneous action of the chloride and bromide tends, of course, to neutralize the error due to each. Thus, in the mixture weighing about 1·5 grm. and consisting of sodium chloride, potassium bromide, and potassium iodide in equal parts, the mean error amounts to 0·0003 grm. −. The largest error in the series is 0·0016 grm. +, when the bromide was at its maximum and no chloride was present; and the next largest was 0·0013 grm. − when the chloride was at its maximum and no bromide was present.

It is obvious that when the amounts of chloride and bromide present are known approximately it is possible to apply corrections which shall eliminate errors in the indicated amount of iodine due to the action of these substances. From the averages of Series L it is apparent that the amount to be added in each case may be obtained by multiplying the product of the weights in grms. of sodium chloride and potassium iodide by the constant 0·004; and the amount to be subtracted, by multiplying the weight in grms. of potassium bromide by 0·0016. Thus, for example, the correction in (24) will be 0·0011 grm. + (=0·5 × 0·56 × 0·004) and 0·0008 grm. − (=0·5 × 0·0016). The individual results of Series L thus corrected will stand as follows:

No. of Exp.	Theory for Iodine.	Corrected amount of Iodine found.	Error.	Mean error.
(1)	0·4080 grm.	0·4079 grm.	0·0001 grm. −	0·0001 grm. −
(2)	0·4091	0·4086	0·0005 −	
(3)	0·4083	0·4086	0·0003 +	
(4)	0·0400	0·0396	0·0004 −	
(5)	0·0400	0·0391	0·0009 −	
(6)	0·0400	0·0400	0·0000	
(7)	0·0400	0·0401	0·0001 +	
(8)	0·0040	0·0037	0·0003 −	
(9)	0·0040	0·0038	0·0002 −	
(10)	0·4077	0·4077	0·0000	
(11)	0·4082	0·4084	0·0002 +	
(12)	0·4086	0·4084	0·0002 −	
(13)	0·0400	0·0403	0·0003 +	
(14)	0·0400	0·0396	0·0004 −	
(15)	0·0040	0·0037	0·0003 −	
(16)	0·0040	0·0037	0·0003 −	
(17)	0·4082	0·4084	0·0002 +	
(18)	0·4138	0·4128	0·0010 −	
(19)	0·4083	0·4191	0·0008 +	
(20)	0·0400	0·0402	0·0002 +	
(21)	0·0400	0·0396	0·0004 −	
(22)	0·0040	0·0040	0·0000	
(23)	0·0040	0·0041	0·0001 +	
(24)	0·4087	0·4086	0·0001 −	
(25)	0·4112	0·4114	0·0002 +	
(26)	0·4083	0·4082	0·0001 −	

The mode of proceeding in the analysis of a mixture of alkaline chlorides, bromides and iodides, according to this method may be briefly summarized as follows:

The substance (which should not contain of chloride more than an amount corresponding to 0·5 grm. of sodium chloride, nor of bromide more than corresponds to 0·5 grm. of potassium bromide, nor of iodide much more than the equivalent of 0·5 grm. of potassium iodide) is dissolved in water in an Erlenmeyer beaker of 300 cm^3 capacity, and to the solution are added 2 grms. of dihydrogen potassium arseniate dissolved in water, 20 cm^3 of a mixture of sulphuric acid and water in equal volumes, and enough water to increase the total volume to 100 cm^3, or a little more. A platinum spiral is introduced, a trap made of a straight two-bulb drying-tube cut off short is hung with the larger end downward in the neck of the flask, and the liquid is boiled until the level reaches the mark put upon the flask to indicate a volume of 35 cm^3. Great care should be taken not to press the concentration beyond this point on account of the double danger of losing arsenious chloride and setting up reduction of the arseniate by the bromide. On the other hand, though 35 cm^3 is the ideal volume to be attained, failure to concentrate below 40 cm^3 introduces no appreciable error. The liquid remaining is cooled and nearly neutralized by sodium hydrate (ammonia is not equally good), neutralization is completed by hydrogen potassium carbonate, an excess of 20 cm^3 of the saturated solution of the latter is added, and the arsenious oxide in solution is titrated by standard iodine in the presence of starch.

With ordinary care the method is rapid, reliable and easily executed, and the error is small. In analyses requiring extreme accuracy all but accidental errors may be eliminated from the results by applying the corrections indicated.

ART. XXVI.—*On the Mineral Locality at Branchville, Connecticut:* Fifth Paper; by GEORGE J. BRUSH and EDWARD S. DANA. *With analyses of several manganesian phosphates;* by HORACE L. WELLS.

IT is now nearly twelve years since we published our first paper* upon the Branchville minerals. It will be remembered that the material which formed the basis of our early work was that which Mr. Fillow had brought to light in his excavations, some two years previous, in search for mica. It was this lot of minerals, sagaciously selected and preserved by Mr. Fillow, that we found so remarkably rich in phosphates of manganese, including a number of new and interesting species.† During

* See this Journal, xvi, 33, 114, July and August, 1878; Second Paper, xvii, 359, 1879; Third Paper, xviii, 45, 1879; Fourth Paper, xx, 257, 1880.

† It may be useful here to recall that our investigations have shown that, besides apatite, amblygonite and some others, the following phosphates are present:

Lithiophilite: a manganese triphylite, essentially $LiMnPO_4$; massive, cleavable, of a salmon-pink to clove-brown color.

Eosphorite: a manganese childrenite, essentially $MnAl(OH)PO_4+2H_2O$; in orthorhombic crystals and massive, of a rose-pink color.

Triploidite: near triplite, essentially $Mn(MnOH)PO_4$ in fibrous aggregates and monoclinic crystals isomorphous with wagnerite.

Dickinsonite: a phosphate of manganese, iron and sodium; in bright green chlorite-like foliated aggregates, rarely in pseudo-rhombohedral crystals.

the years of 1878 and 1879, we carried on a somewhat extended search for these minerals in the ledge from which they had been obtained, but the spot from which the most interesting specimens had been derived was very unfavorably situated for work, being ten feet or more below the level of the ground, and our efforts were only in part successful. Some of the results we have already announced in subsequent papers.

Perhaps the most important result of our early explorations was to prove the presence of large amounts of potash feldspar (microcline) and quartz in the vein—in fact, before we ceased our private work, we had brought to the surface several hundred tons of these minerals. This material was of so excellent quality for technical use and the supply seemed to be so large that negotiations were presently entered into between Mr. Fillow, the owner of the property, and the Messrs. Smith, of the Union Porcelain Works, of Greenpoint, New York, with the final result of the sale of the property to the latter gentlemen. This was accomplished in 1880. Since that time the work of quarrying for feldspar and quartz has been carried forward uninterruptedly and with gratifying success; up to the present time Mr. Fillow informs us that from three to four thousand tons of feldspar and four thousand tons of quartz have been shipped from the locality. The arrangement has proved also a very successful one from a scientific point of view. The Messrs. Smith have very liberally placed at our disposal all the material obtained from the locality which was of no technical value, while the daily presence of Mr. Fillow, with his active interest and keen eye, has resulted in saving for science practically everything which the locality has yielded. The covering of earth was early removed, and the ledge opened to as great a depth as the drainage would allow; since then the drain has been repeatedly cut deeper until in the summer of 1888, ten years after our first work, the time to which we had been constantly looking forward arrived and the deep spot from which the first supply of phosphates came was reached.*

In the meantime, however, the work had not been unproductive, and the contents of our third paper upon certain deposits of lithiophilite, eosphorite and other associated minerals, and of our fourth paper upon the spodumene and its

Reddingite: $(Mn,Fe)_3PO_4+3H_2O$; in pinkish orthorhombic crystals near scorodite in form, also in granular masses.

Fairfieldite: a phosphate of manganese and calcium $(Ca,Mn)_3P_2O_8+2H_2O$; triclinic, usually in foliated masses, of a white or yellowish color and pearly to adamantine luster.

Fillowite: a phosphate of manganese, iron, calcium and sodium; in granular aggregates of monoclinic crystals of a honey-yellow color and resinous to adamantine luster.

* It may be added that at present the depth of the opening is some 40 feet and its length and breadth about 160 by 45 feet.

alteration-products, show in part what was accomplished. In addition to what is mentioned in these papers, the locality has at several different times yielded a not inconsiderable amount of uraninite, in part in octahedral crystals with a specific gravity of 9·3; this has been investigated chemically by Comstock.* With the uraninite have been found two or more uranium phosphates which have not as yet been thoroughly studied. Columbite has also been found in considerable quantity, aggregating more than 500 pounds. This occurs in crystalline masses, and in part well developed crystals and groups of crystals in parallel position of remarkable size. It has a specific gravity of 5·73, and as shown by an analysis by T. B. Osborne† contains 19·2 per cent of Ta_2O_5. Another kind of columbite has also been found in minute reddish brown translucent crystals usually implanted upon the spodumene.‡ This variety Comstock has shown to be exceptionally interesting in the fact that it contains manganese with practically no iron, and further has the niobium and tantalum in the ratio of 1 : 1; it has a specific gravity of 6·59. Other points of interest that have been brought out are the occurrence on a rather abundant scale of a mineral, both massive and indistinctly fully crystallized, which resembles cyrtolite but has not yet been investigated; also of smoky quartz, in part well crystallized, and remarkable for its richness in fluid inclusions (CO_2, etc.) as described microscopically and chemically by Hawes and Wright;§ also of beryl in large columnar masses sometimes two feet or more in length; still further of albite in finely crystallized specimens. Apatite has been found in a variety of forms; one variety, of a dark bluish green, has been found by Penfield‖ to contain 10·6 per cent of MnO. Other kinds are interesting crystallographically and resemble the Swiss crystals in habit and complexity. Mica has been obtained in limited amount of a merchantable form (300 pounds of plates cut to pattern); the most common variety, however, is that occurring in curved plates, presenting a smooth convex surface like a watch-glass; these aggregates have a radiated as well as concentric structure. Specimens of the Branchville mica have been analyzed by Rammelsberg.¶

The most important developments, however, have been those of the summers of 1888 and 1889, when considerable quantities of the manganesian phosphates were brought to light. This result has been especially gratifying to us, since it has given us specimens of all but one of the new species described in 1878 (cf. p. 202), several of which we had almost despaired of

* This Journal, xix, 220, 1880.

† This Journal, xxx, 336, 1885.

‡ Ibid., xix, 131, 1880.

§ Ibid., xxi, 203, 209, 1881.

‖ Ibid., xix, 367, 1880.

¶ Jahrb. Min., ii, 224, 1885.

finding again. It has also afforded another new member of the triphylite group, a sodium-manganese phosphate, which we shall call *natrophilite.* Besides this we have identified another phosphate of manganese, and one which from the first we had hoped to find, viz: the rare mineral *hureaulite,* thus far only certainly known from Limoges, Commune of Hureaux, in France.

The general method of occurrence of the phosphates of manganese is such as to confirm the opinion that we have expressed in a former paper, that the manganesian triphylite or lithiophilite is the parent species. This is beyond all doubt an original mineral in the vein, occurring intimately associated with the albite, quartz and spodumene. With it, sometimes entirely enclosed by it, we find another of the Branchville species, triploidite, which seems to be also an original mineral.

The masses of lithiophilite are as a rule unaltered, showing only a little oxidation on the outer surfaces, and on the fracture surfaces an occasional thin film of a bright blue crystallized mineral in minute amount, resembling vivianite. In some few cases they have a distinct though rough crystalline form, and the planes 110, 120 and 021 have been identified; one of these rough crystals is no less than eighteen inches in length and weighs fifteen pounds. The angles measured are mere approximations, but they are interesting as showing, as has been assumed, that the form of lithiophilite is the same as that of triphylite. We may add here that a small crystal found some years ago resembles fig. 450 in Dana's System.

	Lithiophilite.	Triphylite (Tschermak).
$110 \wedge 1\bar{1}0 =$	48°	47°
$110 \wedge 120 =$	17 –18°	17 31′
$010 \wedge 021 =$	42	43 31

The cleavage angle $110 \wedge 1\bar{1}0$ was found to be 48° 30′ to 49°. Occasionally the masses of lithiophilite are extensively changed; this is true especially of some of the large nodular inclusions in the vein. It is most interesting in these masses to note the change from the perfectly fresh lithiophilite through a zone in which the green chlorite-like dickinsonite is more or less distinctly represented to the hureaulite beyond. This change of the lithiophilite into hureaulite can often be observed, and the interpenetration of the two minerals is well shown under the microscope in sections cut parallel to the basal cleavage. A thin line of eosphorite often crosses the hureaulite. Sometimes with the dickinsonite we have also fairfieldite in clear foliated masses, and reddingite in light pinkish crystals and crystalline masses. It is impossible to lay down any general rules in regard to the order of occurrence of these minerals or their method of arrangement. On the contrary they occur closely together, now one and now another prominent, and it is not uncommon to find five or six of the phosphates in characteristic form on a single hand specimen a few square inches in surface. In one such specimen, for example, we have at one extremity lithiophilite and triploidite, then hureaulite and natrophilite interpenetrated by a narrow zone of eosphorite and again lithiophilite. In another specimen which gives a section into the interior of a nodular mass, we pass from the exterior albite through a nondescript zone blackened by oxidation and showing some dickinsonite, through distinct foliated masses of the same mineral enclosing patches of natrophilite, then hureaulite abundant with fairfieldite and some reddingite, and finally the unchanged lithiophilite.

Much of the material is of the most ill-defined and problematical character, being an intimate mixture sometimes of eosphorite and quartz, such as we have before described, or of others of the phosphates in indistinct form. Typical specimens of the different species are as characteristic as could be desired and recognized at once; in others less characteristic they resemble one another so closely that identification is often a matter of much difficulty. It may be added that much of the triploidite can hardly be told by the eye from a massive red garnet commonly associated with it, while the fairfieldite similarly resembles the albite; in these cases, however, a simple test of hardness is all that is required. We go on now to a detailed account of some of the more interesting species identified.

NATROPHILITE.

The sodium-manganese member of the triphylite group, to which we give the name *natrophilite*, has been identified only in the material obtained during the last summer. It occurs sparingly, usually closely associated with lithiophilite, and upon a superficial examination could be confounded with it, although distinguishing characters are not wanting. It appears in cleavable masses for the most part, the cleavage surfaces often broad, and showing something of a pearly luster. Occasionally smaller grains appear imbedded in the cleavage mass, and these show at times a more or less distinct crystalline form. On one of these the usual planes of triphylite were identified, 110, 120, 021, 001 (cleavage). The angles could not be obtained accurately but were sufficient to determine the forms, viz:

	Natrophilite.	Triphylite.
$110 \wedge 1\bar{1}0 =$	50° 30	47°
$120 \wedge 1\bar{2}0 =$	87	82 1′
$001 \wedge 032 =$	47 –49°	46 29

In crystalline form, then, it agrees as was to be expected with triphylite and lithiophilite. Optically it also corresponds so far as it has been investigated; the optic axes lie in basal section and the acute bisectrix (positive) is normal to the brachypinacoid. The characteristic basal cleavage is always a prominent character, but the brachydiagonal cleavage 010 is less distinct than is shown by lithiophilite, and the prismatic cleavage (110) is interrupted; the measured angle was 50°; these cleavages are seen more clearly in thin sections. The fracture is conchoidal, more perfectly so than with lithiophilite. The color is a rather deep wine-yellow, much like that of the Brazilian topaz. The luster is brilliant resinous to nearly adamantine; it was, in fact, the brilliancy of the luster which first attracted our attention, and which is, so far as the eye is concerned, its most distinguishing character. The mineral itself is perfectly clear and transparent, but the masses are much fractured and rifted. The surfaces are often covered by a very thin scale of an undetermined mineral, having a fine fibrous form, a delicate yellowish color and silky luster. This same mineral penetrates the masses wherever there is a fracture surface of cleavage or otherwise. What the exact nature of this mineral is we are unable to say, since the amount is too small to admit of a satisfactory determination—it appears to be a manganesian phosphate. It is evidently an alteration-product and would seem to imply that natrophilite is rather subject to easy chemical change. In any case this silky film is one of the characteristic features of the mineral, and directs attention to it at once even over the surface of a hand specimen where it is associated with lithiophilite and perhaps three or four other of these phosphates.

Before the blowpipe natrophilite fuses very easily and colors the flame intensely yellow, thus being at once distinguished from lithiophilite. It also gives the usual reactions for manganese. The following is an analysis of natrophilite made by Wells. The specific gravity on two fragments was found to be 3·40 and 3·42.

	I.	II.	III.	Mean.		
P_2O_5	41·03	----	---	41·03÷142=		·289=1 =1
MnO	38·19	----	----	38·19÷ 71=·538	} ·580=2·01=2
FeO	3·06	----	----	3·06÷ 72=·042		
Na_2O	----	16·77	16·81	16·79÷ 62=·271	} ·279=0 97=1
Li_2O	----	0·20	0·19	0·19÷ 23=·008		
H_2O	----	0·40	0·45	0·43		
Insol.	0·81	0·81	0·81	0·81		
				100·50		

The formula is therefore $\overset{I}{R}_2O \cdot 2\overset{II}{R}O \cdot P_2O_5$ or $\overset{I}{R}\overset{II}{R}PO_4$, or essentially $NaMnPO_4$. It will be noticed that iron is present in very small amount only (3 p. c.) and of lithia there is hardly more than a trace (0·2 p. c.). With the discovery of natrophilite, the triphylite group receives an important addition, and we now have:

Triphylite,	$LiFePO_4$	Connected by many intermediate
Lithiophilite,	$LiMnPO_4$	compounds, $Li(Fe, Mn)PO_4$.
Natrophilite,	$NaMnPO_4$.	

These three species are, as is to be expected, closely isomorphous. To them is also related in composition and in some degree in form the new sodium-beryllium phosphate, beryllonite, $NaBePO_4$, which was described by one of us a year and a half ago.*

The relation of natrophilite in origin to the common lithiophilite is an interesting question. In view of the extensive changes that, as we have shown, have taken place in the spodumene, by which the lithium has been removed and its place taken more or less fully by sodium, or sodium and potassium, it is natural to suggest that a similar change has resulted in forming the $NaMnPO_4$ out of $LiMnPO_4$, and this we regard as very probable. Its limited method of occurrence suggests the same thing, although it must be remarked at the same time that it seems to pass into hureaulite as readily as the lithiophilite. If in fact formed from lithiophilite, the change probably took place before the formation of most of the other phosphates.

Hureaulite.

Perhaps the most interesting of recent developments at Branchville is the discovery of the rare mineral hureaulite. Thus far our knowledge of hureaulite has been limited to the account of crystals from Limoges by Dufrénoy† and the later and more thorough description by Damour and DesCloizeaux.‡ In addition we have only the single remark by Websky that it probably occurs at Michelsdorf, Silesia, with sarcopside.

The crystals described by DesCloizeaux belong to three varieties showing two distinct types of form, though having the same composition, as shown by Damour. These varieties are respectively violet-rose, brownish orange and pale rose pink in color. Their crystallographic relation to each other is anomalous, in fact, it would be difficult to find another case equally so. The crystals of the two types have the fundamental prism in common, but otherwise no plane of the one occurs on the other, and what is more remarkable, the symbols assigned to a nnmber of the planes of the second type are complex in the extreme. The axial ratio calculated from DesCloizeaux's fundamental measurements is

$$\grave{a} : \grave{b} : \grave{c} = 1{\cdot}6977 : 1 : 0{\cdot}8887;\ \beta = 89°\ 27'.$$

The planes observed on crystals of the two types are as follows:

* This Journal, xxxvi, 290, Oct., 1888; xxxvii, 23, Jan., 1889.
† Ann. Chim. Phys., xli, 338, 1829. ‡ Ibid, III, liii, 293, 1858.

First type				Second type.			
			DesCl.				DesCl.
b	010	*i-ì*	*g*	*a*	100	*i-i*	h^1
c	001	*O*	*p*	*m*	110	*I*	*m*
m	110	*I*	*m*	*o*	105	$-\frac{1}{5}$-*i*	o^5
g	301	—3-*i*	$o\frac{1}{3}$	*a*	$\bar{1}\bar{5}\cdot0\cdot8$	$\frac{15}{8}$-*i*	$a\frac{8}{15}$
e	011	1-*ì*	e^1	*δ*	435	$-\frac{4}{5}$-$\frac{4}{3}$	*δ*
u	$\bar{3}11$	3-3	*u*	*k*	$\bar{1}\bar{9}\cdot5\cdot8$	$\frac{19}{8}$-$\frac{19}{6}$	*k*
t	$\bar{3}41$	4-$\frac{3}{4}$	*t*	*x*	$\bar{1}\bar{1}\cdot9\cdot10$	$\frac{11}{10}$-$\frac{11}{9}$	*x*
				ε	$\bar{9}\cdot11\cdot10$	$\frac{11}{10}$-$\frac{11}{9}$	*ε*

The Branchville crystals, like those from Limoges, vary in color from pale violet to reddish brown and deep orange-red. The habit of the crystals, however, is nearly constant and the angles also so far as our measurements have gone; they correspond to the second type of the Limoges crystals. The crystals are not easy to decipher, since they are very small, united by parallel grouping and as a rule present only a few planes in such a way as not to exhibit the symmetry. The angles are not as accurate as could be desired, although the crystals are much better than those of Limoges, since DesCloizeaux gives his observed angles to whole degrees in many cases and the majority are stated to be approximations only.

For the sake of greater simplicity of symbols, the position of DesCloizeaux is modified somewhat in that his plane 105 (o^5) is taken as the base and the pyramid *δ* is made the unit pyramid.

For fundamental angles the following have been assumed:

$$100 \wedge 001 = 84^\circ\ 1'$$
$$110 \wedge 1\bar{1}0 = 62^\circ\ 21'$$
$$\bar{1}10 \wedge \bar{4}01 = 70^\circ\ 54'$$

whence we obtain:

$$\grave{a} : b : \dot{c} = 1{\cdot}9192 : 1 : 0{\cdot}5245;\ \beta = 84^\circ\ 1'.$$

The observed planes with the symbols of the corresponding planes so far as observed by DesCloizeaux are as follows:

			DesCloizeaux.	
a	100	*i-i*	100	h^1
c	001	O	105	o^5
m	110	I	110	*m*
α	$\bar{4}01$	4-*i*	$\bar{1}5\cdot0\cdot8$	$a\frac{8}{15}$
β	$\bar{5}01$	5-*i*		
p	223	$-\frac{2}{3}$		
δ	111	—1	435	*δ*
e	$\bar{2}21$	2	$\bar{9}\cdot11\cdot10$	*ε*
k	$\bar{5}11$	5-5	$\bar{1}\bar{9}\cdot5\cdot8$	*k*
z	$\bar{6}21$	6-3		
l	$\bar{8}41$	8-2		

The attempt to transform the symbols of DesCloizeaux, according to the usual methods, into those required by this change of position meets with only partial success. Thus the plane $\bar{1}\bar{9}\cdot5\cdot8$ becomes by the transformation $\bar{4}11$ while the observed angles of DesCloizeaux make it for the axial ratio here taken $\bar{5}11$. As will be seen below the angles of a number of forms on the Branchville hureaulite agree pretty well with the angles measured by DesCloizeaux, with the single exception of the prism. For this he found 119°, while we make it for the Branchville crystals 124° 42′. It is this discrepancy which causes the want of agreement which we have just alluded to. Furthermore, it is seen that the complex symbols of several of the planes, in DesCloizeaux's position and referred to his axes, become simplified when referred to the axes here adopted. Of the planes noted by DesCloizeaux on type 2, all but one ($\bar{1}\bar{1}\cdot9\cdot10$) it will be seen, occurs on the Branchville crystals and to this the symbol $\bar{5}32$ probably belongs in our position. Of the forms of the first type, only the prism occurs with us, but to the other planes the probable symbols in our position may be assigned.

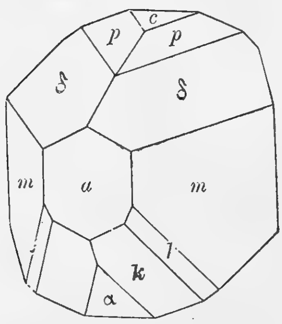
DesCloizeaux.			DesCloizeaux.		
001	*p*	$\bar{1}03$	$\bar{3}11$	*u*	$\bar{1}\bar{2}\cdot3\cdot2$?
011	c^1	$\bar{1}53$	$\bar{3}41$	*t*	$\bar{6}61$?

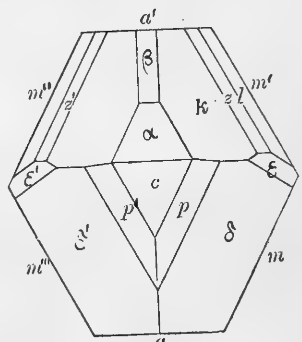
The following table gives the more important angles calcu-

	Branchville. Calculated.	Branchville. Measured.	DesCloizeaux. Calculated.	DesCloizeaux. Measured.
100 ∧ 110	*62° 21′	62° 18′, 62° 25′, 62 27 62 35 62 45	59°	59°
001 ∧ 100	*84 1	83 26	83 29′	83° 39′
" $\bar{1}00$	95 59	96 9	96 31	96 30
" $\bar{1}03$	5 13½			(5 58)
" $\bar{4}01$	50 49		50 42	50 50
$\bar{1}00$ ∧ $\bar{4}01$	45 10	45 54	45 49	45 40
100 ∧ 223	74 47½			
" 111	71 25	71 9		
$\bar{1}00$ ∧ $\bar{8}41$	47 59			
" ∧ $\bar{5}11$	41 40	42 12, 42 14, 42 35		42 10
001 ∧ 223	21 3	21 3, 21 58		
" ∧ 111	29 46	29 40, 29 28	30 40	29 25
" ∧ 110	87 14	87°, 87° 4′, 87 12′	86 42	86
" $\bar{2}21$	51 17		50 17	50 29
" ∧ $\bar{5}11$	59 30			59 30
" ∧ $\bar{1}10$	92 46	92° 56′		
223 ∧ $2\bar{2}3$	37 9	37 37		
111 ∧ 1 1	52 14½	51 54	52 13	51
511 ∧ $\bar{5}\bar{1}1$	35 58	36 7, 36 31	38 33	37
110 ∧ 111	57 28	57 32, 57 22, 57 42	56 2	55 45
" 223	66° 11′	66 12, 67 3		
$\bar{1}10$ $\bar{2}21$	41 29	42 1	43 2	43
" ∧ $\bar{5}11$	51° 9′	51 40, 51 50, 51 52	48 57	49
" ∧ $\bar{8}41$	25° 13′	25 13, 25° 22′		
" ∧ $\bar{4}01$	*70° 54′	70 53, 71° 19′		

lated from our axial ratio compared with our measurements and also with the *measured* angles of DesCloizeaux. It is seen that the correspondence between our measured and calculated angles is not in all cases as great as could be desired, although as much as could perhaps be expected from the nature of the material. It has been stated that the crystals are often grouped in parallel position, but as is common in such cases, the parallelism is not perfect and furthermore the parts show slight variations in position, even when the planes are smooth, which are doubtless to be referred to the same cause.

The habit of the Branchville crystals is short prismatic as shown on figure 1; a basal projection of a more complex form is given in fig. 2. The grouping in parallel position gives rise to a repetition of the prismatic planes which may result in a deep striation or furrowing of this face. Besides this, the zone of planes *m*, *l*, *k*, *a*, is often striated or channeled parallel to their common direction of intersection. The crystals show rather perfect cleavage parallel to the orthopinacoid. For analysis, carefully selected portions of the purest crystals were taken by Prof. Wells. The specific gravity was found to be 3·149. The results are satisfactory as agreeing fully with those of Damour and leading to the same formula. For comparison we quote Damour's analysis of the pale rose crystals which differs but little from that of the yellow crystals; it is to be noted that the violet crystals (type I) have not been analyzed and it is possible that some difference in composition may explain the difference noted in the form. The Branchville mineral contains a little less iron than the Limoges.





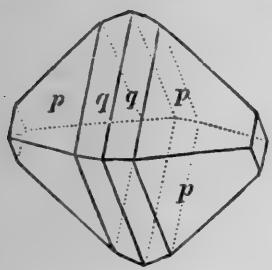
	Branchville. G.=3·149 I.	II.	Mean.			Limoges. rose, G.=3·185
P_2O_5	38·28	38·44	38·36		·270=1·00=2	37·83
FeO	4·76	4·37	4·56	·063		8·73
MnO	42·29	----	42·29	·596	·676=2·50=5	41·80
CaO	0·94	----	0·94	0·17		
H_2O	12·25	12·15	12·20		·678=2·51=5	11·60
Quartz	1·76	----	1·76			Gangue 0·30
			100·11			100·26

The formula is $5RO \cdot 2P_2O_5 \cdot 5H_2O$ or $H_2R_5(PO_4)_4+4H_2O$. The percentage composition calculated for manganese only is: P_2O_5 38·96, MnO 48·69, H_2O 12·35=100.

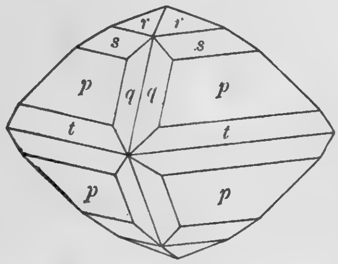
Reddingite.

The species reddingite has been known thus far only in a few specimens, showing it in a granular form of a reddish color, or rarely in octahedral crystals often superficially black from oxidation. The material first found though scanty was sufficient to admit of the determination of the form, which was shown to be similar to that of scorodite and strengite. Among the specimens recently discovered, reddingite is not uncommon, and we have been gratified to obtain it not only well crystallized but also in massive form, perfectly fresh and unaltered. The color is a pale rose-pink, often hardly more than a pinkish-white. The most intimately associated minerals are fairfieldite and dickinsonite, the latter of which is often imbedded in it in isolated scales or more often in stellate groups of green folia. The octahedral habit of the crystals, which appear in occasional cavities, is usually apparent at a glance, but not infrequently the crystals are distorted by the elongation of a pair of pyramidal planes which gives them a misleading oblique prismatic appearance. The common form

3.



4.



of the crystals is shown in fig. 3 from our former paper. Some of the crystals are more complex (fig. 4) and show also the unit pyramids *r*, *s* and *t*, whose symbols are respectively 338, 223, 774. These planes do not give sharp measurements but the angles are sufficient for identification. The axes taken are those previously obtained by us, viz:

$$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}8678 : 1 : 0{\cdot}9485$$

and the measured and calculated angles are,

	Measured.	Calculated.
111 ∧ 338 =	20° 11′	20° 9′
111 ∧ 223 =	10° 10′	9° 54′
111 ∧ 774 =	15° 41′	15° 46′

It seemed especially desirable to have a new analysis of this species, both because the material was more abundant and better than what we had had before, and also since the composition—though in fact fully established—may have appeared to some anomalous, in view of its failure to correspond with that of scorodite and strengite in the degree of oxidation of the manganese and in the amount of water. The new analysis by Wells fully confirms the former one made by him, only differing in the larger percentage of ferrous iron present.* This analysis of a carefully selected portion with a specific gravity of 3·204, gave:

	I.	II.			
P_2O_5	34·90	----	÷ 142 = ·246		= 1·00 = 1
FeO	17·13	----	÷ 72 = ·238	⎫	
MnO	34·51	----	÷ 71 = ·486	⎬ ·735	= 2·99 = 3
CaO	0·63	----	÷ 56 = ·011	⎭	
H_2O	13·18	13·18	÷ 18 = ·732		= 2·98 = 3
Quartz	0·13	----			
	100·48				

The formula is hence $R_3(PO_4)_2+3H_2O$, and if R=Fe:Mn=1:2, this requires P_2O_5 34·64, FeO 17·56, MnO 34·63, H_2O 13·17=100.

Fairfieldite.

Fairfieldite appears among the specimens recently obtained not infrequently, and in a form much fresher and purer than that in which we had it before. It is usually in foliated masses intimately associated with reddingite and fairfieldite, and hardly less so with hureaulite. The color varies from white to yellowish or greenish white; it is usually perfectly transparent and the luster is very brilliant, varying from adamantine to pearly according to the surface on which it is viewed, the latter on the surface of perfect cleavage. A tendency to crystallization is at times apparent but no crystals suitable for measurement have been found, which is to be regretted since the early results left much to be desired. An analysis of the perfectly fresh mineral has been made by Wells. This agrees with those of Penfield previously published; the amount of iron is less and that of the manganese greater, but it is worthy of note that the ratio of 2:1 for Ca:Mn+Fe is still maintained.† The analysis of pure material having a specific gravity of 3·07 is as follows:

* The earlier analysis gave FeO 5·43, MnO 46·29.

† It is interesting to call attention here to the identification of fairfieldite by Sandberger at Rabenstein, Jahrb. Min., i, 185, 1885. It is also worthy of note that a new hydrous phosphate of ferrous iron and calcium, near fairfieldite but with $2\frac{1}{2}H_2O$, has been recently named messelite by Muthmann (Zs. Kryst., xvii, 93, 1889); like fairfieldite it is triclinic. Furthermore the brandtite of Nordenskiöld is $Ca_2Mn(AsO_4)_2+2H_2O$, corresponding exactly to fairfieldite, Œfv. Ak. Stockh., 489, 1888, Groth, Tab. Ueb. Min., p. 80, 1889.

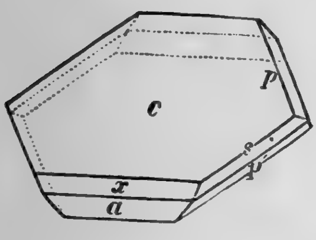
P_2O_5	[37·69*]	÷ 142 = ·265		= 1·00 = 1
FeO	3·42	÷ 72 = ·047	} ·292	= 1·10 = 1
MnO	17·40	÷ 71 = ·245		
CaO	30·02	÷ 56 = ·536		= 2·02 = 2
H_2O	9·81	÷ 18 = ·545		= 2·06 = 2
Quartz	1·66			
	100.00			

The formula is hence essentially $Ca_2Mn(PO_4)_2+2H_2O$, which requires P_2O_5 39·34, MnO 19·67, CaO 31·02, H_2O 9·97=100. This analysis confirms the earlier one by Penfield and further makes it probable that there is a definite ratio of 1 : 2 for Mn (with Fe) : Ca.

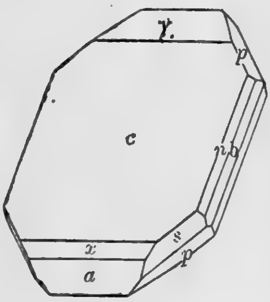
DICKINSONITE.

One of the most remarkable and novel of the species first described from Branchville was the chlorite-like dickinsonite—a mineral of a bright green color, micaceous structure and pseudo-rhombohedral form. Recent developments have enabled us to add materially to our knowledge of the species. The number of specimens obtained is relatively large and in some of them it shows itself in tolerably well-defined crystallized forms. It will be remembered that for our earlier work we had only one or two minute crystals. The habit of most of the crystals now found differs from that before described, fig. 5, the hexagonal form is rather rare and the crystals appear as rectangular tables united in slightly diverging groups, fig. 6.

5.



6.



A closer examination shows that they agree with the same fundamental form before accepted. These crystals are elongated parallel to the orthodiagonal axis, and the basal surfaces are bent and striated in this direction. In addition they show on the edges, sometimes in traces only, the pyramidal planes, which when developed give the hexagonal habit before noted. In addition to the planes *a*, *b*, *c*, *x* (301), *p* ($\bar{1}$11) and *s* ($\bar{2}$21), we have identified also a steep clinodome, *n*, which has the symbol (051) and a hemi-orthodome, *y* ($\bar{1}$03). We retain our former axial ratio

$$\dot{a} : b : \dot{c} = 1·73205 : 1 : 1·19806;\ \beta = 61°\ 30'.$$

* By difference.

And the measured and calculated angles are:

	Calculated.	Measured.
001 ∧ 051 =	79° 15′	79°
001 ∧ $\bar{1}$03 =	12 50	13–14

Optically we find the crystals as before stated to be biaxial, the optic axes being situated in the clinodiagonal section and the bisectrix nearly normal to the cleavage-face; the double refraction is negative and the axial angle large.

Besides the crystals occasionally appearing in the cavities, and often united in slightly diverging groups with edges parallel to *b* projecting, the mineral occurs foliated to almost massive and granular, the folia, however, usually distinct and often grouped in rosettes or stellate forms.

Dickinsonite is the species about whose composition we felt most doubt when we first published. The material then in hand was very scanty and not entirely pure, and although excellent analyses were made by Penfield, their interpretation was a matter of some doubt because of admixture of more or

DICKINSONITE, BRANCHVILLE.

Analysis of first sample.

Sp. Gr. 3·143,

	I.	II.	Mean.			
P_2O_5	39·57	----	39·57 ÷ 142 = ·279			=1·00=1
FeO	----	13·25	13·25 ÷ 72 = ·184	}		
MnO	31·74	31·42	31·58 ÷ 71 = ·445	}		
CaO	2·15	----	2·15 ÷ 56 = ·039	}		
MgO	trace			}	·814	=2·92=3
Na_2O	7·47	7·44	7·46 ÷ 62 = ·124	}		
K_2O	1·49	1·55	1·52 ÷ 94·2 = ·017	}		
Li_2O	0·20	0·14	0·17 ÷ 34 = ·005	}		
H_2O	1·66	1·65	1·65 ÷ 18 = ·094			=0·34=⅓
Quartz	2·58	2·58	2·58			
			99·93			

Analysis of second sample.

	I.	II.	Mean.			
P_2O_5	40·89	----	40·89 ÷ 142 = ·288			=1·00=1
FeO	12·96	----	12·96 ÷ 72 = ·180	}		
MnO	31·83	----	31·83 ÷ 71 = ·448	}		
CaO	2·09	----	2·09 ÷ 56 = ·038	}		
MgO	none	----		}	·811	=2·82=3
Na_2O	----	7·37	7·37 ÷ 62 = ·120	}		
K_2O	----	1·80	1·80 ÷ 94·2 = ·019	}		
Li_2O	----	0·22	0·22 ÷ 34 = ·006	}		
H_2O	1·64	1·62	1·63 ÷ 18 = ·092			=0·32=⅓
Quartz	0·85	0·79	0·82			
			99·61			

less eosphorite as well as quartz. Two independent sets of new analyses have been made by Professor Wells. The material for the first was picked with great care, but in order to remove all question as to whether the results gave the true composition of the mineral, a second and independent analysis was made. For this the very best material was selected and after being separated was minutely examined microscopically to make sure of its purity. The results as will be seen are identical with those of the first.

The two samples were picked from separate specimens and the material was apparently very pure. Unusual care was taken in picking the second sample and its purity is indicated by the small amount of quartz present.

The formula indicated by both the analyses is $3RO . P_2O_5, \frac{1}{8}H_2O$ or $R_3(PO_4)_2+\frac{1}{8}H_2O$ where $R=Mn, Fe, Ca, Na_2, K_2$ and Li_2. There is no simple ratio between the alkalies and the remaining bases. The results vary considerably from those of Penfield in his original analysis. This is undoubtedly due to the fact that the present material was much purer than that analyzed by him. Penfield found about 14 per cent CaO, (probably due to admixed fairfieldite) only about 6 per cent of alkalies and 3·87 per cent of H_2O. The formula which he arrived at, however, is confirmed except in the amount of H_2O. It will be seen that the composition now established is essentially the same with that deduced for fillowite on the basis of Penfield's original analysis.

Fillowite.

The fact just stated, that our former formula for fillowite is the same as that now obtained for dickinsonite, has made us very anxious to prove that our early results were trustworthy, especially since the material in hand at the time of our first investigation was very scanty. Unfortunately, among the large number of specimens recently obtained from Branchville, we have not succeeded in finding a trace of this mineral. We have been forced consequently to revert to the few original specimens still in hand. The best of these we gave to Mr. Wells, and from it he picked out about 0·75 gram, in the homogeneity of which he had entire confidence. A new analysis of this has been made by him with the following results; for comparison we quote the original analysis by Penfield.

		Ratio.			Analysis (1878) Penfield.
P_2O_5	39·68	÷ 142 = ·279		1·	39·10
FeO	9·69	÷ 72 = ·135			9·33
MnO	39·58	÷ 71 = ·557			39·42
CaO	3·63	÷ 56 = ·065	·847	3·04	4·08
Na_2O	5·44	÷ 62 = ·088			5·74
Li_2O	0·07	÷ 30 = ·002			0·06
H_2O	1·58	÷ 18 = ·088		0·31	1·66
Quartz	1·02				0·88
	100·69				100·27

It will be seen that the two analyses agree throughout and the formula, is the same, viz: $R_3P_2O_8+\frac{1}{3}H_2O$. As noted above it is identical with that of dickinsonite, although the latter species contains more alkalies and less manganese. The two species are then essentially dimorphous forms of the same compound, and the relation between them is made all the more interesting in that with the striking differences in physical characters, there is yet an obvious relation in form. Dickinsonite is monoclinic with marked pseudo-rhombohedral symmetry and of fillowite the same is true as we have proved by a reëxamination of fragments parallel to the distinct but interrupted basal cleavage. Moreover the dimensions of the forms show a close relation, thus we have:

	Dickinsonite.	Fillowite.
$100 \wedge 001 =$	61° 30′	58° 31′
$001 \wedge \bar{2}21 =$	61 8	58 40
$001 \wedge 221 =$	61 8	58 40

We have then in these two species an example of a very close and interesting case of dimorphism. The suggestion that the two could be regarded as independent forms of the same mineral differing in habit and state of aggregation could not possibly be made by one who had seen and examined the specimens. We have still hope that in future explorations at Branchville we may find a new supply of this rare and interesting species, named in honor of our good friend, Mr. A. N. Fillow.

Art. XXVII.—*A simple Interference Experiment;* by Albert A. Michelson.

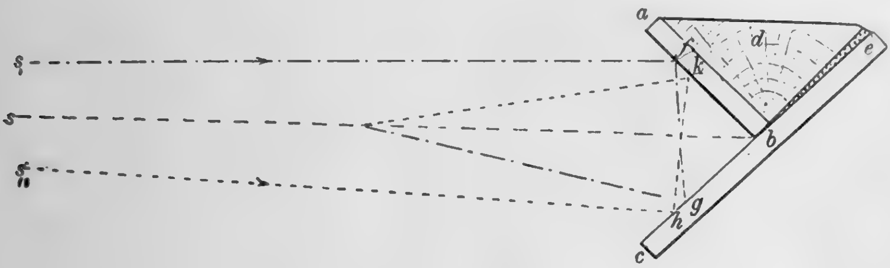
There is probably no experiment connected with the wave-theory of light of greater fundamental importance than the justly celebrated one known as "Fresnel's mirror experiment," and accordingly many find it necessary to repeat the experiment for their own edification or for class demonstration.

Without the use of rather elaborate and costly apparatus even skilled experimenters find some difficulty in producing the desired effect—the interference of two pencils of light as manifested by the appearance of colored fringes on a screen, or in the focus of an observing lens; and unskilled observers find it almost impossible, even with these aids. Even when produced under the most favorable conditions the phenomenon is complicated and often much obscured by diffraction effects.

A very considerable improvement is effected by the substitution of Fresnel's "bi-prism," though in this case one of the chief points of interest is lost; namely, the change of breadth of the bands with alteration of angle. The phenomenon is also complicated by the dispersion of the glass.

The following method has the advantage of being easily within the reach of even unskilled persons, and of giving the required result in all its purity.

Fasten a piece of plane glass *ab*, fig. 1, (selected plate glass will answer, though sextant glass is much better) to a right angled prism of wood *d*; then press *d* against a second piece



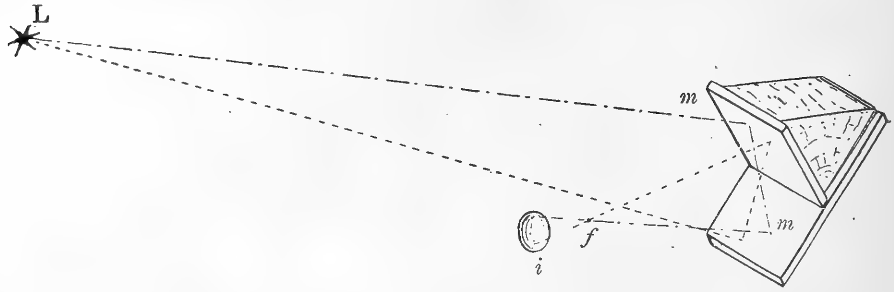
of plane glass *ce* by means of a little soft wax, so that the angle *abc* is a little less than a right angle. If the light from a distant electric arc lamp be allowed to fall on the glasses (which should be silvered on the front surfaces) two rays $s_{,}$ $s_{,,}$ starting in the same phase, after reflections at *f*, *g* and *h*, *k*, respectively, will meet somewhere in the line *bs* in the same phase, the two paths being exactly equal.* Accordingly this line is the locus of the central bright fringe and the system of fringes may readily be observed through a lens of about an inch focal length whose axis is anywhere along this line.

The figure is drawn for clearness in the vertical plane containing the source, and if the intersection of the two surfaces (projected at *b*) were at right angles with *sb* it would be necessary to deflect part of the light to one side by a transparent mirror. But the appearance of the fringes is in no wise changed if the apparatus be rotated through a horizontal angle *a*. The line *bs* is then rotated through 2*a*, and there is no difficulty in observing the fringes directly.

It will be noted that no adjustments whatever are necessary. All that is required is that the surfaces be fairly true and the angle slightly less than 90°. This last condition can be readily fulfilled by making the two images of a distant object nearly coincide.

*This is true whether the surfaces form equal angles with *sb* or not.

The following may serve as a guide to the general disposition of the apparatus. Fig. 2.



L is the arc lamp (if provided with a shade the latter should be transparent) *mm*, the two mirrors, *f* the fringes in the focus of the lens *l*, the eye being at an equal distance on the other side of the lens, *Lm* may be 100 meters and *mf* one meter or more.

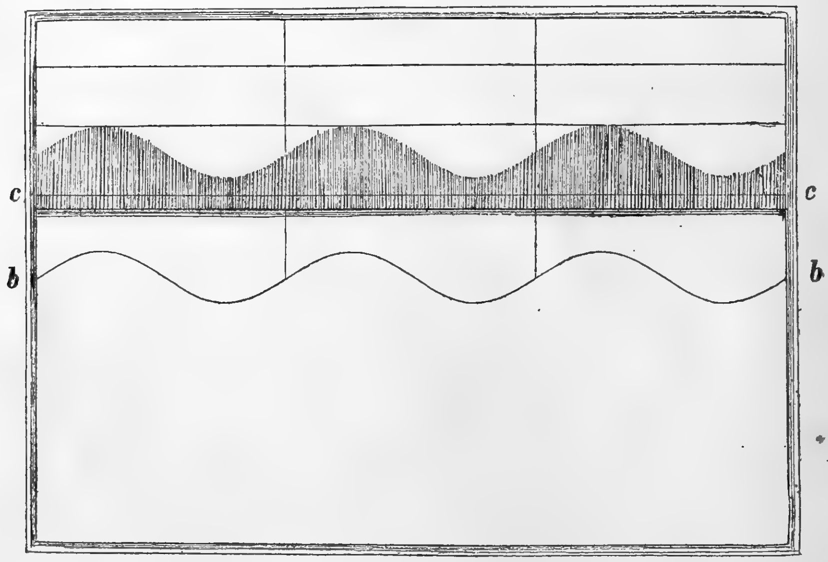
The fringes under these conditions appear as a series of fine lines parallel to the intersection of the surfaces *ab* and *bc*.

If the source be distant and the angle between the mirrors, $90-a$, and the wave length, λ, then it may readily be shown that the width of the fringes is $\lambda/4a$.

Art. XXVIII.—*An Improved Wave Apparatus;* by John T. Stoddard.

The apparatus shown in the cuts was made several years ago for the purpose of demonstrating to my classes the formation

1.

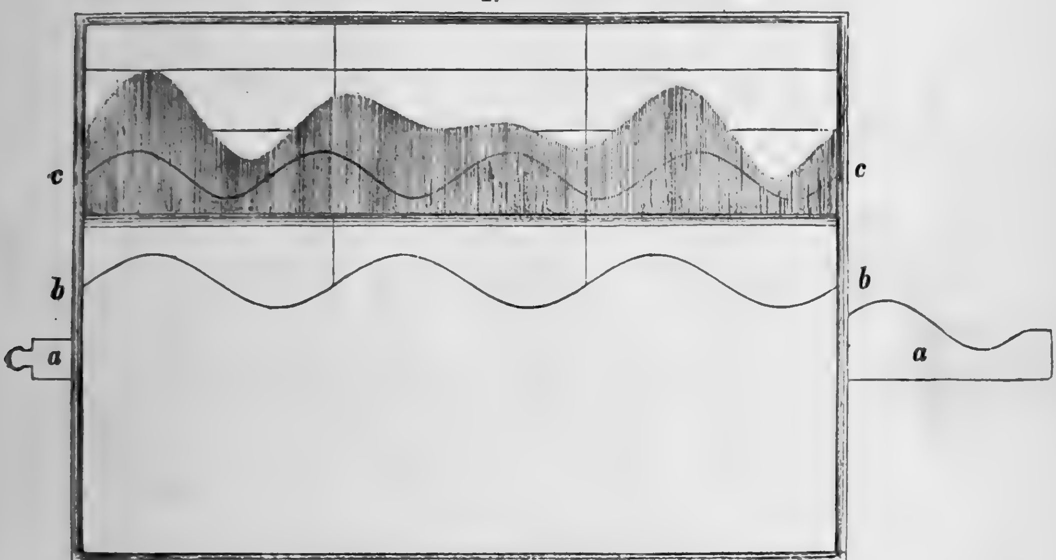


of the compound curves representing the combination of two simple sound waves. It has answered its purpose so well that a brief description may be of interest.

The apparatus consists of a frame of white wood, holding some 270 ebony strips whose tops are trimmed to a sinusoidal form (fig. 1). The strips are 11^{mm} wide, about 4^{mm} thick and from 23 to 31^{cm} long. They are supported on a straight edge projecting 5^{mm} from the back of the frame. Three simple waves having a wave-length of 36^{cm} and an amplitude of 4^{cm} are represented. Vertical white lines mark off the single wave-lengths, a line is drawn on the strips parallel to the edge on which they rest, and the "fundamental" is reproduced in the parallel curve drawn on the front board of the apparatus.

Wave forms cut out of thin board can be introduced below the strips (*aa*, fig. 2), through a slit in the side of the frame, and raised by a simple arrangement at the back to a height which is sufficient to lift the strips from their supporting edge. This

2.



done, the tops of the strips assume the form of the combination curve, while the white line on the strips reproduces the sinusoid on which they rest. As the fundamental is shown on the front board below, one can compare at leisure the component curves and their resultant. The considerable wave-length and amplitude of the fundamental as well as the thinness of the ebony strips render the combination curves fairly smooth. Since three waves of the fundamental are given, it is possible to produce a complete period of the curve representing the interval of the fourth [3 : 4], and one or more periods of all intervals expressed by simpler ratios. The effect of difference of phase is readily demonstrated, the straight line representing the "interference" of two elementary tones of the same pitch and intensity being sharply produced.

Smith College, February, 1890.

ART. XXIX.—*On a recent Rock-Flexure;* by FRANK CRAMER.

THE Combined Locks pulp mill, located on the Lower Fox River, about six miles northeast of Appleton, Wis., is a long, low stone building (about 40 by 248 feet), and set below a head of seventeen feet of water. The direction of its long axis is northwest and southeast. The river flows at right angles to this axis until it passes the end of the mill, and immediately turns east and flows to a point a short distance beyond the mill, where it turns to the north. At about eight o'clock on the morning of the 7th of September, 1889, an accident involving considerable damage happened to this mill.

A solid cement pier, 14 feet through at the top and 16 feet through at the bottom, forms the end of the great dam and the river-end wall of the mill as far as the eaves. Upon this, at its inner edge, is set a two-foot wall which supports the shed roof of the mill. This solid stone pier (P, fig. 1) was cracked from side to side and from top to bottom, and the nearly perpendicular crack gaped between one and two inches at the top and almost none at the bottom. The northeast (down-river)

1

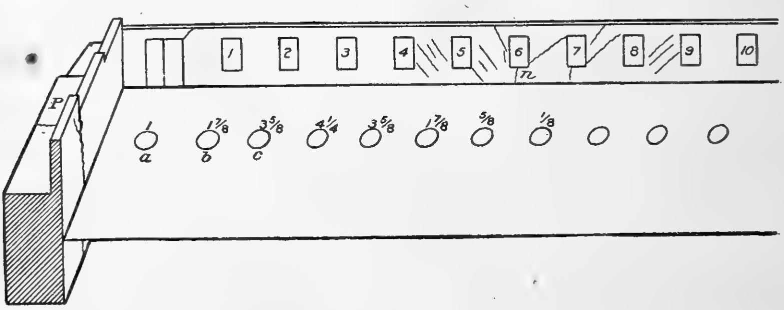


Fig. 1. Diagram showing N.W. end wall and N.E. side wall of mill, with floor in position; other walls and roof omitted. P, cement pier, *a*, *b*, *c*, etc., pulp-grinders, 1, 2, 3, etc., windows. Total length of building, 248 feet.

wall of the mill, running at right angles to the pier, was broken by a symmetrical set of cracks which indicate that the line of disturbance passed under this wall 94 feet from the pier. At this distance there is a perpendicular crack under the sixth window (*n*, fig. 1) One or two smaller cracks run parallel with it. On each side of this crack there are a number of cracks inclined at an angle of 45 degrees, their lower ends directed toward this perpendicular crack. The cracks on the two sides are nearly equal in number, at nearly equal distances from each other, and mar the wall to a distance of about 30 feet each side of the sixth window.

The mill contains 18 or 20 large and heavy pulp grinders, each machine employing two water wheels. These grinders were set in a row, extending through the whole length of the mill about midway between the long walls; and they were all set at exactly the same level. After the accident, the first machine (*a*, fig. 1), next the cement pier, stood an inch above the level of the long row of undisturbed machines in the southeast end of the mill; the second (*b*) had been raised $1\frac{7}{8}$ inches, the third $3\frac{5}{8}$ inches, the fourth $4\frac{1}{4}$ inches, the fifth $3\frac{5}{8}$ inches, the sixth $1\frac{7}{8}$ inches, the seventh $\frac{5}{8}$ of an inch and the eighth $\frac{1}{8}$ of an inch. The set of figures indicating the amounts to which the first eight machines were lifted, is as symmetrical as the set of cracks in the northeast wall; and the fourth machine, which is lifted most, lies in a straight line with the perpendicular crack in the northeast wall and the gaping crack in the pier. The axis of the disturbance passed in a straight line under the mill, diagonally across the north corner. Its direction is nearly northwest and southeast, and parallel with the course of the river between the two bends.

The character of the disturbances and their intimate connection compel the conclusion that they were all produced by a single force. The crack in the cement pier alone might have been produced by the sagging of its lower end; but the application of the simple laws of force to the set of cracks in the northeast wall, proves that the force that produced them acted perpendicularly upward. The inclined cracks need only be extended to form two sides of the parallelogram of forces, and the perpendicular crack becomes the diagonal that indicates the direction of the force, the components of which produced the inclined cracks. To assure himself beyond a doubt that the mill had not given way, Mr. O'Keefe, the gentleman who had charge of its erection, ran the levels again from the bench-mark that was used to secure those levels when the mill was built, and found that nothing in the whole mill was below the level at which it had been placed. A bulge was formed in the floor, and its axis connected the cracks in the pier and the northeast wall; and there is a similar bulge in the roof. The cracks, the figures indicating the distances to which the machines were raised, and the other facts mentioned prove beyond a doubt that the axis of disturbance was an axis of uplift; and that the damage was done by the formation of a nearly symmetrical ridge in the bed-rock. The mill was built on the Galena limestone, which forms the bed of the Lower Fox River at that point. The uppermost layer, on which the walls and piers were set, is two and a half feet thick, and dips to the southeast one foot in two hundred and forty-eight. This layer was nowhere broken and everywhere nearly plane when the foundations were laid. An unsuccessful attempt was made to examine this layer after the accident by means of a protected electric light. But by careful sounding it was found that this uppermost stratum is no longer plane. Along the inside of the cement pier opposite the crack, the water is not so deep by a whole foot as it is in the neighboring parts of the tail-race; but from this point it grows gradually deeper in both directions. This ridge (*c*, fig. 2), can be traced, but not so clearly, diagonally across to the northeast wall, and its axis is the same as that of the disturbances above. Although there was no evidence of a general crushing, irregular, thin, freshly broken pieces splintered from the thick upper layer were brought up by the man who was sent into the water soon after the accident to examine the rock bottom.

2.

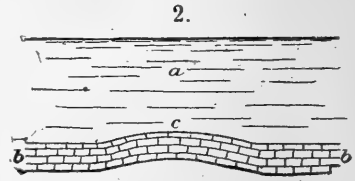


Fig. 2. Section of ridge: *a*, water; *bb*, limestone.

Under the floor of the mill there is a row of iron beams that supplement the stone piers that support the floor and machines. The beams that stand on the ridge are bent (*d*, fig. 3); while one of them, in the deeper water just beyond the ridge, is not only not bent but stands straight and loose in the water (*e*, fig. 3). About 250 feet from the mill there is a new artesian well 225 feet deep. It was flowing at the time of the accident, but not more than three minutes afterward it had stopped and did not start again until several weeks later, when the pipe was given a few blows at its upper end. It then began to deliver water again, but in diminished quantity. Edwards and Orbison, the civil engineers, report that when they built the dam that furnishes the power for the mill, a year ago, they found in the river bed two lines of fracture and crushed rock, and that these lines of fracture in the bed rock are parallel with the axis of the recent disturbances.

3.

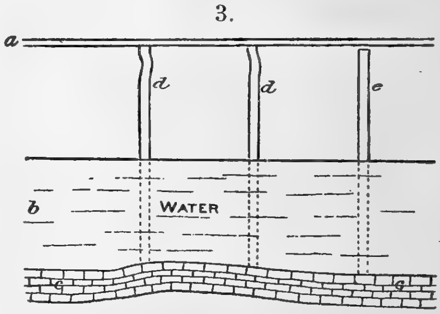


Fig. 3. Section of mill floor and ridge, at right angles to fig. 2: *a*, floor; *c*, limestone; *d*, *d*, *e*, iron pillars.

The character of the cracks in the walls, the fact that the first eight machines, which lie between the breaks in the pier and the northeast wall, are lifted above the level at which they were set, the distances to which those machines were lifted, the bulging of the floor and roof, the ridge in the rock under the mill, the condition of the iron supports under the floor, and the fact that nothing in the mill is below the level at which it was placed when the mill was built, all point to the same cause. These different lines of evidence are inseparably connected, and taken together amount to a demonstration that the rock under the mill suffered an uplift. The effect on the artesian well proves that the area of disturbance was not confined to the mill; and the parallel fractures out in the river bed show that similar movements have occurred before. The irresistible conclusion is that a movement in the rock was produced by lateral thrust under the very eyes of men.

There can be little doubt that the building of the mill provided the occasion for the movement in the rock. Not only was a great mass of water held up by the new dam, and considerable earth removed in the building of the mill, but in getting out stone for the dam and mill two quarries, each several feet deep, were made in the river bed, one above the dam and the other below the mill. The axis of the disturbances in and under the mill runs from one quarry to the other; and this fact indicates that the break occurred along a line whose weakness was at least partly determined by recent changes.

The Fox River Valley is an almost perfectly level clay plain, cut by deep ravines that run back to varying distances from the river and form the drainage system of the plain. The river has cut its way through the clay and flows on a rock bottom between banks from 60 to 90 feet high. The rock underlying the plain is therefore subjected to a very great and uniform pressure, over an area extending back several miles from the river. The river makes two bends at the point where the mill is located, and the two lines of fracture and crushed rock out in the river, and the line of disturbance in and under the mill are parallel with each other and with the course of the river between the two bends. This parallelism is suggestive, and would be in harmony with the theory that the phenomena were due to lateral pressure in the river-bed induced by pressure of the overlying clay on the adjacent rock. But other phenomena, which have been observed in the neighborhood, preclude the adoption of this theory as an explanation.

At Kaukauna, about two miles down the river from the Combined Locks, Col. H. A. Frambach built a paper mill some time ago. The work of cutting a tail-race in the rock was facilitated by the presence of two joints 30 feet apart. These joints, whose direction was nearly at right angles to the course of the river, converged slightly shoreward and passed downward to an unknown depth. The perpendicular faces were in close contact in both seams; and the strata between the two seams were slightly bowed up in the middle (*a*, fig. 4).

Although the layers were still in position and presented smooth joint faces, the rock, for a distance of about two feet back from both faces of both seams, was splintered by a large number of small fractures parallel to the plane of bedding (*bb*, fig. 4). The faces of these fractures, like those of the joints, were rusty from the decomposition of pyrite. When this part of the rock was broken with a hammer, at the time the layers between the joints were removed, the hammer rebounded as usual when the rock was struck from one direction, but failed to rebound when the rock was struck at right angles to that direction. When it broke it shivered into small pieces.

4.

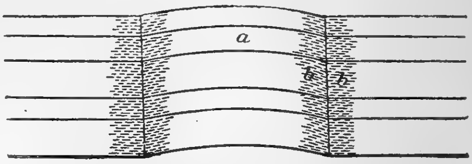


Fig. 4. Section of anticlinal at Kaukauna, Wis.

Evidently a steady and long-continued pressure was brought to bear on the faces of the joints until the layers between them were bowed up and the ends had undergone the preliminary fracturing. And the pressure ceased or the rock was removed just before the crisis came; everything was ready for the production of another "line of fracture and crushed rock." If this is the explanation of the condition of the rock along and between the joints, the theory of pressure of superincumbent mass is inapplicable, for the axis of the disturbances in this case is at right angles to what the theory calls for. But this axis is parallel with the axes of the fractures and folds at the Combined Locks. The two sets of phenomena are less than two miles apart, and the case at Kaukauna seems to be simply a stage through which the rock at the Combined Locks had already passed. They are so intimately connected that a common cause for all of them must be sought. The movements were without doubt all produced by slowly applied and long continued lateral pressure. But if the movements were superficial, as there seems to be some reason for believing, a superficial cause must be sought.

It would be difficult to assign a cause from the study of these cases alone; but it seems reasonable to class them with similar ones observed in other parts of the country. Mr. G. K. Gilbert has propounded a suggestive theory in explanation of phenomena in many respects similar to those presented here.* He believes that sufficient lateral pressure to account for them has been developed in post-glacial times, from the expansion of the superficial strata resulting from the rise in temperature after the disappearance of the ice. This theory has still to be

* See this Journal, vol. xxxii, p. 324; and Proceedings of A. A. A. S., 35th meeting, p. 227.

tested by the answer to the question whether similar phenomena occur outside of the area of glaciation. A negative answer would form a strong support to Mr. Gilbert's theory; and an affirmative would compel search for a more general cause or a distinct one.

Lawrence University.

ART. XXX.—*On the Origin of the Rock Pressure of the Natural Gas of the Trenton Limestone of Ohio and Indiana;* by EDWARD ORTON.

DURING the last five years, there has been developed within six counties of northwestern Ohio, the most important single source of petroleum now known in the United States. During the same time, within the same territory and from the same geological horizon, several separate gas fields of extraordinary vigor and volume have also been brought to light. Following these surprising developments in Ohio, similar discoveries of gas have been made in the contiguous districts of northeastern and central Indiana The new gas field of this last-named State, is by far the largest continuous gas field known in the world, its original area being not less than 2000 square miles.

The stratum which has yielded these remarkable supplies is the Trenton Limestone, one of the best known elements in the geological scale of North America. Although some phases of its outcrops had long been recognized as petroliferous, no one was prepared for its present enormous production. From single wells, 5⅝ inches in diameter, 5000 barrels of oil have flowed in a day, and to at least one well a total production of 200,000 bbls. is already credited. The gas wells of the formation are equally prolific. The maximum production thus far has been recently reached in an outflow of 33,000,000 cubic feet a day from a single well. A score of wells can be named, each of which exceeds in its daily flow 10,000,000 cubic feet of gas.

It is well known that the oil market of the country is in no sense an open market in which prices can freely adjust themselves to values. The severest possible repression has been imposed upon the production of the Trenton limestone, by fixing and holding the price of the oil derived from it at 15 cents a barrel, but the inherent vitality of the new source is shown in the fact that even at this rate more than 10,000,000 barrels were brought to the surface in 1889. Natural gas derived from the same formation is now furnishing all of the fuel and much of the artificial light that is used by a population of at least 500,000 people within the districts named above, while an extraordinary volume of manufactures has been established on the new source of power.

The exploitation, upon which the remarkable developments above indicated are based, has furnished better opportunities in some respects for studying the phenomena and deducing the laws of the accumulation of petroleum and gas than any other American field has supplied. In the first place, the surface of the country in which the drilling has gone forward is so nearly level that all of the wells can be easily referred to a common base, as for example, to mean tide; in the second place, the series of strata penetrated by the drill is so uniform and so well marked that sharp and accurate determinations of all the important facts of stratigraphy are possible, and in the third place, the facts of structure are free from all complications, so that the effects due to them can be clearly and readily followed.

But a single one of the laws of the production of gas and oil as brought to light by this recent experience will be considered in the present paper, that, namely, pertaining to the *rock pressure* of gas; but before taking up this subject, a few preliminary statements, involving some of the laws already recognized, are required.

Preliminary Statements.

1. The gas and oil of the Trenton limestone are held in porous portions of the stratum. Neither caves nor fissures have been found by the drill and none are necessary.

2. The porosity of the limestone is due to the dolomitization which it has undergone. The portions of the stratum thus replaced seem to have been originally crinoidal limestone of a good degree of purity. The spaces left by imperfectly interlocking crystals give the rock great storage capacity, as great probably as the coarsest sandstones possess.

3. The porous beds are distributed through the uppermost portions of the stratum. None have been found as low as 100 feet below the surface, and almost all occur at less than half this depth. Several consecutive beds of dolomite, separated by ordinary and generally impure limestone, are occasionally found in the section. These petroliferous beds commonly range from seven to ten feet in thickness: they rarely rise to fifteen feet. Without dolomite in the Trenton limestone there is no petroleum. The dolomitized regions of the Trenton limestone are exceptional. They appear to extend from central Ohio northward through Michigan and they certainly extend westward through Indiana. To the south and east of these regions, the Trenton limestone lacks this character and is unproductive as to gas and oil.

4. The gas and oil are separated in every division of the field where both occur by lines of geographical level. Proper relief of the porous rock in the shape of arches or terraces is indispensable to gas fields and oil fields. The more pronounced the forms and the amount of the relief, the greater the accumulation.

5. Salt water or bittern is invariably found at a depth, constant for each subdivision of the field, in the lower levels of the porous rock, constituting a dead line for the oil and gas. The water is directly in contact with the oil or in the absence of oil, with the gas that is held in the arches or terraces, as is proved by the behavior of wells on the margins of the field. It is highly mineralized, having a specific gravity of 1·1.

6. When a well is drilled outside the dead line, the salt water rises more or less promptly as soon as the porous bed of the Trenton is penetrated. These salt water tracts are very extensive as compared with the areas of gas and oil, occupying hundreds of square miles to one of the former.

7. The height to which the salt water rises in the various portions of the new gas and oil fields, appears to be nearly constant. It reaches an elevation of about 600 feet above tide. If the elevation of the surface is less than 600 feet, as in portions of the Wabash Valley, the salt water flows from the well mouth.

8. The rise of the salt water to the level named is unquestionably artesian in origin. It implies a head of water, established through continuously porous rock, from some more or less distant outcrop. The fact that the outcrops of the Trenton limestone on the shores of Lakes Superior and Huron are dolomitic and consequently porous, and that they are also about 600 feet above tide, suggests this region as the source of the pressure which is shown in the ascent of the salt water in the gas and oil fields. The Trenton limestone is dolomitic as far as it has been followed under the surface of the State of Michigan, both southward from Lake Superior and northward from the Ohio boundary, the facts as to the latter being obtained by the drill.

Rock Pressure.

By the rock-pressure of gas is meant the pressure in a well which is locked in so that no gas can escape. The tubing of the well becomes in this way a part of the reservoir and shares its pressure. This rock pressure varies greatly in different fields and to a less extent in different wells of the same field. It sometimes reaches the enormous figures of 800, 900, or even 1000 lbs. per square inch. Pressures of 400 to 600 pounds to the square inch are not unusual. The phenomena connected with the escape of gas from a high pressure well are among the most startling in the whole range of mining engineering operations.

There is generally a rough relation between the depth of the well and its rock pressure. The deeper the well, the greater the pressure to be expected, but this relation is by no means constant. Wells of the same depth below the surface may vary widely in rock pressure.

It is the original rock pressure which is needed in these inquiries, and this can be obtained at but one date in the development of a field, and that is at the very opening. Reduction of pressure speedily follows exploitation, and goes forward more or less rapidly as the development proceeds. When a field is locked in, however, after having been opened, there is a tendency to regain the original pressure. The pressure falls through considerable areas at the same time when drainage of gas is going on from any point within them. The rock pressure is a factor of great importance in every gas field. By it, the distance to which the gas can be sent to market, the size of the tubing employed and also the size and strength of the pipe lines are all to be determined.

To what is this rock pressure due? Three answers have been proposed, viz: (1) it is due to the weight of the rock that overlies the reservoir; (2) it is due to the expansive nature of the gas itself; (3) it is due to the pressure of the salt water column which holds joint occupation with it of the porous rock. The facts derived from the new fields demonstrate the truth of the last answer, so far at least as Trenton limestone gas is concerned.

A column of salt water, one square inch in section, one foot in height, and having a specific gravity of 1·1 weighs (and will consequently exert a pressure of) about ·476 pounds avoirdupois.

Knowing as we do the height to which the salt water rises in the Ohio and Indiana gas fields, when the porous rock containing it is reached by the drill, viz: 600 feet above tide, we find in this figure an element that we can employ in every subdivision of the field. If the gas is found at sea-level, it will have upon it a weight of $600 \times \cdot476$ lbs. In other words, its rock pressure should be 286 lbs. If the gas is found *above* sea-level, its rock pressure should be reduced in proportion to the reduction of the water column; if found *below* sea-level, its pressure should be correspondingly increased.

The facts derived from the development of the new fields furnish data by which the validity of the explanation above given can be tested.

At Muncie, Indiana, the gas was found in the first wells at very nearly sea-level. At Marion, Indiana, in well No. 3, the gas was struck at 78 feet below tide. In the Dwyer Well, St. Henry's, Ohio, it was found 200 feet below tide; at Findlay, in the Pioneer Well, at 336 feet below; at the Godsend Well, Wood County, at 395 feet below; at Upper Sandusky, in City Well, No. 1, at 478 feet below; and in the Loomis Well of Tiffin, at 747 feet below tide. The rock pressures, therefore, of these several wells should be found by multiplying the number representing in feet the entire length of the water column by which the gas is compressed in each well by ·476 lbs. The lengths of the effective columns in the several wells above named are as follows: 600, 678, 800, 936, 1078 and 1347 feet. The results of the calculations on the basis above indicated, are shown in the following table, in which also other data as to the wells, including their first recorded pressures are given.

	Location of wells.	Depth to Trenton limestone.	Relation of gas rock to sea-level.	First recorded pressure.	Calculated pressure on basis indicated above.	Remarks.
1	Muncie, Ind,	950 ft.	at sea-level	280 to 290 lbs.	286 lbs.= 600 × ·476 lbs.	Figures as to wells are approximate.
2	Marion, Ind., Well, No. 3,	870 ft.	78 ft. below	323 lbs.	323 lbs.= 678 × ·476 lbs.	
3	St. Henry's, O., Dwyer Well,	1156 ft.	200 ft. bel'w	375 lbs.	381 lbs.= 800 × ·476 lbs.	Pressure first noted several months after completion of well.
4	Findlay, O., Pioneer Well,	1096 ft.	336 ft. bel'w	450 lbs.	445 lbs.= 936 × ·476 lbs.	Pressure reported by driller, perhaps given in round numbers.
5	Wood Co., O., Godsend Well,	1136 ft.	395 ft. bel'w	465 lbs.	474 lbs.= 995 × ·476 lbs.	Pressure not noted at opening of field.
6	Upper Sandusky, City Well, No. 1,	1278 ft.	478 ft. bel'w	515 lbs.	513 lbs.= 1078 × ·476lbs	Pressure reported by gas trustees.
7	Tiffin, O., Loomis Well,	1455 ft.	747 ft. bel'w	600lbs. +	641 lbs.= 1347 × ·476lbs	Gauge read only to 600 lbs.: a considerable excess indicated by it.

The results shown in the preceding table are strictly representative, and no facts from the new fields are known to the writer that militate against the conclusion which these calculations oblige us to adopt, viz: that *the rock pressure of the gas of the Trenton limestone is due to the pressure of a water column under which it is held in the arches of the rocks.* While this explanation of the rock pressure of gas is here applied only to the new fields of Ohio and Indiana, it seems probable that it is applicable to all gas fields.

Columbus, Ohio.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Lowering of the Freezing point of Metals by the addition of other Metals.*—Heycock and Neville have investigated the lowering of the solidifying point of a metal which takes place when a small quantity of another metal is dissolved in it in the liquid state. In the first experiments, a number of units of mass corresponding to the atomic mass of each of several metals was dissolved in one hundred atomic masses (11800 units of mass) of melted tin, and the temperature of solidification noted. The difference between this and the solidifying point of the pure metal is called the atomic fall. For Na, this was found to be 2·5°; for Al 1·34; for Cu 2·47. for Zn 2·53; for Ag 2·67; for Cd 2·16; for Sb a rise of 2·3; for Au 2·80; for Hg 2·3; for Tl 2·6; for Pb 2·6; and for Bi 2·10. The next series of experiments was made with sodium as the solvent; a cylinder of cast iron 6 to 8 inches high and 5 inches in diameter being used, in the axis of which was a hole 1 to 2 inches in diameter and 4 inches deep, within which worked an annular stirrer. This cylinder was heated by a gas burner, being wrapped with asbestus cloth so that it cooled at the rate of only a degree in two minutes. The temperatures were noted on a thermometer having an arbitrary millimeter scale and reading to nearly one-hundreth of a degree. From 20 to 30 grams of sodium were melted in this cylinder and covered with a layer of paraffin. The whole was then raised to the boiling point of the paraffin, the metal added in the state of fine division, the mixture well stirred and the whole allowed to cool. The thermometer fell steadily to a certain point, then rose suddenly through one or two degrees where it remained stationary for several seconds, sometimes a minute. The highest temperature reached during this surfusion was taken to be the freezing temperature of the alloy. The first point noted was that sodium even at 250° dissolved only a few metals; Au, Li, K, Hg, Tl and In dissolving freely, Pb and Cd sparingly, while Zn, Sn, Al, Mg, Ag, Pt and Fe did not dissolve in appreciable quantities. On placing a clean piece of the sodium alloy in absolute alcohol, the dissolved metal separated as a fine powder generally crystalline. In the case of gold, 100 atomic units of mass of sodium were found to keep in solution 3·5 atomic units of mass of this metal, forming a saturated solution behaving like a weak solution of sodium chloride in water as observed by Guthrie. The atomic fall per atomic mass-unit for this alloy was 4·578°, the temperature of solidification being remarkably constant at 81·92°. On treating with alcohol the gold separates in fine needles. An alloy obtained by diluting this saturated alloy with sodium, gave on analysis gold 15, sodium 85·03 per cent and had a density of 1·152; the calculated density being 1·141. Thus showing that the density of the alloy is a mean of that of its constituents and

that it is a mixture; although no separation of its constituents took place on keeping a column of it in fusion for 48 hours, the composition of the alloy being substantially the same throughout. With thallium, 4·384 atomic units of mass lowered the solidifying point of 100 atomic mass-units of sodium nearly twenty degrees; being a fall for one atomic unit of mass of 4·468 degrees. The point of saturation was not determined. In the case of mercury, although there is a considerable evolution of heat and light on mixing it with the sodium, yet the atomic falls produced by the successive additions do not indicate the formation of a definite compound as would be expected. The addition of 3·228 atomic mass-units of mercury to 100 atomic units of sodium lowered the solidifying point 14·12°; being 4·374° for each atomic mass-unit. When thallium and mercury were both added to sodium, while the atomic fall due to the Hg was 4·4 and that due to the Tl was from 4·09 to 4·27, that produced by both was from 4·16 to 4·26, substantially the same. At the temperature of 95·43° 3·05 per cent cadmium was found to saturate sodium; this quantity being 0·6475 atomic units of mass to 100 atomic mass-units of sodium; the atomic fall resulting being 3·173°. The addition of 3·455 atomic mass-units of potassium to 100 atomic mass-units of sodium lowered the freezing point 11·56°; corresponding to an atomic fall of 3·345°. In the case of lithium the atomic fall was 1·11°, in that of lead 4·6°, and in that of indium 3·49, at the saturating point.—*J. Chem. Soc.*, lv, 666, November, 1889. G. F. B.

2. *On the Chlorides of Selenium.*—CHABRIE has subjected the chlorides of selenium to investigation and has observed that the tetrachloride may be obtained in large and well formed crystals by heating the ordinary product to 190°–200° in the end of a sealed tube. The vapor density of this chloride could not be determined by Victor Meyer's method at 360°, even in an atmosphere of nitrogen, two molecules of this substance dissociating at this point into one molecule of Se_2Cl_2 and three molecules of chlorine. Selenous chloride, however, is quite stable, distills unchanged at 360° and has a vapor density of 7·95, approximately. With regard to the chemical reactions of the tetrachloride, the author finds that the action of benzene upon it is precisely the same as that which is produced by heating to 360°; the selenium being left in the form of selenous chloride and the chlorine forming chlor-benzene. If, however, the mixture is made in presence of aluminum chloride, the reaction is quite different. So that on treating the resulting solution with water, and fractioning the oily product three substances are obtained: one, boiling at 131°–133°, consisting of monochlor-benzene C_6H_5Cl; a second, passing over, under a pressure of a few millimeters of mercury, at 227°–228° consisting of phenyl selenide $(C_6H_5)_2Se$, and appearing as a yellow oil having a density of 1·45 at 19·60; and a third, boiling under the above reduced pressure at 245°–

250°, and consisting of another new compound having the composition $(C_6H_5)_3Se_2 . C_6H_4Cl$. This last fraction is a red oil having at 19·60 a density of 1·55. On standing it deposits yellow crystals having a powerful odor, which on re-crystallization from alcohol may be obtained in long rhombic prisms. This substance is seleno-phenol $(C_6H_5)SeH$, analogous to thiophenol and mercaptan; and like these bodies its alcoholic solution reacts readily with mercury and silver salts, the latter affording the compound C_6H_5SeAg.—*Bull. Soc. Chem.*, III, ii, 788, Dec., 1889. G. F. B.

3. *On the Production of Sodium carbonate by the Electrolysis of the Chloride.*—A series of experiments by Fogh made at HEMPEL's suggestion, showed that the difficulty in electrolyzing metallic chlorides lay in the fact that whenever the decomposition products were readily soluble, they were in their turn decomposed so soon as they reached a certain limit. If, however, the products of electrolysis were difficultly soluble, no such secondary action took place and all the electric energy was expended on the primary decomposition. Inasmuch as sodium carbonate and hydro-sodium carbonate are difficultly soluble in a saturated solution of sodium chloride, Hempel concluded that by the introduction of carbon dioxide into the apparatus, salt could be directly converted by the current into sodium carbonate and chlorine. The apparatus which he has contrived for this purpose consists of a circular kathode of perforated iron and a similar anode of carbon, having between them a disk of asbestus paper. Outside of each electrode is a ring of porcelain and a disk of glass forming chambers for containing the materials, a glass tube carrying carbon dioxide into the kathode chamber and another carrying the chlorine away from the chamber containing the anode. A lateral tube of considerable size permits the salt to be fed continuously to the anode, the water removed by the crystallized carbonate being replaced through it. An electromotive force of 3·2 volts is required to decompose the salt and one of 2·5 volts to overcome the polarization of the plates; though if both plates are of carbon, the counter electromotive force of polarization is absent. With a current of 1·73 amperes, 0·930 gram of chlorine is produced per hour. So that by the use of a dynamo, 64·5 grams of chlorine and 259·8 of sodium carbonate $Na_2CO_3(H_2O)_{10}$ would be produced per horse-power per hour. The same general idea is the basis of a patent taken by Marx since the author began his experiments; but the mechanical arrangements of Marx's apparatus were bad and the results were not satisfactory.—*Ber. Berl. Chem. Ges.*, xxii, 2475, Oct., 1889. G. F. B.

4. *Barium cobaltite.*—ROUSSEAU has shown that cobalt dioxide possesses acidic properties. If barium chloride mixed with barium oxide be fused in a platinum crucible, and cobaltic oxide Co_2O_3 be added in successive small portions, a crust of barium cobaltite forms on the surface. After cooling and washing with hot water and acetic acid, brilliant black hexagonal laminæ are obtained having the composition $BaCo_2O_5$, which are soluble

in strong hydrochloric acid with evolution of chlorine. If during the heating the superficial layer be continually pressed into the fused mass, the composition of the crystals approaches the formula $BaCoO_3$. At a higher temperature large iridescent black prisms are obtained, having very closely the composition $BaCoO_3$, but containing a trace of barium platinate. The temperature of their formation is between 1000° and 1100°.—*C. R.*, cix, 64; *J. Chem. Soc.*, lvi, 1115, Dec., 1889. G. F. B.

5. *On the Constitution of Dextrose.*—SKRAUP has made experiments on the pentabenzoyl derivative of dextrose and has afforded evidence that the view of Fittig and of Tollens that this sugar may be considered as an ether derived from a hepta-hydric alcohol, and therefore as having the formula

$$OHCH_2[CHOH]_3\overset{O}{\overbrace{CH.CH}}.OH,$$

is correct. The above dextrose derivative is not oxidized by permanganate to pentabenzoyl gluconic acid; and on treatment with phenyl-hydrazine, two dextrose compounds result, one derived from $C_6H_{12}O_6$, the other from $C_6H_{12}O_6.H_2O$.—*J. Chem. Soc.*, lvi, 1136, Dec., 1889. G. F. B.

6. *Electrical Undulations.*—MM. EDOUARD SARASIN and LUCIEN DE LA RIVE in repeating Hertz's work upon this subject have discovered that the oscillatory character of the electrical charge on a wire submitted to induction, instead of being invariable in character like the vibrations of an elastic column submitted to motions of a definite period, depend, on the contrary, upon the resonator employed by Hertz to explore the wire. The phenomena observed by the above mentioned authors is termed multiple resonance. Cornu, on the occasion of the presentation of the communication of the authors of the results of their experiments to the French Academy, remarked in substance as follows. The theory of Hertz depends upon two distinct elements:

(1.) The hypothesis that the spark from a Ruhmkorff coil produces an oscillation of a fixed period, determined by the construction of the exciter.

(2.) Upon the observation of an apparent periodicity in the electrical state of the wire submitted to electrical oscillations. The experiments of MM. Sarasin and de la Rive throw great doubt upon Hertz's work. Since in the expression $\lambda = VT$ in which λ = wave-length, V = velocity of propagation of induction in the wire under examination, T = period of oscillation of the exciter, it is shown that either T is not fixed which is contrary to the fundamental hypothesis, or that V varies with the exploring apparatus, which is absurd, since V should represent the velocity of propagation of induction, a specific constant.—*Comptes Rendus*, Jan. 13, 1890, p. 72. J. T.

7. *Experiments with Hertz's Vibrations.*—Professor G. F. FITZGERALD states that on connecting a delicate galvanometer with a Hertz resonating receiver, every time a spark passed the galvano-

meter was deflected, the direction of deflection changed with the reversal of the primary induction. No satisfactory explanation of this deflection is given. Mr. Trouton, who has worked with Professor Fitzgerald upon the Hertz effect, states that the phenomenon observed by MM. Sarasin and de la Rive was noted by Hertz, "It seems as if a vibrator did not send out a line spectrum," so to speak, but sends out a band spectrum, the center of which is the brightest. The period then, of a vibrator is that belonging to the center of this band. "It is obviously of importance for the central period of the resonator employed to coincide with the velocity of the disturbance, for this is presumably the period given by theory. This is practically done when arranging their relative sizes, so as to obtain greatest intensity." Mr. Trouton does not agree with Cornu in his view of the important bearing of the experiments of MM. Sarasin and de la Rive upon Hertz's work.—*Nature*, Jan. 30, 1890, p. 295. J. T.

8. *Note on the Absolute Viscosity of Solids, Liquids and Gases;* by C. BARUS. (Communicated.)—In case of gases and of mobile liquids, viscosity is expressible in *g/cs* units with facility, and data are available in great number. This is not true for solids, nor even for viscous liquids. Suitably integrating the elementary transpiration equation, I obtained two methods, by which the viscosity (η) of glycerine can be measured in a few minutes, and the viscosity of substances of a pitchy consistency (marine glue) in a few months. Thus I found for glycerine $\eta=5$; for marine glue, $\eta=200\times10^6$; for paraffine, $\eta>2\times10^{11}$. Even marine glue or hard pitch is therefore at least 20 billion times as viscous as water at the same mean atmospheric temperature.

For solids I devised two new methods, one of which is comparative and somewhat crude, the other direct, dynamic and sharp. I found for hard steel, during the first hour after twisting just within the elastic limits, at mean atmospheric temperature, $\eta=10^{17}$ to 6×10^{17}; for soft steel, $\eta=6\times10^{17}$ to 6×10^{18}, under the same conditions. Limits must here be given because solid viscosity, even apart from the material operated on, is essentially a function of time, strain and temperature, of a kind which cannot well be tersely specified. Both viscosity and its rate of increase with time under the same given conditions, are magnitudes which increase together.

With these data in hand I submit the following *g/cs* scale of the *solidity* of the three states of aggregation: I. Gases and vapors, $\eta=10^{-5}$ to ?; II. Andrew's critical state, $\eta=$? to ?; III. Liquids, $\eta=$? to 10^2; IV. Viscous liquids, $\eta=10^2$ to 10^{11}; V. Solids, $\eta=10^{11}$ to 10^{20}. Since for ether at 30°, $\eta=9\times10^{-4}$, and for oxygen at 0°, $\eta=2\times10^{-4}$, it is not improbable that the critical state may be definable by a narrow limit of viscosity. Data are wanting.

The scale proposed indicates the positively astounding range of variation of the chief variable of our material environment,—bearing in mind that throughout the whole of this great interval viscosity nowhere transcends the scope of the senses.

9. *Absolute Measurements in Electricity and Magnetism* by ANDREW GRAY. Second Edition revised and greatly enlarged. 384 pp. 12 mo. London and New York, 1889. (Macmillan & Co.) A first edition of this work was published in 1884, (this Journal, vol. xxvii, 487); since that time the author has issued the first volume of a larger and more exhaustive work on the theory and practice of Absolute Measurements in Electricity and Magnetism, a second volume of which is now in press. Excellent as is this last mentioned work, it does not take the place to the student of the more elementary one which preceded it. It is well therefore that the author has been induced to revise the latter; in its present expanded form the student will find it a most satisfactory guide to the methods of quantitative measurement which form the foundation of modern electricity.

10. *Elementary Lessons in Electricity and Magnetism*, by SILVANUS P. THOMPSON. 456 pp. 12mo. London and New York, 1889. (Macmillan & Co.) The first publication of this admirable little book was noticed in vol. xxiii, of this Journal. Since that time it has been repeatedly revised and the present issue is of the forty-third thousand. No better proof than this remarkable reception is needed of the excellence of the work and of its adaptation to the wants of the particular class of students for whom it was prepared.

II. GEOLOGY AND MINERALOGY.

1. *Sedgwick and Murchison, page* 167.—It is a pleasure to announce that the paper of Murchison published in the Philosophical Magazine for July 1835, is republished in the *American Geologist* for February.

With regard to the Lower Silurian, the term *Cambro-Silurian*, which is used already by the Canadian Survey, might serve, supposing another name needed, if its signification accorded with geological usage. It means, as employed in Canada, a formation that is neither Cambrian nor Silurian, but which lies between the Cambrian and Silurian formations. This is out of harmony with the terms *Permo-Carboniferous, Jura-Trias, Calciferous-Trenton*, and the like; which stand for combinations of the formations indicated, and especially where their separation is at present difficult or impossible. Such terms are too useful in the science to be dispensed with. J. D. D.

2. *The Calciferous Formation in the Champlain Valley.* Notes from a paper presented before the Geological Society of America, at its winter meeting, Dec. 26–28, 1889, by E. BRAINERD and H. M. SEELY.—The region under investigation extends east and west from the flank of the Green Mountains to the Adirondacks, a distance of about twenty miles, and north and south from Phillipsburgh, Canada to Benson, Vt., and Ticonderoga, N. Y., near eighty miles.

In this valley all the formations of the Lower Silurian are represented. On the east the rocks are much metamorphosed; on the west, part are under the waters of Lake Champlain. The rocks may be best studied along the shores and on the islands of the lake.

The term Calciferous is used in its original signification, and includes all the rocks lying between the Potsdam lying below, and the Chazy above. The boundary lines are at present provisional. The lower is just above the fossiliferous Potsdam, the upper just below a sandstone which is assumed to be the base of the Chazy, one recognized by the Canada survey, and which may possibly correspond to the St. Peters Sandstone of the west.

The Calciferous formation is essentially one of magnesian limestone; it contains, however, pure sandstone, pure limestone, together with mixtures of these, a calciferous sandstone, whence the name.

The rocks have a greater thickness than previously attributed to them, and contain many fossil forms. Subdivisions are made, based upon lithological and faunal characteristics. These are named A, B, C, D and E, and are read from below upwards.

Division A rests upon the uppermost member of the Potsdam. The rock is a dark bluish gray magnesian limestone, mostly massive, more or less siliceous, weathering dark or sometimes with a tinge of yellow. White quartz nodules appear in some of the higher layers, and near the top, large masses of black chert. Thus far no distinguishable fossils have been obtained. It has a thickness of 310 feet.

Division B is marked by the presence of nearly pure reticulated limestone, weathering white, intermingled with light colored dolomite. The bedding is obscure. The pure limestone which occurs near the middle and again at the upper part is like the Birdseye limestone in flinty compactness and fracture. Well-marked fossils are found in B. Thickness, 295 feet.

Division C is sharply separated from B below by a peculiar fine-grained sandstone containing calcareous matter, and which on weathering resembles fine-grained wood. Some of these layers are pierced with worm burrows. Thickness, 350 feet.

Division D is made up of many varying rocks. Blue limestones form the base. Above are magnesian limestones, and sandy limestones, the latter weathering to a rusty rotten stone. Still above are dark magnesian limestone and tough sandstone, sandy limestone weathering into bands, blue limestones with very tough slaty layers which give it a peculiar and characteristic appearance on the exposed edges, pure limestone and sometimes conglomerates. Very fossiliferous. Thickness, 375 feet.

Division E has fine-grained magnesian limestones weathering various tints. Occasionally pure limestone layers occur, and rarely thin layers of slate. The limestones and slates are fossiliferous. Thickness, 470 feet.

For all the five divisions of the formation there is a thickness of 1800 feet.

Sections of the rocks in different localities show great uniformity in characteristics of thickness and lithological structure.

A typical section from which the above measurements were taken is found in Eastern Shoreham, Addison County, Vt. In this section not only are all the strata of the Calciferous seen, but the whole Lower Silurian appears from Potsdam to Utica Slate in a continuous series. This locality was first pointed out by Rev. Augustus Wing, and denominated the "Bascom Ledge." [This Journal, 1877, vol. xiii, p. 343.]

The paleontology of the Calciferous is not complete, though good advance has been made. Division A has not yielded distinguishable fossils. Division B seems to be the horizon of the original *Orthoceras primigenium* of Vanuxem. It contains also the remarkable banded masses which at one time were regarded as concretions and were figured and described as such by Dr. J. H. Steel. [This Journal, June, 1825, vol. ix, pp. 16–19.] Mather, in his N. Y. Report, recognizes their organic origin. Probably the fossil is a Cryptozoon and the form may be known as *Cryptozoon Steeli.*

Division C, besides containing the numerous worm burrows at its base, *Scolithus minutus*, according to Wing, holds some poorly preserved forms of gasteropds and cephalopods.

Division D is rich in fossils. Sponges, brachiopods, gasteropods, cephalopods, trilobites and ostracods appear. The abundant fauna of the Fort Cassin rocks belongs here. Thirty-five genera have been gathered.

Division E, though apparently not so fossiliferous as D, adds new forms, generic as well as specific, and brings the number of Calciferous genera above forty with species numbering from one to ten.

Besides the section referred to at Eastern Shoreham, other exposures have been investigated. One section from the vicinity of Ticonderoga takes in Mt. Independence, Lake Champlain, and the grounds of the old Fort. The rocks at Orwell, Fort Cassin, Charlotte, Providence Island, and Phillipsburgh, Canada, expose a part or the whole of the divisions of the Calciferous.

The series of rocks at Phillipsburgh extend from four to five miles into Vermont. Logan's division A with its three subdivisions, seven hundred feet in thickness [Geol. Canada, p. 844], is lithologically identical with the divisions A, B, and C, respectively of the Calciferous. The fossil *Cryptozoon Steeli* [n. sp.] is seen in the reticulated limestone of A 2, at Phillipsburgh. Similarly the first four of Logan's division B correspond to the later division D of the Calciferous both in lithological character and in fossils. (Geol. Canada, pp. 278, 279.) The beds of the Calciferous sandstone are as peculiar at Phillipsburgh as at Shoreham.

A similar comparison might be made between the Calciferous of Lake Champlain and the 1830 feet of strata on the northwest coast of Newfoundland, (Divisions D to L of Geol. Canada, p. 865, et seq.).

Misapprehensions in regard to some of the rocks of Vermont are to be corrected. Certain slates referred to the Calciferous belong properly to the Utica Slate. Very little slate has been observed in the Calciferous, and this in the upper part of Division E.

The Birdseye formation is very scantily represented in Vermont. A rock covering a few square rods containing *Phytopsis tubulosum* Hall, is found in Benson. The fine-grained limestones so like the Birdseye in texture must be distributed among the strata below. Part will go to Calciferous B, a part to Calciferous D. Here come the Fort Cassin rocks. Middle Chazy will take a small part; upper Chazy much more. *Calymene multicosta* Hall, with its associated fossils, belongs here in the upper Chazy. The fine-grained limestone which holds this interesting group of fossils is still beneath seventy-five feet of Rhynchonella rock. Above this, if anywhere, the Birdseye should appear.

Attempt is not made to correlate the Calciferous of the Champlain Valley with that of the western States. Rocks of similar Calciferous character appear in the valleys of the Hudson and St. Lawrence, as well as that of the Champlain; suggesting that the same physical conditions of sedimentation and like forms prevailed. The deposits marking the position of an ancient sea beach not far from the borders of the Archæan terrane.

3. *Geological Survey of Canada, Annual Report for the year* 1887–88; ALFRED R. C. SELWYN, Director. Vol. III, New Series, Parts i and ii.—This Report, after a general review of the work and results of the year by Dr. Selwyn, contains first a Report by G. M. Dawson on an exploration of the Yukon District, and an adjacent part of British Columbia, treating of its geography, climate, resources and geology, and, in appendixes, of its vegetation, Indian tribes, zoology, rocks and meteorology. Mr. Dawson states that the Coast Ranges have an interrupted granitoid axis (consisting of granite and granitoid rocks) from Fraser's River northwestward to the 60th parallel, about 900 miles; and that the formations of British Columbia in general continue northwestward, with little variation. West of the Coast Range in the Coast Archipelago near Wrangell, Juneau and Sitka, occur argillites which, as fossils have not yet been detected, may be provisionally classed as Triassic. East and northeast of the Coast Range the rocks are largely Paleozoic. On the Dease, the Frances, and on Tagish Lake, Carboniferous limestone is found containing Fusulina, like that of British Columbia; this rock occurs along a belt of 800 miles or more. Granitic areas occur over this area in two ranges; one from Dease Lake (130° W. and 58½° N.) to 40-mile Creek (141° W. and 64½° N.) and the other east of Frances Lake (129° W. and 61° N.) and Pelly Lakes (129½° W. and 62° N.); The rocks resemble the Archæan granites of the Gold Range of British Columbia. Triassic rocks were found on the Stikine River at Glenora, and Cretaceous and Laramie on the lower part of the Lewes on Lake Labarge and elsewhere. Jade was met with in large masses in the gravels of the Lewes.

Other reports of the two volumes are as follows: A. Bowman on the Mining District of Cariboo; J. B. Tyrrell, on the Duck and Riding Mountains, in N.W. Manitoba; A. C. Lawson, on the rocks of the Rainy Lake region; E. D. Ingall on Mines and Mining on Lake Superior; A. P. Low, on part of the country east of Hudson Bay; R. W. Ells, on the geology of a portion of the Province of Quebec,—a report noticed at length at page 101, by Mr. C. D. Walcott; L. W. Bailey and W. McInnes on portions of northern New Brunswick and adjacent parts of Quebec and Maine; R. Chalmers, on the surface geology of N. E. New Brunswick; G. M. Dawson, on the mineral wealth of British Columbia; E. Coste, Statistical Report on the production, exports, and imports of the Minerals of Canada; G. C. Hoffman, Chemical contributions.

Messrs. Bailey and McInnes illustrate in their report the paleozoic geology of northeastern Maine, and apppear to show that the rocks of this part of Maine in Aroostook Co. are Upper Silurian rather than Devonian, which they are made in the Geological Reports on Maine.

4. *Manual of Palæontology, for the use of Students, with a general Introduction on the principles of Palæontology;* by HENRY ALLEYNE NICHOLSON, F.G.S., Prof. Nat. Hist. Univ. of Aberdeen, and RICHARD LYDEKER, B.A., F.G.S. 3d edit. rewritten and greatly enlarged. 2 vols. of 1624 pages. Edinburgh and London. (Wm. Blackwood & Sons.)—The title page says, "greatly enlarged;" expressed in figures the enlargement is from 1040 to 1624 pages, or more than one-half; and this increase in size indicates very imperfectly the actual additions in new matter and illustrations. It is, as the authors claim, essentially a new work. The part on the Invertebrates, covering 775 pages, has been prepared by Prof. Nicholson, and that on the Vertebrates, 600 pages, by Mr. Lydekker, the author of reports connected with the Geological Survey of India on the fossil Vertebrates; and about 100 pages on fossil plants are by the joint authors. The classification follows mainly the latest authorities, and the descriptions are full and present a judicious review of recent opinions in cases of doubt, besides having, after each subject, a table of references to publications. We should separate the Trilobites from the Crustaceans, and make some minor modifications; but these are points about which there is reason for difference in judgment. Excellent figures are in profusion, representing often the interior structure as well as exterior forms, and some are from new observations by the author. This manual is the only one of the kind in the English language and will be found of great value by teachers and students in geology or paleontolgy. Prof. Nicholson's personal work in America supplied him with part of his facts, and has enabled him to appreciate and use American sources of information. The volumes are made attractive also by the very liberal style of publication.

5. *Elemente der Paläontologie* bearbeitet von Dr. Gustav Steinmann, Ord. Prof. Geol. u. Min. Univ. Freiburg, unter mitwirkung von Dr. Ludwig Döderlein, Director, Nat. Mus., Strasburg, Privatdocent für Zoologie. 2d Half, pp. 337 to 348, 8vo. Leipzig, 1890. (Wilhelm Engelmann.)—The first part of this important work has been noticed on page 235 of volume xxxvii of this Journal. This *second half* completes the account of the Invertebrates on page 515, and devotes the remaining 333 pages to the Vertebrates. The work is concise in its method, so that its 850 pages cover the whole ground with remarkable completeness. Besides detailed descriptions, tables are introduced to illustrate characteristics of groups, distribution of genera in time, geographical distribution, and also the literature of the different subjects. The illustrations of species and structure are all admirable, and in great numbers; and the publisher has done justice to the fine cuts in the style of printing and the quality of paper. While the figures range over the same groups as in the English work above mentioned the most of them are different, and in this and other ways the two works conveniently supplement one another. They are both excellent, and good companions. In classification there is a similarity. But the Solenhofen Jurassic bird is made by Prof. Steinmann the basis of one of the subdivisions of Reptiles—the Saurura; and the fine figure in the work of the specimen in the Berlin Museum, from the memoir by W. Dames, goes far toward sustaining this reference.

The Trilobites have the same place as in Prof. Nicholson's work, that is, with the Crustaceans, under the name of Palæostraca. The serious objection to this is that the Trilobite and Crustacean lines commence together in the Lower Cambrian and give no evidence of successional connection in their beginning or afterward; they continue separate and unaffiliated to the present time, being represented, as long held, by the modern Limulids, and also, as has been shown by Van Beneden, through the Eurypterids by the spiders. The Crustaceans appear first under two types, the Ostracoid and Caridoid, and continue along each, with small divarications, and with rising grade in the latter until now. The Trilobite line, therefore, had in no part true kinship with that of the Crustacean.

III. Botany and Zoology.

1. *Manual of the Botany of the Northern United States, including the district east of the Mississippi and north of North Carolina and Tennessee;* by Asa Gray, late Fisher Professor of Natural History in Harvard University.—Sixth Edition (Revised and extended westward to the 100th meridian); by Sereno Watson, Curator of the Gray Herbarium, Harvard University, and John M. Coulter, Professor of Botany in Wabash College, assisted by specialists in certain groups. 760 pp. 8vo. With 25

plates, illustrating the Sedges, Grasses, Ferns, etc. New York and Chicago, 1890. (Ivison, Blakeman & Company.)

It is now more than twenty-two years since the fifth edition of Gray's Manual was published. At that time only the first volume of Bentham and Hooker's *Genera Plantarum* had appeared, and Dr. Gray was able to adopt such of their conclusions as pleased him only through the polypetalous orders. The Genera was finished in 1883, and in 1886 Dr. Gray gave his final revision of the Gamopetalous orders of the North American flora. These works and other great advances in Systematic Botany have for several years rendered a new edition of the Manual very desirable, and it is understood that Dr. Gray was hoping to undertake himself the task of preparing it. After his death the labor naturally fell to the lot of Professor Watson, who has availed himself of the assistance of Professor Coulter, the author of the *Manual of the Botany of the Rocky Mountain Region*, and has also had, as the title shows, the aid of specialists in certain groups. The editors have extended the area covered by the work, so as to meet that of Coulter's Manual, and have included an account of the *Hepaticæ*, prepared by Professor Underwood. Aside from these additions, the principal changes are, 1st, the interpolation of such native plants as have been found since 1867 within the territory covered by the Manual, together with the exotics which have since that time gained a foothold, 2d, the entire re-arrangement of the gamopetalous orders after Ericaceæ in accordance with the system given in the *Genera Plantarum*, and a similar re-arrangement of the apetalous and monocotyledonous orders. The *Ilicineæ* are placed among the polypetaleæ; *Diapensiaceæ* replaces *Galacineæ; Plantaginaceæ* stands at the end of gamopetaleæ; *Saururus* is referred to *Piperaceæ*, and the birches and alders constitute a suborder of Cupuliferæ. The old division of the monocotyledonous orders into Spadiceous, Petaloideous and Glumaceous plants is discarded, and the prime distinction is now found in the inferior or superior position of the ovary. These, and other similar changes, were fairly demanded by the advance in the general principles of systematic botany.

The Analytical Key to the Natural Orders of the fifth edition was largely artificial in its character, and occasionally brought near together orders having no very close real affinity. This is replaced in the present edition by a Synopsis in which nearly all the orders follow the same sequence that is observed in the body of the work, the only exception being in the case of the 127th order, *Eriocauleæ*, which for the sake of convenience is placed in the Synopsis at the end of the group headed by *Liliaceæ*, instead of being in its true place as the first of the glumaceous orders. A noticeable improvement is the more general arrangement of the genera of each order, and the species of each genus, in a descending series, from the most highly developed down to the lowest forms. The application of this method is seen in *Polygala*, which now begins with the most showy species, *P. paucifolia*, has the less showy purple-flowered species next, and ends with the yellow-flowered forms. So again in the genus *Carex*, contributed by Professor Bailey, the large and showy *Physocarpæ* are placed first, and the less highly developed species of the section *Vigneæ* at the end. In *Hepaticæ*, also, *Frullania* leads off, as being most specialized, and the simpler forms follow in due downward progression, the *Ricciaceæ*, simplest of all Acrogenous plants, closing the series. In each genus only the native species have numbers, and their names are printed in full-faced Roman type; while the names of introduced plants are printed in small capitals, and not numbered. As would of course be expected the whole number of plants described is much greater than in the last edition. Taking only the indigenous phænogams and pteridophytes for comparison, the number recognized in 1867 was 2357; it is now 2753, an increase of nearly 400. The westward extension of the flora described will account for most of this increase. It may be noticed especially in such genera as *Psoralea*, *Dalea*, *Petalostemon* and *Astragalus*, in which there is a considerable increase of species, and in the introduction of *Aplopappus*, *Grindelia*, *Townsendia*, *Orthocarpus*, *Eriogonum*, etc., all genera characteristic of the Rocky Mountain or the Pacific coast floras.

A few more southern plants have now been found north of the Carolinas and Tennessee, and a still smaller number of high northern plants have been lately gathered within our district for the first time. Really new discoveries within the old geographical limits are of course very few:—*Epipactis* takes its place among the Orchids, and in *Clematis*, in *Arabis*, in *Phacelia*, in *Pedicularis*, in *Carex*, and perhaps in a few other genera, an occasional novelty is described. A slight increase is due to the recognition of specific rank in forms not counted as species in former editions, as, for instance, in *Ranunculus* and in *Tilia*.

Some rectification of the names of species and genera, and even of orders, is unavoidable; and the number of such changes is considerable, though far less than one school of botanists would have desired to see. That pretty spring-flower, the Rue-anemone, becomes *Anemonella thalictroides*; what has been called *Thalictrum Cornuti* is now *T. polygamum*; *Ranunculus ambigens* is given in place of *R. alismæfolius* of the old Manual, because the true *R. alismæfolius* is something different; *Buda* is accepted as the first generic name for what was heretofore called *Spergularia*, and similar changes may be found here and there throughout the volume. The preface says:—"In case of question respecting the proper name to be adopted for any species, Dr. Gray's known and expressed views have been followed, it is believed, throughout the work. While reasonable regard has been paid to the claims of priority, the purpose has been to avoid unnecessary changes, in the belief that such changes are in most cases an unmitigated evil." Dr. Gray's views are certainly well understood, and are known to have been in accord with the teachings and the examples of Robert Brown, Bentham, the Hookers and other great masters of scientific nomenclature; and an examination of this book shows that these views have been faithfully and judiciously followed. Witness the authors' golden silence respecting such names as *Anthophyta*, *Castalia*, *Unifolium* and *Hicoria*.

In describing the grasses the organs which we have learned to call the *outer* and *inner palets* are respectively termed *flowering glume* and *palet*. This change is in accordance with the usage of the *Genera Plantarum*, and of the Rocky Mountain Flora, and yet it hardly seems to be in the direction of simpler and clearer language. The homologies of the flower of grasses are still somewhat unsettled, and the old terms have done such good service in past times, that one would think they might be trusted a little longer.

The Gymnosperms keep their old position at the end of the exogenous class, and it is very certain that Dr. Gray would never have consented to any different place for them.

At the end of the text is a table of orders, with the number of genera and species, native and introduced, the exotic species being almost an eighth of the whole. Then follows a glossary of ten pages, giving brief but sufficient explanations of about seven hundred technical terms. In the Index one is glad to find the names of the species of the genera *Carex*, *Aster* and *Solidago*. The twenty-five plates consist of the old twenty plates of the fifth edition, with the addition of one new plate of grasses, and four plates of *Hepaticæ*, three of them borrowed from the edition of 1857, and one entirely new. D. C. E.

2. *On the Roots of Saprophytes.*—F. Johow in his memoir on Humus-plants free from Chlorophyll, (Pringsheim's Jahrbücher, vol. xx, p. 488) gives an interesting account of the organs of these peculiar plants. The roots and root-like structures are classified in a convenient manner, but the intermediate forms break down all sharp lines of demarcation. The range of plants with saprophytic absorptive organs is larger than is usually supposed. The orders Orchidaceæ, Burmanniaceæ, and Ericaceæ furnish the more numerous examples, after which comes the order Sentianaceæ. In every case the development of the root system is slight so far as its superficial exposure is concerned, in some instances there is almost a complete reduction. The underground organs have the power of forming buds which, after their unfolding, may be practically isolated from the parent stock. And, as examples cited by Drude and Irmisch show, some of there adaptations secure comparative immunity of the species from the destructive effects which would follow if propagation depended on the seeds alone. As might be suspected, the mechanical system in all these underground structures is of the least possible complexity. G. L. G.

3. *Genesis of the Arietidæ;* by Alpheus Hyatt. 238 pp. 4to, with 14 plates, Memoirs Mus. Comp. Zool., vol. xvi, no. 3. Published in conjunction with the Smithsonian Institution.—This memoir is the result of many years of work and thought, and

one of the most important of recent contributions to the subject of evolution. Like most American writers on evolution, the author attributes only a secondary importance to the principle of Natural Selection. In place of it he uses the expression physical selection, and explains it as "the production of suitable modifications by the action of forces which changed in a similar way large numbers of the same species, perhaps nearly all the individuals in the same locality or same habitat, within a comparatively limited period of time. The changes express the general tendencies to modification due to the response to physical causes on the part of the common radical and common organization. Another principle recognized is that whatever the order in the progressive development of a group, there is ordinarily the reversal of this order in retrogressive or degradational development. A third is acceleration in development, or the tendency in any variation in a progressive series to be inherited at earlier and earlier stages. A fourth is the fundamental principle of Agassiz, the basis of much of Mr. Hyatt's work, the parallelism between the steps in the development of an individual and those in the history of the group to which it belongs. These and other general ideas, brought out in Mr. Hyatt's essay of 1883, on the Fossil Cephalopods in the Museum of Comparative Zoology, are exemplified in various ways throughout this new elaborate work, and illustrated by excellent figures of all the species of the group of Ammonites under consideration—in which illustrations Mr. Hyatt shows that he is also an artist. An analysis of the work would require an article of many pages.

Among the principles one of a physiological character appears hardly to have its importance recognized by Mr. Hyatt, and is often overlooked by others. It is the familiar principle on which the breeder relies, the tendency of a variation, however begun, to become augmented by interbreeding, when the variety is one that admits of it. It is not "like producing like," but producing more than this; it is augmenting or accumulating in its effects, and often until the likeness in one character or another is largely lost; and it may affect thus either a generic, family, or tribal character as well as a specific; and all this by simply continued interbreeding, with healthful feeding and nothing more. Darwin began his work on the Origin of Species by illustrating the principle at length, but he failed to give it its true place because he assumed that variations in the individuals of a region would be too few for success without aid from natural selection. But if a variation takes place simultaneously or nearly so in most of the associated individuals of a region, as Mr. Hyatt holds, and as is probable amidst like environment conditions, then it may work as if under man's guidance, without natural selection or further physical selection. And the results under such circumstances will be permanent and normal, free from the extravagances of man's forcing work, because nature's healthful work is always slow and normal. This physiological law of *accumulative breeding*, while leaving unexplained the origin of the variety, has long appeared to the writer to account for much in the history of a variation that is ordinarily attributed to outside conditions or natural selection. J. D. D.

IV. Astronomy.

1. *Transactions of the Astronomical Observatory of Yale University*, Vol. I, Part II.—Dr. Asaph Hall, Jr., has spent the larger part of four years' labor in the determination, by use of the Yale heliometer, of the orbit of Titan and the mass of Saturn, and in this publication are given his observations, and their reduction. The work has been done under the general direction of Dr. Elkin, who has charge of the instrument. There has been an uncertainty of about $\frac{1}{200}$ part in previous determinations of Saturn's mass, and the importance of this element in the theory of the planets made it very desirable that there be a new determination. Dr. Hall finds the mass $1/3500{\cdot}5 \pm 1{\cdot}44$, a result substantially agreeing with that of H. Struve, and with that of Bessel when the proper correction has been applied to Bessel's scale-values. Prof. Hall, from observations with the Washington refractor, had found by different methods four different values of the mass, three of which were decidedly larger than the one found by the Yale heliometer.

2. *The Algol System.*—Dr. Vogel, from his observations of the motions of Algol in the line of sight, finds (*Astron. Nachr.*, No. 2947) that the star before the minimum has at quadrature a velocity of + 5·3 miles (German) toward the earth, and after the minimum a velocity of — 6·2 miles. This gives a mean motion of the system — 0·5 miles, and an orbital motion of 5·7. Combining these with the observed laws of change of brightness and assuming that there are two bodies one brighter than the other moving in circular orbits about their center of gravity, he offers the following provisional scheme of the system.

Diameter of principal star	= 230,000 miles (German).
" companion star	= 180,000 " "
Distance of the centers	= 700,000 " "
Orbital velocity of companion star	= 12 " "
Masses, (assuming equal density)	= $\frac{4}{9}$ and $\frac{2}{9}$ of sun's mass.

3. *Rotation of Mercury.*—Prof. Schiaparelli announces in the *Astronomische Nachrichten* an interesting determination of the period of rotation of Mercury. This planet he finds behaves toward the sun as the moon does toward the earth, its periods of rotation on its axis and revolution in its orbit about the sun being equal to each other.

OBITUARY.

Chester Smith Lyman.—Prof. Lyman, Professor of Astronomy and Physics in the Sheffield Scientific School of Yale University, died on the 29th of January, at the age of seventy-six. He was graduated at Yale College in 1837, and at the Theological School of the University in 1840. His health failing and unfitting him for his work as a clergyman, he made a voyage to the Hawaiian Islands in October, 1845, and the following year made observations on the volcano of Kilauea which led him to the announcement of a principle in volcanic action before unrecognized, that of "the bodily upheaving of the lower floor of the crater (an area two and a half miles long and two-thirds of a mile in mean breadth), by subterranean forces," to a height above its level six years before of at least three hundred feet. From 1847 to 1850 he was in California, and during this interval—that in which the discovery of gold was made—several notes by him on products of the gold region appeared in this Journal. In 1857, Mr. Lyman was appointed Professor of Industrial Mechanics and Physics in the Sheffield Scientific School. In 1870, on a division of the professorship, the title was changed to Sheffield Professor of Astronomy and Physics. Papers by him have been published in this Journal from time to time on astronomical and physical subjects. For several years Professor Lyman held the position of President of the Connecticut Academy of the Arts and Sciences. He leaves a son and two daughters.

John Huntington Crane Coffin.—Professor Coffin, the veteran mathematician and astronomer, died at Washington in January last, in his seventy-fifth year. He was born at Wiscasset, Maine, Sept. 15, 1815, was graduated at Bowdoin College in 1834, and was made Professor of Mathematics in the United States Navy in 1836. He served at sea and in nautical surveys until the time when the United States Naval Observatory was ready for active work. He was then detailed for duty in that institution, where Jan., 1845, he took charge of the Mural Circle. He gave his time exclusively to that instrument till 1851, when his eyes began to fail owing to the severe usage to which they had been subjected. He prepared the descriptions and discussions of the work with the Mural Circle, in the Washington Observations 1846–9. In 1853 he was ordered to duty at the Naval Academy, at Annapolis where he was engaged in instruction until 1866. In this year Professor Winlock was made director of Harvard College Observatory, and Professor Coffin succeeded him as Superintendent of the "American Ephemeris and Nautical Almanac." This peculiarly important office he filled for eleven years. Among his other contributions to astronomy was a memoir on the total eclipse of the sun, August, 1869. He was one of the original members of the National Academy of Sciences, and for several years was its treasurer. He received the degree of LL.D., from Bowdoin College fifty years from his graduation in Arts. He was a man of rare simplicity of character, kindliness of disposition, and devotion to truth.

Rev. Stephen J. Perry, S. J.—Astronomy has sustained a serious loss in the death of the genial and energetic Director of the observatory, at Stonyhurst. Father Perry had gone to the Salut Isles to observe the recent solar eclipse. The photographs were successfully taken, but he from exposure was taken ill of dysentery and died at sea five days after the eclipse.

CONTENTS.

SCIENTIFIC INTELLIGENCE.

VOL. XXXIX. APRIL, 1890.

Established by BENJAMIN SILLIMAN in 1818.

THE

AMERICAN JOURNAL OF SCIENCE.

EDITORS

JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS JOSIAH P. COOKE, GEORGE L. GOODALE AND JOHN TROWBRIDGE, OF CAMBRIDGE.

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

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XXXIX.—[WHOLE NUMBER, CXXXIX.]

No. 232.—APRIL, 1890.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1890.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. XXXI.—*The Æolian Sandstones of Fernando de Noronha*; by John C. Branner.

Besides the rocks of igneous origin which make up the great body of the island of Fernando de Noronha* and its outliers, there is a sandstone covering about one-third of Ilha Rapta, part of São José, and small areas of the main island near the Lancha on the northeast, the high shore east of Atalaia Grande, that along the southwest side of the Sueste Bay, and forming all the exposed parts of Ilha Raza, Ilha do Meio, and the Chapeo at the mouth of Bahia do Sueste. Though these rocks make up but a small part of the island, and are but the remnants of their former extension, they afford some interesting facts in the island's history. No good fossils were found in them, but there is an abundance of fragments of shells, corals and other calcareous skeletons, all of organisms now living about the shores of the island, showing the rocks to be of recent origin.

In an article by Rev. T. S. Lea, published in the Proceedings of the Royal Geographical Society for July, 1888, these rocks are spoken of as "reef rock" and as "a sort of reef formation laid bare at low water and closely resembling the Recife† of Pernambuco. At certain points a very similar

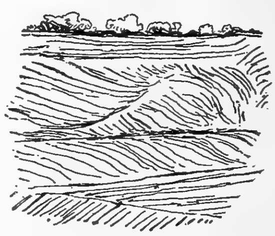
* See The Geology of Fernando de Noronha by J. C. Branner, in this Journal for Feb., 1889, pp. 145–161, and Petrography of Fernando de Noronha by G. H. Williams, ibid, March, 1889, pp. 178–189. The map accompanying the former paper should be consulted in connection with the present article.

† The word Recife as it stands means a certain part of the City of Pernambuco. The author doubtless means the "recife" or reef in front of that city.

rock is found at considerable heights above the sea." He also says that "raised beaches, therefore, seem only to exist on basalt, and in close connection with a phonolite peak."

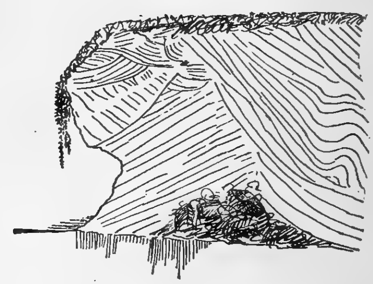
I am unable to see that basalt or phonolite have anything to do with the matter. The gross structure of the sandstone shows that its material was originally deposited in the form of sand-dunes; its beds standing at all angles at which loose sand can stand (see figs. 1 and 2). A microscopic examination

1.



Section on Ilha Rapta.

2.

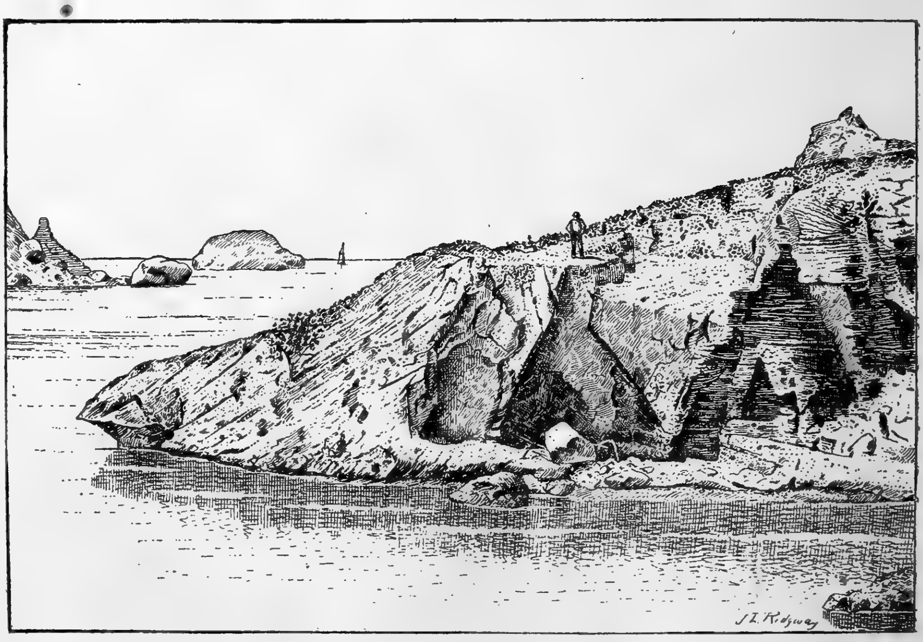


An exposure on Ilha Raza.

shows that this material has been consolidated by the interstitial deposition of carbonate of lime.

The rock varies somewhat in lithologic characters, being in some places so open and porous that it may be crumbled in the

3.



Æolian sandstone in the Bahia do Sueste.

fingers, and in others so hard and compact that when struck with the hammer it rings like "clinkstone." In places it is made up entirely of organic matter cemented by carbonate of lime, and again it contains more or less sand and ashes derived from the igneous rocks, and thrown up by the sea along with the calcareous matter. Where the calcareous matter is most abundant and the rock is soft and easily quarried it is burnt for lime, while in other places it contains too many impurities to admit of it being used for such purposes. The principal locality from which rock is taken for the manufacture of lime is on the south side of the Bahia do Sueste (fig. 3). The deposit has been extensively undermined by the water and its abrupt faces display well its dune structure. The bedding shows that the material must have been blown to its present position from a southern or southeastern direction. Where this æolian sandstone comes in contact with the igneous rocks at this place its stratification planes stand at a high angle, showing that they were formed by the sand having been blown over the top of a dune. This wind-bedded material continues beneath the water line at this locality, and rises to a height of forty feet or more above it. The pieces of rock used for lime are taken out in flakes half an inch and more in thickness and carried to the lime-kiln. The burning requires from three to four days. The lime is somewhat impure from the admixture of small fragments of igneous rocks.

The following is an analysis* of a sample of the more porous parts of this rock burned for lime.

Analysis of specimen dried at 110°–115° Centigrade gave:

Silica	2·20	per cent.
Alumina	0·79	"
Ferric oxide	0·87	"
Lime	0·27	"
Magnesia	0·89	"
Calcium phosphate	0·67	"
Calcium carbonate	97·27	"
Magnesium carbonate	0·49	"
Potash	0·15	"
Soda	0·22	"
Total	101·72	per cent.
Water at 110°–115° C.	0·25	"
Soluble in concentrated nitric acid	96·67	"

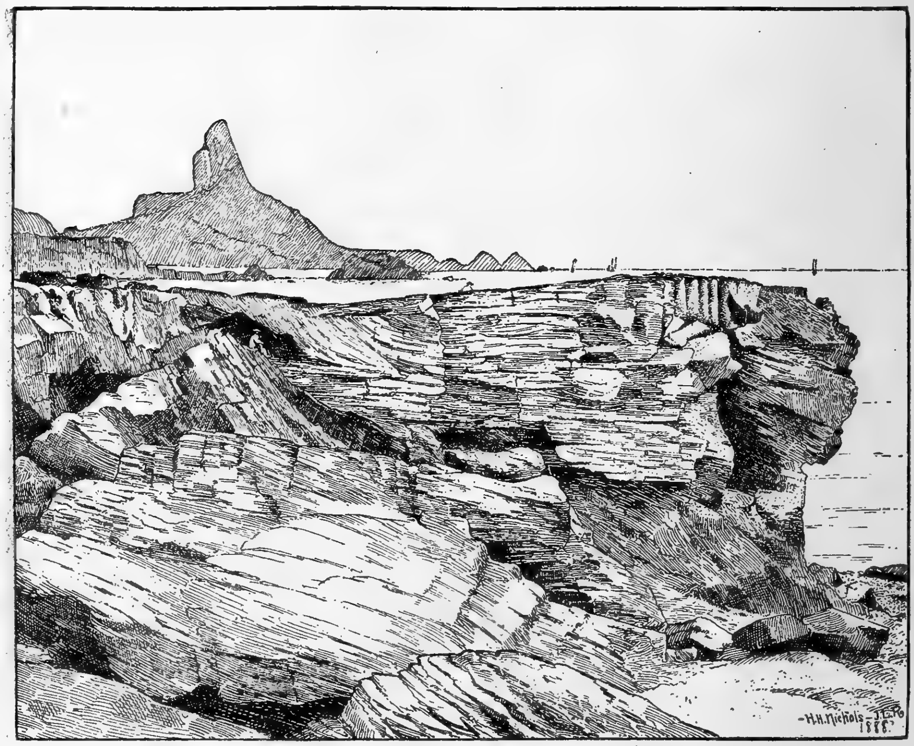
Examined under the microscope this rock is found to be made up entirely of triturated organic remains such as bits of shells, spines and shells of sea-urchins, corals, nullipores, foraminifera, and the other calcareous growths such as cover the

* Analyses by R. N. Bracket.

rocks in many places about the island, all of which is cemented by carbonate of lime. For the most part it is very porous, and the cavities are seen to be gradually filling up by the building into them of crystals of carbonate of lime. No quartz has been found in any of the specimens examined microscopically.

On Ilha Raza the bedding of this rock is beautifully exposed in a perpendicular bluff 40 feet or more in height, at whose base lie the enormous fragments that have fallen by their own weight after having been undermined by the ocean (see fig. 4).

4.

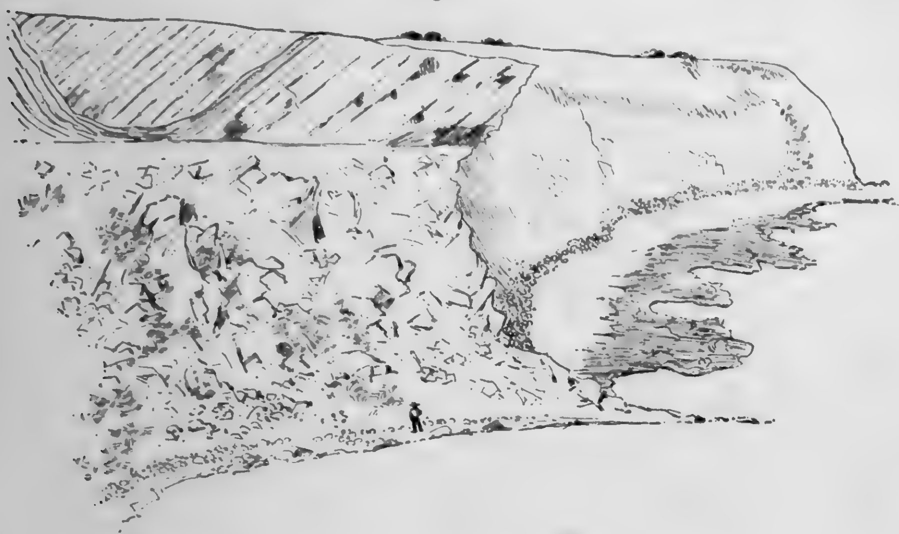


Cliff and fallen blocks of sandstone, Ilha Raza.

The wind-made bedding of the material is well shown in many parts of this exposure.

On the southeastern corner of Ilha Rapta sandstone caps the igneous rock, and rises to a height of 50 feet or more above the water (see fig. 5). Here is situated the great "blow-hole," shown in fig. 8 and described at the end of this paper, where the waves of the ocean operating through hidden passages in the rocks near the mean tide line forces a powerful jet of spray through a narrow opening to a height of more than a hundred feet, and the prevailing winds carry it east and north over the island. The water from this spray has attacked the sandstone, leaving it with a deeply etched surface, the more resisting points, from one to three feet high, being so jagged and so close together that it is almost impossible for one to walk over them (see fig. 8). On the southeastern side of Ilha Raza the same etching of these calcareous sandstones has been caused by the surf blowing over the island (see fig. 6).

5



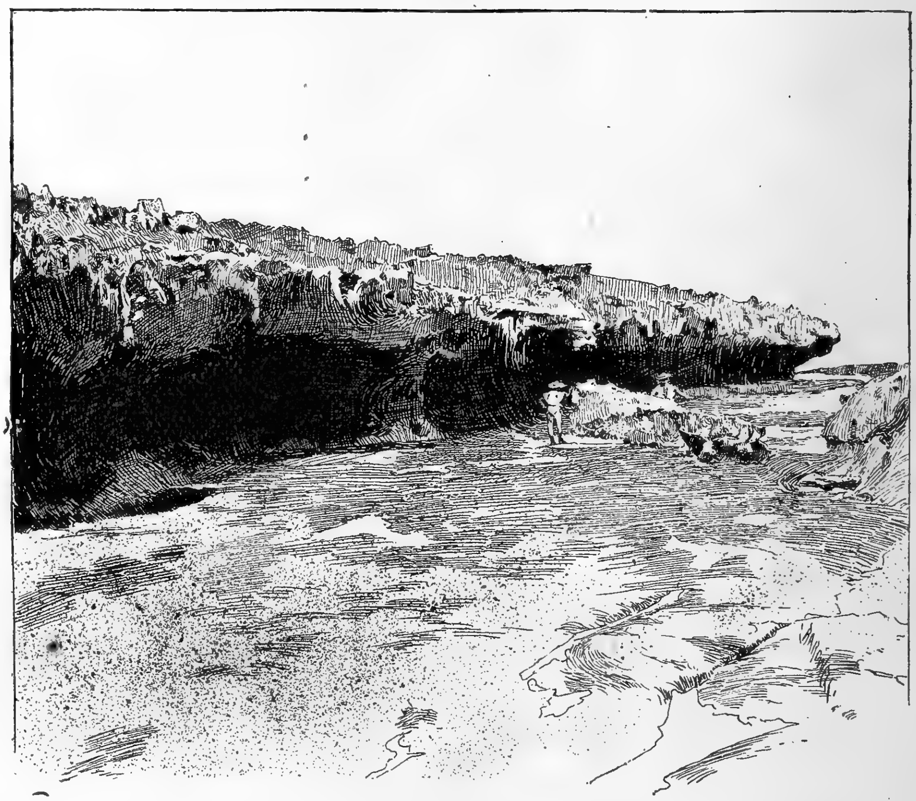
Æolian sandstone capping eruptive rocks on Ilha Rapta.

The southern side of Ilha Raza has been deeply undercut by the water. The rock here is more compact than at most of its exposures. Great caverns are at first worn along the line at which the force of the surf is greatest at high tide. These excavations are carried forward upon a flat floor which extends all along the southern side of Ilha Raza (fig. 6). When the undermining has reached a certain point the roof or edge of the islands breaks and falls upon this floor whence it is soon removed by the surf. It is to be remarked that all the debris coming from the destruction of the sandstone at this place is carried away by the undertow leaving the stone floor clean, as shown in the accompany illustration. I am inclined to think, however, that the removal of these rocks is due to a considerable extent to chemical action. That the salt water does dissolve the rock is clearly shown by the etching produced by the spray wherever it is blown over these sandstones. Undermining by the ocean is seen wherever these æolian sandstones occur—on Ilha Rapta, Ilha do Meio and Ilha Raza, on the Chapeo and elsewhere, but the stone floor left by the removal of the rock is most extensive on Ilha Raza.

A shelf similar to that above described usually answers the purpose of a landing place on Ilha Rapta. There is no beach on that island, and a boat or jangada can be brought beneath one of these projections at low water, enabling one to disembark by climbing up on the ledge.

It has already been noted that the wind-bedding of these sandstones upon Ilha do Meio is continued beneath the water at low tide, and that the island is now lower than it has been at some time in the past* (see fig. 2). It may be of some corroborative interest, at least, to state that the writer had reached

6.



Caverns cut by the surf on Ilha Raza.

a similar conclusion before having seen this opinion of Mr. Buchanan. Other facts, however, show that the island has experienced other changes of elevation than this single depression. That the rocks forming Ilha do Meio, Ilha Rapta, Ilha Raza, and the solitary block between the main island and São José known as "O Chapeo" are wind-bedded there can be no question. In the cases of the sandstone east of and lying against the base of Atalaia Grande, and that on the south side of the Bahia do Sueste, the wind-bedding is even more clearly shown. In the rocks of Ilha do Meio, Ilha Rapta, Ilha Raza, and in the Bahia do Sueste, this peculiar bedding is continued beneath the water line, showing, as Mr. Buchanan suggests, that the island has once stood at a higher elevation.

* The Voyage of the Challenger, by Sir Wyville Thomson, N. Y., 1878, vol. ii, p. 100 *et seq.* The opinion is credited to Mr. Buchanan, and the island is spoken of as Booby Island.

It should also be noted, however, that some of these sandstone beds, rest immediately upon beach-worn pebbles and cobble-stones. In the case of the great block of sandstone, about 25 feet high, which is the remnant of an island near São José, known as the Chapeo, the underlying conglomerate is extremely hard and is well exposed at low tide. On the southeast side of Ilha Rapta and on Ilha Raza they can be seen, though not so well exposed as at the Chapeo. Inasmuch as the cobbles must have been worn before they were covered by sand, the island must have stood at a level somewhat lower than its present one while the cobbles were being made, and as the wind bedding could not be produced below the surface of the water or in sand to which the waves had access, the island must have been elevated somewhat before the dunes were blown over and deposited upon the cobble-covered beaches.

It is worthy of note that all these æolian sandstones lie upon the eastern or southeastern sides of the island, that they occur at a pretty high elevation, (70 feet on Ilha do Meio, 90 feet on São José and about 100 on Ilha Rapta and at the base of Atalaia Grande) and that they are entirely disconnected with any of the small existing sand beaches. The former beaches must have been much more extensive than any now about these islands, for there is nowhere upon these shores a beach comparable in extent, size or thickness with the exposed beds of these calcareous sandstones, and the sea-bottom is everywhere rough and more or less rocky, a fact which precludes the idea of these beds having once existed as sediments or as immediate beaches. I have already expressed the conviction,* that these sands were blown up from the south or southeast, a conviction sustained both "by the geographic positions of the various beds, by the absence of such rocks at corresponding elevations on the opposite sides of the islands, and by the internal structure of the rocks themselves, the steeper face being toward the north or the northwest. But as there is now no beach from which this sand could have been derived,† we must conclude that the island was, not long ago, wider to the southeast, and that there were upon that side of it sandy shores, upon which a great abundance of organic remains was thrown and ground to sand. These sands were then blown across the island to and upon the opposite shore, burying the former bowlder-covered beach near São José beneath 75 to 100 feet of sand, and piling it up considerably higher than the highest parts of the existing sand-rock." They joined into one what are now the separate islands of São José,

* Ibid., p. 161.

† There are some beautiful miniature bays about the coast, but there are but few smooth beaches and these are very small.

Ilha Raza, Sella à Gineta, Ilha do Meio, Ilha Rapta, and the northeast point of the main island, while rain, charged with carbonic acid, falling upon it, and the spray blown over it from the surf, dissolved out the carbonate of lime, carried it downward and re-deposited it, thus solidifying the sand into a hard rock, upon which the ocean has gradually encroached from both sides.

7.

Sandstone rim at the base of Atalaia Grande.

The southeastern side of the island is being cut away much more rapidly than the northwestern side. This is due to the prevalence of east winds, and the northeast-southwest position of the longer axis of the group.* On the south side the spray attacks the rocks over the surface, while the more violent surf undermines them. The action of both these forces may be seen in fig. 6.

At the base of Atalaia Grande on its eastern side, the æolian sandstones form a narrow rim or shoulder, about one hundred

* During the months of July and August, 1876, the wind was almost constantly from the east, varying occasionally to a few points south of east or north of east.

feet above mean tide. The encroachment of the sea has removed the supporting igneous rocks, and great fragments, some of them over fifty feet across and twenty feet in thickness, have slid down to the beach. This ledge and its fallen fragments are shown in fig. 7. Where these rocks abut against the hill, they have a steep dip toward the island, suggesting that the bedding was produced by sand having been blown over the top of a dune.

Of the ancient sands but few unconsolidated remnants are now to be found upon these islands. On the top of the ridge at the extreme northeast point of the island is some not hardened into solid rock. This sand like that of all the present beaches about the island has a clearly marked sonorous property, crunching and creaking beneath the feet like dry snow.

In 1881 the Brazilian Minister of Agriculture sent a commission to Fernando de Noronha to examine and report upon the phosphate of lime found on Ilha Rapta. This phosphate of lime overlies the æolian sandstone of that island, and Mr. Derby says in his report* that it is probably the insoluble residue from a deposit of guano, the parts soluble in water having been washed out by rains. Mr. Derby's explanation is no doubt the correct one. It may be added, however, that this phosphate occurs over the etched surface of the calcareous rock, and this rock has doubtless added to the total amount of phosphate of lime on the island for this amount would be materially increased by the presence of the calcareous rock underlying the deposit. The rainwater would dissolve from the guano the soluble phosphates of lime and ammonia and these, upon coming in contact with the carbonate of lime beneath, would form insoluble phosphate of lime and soluble carbonate of ammonia, the latter being carried off.

The writer observed several illustrations of the formation of solid rock-like masses of the insoluble phosphate of lime in what seem to have been crevices or porous vertical streaks in the calcareous rock. Of the following analyses, No. 1 is of this hard phosphatic rock broken from the indurated æolian sandstone.

It is noteworthy that typical specimens of these æolian sandstones, whether very porous or compact, and whether from Ilha Rapta or elsewhere, show upon analyses the presence of some phosphate of lime. Analysis 2, beyond, is of the average clean and compact part of the Ilha Rapta æolian sandstone. The piece was broken from one of the tall jagged points left by the etching out of the surface by the combined action of rain water and ocean spray.

* My copy of this report has for title simply "O Phosphato de Cal;" it bears neither place nor date of publication, but it was probably published by the Brazilian government in 1881 at Rio de Janeiro.

1. Specimen dried at 110°–115° C.:

Silica	1·77 per cent.
Alumina	8·81 "
Ferric oxide	6·35 "
Lime	0·15 "
Magnesia	0·13 "
Calcium phosphate	18·35 "
Calcium carbonate	41·62 "
Magnesium carbonate	22·17 "
Potash	0·12 "
Soda	0·48 "
Loss on ignition	1·81 "
Total	101·76 per cent.
Water at 110°–115° C.	1·44 "
Soluble in concentrated nitric acid	95.94 "
Insoluble in " " "	4·06 "
Total	100·00 per cent.

2. From the surface of the æolian sandstone from Ilha Rapta. Specimen dried at 110°–115° C.:

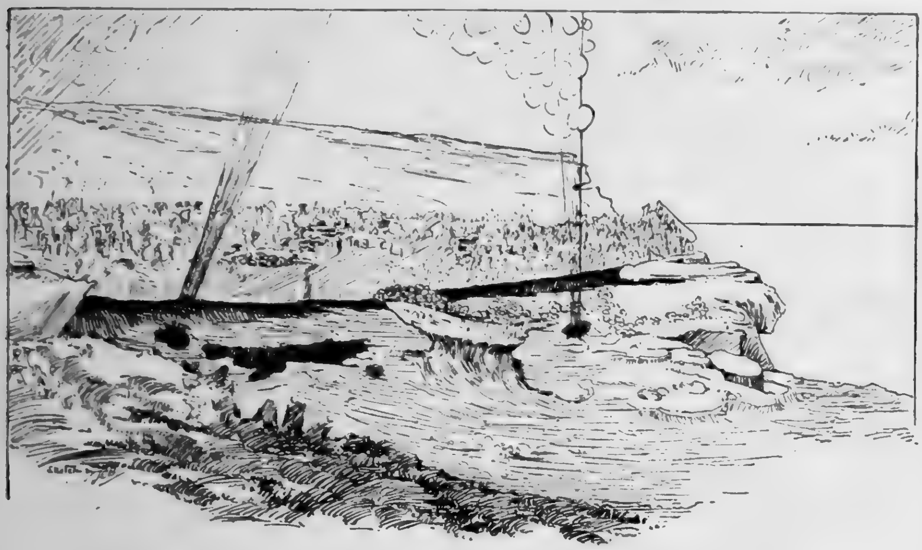
Silica and matter insoluble in concentrated nitric acid	0·09 per cent.
Alumina	0·45 "
Ferric oxide	0·13 "
Calcium phosphate	0·82 "
Calcium carbonate	98·33 "
Magnesia	0·64 "
Potash	0·10 "
Soda	0·20 "
Total	100·76 per cent.
Water at 110°–115° C.	0·17 "
Soluble in concentrated nitric acid	99·91 "
Insoluble in " " "	0·09 "
Total	100·00 per cent.

It should be noticed also that the analysis of the very porous rock from the Bahia do Sueste used for making lime shows the presence of phosphate of lime.

In his report upon the phosphate beds of Ilha Rapta Mr. Derby refers to a piece of a Millepora having been found in the higher parts of the calcareous sandstone beds of that island and from this he seems to infer that they were deposited under water. Of the many pieces of organic remains I have found in this rock I have never seen one whose presence so high above water might not readily be explained by supposing it to have been blown up a gently sloping beach by the wind. The place referred to by Mr. Derby is, however, a peculiar one in this respect, and not only animal remains but stones the size of a man's fist may be found where, under ordinary circumstances, it would be quite impossible for the wind to blow them.

On the south side of Ilha Rapta where the æolian sandstone comes in contact with the underlying eruptive rocks, at a place known as the *Funil* or "blow-hole" already referred to, a maze of subterranean channels has been cut out by natural processes. The upper part of the sandstone is worn away leaving a thin but compact horizontal crust forming the roof

8.



of these caverns (see fig. 8). Through this roof are three or four openings, and at certain stages of the tide the waves beating against the shore, at this point V-shaped in outline, crush and compress into these subterranean channels great bodies of air which, when they happen to be carried to the openings through the roof, escape with enormous violence. I have seen the spray from one of these holes (the one seen on the left in the sketch), thrown to a height of more than a hundred feet. Sometimes but little water is ejected, the air escaping with a loud explosion and resembling hot air rushing under pressure from a furnace. These explosions come principally from the vent shown on the right in the illustration. At other times a great body of water spurts from the largest of the openings—the one in the middle of the foreground. One of the prisoners living on Ilha Rapta told me that he had known fishes and stones to be thrown out by these jets of water and to fall on the sandstone above. There are a few loose stones lying over the surface of the calcareous rock within the range of the falling spray, and it is not improbable that fragments of corals, impossible of transportation by the wind, might be in this way thrown upon the higher parts of the calcareous sandstone.

ART. XXXII.—*A Mountain Study of the Spectrum of Aqueous Vapor;* by CHARLES S. COOK.

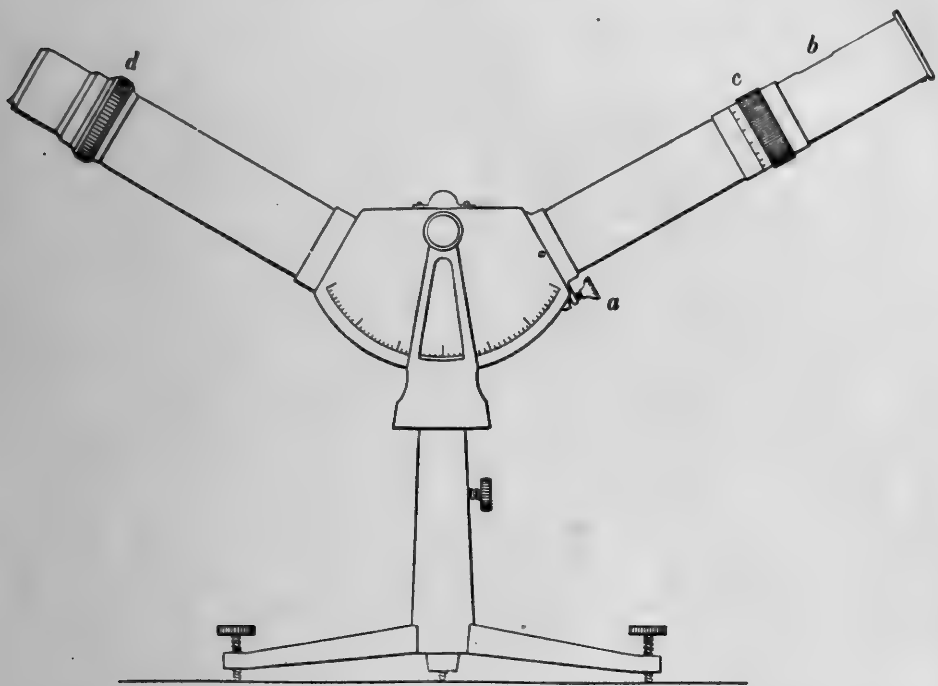
A COMPLETE study of the Solar Spectrum necessarily includes, not only a determination of the position of all lines, but also an estimation of their relative intensities. While the means of determining the position of lines leaves little to be desired, it is a remarkable fact that no satisfactory method of measuring the intensity of the absorption lines has been devised. The instrument devised by the writer for the study of the variations of some of the terrestrial lines has done excellent service, and it is possible that it might be adapted to more general use in the study of the spectrum. While observations have been made on a number of the atmospheric lines due to dry air, the study of the aqueous vapor lines has proven most interesting. Two spectroscopes of identical construction were made especially for this work. They were provided by the United States Signal Service.

The first requisite in such an instrument is that it shall give a bright spectrum. As observations must be made on dark, stormy days, every effort must be made to secure a strong illumination. This is attained by the use of a large collimating lens and prism, and a large angular aperture for the collimator, which makes it best that the collimating tube be short. Only moderate magnifying power in the observing telescope is desired, as a high power would make the spectrum appear faint.

Another requirement of a general nature is that such a spectroscope shall be so designed that it is not liable to be accidentally thrown out of adjustment; for a slight change in the focus or in the width of the slit, while it might not be detected, would make a great error in the photometric value of the spectrum lines. For this reason, each draw-tube should be provided with a set screw, and the slit adjustment should be controlled by parts which are inclosed within the cap at the end of the collimator. Reference is not made here to a brass cover which must be removed when the instrument is used, but rather to a cap with a plane glass front which is never to be removed during the course of a series of observations. This last requirement, unfortunately, is not met in the spectroscope as constructed for use, as the maker violated his instructions in that particular, as he did not find it convenient to inclose the adjusting collar *d* in the cap. Fig. 1.

The instrument has an altazimuth movement, and is provided with leveling screws and a spirit level, which last is fastened to the top of the prism case. A graduated arc shows the angle which the tube makes with the horizon. At "*a*" is the screw by which the telescope is turned to view different parts of the spectrum. The attachment which permits of a photometric measurement of absorption lines appears at "*c*."

1.



The object sought is the production of an artificial line whose intensity can be varied at will. This fictitious line is placed alongside the spectral line which is to be measured, and the intensity of the former is then varied until the two appear like. As this variation in the blackness of the artificial line is effected by the use of a micrometer screw, its readings constitute an arbitrary value of intensities. The artificial lines (there are a pair of them) are diffraction fringes. They are produced by a single silk fiber placed slightly beyond the focus of the eye-piece. As seen in a telescope or microscope, such fringes are quite indistinct; but in the spectroscope, the fiber is in light which is practically monochromatic, which greatly favors distinctness of definition. Much improvement is effected also by viewing the spectrum through a narrow opening parallel to the fiber and consequently parallel also to the spectral lines. A piece of blackened brass is placed on the eye lens next the eye. In this cover is cut a slit one millimeter wide, extending entirely across the lens. It is found that the definition of the artificial line is improved if this observing slit is eccentric. The edge of the slit should be placed at the center of the eye lens, making the slit one-half a millimeter displaced upward or downward.

The variation in the comparison lines is effected by turning the micrometer screw or collar "*c*." The rotation of this collar causes a diaphragm bearing the silk fiber to slide within the observing tube and so remove the cross line from the focus as far as desired. As the fiber is withdrawn from the focus, the single sharp image of the line is replaced by a pair of sharp lines exceedingly close together. On further motion, these diffraction lines slowly separate, becoming fainter until they finally become invisible. Whole revolutions of the micrometer screw are read at "*b*," where a portion of the sliding diaphragm is exposed. The screw itself is divided into tenths, and these tenths constitute the arbitrary units of intensity used. The whole range of the instrument is about four revolutions of the screw, or a range of forty of these units. The probable error of the mean of a series of readings such as was usually taken is found to be somewhat less than one of these units.

No good work can be done with such instruments without carefully shielding both eyes from extraneous light. The observations were nearly all made on a single line of the aqueous vapor spectrum, the strongest of them all, the line in the red near the "D" line.

Observations were made regularly at altitudes of 5 degrees, 10 degrees, 20 degrees, 30 degrees, and 90 degrees, for a time at the horizon also.

In the mountain work, the two duplicate instruments were used in simultaneous observations. Although they were of identical construction a comparison was made, the assistant and myself making readings side by side and comparing results. A difference of a very few units was observed, clearly due to a difference of eye-sight.

The observations described in this paper form a part of a series continued with a few interruptions during several years, most of them being made at the Shattuck Observatory of Dartmouth College, Hanover, New Hampshire.

Three trips have been made to the White Mountains, with the idea of studying the behavior of the spectrum of aqueous vapor. The first trip resulted in little or nothing of value, the unfavorable nature of the weather, among other reasons, defeating the purpose in view. A second and more successful trial was made in the summer of 1886, and again in 1887, a stay of two weeks being made each summer. The most important object sought was to gain some evidence as to the height to which aqueous vapor extends during stormy weather; or, more comprehensively, in how far the spectroscope is competent to give information as to the height of vapor in all kinds of weather. Other questions were also considered, and more or less information bearing on them was gained.

The mountain selected was Moosilaukee Mountain, one of the outlying peaks of the White Mountain range. The altitude above sea level is 4,811 feet. Observations were made at the summit at frequent intervals, while an assistant, Mr. E. B. Frost, made simultaneous observations at a station well down toward the base. The horizontal distance between the stations was about three miles. The difference of altitude was very closely 3,000 feet. In addition to the spectroscope readings, the ordinary meteorological observations were taken.

On studying the varying appearance of the aqueous vapor lines in the solar spectrum, one is impressed by the very wide range of variation in their intensity. One day the strongest of these lines may be almost invisible, while a few days later it is no exaggeration to say that its intensity is forty times as great, perhaps I might safely say sixty or more times greater. Assuming as we may that for a single line the light absorptive power of the vapor is proportional to the amount of vapor traversed, we are led to infer that on the second day there was at least forty times as much vapor present as on the first day. Does this mean that the absolute humidity was forty times as much? The hygrometer shows nothing approaching such a range. During the summer weather rarely does the amount of water in a cubic foot of air on a *wet* day exceed by more than five times that present on a *dry* day. Instead of assuming that the air holds forty times as much per unit of volume, is it not nearer the truth to assume rather that the vapor extends upward forty times as far in the atmosphere? I say nearer the truth, with certainly no desire to deny the effect due to other causes. But I do wish to emphasize, and strongly, that the prevailing disposition to associate the varying vapor spectrum with varying humidity, with tacit understanding that other factors are acting, is all wrong. We should associate the varying spectrum with varying vapor altitudes, remembering always that other factors play a subordinate part. It is true that a chart on which are platted together vapor line intensity and absolute humidity does show a very fair, indeed I should say a close accordance; but this is due in the main not directly to an interdependence, but rather indirectly to the fact that damp air and high vapor altitude generally go together.

At the time the observations were made on the mountain, the importance of the question of vapor altitude was not appreciated. It was thought, as indeed is true, that the difference between the spectra observed at the two stations with identical instruments would represent the absorption of the stratum of the vapor between the stations, i. e., a depth of 3,000 feet. It was carelessly presumed that in consequence the spectrum difference would be greatest whenever this 3,000 feet of air contained the most water—when its humidity was greatest. After returning home, the figures obtained were tabulated, and the results platted in curves. To my surprise no such relation appeared. Indeed, there was rather more than a suggestion of the contrary—the paradoxical appearance that the more vapor present in the 3,000 feet of air, the less the light absorptive effect produced by it. The effect of altitude of vapor was then more closely considered, and it was at once apparent that if there were great variation of altitude its effect might be as observed. Let us illustrate this point by the facts observed. On many days, so little vapor was there above the level of the summit of the mountain that the aqueous vapor spectrum contained no line of measurable strength; indeed, it was sometimes invisible. At the same time at the lower station the line was very easily measured. Indeed, once only did the line utterly fail to appear at the lower station. This was after a long storm, and about twenty-four hours after the rain ceased, and about twelve hours after the clouds broke away.

On another occasion, the day following the close of a heavy storm, about thirty hours after the rain ceased, and about seven hours after the clouds broke away, a very faint spectrum was observed at the summit. Here it could be directly seen that there was much vapor at a low level, with exceedingly little at a high level. The spectroscope acted just like a telescope. When pointed at the horizon, a very distinct line was seen measuring 25 units. When elevated 5 degrees, a very faint line of only 6 units was seen. A most striking and unusual difference for this small difference of altitude. The lower stratum of air in direct contact with the earth was well charged with moisture by evaporation from the wet earth, while the upper air was completely exhausted of moisture by the storm which had passed. The air was exceptionally clear at this time—as clear as I have ever seen it.

During several equally clear days in September, when the weather was cool, and the air very dry, the line at the horizon ranged between 0 and 10 units. It was only in fair weather and long in advance of rain that the spectroscope revealed no vapor above the mountain top.

Returning now to the point under consideration, we have noted a condition of the atmosphere when there is no vapor line to be seen at the top, with a moderately strong line of say 25 units at the base. The spectroscope difference is then 25 − 0 or the whole 25 units. The maximum difference between the two stations is then obtained when the vapor line is 0 at the summit. This difference will be a minimum when there is a very great amount of vapor above the summit. It is easily seen that if the vapor extends to a height of several miles in all, the vapor contained in the stratum of 3,000 feet which we are studying becomes a small factor in the whole. The observer at the top of the mountain we suppose has several miles of damp air to look up through. The observer at the base has this same distance of several miles plus 3,000 feet. The spectra will not be proportionally very different. We repeat then that the minimum difference between the spectroscopic observations at the top and bottom of the mountain will be observed when the vapor extends to the greatest height in the atmosphere. This will naturally be during the progress of a storm. It is found that such is the case.

In looking over the records, I find the difference very generally small in threatening weather, becoming sensibly 0 in case of actual storm with precipitation.

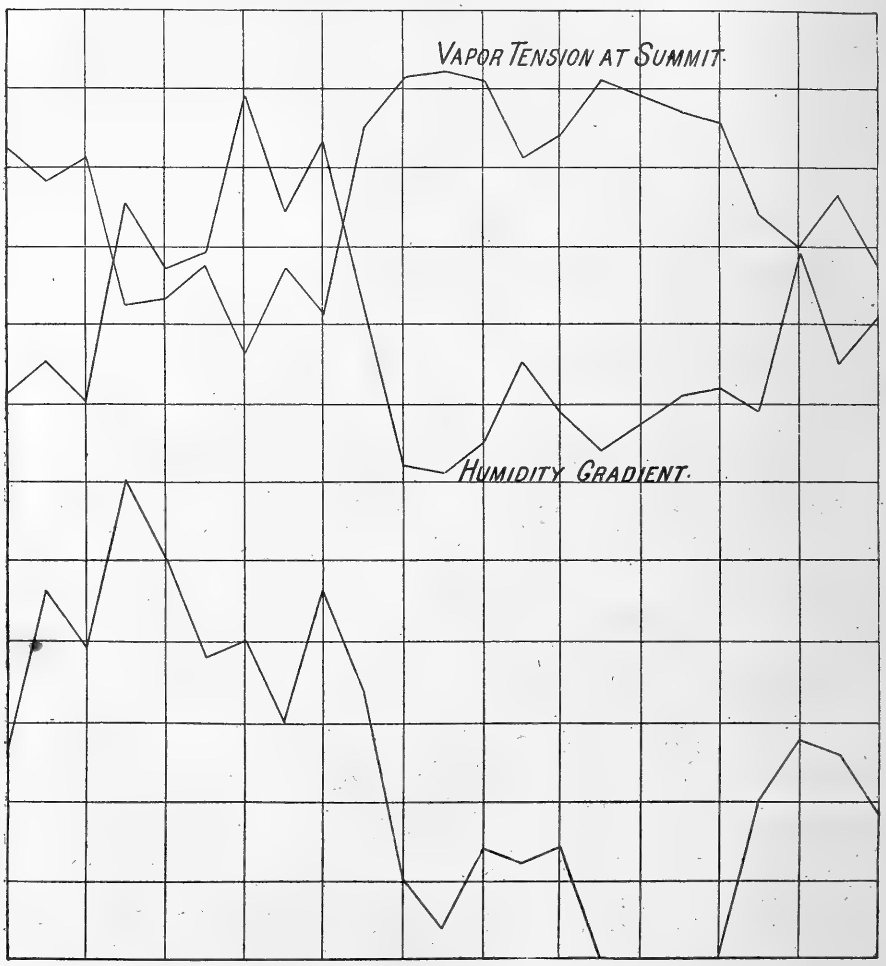
In only one case is the reading at the upper station greater than a simultaneous one lower, 8 units in this case. This represents an impossibility, and means simply an error in the reading on the part of one of the observers. A difference of 1 to 3 units is not considered significant, in view of the very considerable difficulty of such work. When we consider that the two observations were, from the circumstances of the case, made absolutely independently, with constant and large fluctuations in the readings, and that the observation is one of great delicacy, we must consider this result a very gratifying one.

Let us see what light is gained from averaging the observations as far as possible. (We are obliged to exclude many observations mainly on account of the interference of clouds.) We have seen that the difference is a maximum when the line is 0 at the top, i. e., when the absolute humidity is least. I assume a vapor tension of 0·4 inch as the average humidity at that altitude, and find the mean of all spectroscopic differences when the vapor tension was less than this; and also in the same way when the tension is greater than this. With a tension of more than ·4, the mean difference (17 readings) is 8·5 units. With a tension of less than ·4, the mean (14 readings) is 15·7 units—a ratio approaching two to one, and amply sufficient to establish the point. The same thing is illustrated by a diagram. Fig. 2. It compares the same two quantities, having a curve for spectral difference,* and one for the summit humidity. The two should correspond. A third curve is added which should be antithetical. This curve represents the difference of vapor tension at the base and summit; in other words the humidity gradient. If the humidity falls off but little in ascending the mountain it seems probable that one would have to go to a great height in the atmosphere to reach a point of low

* This is the lowest of the curves on fig. 2.

humidity. On the other hand it is assumed that if the humidity falls off rapidly vertically there will be little moisture in the upper atmosphere. If the spectroscope is a competent witness, we must believe that at times no significant amount of vapor exists above the level of a mountain top

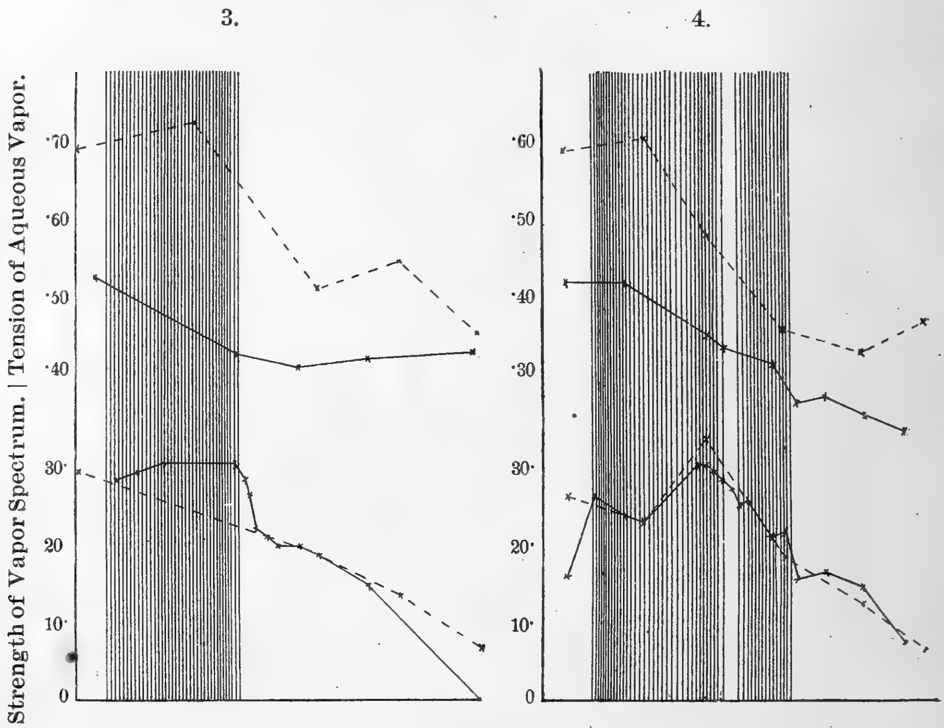
2.



whose sea level altitude is over 0·9 mile, which height for convenience of discussion we will call a mile. This no doubt no one would call in question. The spectroscope would also lead us to believe that at times there exists at a height greater than one mile such a quantity of vapor that an additional 0·6 of a mile of very damp air is not a significant addition. It is true that in stormy weather observation is difficult, so that the closest work cannot be done; it is very hard to say how great a proportional part could be easily recognized. Some rough idea of this may perhaps be gained from the diagram displayed.

A question of much interest is the effect of the passage of light through clouds. It is certain that the optical effect of storm clouds is at times something very great, I may say enormous. This has long seemed to call for some explanation. I regret to say that I am far from being able as yet to establish any theory, and can only submit certain evidence bearing on the question. I conceive that there are three causes which may act separately or conjointly to produce the great absorption of light by storm clouds. We may conceive (1) that a storm corresponds to a great altitude of aqueous vapor, and a consequent great length of air column traversed by the rays of light. (2) That a cloud allows light to pass by a process of multiple reflection: the particles of mist being so close together, it is conceivable that the broken lines representing the actual path of any one ray of light would when rectified have a length of several times the actual thickness of the cloud. (3.) That water when passing from the form of vapor to that of a liquid, i. e., while in the act of condensation, has an abnormally great effect. This view has had its advocates, but I know of no physical evidence of such action, and am rather disposed to believe that the idea was put forward merely as a possible explanation of this cloud action, with no other evidence in its favor. A direct test of this third theory of the abnormal effect of saturated air or perhaps more accurately of nascent cloud, has been made repeatedly by the writer. Doubtless, many present have watched from a high mountain the formation of cumulus clouds on a sunny morning, and have noticed that the lower surface is an almost perfect plane. The upper surface may be ever so much broken and piled up in rounded masses and columns, but the lower surface is ever plane. As the air rises steadily, the upper part of the cloud is seen to ascend while the lower part is stationary, the cloud particles here being renewed as fast as they rise. At the lower surface, then, we have continuously nascent cloud, and light traversing this stratum should show abnormal absorption if it exists. The result of observation is negative as far as recognizing such an effect is concerned. It must be said, however, that the illumination is poor necessarily, and for this reason it cannot be claimed that the theory is disproven.

Now while more than one of the above causes of absorption may well be concerned, it seems that any very marked predominance of one of them can be discovered if it exists. For this reason, I was interested to determine if when both stations were immersed in a storm cloud the 3,000 feet of cloud between would give much difference of line. But storm clouds will not come at one's bidding; and when they do come they are very likely to come at night, consequently the amount of evidence is not very satisfactory. Only twice were the conditions favorable, that is, on only two days could the tests be made. The readings taken showed no difference within the limits of reading of the instruments. How closely the two readings agreed is shown in the diagram. Figs. 3 and 4. The shading indicates rain-fall, the heavier shading corresponding to rapid precipitation. The full lines represent observations at



the summit, the broken lines those at the base of the mountain. Unfortunately in the first instance as shown in figure 2, very few observations were taken at the base so that the comparison is not satisfactory.

An observation made on the mountain top August 6, 1887, gives quite direct evidence on the relative efficacy of damp air and storm cloud in producing a spectrum. As the chart shows, it had rained steadily during the previous night and from 9 to 12 of the forenoon, and during two hours of this my assistant's record says that it "rained furiously." At 12.15 the rain ceased falling. As usual the intensity of the vapor line fell off rapidly (see fig. 4). Fifteen minutes after the rainfall ceased, the clouds in which the mountain had been immersed broke away for a few minutes. We saw far above us bright cirro-cumulus clouds, thin and much broken, showing considerable blue sky through the breaks. The zenith reading with the spectroscope was 22, an exceedingly large reading for a zenith reading on a nearly cloudless sky. I believe it is the highest reading ever obtained on such a sky.

It can only be explained as due to the very high vapor concerned in the storm just ceasing. It is of course very unusual for the air to clear so soon after rain ceases. It is to be noted that the vapor line was not so very much less intense on the sky and thin cloud than it was on the storm cloud an hour before when it was "raining furiously." Some three hours later, i. e., at 3.15, the cloud had settled down again so thick that spectroscopic readings became difficult, yet the line had diminished to an intensity of 15. Whatever weight we may assign to those observations must be thrown in favor of the first cause mentioned, viz: that the great optical effect of storm clouds is due to their being associated with a very high altitude of vapor. As 3,000 feet of cloud seemed to exert no great optical effect, the second cause suggested (multiple internal reflection) does not appear as the predominating source of action. The result is no more favorable to the theory of abnormal action of saturated air. Much more conclusive evidence could be secured if one of the observers were above a storm cloud. A brisk shower would answer the purpose quite well. With such conditions, the effect due to the cloud would be isolated, and it would appear that the question would be solved. Unfortunately, no such conditions presented themselves to us.

It is rather remarkable that no amount of fog appears sufficient to produce any spectroscope effect. At Hanover, where most of the observations have been made, dense fogs are very common, especially during the fall. Innumerable observations have failed to detect more than a trace of action. Often in the morning the darkness would be so great that one would be very uncertain as to the weather, the presence of clouds as well as fog appearing probable. The sky might be so dark as to make readings difficult, sometimes they were as difficult to make as in the presence of a storm. Under such circumstances, the spectroscope infallibly discriminated, rarely showing any line at all in case of mere fog, while in the presence of storm cloud it would be strong. The mere matter of brightness or darkness of a stratum of cloud gives no clue as to the strength of the line to be observed. Considerable attention has been given to this point. As an example, I will give the result of a comparison made Aug. 25 and 26, 1886, the observations being on the summit of Moosilauke Mt. The 25th was stormy, rain beginning to fall at noon, falling steadily till 2, and intermittently afterwards. About 0·2 of an inch fell in all. Observations taken on the cloud or rather in the cloud as the mountain was enveloped constantly, during the lulls, i. e., when it was not raining, gave readings of 16, 21, 24, 23, 25 and 20. On the next day no rain fell but otherwise the conditions of things appeared to be the same, but the aqueous vapor spectrum was very faint. To quote from the record made at the time: "At noon with clouds of the same darkness, and with the circumstances all apparently the same as on yesterday, the line is very faint. Hence the clouds at noon, at the time of their greatest illumination, gave readings of as great difficulty as yesterday, and yet they are all persistently 0." On the preceding day, they had averaged 21. At four in the afternoon the cloud grew evidently thin, and at six the sun could be easily distinguished. This is but one of many instances that might be quoted. An excellent example of the discriminating power of the instrument in this direction is worth giving here. During daylight of Aug. 5, 1886, a storm rapidly gathered. During the night rain fell steadily. During the forenoon of the next day, Aug. 6, it rained very heavily. We were closely wrapped in cloud all day, the vapor line being 15 to 30. The third morning we found ourselves in cloud as usual. The spectroscope gave a vapor line of 0. At the breakfast table, at about nine, one of the guests (a professor of Civil Engineering, who ought to be a good practical weather prophet if anyone, surely) remarked it was a most discouraging outlook. I was very happy to assure him that "the cloud was only a cap, or at most part of a thin sheet of cumulus cloud which could not possibly give us any more rain; that the storm was all past, and nothing but fair weather clouds remained." In about two hours the clouds lifted, revealing the clearest of atmospheres, and showing us that the cloud layer was very thin broken cumulus. It was an exceptionally fine day.

To sum up the points considered:

1. The spectroscope is competent to give trustworthy evidence as to the amount and distribution of aqueous vapor in the atmosphere.

2. The spectroscope studies vapor height primarily, and humidity only secondarily.

3. During stormy weather vapor ascends to altitudes greater than is usually supposed.

4. The great absorption of storm clouds is due to their great thickness, or to extensive strata of damp air associated with them, more than to any peculiar behavior as clouds.

ART. XXXIII.—*On the occurrence of Basalt Dikes in the Upper Paleozoic series in Central Appalachian Virginia;* by NELSON H. DARTON, U. S. Geological Survey. *With notes on the Petrography;* by J. S. DILLER, U. S. Geological Survey.

DURING a recent detailed examination of the geology of the Appalachian region west of Staunton, Virginia, the writer discovered a number of small basalt dikes traversing the Upper Silurian and Lower Devonian beds in Highland county, Virginia, and Pendleton county, West Virginia.

The most conspicuous outcrops are about a mile SSW. of Monterey, in a remarkable conical hill rising abruptly 60 to 70 feet above the valley of Lower Devonian black slates. Owing to the deep disintegration and debris of the basalt, the outcrops on the hill slopes are few, short and unsatisfactory, so that only the more general relations could be determined. The dike extends through the center of the hill and is a nearly vertical, irregularly lenticular mass varying from fifteen to twenty-five feet in thickness and bearing numerous small branches. It does not appear to have materially altered the enclosing shales, or disturbed their gentle dip except in the immediate vicinity of the dike. On the eastern side of the hill the contact is characterized by the presence of large masses of breccia, consisting of shale and sandstone fragments imbedded in basalt. The trend of the dike is SW. and NE., while the strike of Appalachian folds in this region is SSW. and NNE. At this locality the basalt was not found to extend beyond the area of the hill, but on the mountain slope, two miles westward, there is a dike of similar material penetrating the Silurian (Oneida-Medina) sandstone.

The next occurrence observed was on the west slope of Jack Mountain on the road to Doe Hill, Virginia, where an obscurely exposed dike penetrates the Silurian (Lower Helderberg-Niagara) limestones along a NE. and SW. line and in trend with the Monterey outcrops.

Three miles east of this exposure is another dike in a knoll two miles WSW. of Doe Hill, just north of the road to Jack Mountain. This dike forms a prominent outcrop over a small area, extending for a short distance across a Silurian-Devonian (Oriskany) sandstone and Silurian limestone belt with a width of about twenty feet. Its contact relations could not be determined.

Two other small outcrops were found, both in the southern part of Pendleton county, West Virginia. One is an obscure exposure in Lower Devonian slates, crossing the road two and a half miles due north of Doe Hill and the other a dike in Silurian limestones the same distance due NE. of Doe Hill near the road that extends NW. from Palo Alto.

The nearest known outcrops of other intrusives are the basalt dikes near Wier's Cave, 40 miles east, and those near Brooks' Gap, 5 miles NW. of Harrisonburg, Va., to which Mr. H. R. Geiger has called my attention. The nearest trap areas in the Trias, are 70 miles east.

Petrographic notes by J. S. Diller.

Four specimens collected by Mr. Darton at the localities mentioned above have been examined microscopically. One is of the contact breccia and the other three are of the dikes. All are of the holocrystalline porphyritic type of basalt and differ but little among themselves. The one from the west slope of Jack Mt. on the road to Doe Hill is the best type. The porphyritic crystals of olivine and augite in about equal numbers vary from 1 to 5 millimeters in diameter, and are sufficiently abundant to render the rock conspicuously porphyritic. The dense dark groundmass under the microscope is seen to be composed of plagioclase, augite and magnetite.

The porphyritic crystals of augite are of orange gray color, often with deeper colored brownish borders. The crystal faces are usually rough and jagged. In the groundmass the augite is irregular granular and that of the second generation is frequently clamped between the small feldspars. The olivine appears chiefly in porphyritic grains whose outlines suggest crystalline form. Small grains in the groundmass are less common. Like the augite it includes some magnetite, and furthermore a few crystals of a brown octahedral mineral supposed to be picotite. The plagioclase is scarcely as abundant as the augite. It is of a basic variety and the lath-shaped crystals are usually smaller than ·01×·05 millimeters. Magnetite in crystals and irregular grains is well represented both in the groundmass and as inclusions in other minerals, especially in the augite and olivine. An interesting feature is the occasional presence of small scales of biotite in the groundmass, in which respect it resembles the eruptives of the Triassic areas along the Atlantic slope.

The basalt from the hill a mile SSW. from Monterey differs slightly from the one already noted, being less porphyritic. No mica was discovered in its groundmass. The fragment from the dike of the knoll two miles WSW. of Doe's Hill looks in the hand specimen very like the one from the west slope of Jack Mt., but in thin section it is conspicuously different. Granular augite in the groundmass is much less distinct and opaque black grains became very abundant rendering the section much less transparent. The rocks, however, are all of the same type and their differences so slight that they very probably all belong to the same system.

A specimen collected by Mr. H. R. Geiger from a dike in limestone of the valley near Brook's Gap, 5 miles northwest of Harrisonburg, Va., is closely related in composition to those collected by Mr. Darton farther to the southwestward. It is holocrystalline but not porphyritic, and characterized by the structure which Judd has designated ophitic. The magnetite and granular olivine are much less abundant than the augite and the lath-shaped plagioclase. The locality last named is nearer the Triassic than those in the region of Monterey. At a point 3 miles south of Lovettsville, Loudon Co., Va., in the Blue Ridge district and nearer the Trias than any of the other localities, Mr. Geiger discovered another dike from which he collected a hand specimen that in every way resembles the Triassic eruptives. This similarity is fully borne out by a microscopic examination which shows the rock to be composed essentially of augite and plagioclase, and to have a regular ophitic structure like the majority of those within the Mesozoic belt.

It is well known that the eruptives associated with the Trias of the Atlantic slope from Massachusetts to North Carolina extend beyond the limits of that formation in Pennsylvania and several other States, but as yet it appears that comparatively little is known of their real distribution. Their wide extent and remarkable uniformity of composition offers an interesting field for investigation.

Petrographic Laboratory, U. S. G. S.,
Washington, D. C., Dec. 31, '89.

ART. XXXIV.—*Additional Notes on the Tyrolite from Utah;* by W. F. HILLEBRAND and E. S. DANA.

1. *Composition of Tyrolite*, by W. F. HILLEBRAND.

ON a former occasion* in discussing my own and Mr. Pearce's analyses of the mineral supposed to be tyrolite, I proceeded on the assumption that the SO_3 found by both of us should be excluded as probably derived from admixed gypsum. Since then I have made another analysis on material collected by myself at the Mammoth Mine, in September, 1888. So pure did the material appear to be that strong hopes were entertained of finally settling definitely the composition of the

* Notes on certain rare copper minerals from Utah, this Journal, III, xxxv, 300, 1888.

mineral. That these hopes were fallacious a comparison of the subjoined analysis with the earlier ones at once shows:

CuO	45·08
CaO	6·78
As_2O_5	28·52
H_2O	17·21
SO_3	2·23
Fe_2O_3	0·08
Insoluble	0·16
	100·06

The percentage of SO_3 is practically the same as formerly found (2·27 and 2·45 per cent). Under the microscope there appeared no foreign impurity approximating in any degree to 6·8 per cent of the whole mass, which would be the amount of gypsum represented by the SO_3 found. It therefore appears necessary to consider the latter as a proper constituent of the mineral, but the construction of a probable formula is not rendered thereby less difficult, and will not now be attempted.

A few words may properly be added in reference to the behavior of the mineral on drying over sulphuric acid and on heating. That the large amount of water given off to dry air is not altogether or probably even in large measure hygroscopic water, appears from the following table, which shows the loss sustained by 1 gram of the powdered mineral in a desiccator over sulphuric acid.

Hours exposed.	Loss.
18	·0231 gram.
26	·0083 "
23	·0029 "
24	·0012 "
23	·0008 "
24	·0001 "
25	·0003 "
24	·0002 "
24	·0003 "
48	·0006 "
24	·0002 "
283	·0380 "

Purely hygroscopic water would probably have been entirely removed from a mineral like this after a very few hours exposure. The table shows also that the element time may often play an important part in determinations of this kind. The experiment might reasonably have been considered ended after the 158th hour when a loss of but $\frac{1}{10}$ mg. was shown during 24 hours, but nevertheless a nearly steady loss of $\frac{3}{10}$ mg. per day took place for six days more, and might have been longer observed but for the interruption of the experiment. This may account for a marked discrepancy between the amount lost at 280° C. in a former experiment (l. c. p. 302)—10·34 per cent—and that observed in the present case at the same temperature—14·33 per cent. In the latter the drying and heating at continually rising temperatures had continued during a period of 528 hours, the weighings being made usually from day to day, whereas in the former case the duration of the experiment was much shorter and the intervals between weighings were but a few hours each.

2. *Crystalline form of Tyrolite*, by E. S. DANA.

Among the specimens of tyrolite recently received from Dr. Hillebrand, there are several which are crystallized with sufficient distinctness to allow of a somewhat more complete determination of the form than has hitherto been possible. The crystals are in thin tables or scales flattened parallel to the basal plane of cleavage, and they are united by one edge so as to form radiating fan shaped groups having a rounded and deeply striated exterior. Occasionally minute isolated crystals can be observed. These are seen under the microscope to be bounded by the pinacoidal edges parallel to which extinction takes place; further, the bisectrix is found to be sensibly normal to the tabular plane of cleavage, so that they can be referred to the orthorhombic system with little question. Besides the pinacoids, the crystals are bounded by two prisms, 110, and 120, the former having a normal angle in front of 86°, while the latter is inclined to 010 at an angle of 28°. From the first angle we calculate:

$$\breve{a} : \bar{b} = 0.9325; \quad 120 \wedge 010 = 28° \ 12'$$

No planes were observed which could fix the length of the vertical axis. The crystals are elongated parallel to the macroaxis and the optic axes lie in the brachydiagonal section, the bisectrix being normal to the base; the character of the double refraction is negative and the axial angle large.

ART. XXXV.—*The Origin of the Soda-Granite and Quartz-Keratophyre of Pigeon Point*; by W. S. BAYLEY.

(Published with the permission of the Director of the U. S Geological Survey.)

IN this Journal for January, 1889,* the writer described a red rock from Pigeon Point, Minnesota, with the characteristics sometimes of a soda granite, sometimes of a quartz-keratophyre. The first is a fine grained, drusy rock, speckled with little spots of a dark-green color. It is composed essentially of a hypidiomorphic granular aggregate of two feldspars, quartz, chlorite

* Jan., 1889, pp. 54–63.

and a few subordinate constituents. The second variety resembles quartz-porphyry. Well terminated quartz crystals and occasional brick-red and greenish white feldspars are scattered through a very fine grained, dark red or purple groundmass, whose major portion consists of a granophyric intergrowth of quartz and red feldspar. Both rocks exhibit in such a marked degree the features of igneous rocks that it was concluded, mainly on the evidence of their structure, that they were original eruptives, i. e., that they both solidified from a molten magma which was derived from some place within or beneath the earth's crust. In the article referred to it was stated that "All the field relations seem to point to the *original* character of the rocks. They occur in dikes and veins intersecting other rocks, and the contact between them and the quartzites which they cut is sometimes clearly seen. It must be confessed, however, that without microscopical and chemical evidence of the identity of these rocks with the quartz porphyry [of the Lake Superior region] their true nature would be difficult to discover from the field relations alone. A more careful examination of the structure of the point, will probably reveal facts which will place beyond doubt the conclusions reached by the microscopical examination."

Since the above was written a second visit to Pigeon Point has been made, but contrary to expectation the relations of the red rock to the gabbro and the quartzites, with both of which it is in contact, appear to contradict the above statements rather than to affirm them.

As indicated in a previous article* the rocks on the point comprise evenly bedded slates and quartzites, a large mass of olivine-gabbro, trap dikes cutting the gabbro and the bedded rocks, and a red granitic and porphyritic rock. The latter occur in large quantity only between the gabbro and a series of contact rocks, which have evidently resulted from the slates and quartzites by alteration. (See map, fig. 1.) The granular rock passes by imperceptible gradations on the one hand into the gabbro, and on the other into the quartzites. From the larger masses of the red rock dikes and veins extend into the members of the contact belt. In a few places large bodies of the same rock have been forced under the unaltered fragmentals and have thrown them into gentle folds. The red rock is found in largest quantity where the contact belt is widest, and is absent from those places in which there are no indications of a metamorphic action in the slates and quartzites.

On the other hand, there are several places on the point where the gabbro and the quartzites are separated by two or more members of the contact belt without the interposition of

* This Journal, May, 1888, p. 388.

any of the red rock. At the falls of Pigeon River, on the north side of the point at its extreme western end, a large mass of gabbro has cut through slates and quartzites and has altered them in a manner somewhat analogous to the alteration of similar rocks by granite and other plutonic rocks.

At other places, notably on the north side of the point, the gabbro and fragmental rocks are in contact without the least trace of any alteration in the latter.

From the relations of the gabbro, the red rock and the contact belt, it is plain that either the gabbro or the red rock is the cause of the contact belt. If the latter, the red rock is a true irruptive; if the former the red rock is either an irruptive between the metamorphosing agent and the products of its action, or is itself one of these products.

It is the object of the present note to point out the reasons that lead the writer to the conclusion that the red rock is of contact origin, that it has been produced by the action of the gabbro upon the slates and quartzites. At first glance it would appear that the evidence is strongly in favor of the red rock as the cause of contact phenomena. This view is apparently favored by the fact that the gabbro has produced no very great alteration in the surrounding sedimentary beds in those localities where no traces of the occurrence of the red rock can be found. It has not affected the bedded rocks on the north side of the point, nor are immense dikes of a similar rock known to have produced any change in the slates and quartzites at other points along the north shore of Lake Superior. If, however, we examine these facts critically it will be found that they do not exclude the possibility of a secondary origin for the red rock, or of the active agency of the Pigeon Point gabbro in promoting the metamorphism of the elastic beds.

The existence of the keratophyre in dikes and veins in the contiguous slates and quartzites show conclusively that it once existed in a plastic condition. Its structure indicates that it once existed as a molten magma, or in such other condition as would allow of its complete crystallization, unless we assume with Wadsworth* and Judd† that the porphyritic and granophyric structures may arise from secondary causes. The impregnation of the contact rocks by the material of the red rock is further evidence that this was once in a liquid state.

If we assume the original molten or liquid condition of the red rock, as it seems we are perfectly justified in doing, all of its present characteristics are explained, whether it be regarded as an extraneous igneous rock or whether it be considered as a final product of contact action. In either case its most charac-

* Geol. and Nat. Hist. Surv. of Minn., Bull. No. 2, pp. 12 and 68.
† Quart. Jour. Geol. Soc., May, 1889, pp. 175–178.

teristic features would be those of a plutonic rock, since the conditions under which it solidified (as shown by the nature of the contact phenomena) are those that give rise to the distinctive features of plutonic rocks. The porphyritic structure noted in a few places must be due to local conditions that prevailed only at a few localities. Under this assumption are explained the intrusion of the keratophyre into the slates, the crumpling of the latter and the alterations effected in those near the sides of dykes of the former, and in fragments included within its mass.

The distribution of the red rock, its occurrence only between the gabbro and the altered quartzite, is the strongest argument in favor of its secondary origin. A glance at the map will

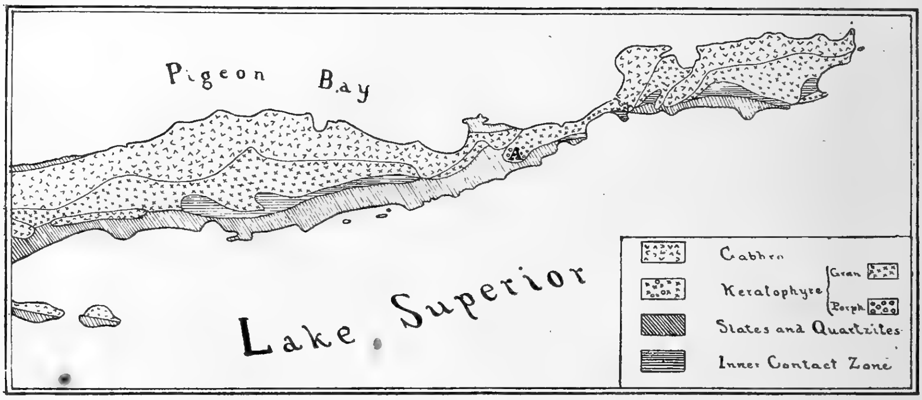


FIG. 1.—Geological Sketch Map of Pigeon Point. Scale 1 in. = about $1\frac{1}{4}$ miles.

show that the red rock occurs only in areas lying between the gabbro and the members of the contact belt.* At no other places is it found, except in the form of dikes directly connected with the larger masses of the rock. If it can be shown that the contact rocks owe their origin to the presence of the gabbro near them, it will follow as a natural probability that the red rock is likewise of contact origin. Whereever it exists there is on one side of it the gabbro and on the other side two or more members of the contact belt. Its position is that of a member of the contact belt. It follows the sinuosities of the gabbro as no irruptive rock would be likely to do, and is present in greater or less amount according as the contact belt beyond it exhibits contact phenomena in greater or less degree. Where this contact action has been most intense there is found the greatest amount of the red rock; where the action has been less in degree the amount of

* In consequence of the small scale upon which the map is drawn only the zone of most intense alteration is represented on it. The outer zones of the contact belt extend along the entire southern edge of the gabbro and the red rock, throughout all that portion of the point represented in the map.

the red rock decreases until finally none is present. However, when the red rock is wholly absent contact action is yet often marked. One or even more of the contact zones may be present, but that which indicates the most intense action has disappeared. It is plain, then, that the red rock as an independent irruptive is inadequate to explain the whole of the contact belt. On the other hand, the phenomena of distribution of the various rocks are such as would be expected were the gabbro the cause of the existence of the red rock and the contact zone. If the red rock is a result of contact action we should expect to find it between the gabbro and the outer members of the contact belt—in greatest quantity where the other contact effects are best exhibited, and in small quantity where the other contact products are scant in amount. Where the effect of the metamorphosing rock upon the quartzites is very slight, the red rock should be absent.

The great differences in the intensity of the action of the gabbro upon the surrounding bedded rocks may be readily explained by supposing that the orifices through which the rock was extruded were situated at those places where the contact belt is widest, and the red rock is present in greatest amount. In the neighborhood of these orifices, the intruded rocks would have been subjected to the influences of the presence of a molten mass near them for a considerable length of time. Where the contact products are not abundant, the molten gabbro may have escaped from its channel and thrust itself between contiguous beds of the clastic rocks, as is known to be the case in several of the localities where the contact effects are slight.

The presence of a contact belt around the gabbro on Pigeon Point, while it is absent, in most cases at least, from around the dikes of a similar rock abundant in other portions of the Lake Superior region, needs explanation if the view that this rock is the cause of the contact belt in the former locality is to be accepted. It may readily be accounted for by the fact that, whereas, the gabbro along the north shore of the lake is in the form of simple dikes, the rock on Pigeon Point possesses many of the characteristics of a boss.*

That the gabbro upon the point is fully capable of producing contact effects is plainly shown by the existence of contact phenomena at the falls of Pigeon River, and at other places where there is no indication of the presence of the red rock in the vicinity.

The effect of the gabbro upon the quartzites and slates of the point can be studied directly in the inclusions of the latter

* Cf. N. H. Winchell, Ninth Ann. Rep. Geol. and Nat. Hist. Survey of Minnesota, p. 63.

rocks in the former. In those portions of the contact belt nearest the gabbro (indicated on the map by horizontal lining), more particularly in the western portion of the point, there is a band of breccia of varying width. This consists of a cement of gabbro, or of one of the most basic of the intermediate rocks (a mixture of gabbro and red rock),* holding numerous inclusions of slate and quartzite. The slate fragments in this breccia have been altered like the slates in the innermost contact zone. The fragments of quartzite are fringed by a rim which is exactly like the material of the keratophyre. One fragment that shows this red border most beautifully is a rhomboidal block of pink quartzite, about seven feet in length and four feet wide. Surrounding it is a bright red border some two and a half or three inches in width. In the thin section the material of this border is observed to have the granophyric structure of the red rock. Fan-like groups of feldspar and quartz extend perpendicularly from the bounding planes of the inclusions. Since this rim is probably the result of the fusion of the peripheral portion of the fragment by the surrounding rock, and its structure and mineralogical composition are identical with these of the red rock, it may fairly be concluded in the absence of any evidence to the contrary, that the red rock itself has been produced in the same way by the fusion of the quartzites (and slates) by the gabbro.

Moreover, if the red rock is a fused sedimentary, there should be intermediate stages in the transition from a clastic rock to a crystalline one. The red quartzites of the inner contact belt have a structure that can be explained by supposing them to be quartzites whose interstitial feldspathic and chloritic substance has been fused, or by regarding them as fragmental rocks into which the liquid magma of the red rock has been squeezed by pressure. In either case the porphyritic and irregularly outlined quartz crystals so commonly found in these rocks are probably the corroded remains of the original grains of the quartzite. On the top of the porphyry bluff, whose position is indicated on the accompanying map (A), the porphyritic red rock is abundant on the west side of the cliff. As we proceed eastward mottlings are discovered in it that resemble the mottlings characteristic of certain zones of the contact belt. On the extreme eastern side the prevailing rock is an altered red quartzite. No line of demarkation can anywhere be discovered between the different types.

Although these gradations may not serve to prove positively that the quartzites by fusion gradually pass into the red rock, the almost universal presence of transitional phases between the red rock and the altered quartzites in those places where

* This Journal, Jan., 1889, p. 58.

the red rock is present, taken together with the fact that contact rocks are found in positions where they cannot have been produced by the action of the keratophyre, seems to point to this conclusion as the most probable one.

From the evidence at hand it would appear that the red rock is a product of contact action between the gabbro and the bedded rocks, rather than an independent irruptive that has altered the slates and quartzites. No conclusive evidence bearing upon the question is available, but if the assumption of the secondary origin of the red rock is made, all the facts observed with reference to the distribution of the rocks on the point are readily explained; not a single one but is in accord with this supposition. On the other hand, if the red rock is assumed as the metamorphosing agent, there remain to be explained the contact phenomena around the gabbro in those places where the red rock is absent, and the peculiar distribution of this rock. The view that the gabbro is the cause of the alteration of the slates and quartzites, and the red rock is an independent irruptive between the former and the latter, meets with the same objection as does the supposition that the red rock is the cause of the contact belt. The presence of the red rock only between the gabbro and the contact rocks, and in great quantity only when the contact phenomena in the adjacent quartzite evince intense action, is a mode of distribution for an independent irruptive rock, which, to say the least, is peculiar. Since, therefore, objections can be raised to any view that regards the keratophyre as an original irruptive, and since, on the other hand, every fact observed, either with reference to the gabbro or to the red rock, accords with the assumption that the latter is a product of contact action, and none can be found that contradict this supposition, it would seem gratuitous to regard the red rock as having originated in any way but by the fusion by the gabbro of the fragmental rocks that lie upon one side of it. The latter are slates and quartzites, many of which are highly feldspathic. Chemical analyses of these show them to have a composition not very different from that of the red rock itself.

It is hardly necessary to refer to the important bearing of the above conclusion upon the discussion of the origin of igneous rocks. The general view with regard to these is that they have reached the surface from some permanent or temporary reservoir of molten material below the earth's crust. On the other hand, many geologists hold to the belief that some of the igneous rocks have resulted by the metamorphism of sedimentary beds. Granite for instance is regarded as a metamorphosed sandstone. The only basis upon which this conclusion rests is the supposed gradation of gneiss into granite.

No positive evidence of the change of a fragmental into a holocrystalline rock, with the characteristics of an igneous one, is available, except, perhaps, where the former have been affected by dynamo-metamorphism and have been squeezed into the surrounding massive and stratified rocks.*

The red rock of Pigeon Point, however, has a thoroughly crystalline structure throughout its greater part. It occurs as dikes, bending and crumpling beds of other rocks beneath which it has been thrust, and in every other respect acts exactly like the most typical igneous rock. If its origin is indeed secondary, we have in it the first instance in which a fragmental rock can be traced into its corresponding holocrystalline derivative, and we can explain the change without the interposition of the indefinite "metamorphic processes," that are relied upon to explain so many of the difficult problems that arise in the study of rocks.

A detailed description of the rocks of the contact belt and a fuller discussion of the origin of the red rock associated with them, will appear in a forthcoming Bulletin of the U. S. Geological Survey.

Geological Laboratory of Colby University, Dec. 24, 1889.

ART. XXXVI.—*Recent Contributions to Dynamical Meteorology;* by FRANK WALDO.

IN the American Meteorological Journal for July, 1887, I have mentioned the most important papers that had appeared, up to 1886, on the subject of Dynamical Meteorology. Since then a number of important additions have been made to the literature of the subject, and it is of these that I propose to make a brief mention. While in the above mentioned article there were given only a very few of the three-score papers comprising the whole literature of the subject, in the present list, all of the important very recent papers that have come to my notice are catalogued. Copies of most of these papers were received, from the authors, shortly after their publication, and it was my intention to translate the shorter ones for republication in American journals (as a continuation of the still unprinted Signal Service translations of the Guldberg and Mohn, Oberbeck and Sprung papers), but the information that some of these recent memoirs had already been translated made such a work unnecessary. As, however, not all of the papers in my list will be published in translation, the following remarks may be found of use: and especially to those readers who may be interested in the development of meteoro-

* Reusch: Bommeløen og Karmøen med omgivelser geologisk beskrevne. Kristiania, 1888.

logical theories, but who have not been able to keep informed concerning the appearance of new foreign articles on the subject. As there are so many papers to be mentioned, I have merely endeavored to give a general idea of the nature of each one, and have indicated the attitude of the writers toward meteorology by a slight reference to other work done in this same direction. If I had attempted to give an account of the methods and results of each one, not more than two, or possibly three, of the fourteen papers mentioned here could have been reviewed within the limits of this article; and that would not have shown so clearly as I wished to bring out, the renewal of interest which is taking place concerning progress in the theoretical development of meteorology. Special attention is called to the lack of interest shown on this subject by English and American physicists; at least if we are to judge of the interest by the number of contributions relating to it.

1. Werner Siemens, Ueber die Erhaltung der Kraft im Luftmeere der Erde, Sitzungsberichte d. k. preuss. Akad. d. Wissenschaften, 1886, xiii, (4 März.) 15 pages.
2. Max Möller, Ueber Verluste an äusserer Energie bei der Bewegung der Luft, Meteorologische Zeitschrift. Sept., 1887, 6 pages.
3. Werner Siemens, Zur Frage Luftströmung, Meteor. Zeit. Dec. 1887, 4 pages.
4. Diro Kitao, Beiträge zur Theorie der Bewegung der Erdatmosphäre u. d. Wirbelstürme, Journal of the College of Science, Japan, vol. i, Part II. Tokio, 1887, 96 pages in I Abhandlung.
5. Same title, same journal, vol. ii, 75 pages in II Abhandlung.
6. A. Oberbeck, Ueber die Bewegungserscheinungen der Atmosphäre, Sitzungsberichte d. k. preuss., Akad. d Wissenschaften, Part I, März. 15, 1888 (No. xiv) 13 pages.
7. Part II. Same title, Nov. 8, 1888 (No. xliii), 10 pages, with corrections to Part I.
8. A. Oberbeck, Ueber die Bewegungserscheinungen der Atmosphäre, Naturwissenschaftlichen Rundschau, 1888, 13 pages. (Reprint. Meteor. Zeit. Aug., 1888).
9. H. von Helmholtz, Ueber atmosphärische Bewegungen—Sitzungsberichte d. k. preuss., Akad. d. Wissensch, May 31, 1888. (Reprinted Meteor. Zeit. Sept., 1888, 12 pages).
10. Max Möller, Der Kreislauf der atmosphärischen Luft zwischen hohen und niederen Breiten, die Druckvertheilung und mittlere Windrichtung, aus dem Archiv der Deutschen Seewarte, X Jahrgang, 1887. No. 3, 28 pages.
11. Dr. Vettin, Ueber die Volumina der in die barometrischen Minima und Maxima hinein, und aus denselben herausstromenden Luft, aus dem Archiv der Deutschen Seewarte—XI Jahrgang, 1888. No. 5, 24 pages.

12. Wilhelm von Bezold, Zur Thermodynamik der Atmosphäre Theil I. Sitz. der k. preuss. Akad. d. Wissenschaften, April 26, 1888. (No. xxi). 38 pages.
13. Theil II. Same title. Nov. 22, 1888. (No. xlvi). 18 pages. (Theil I and Theil II reprinted in the Meteor. Zeit. Jun., Jul., Aug., 1889.)
14. William Ferrel, A Popular Treatise on the Winds; New York, 1889, 505 pages.

No. 1.—Meteorologists are very attentive to the ideas put forth by those physicists who have made a world-wide reputation in some other branch of study, and who have at last turned their attention to those branches of meteorology which need the clear insight of genius added to rare knowledge of physics to investigate them if any satisfactory conclusions are to be attained. It is under these conditions that we welcome Siemens's contribution to that branch of dynamical meteorology which on account of the difficulties of treatment has been one of the least satisfactory. Recognizing the solar energy as the initial cause of the great atmospheric motions, the author applying the principles of rotation velocity and *living force,* by methods more nearly represented by the conception of the potential of force, reaches conclusions that are in the main coincident with those found by Professor Ferrel in his studies of thirty years ago. The physical conditions which give rise to various special phenomena of rainfall have been treated in a general way in explanation of such features as the rainfall in the temperate zones. It seems that Siemens has given his views without having made himself thoroughly acquainted with the results already obtained by previous workers in this same field, and that he was not familiar with many of the points stated by Sprung in the excellent summary given in his Lehrbuch. As it is, some of the ideas which the author advances as novel have already been more or less satisfactorily treated by others. Still, such questions as the origin and maintenance of barometric maxima and minima, and the mechanics of spout phenomena, need further treatment, and every new view, if based on accepted principles, is a help toward the final discovery of the actual truth, which cannot be said to be reached at the present time.

No. 2.—The paper of Siemens just mentioned called forth this short, but practically important communication from Max Müller. (Mr. Müller is a young engineer of Hamburg who has written several very suggestive semi-popular papers on the mechanics of the lesser atmospheric motions, and which have shown an unusual grasp of the subject). In the present paper the author calls attention to the important factor which the loss of living force by friction of the air in contact with the rough earth may become in the formation of the atmospheric motions. The frictional influence of rough ground is more or less pronounced according to the peculiarities of the air currents; whether they are ascending, descending, or horizontal. The author investigates this action in some general types of circulation. He contrasts the peculiarities of two continental atmospheric depressions; in the one an upward current preponderates, while in the other a downward current is the ruling one. In the first case, the one in which the depression has a warm center and an upward current, the relatively quiet air near the surface of the earth carries with it no great force and in fact has a retarding influence on the upper currents; and in the second case, where the depression has a cold center and there is a downward current, the feeding current easily acquires a great velocity. These two conditions cause very different results, and the author brings out these differences. It must be remembered that Ferrel first pointed out that at the poles there is a depression of the second class, and that the great movements of the masses of air to the eastward in middle latitudes are but a part of this great system. The author, however, thinks that Ferrel has not sufficiently considered the effects of friction, and he modifies Ferrel's numerical results so much that in some cases he reverses the latter. Treating of the mixing of air masses having different velocities the author does not agree with the results obtained by Siemens in No. 1. He thinks that the transmission of force does not take place according to the law of preservation of living force, when we wish to compute the resulting velocity, but it follows the law of inelastic impacts. This he proceeds to illustrate by a short computation.

No. 3.—This article was called out by Möller's strictures in No. 2 against Siemens's methods in No. 1. Siemens thinks that Möller's conceptions are wrong as to the waste of force by friction, and assumes that the layers of air close to the earth are in relative rest, and the thickness of this layer depends on the roughness of the surface; while the upper air layers are practically free from these frictional influences. As regards the mixing of currents having different velocities, Siemens shows that his assumption concerning this question does not affect his general results; and as for Möller's use of the theory of inelastic impacts, he merely remarks that the necessities of the question do not call for its consideration. Siemens regards the coincidence between his and Ferrel's views of the atmospheric motion in the neighborhood of the 35th parallel as accidental, as Ferrel has not considered the inertia or the friction, while he (Siemens) has taken into consideration by computation the final condition of equilibrium. Siemens thinks that an important reason for the incompleteness of Dove's theory was that the doctrine of the conservation of force had not then been established. The author then proceeds to account for the low pressure at the poles, and also the formation of "maxima" and "minima" and other local differences of air pressure.

No. 4 and *No. 5.*—Dr. Kitao, the author of these two papers, which are really a single memoir published in two parts, is professor of physics and mathematics in the Imperial Academy of Forestry and Agriculture at Tokio. I have not been able to obtain a copy of No 4 (Part I.), and can therefore, give only a surmise as to the value of this portion, basing my views on an examination of No. 5 (Part II.). It was with curiosity, which however rapidly changed to surprise and admiration, that I took up this paper. Coming as it does from a Japanese, whose name had not been previously connected with meteorology (so far as I am aware), this paper, treating of the most difficult branch of meteorology in such a manner as to place it in the front rank among those in which the principles of mechanics are applied to the motions of the atmosphere, should receive the careful attention which it deserves. The method of reasoning adopted by the author is one that would naturally commend itself to a mathematical scholar who had mastered modern methods of hydrodynamical analysis, such as is to be found in the works of Thomson and Tait, and a few Continental text books. While I am not prepared to enter into details as to my reasons for thinking so, yet it appears to me that although this paper is probably of great theoretical value, and it will be found very suggestive to the student of meteorology, yet its full practical value has yet to be shown. As a logical mathematical development of the general theory of the motions of an atmosphere it is certainly a remarkable chain of reasoning. In No. 5 (Part II.) no mention is made of what has been done by other investigators in the same field, and in fact the author seems to have worked out the whole matter for himself. The methods of analysis certainly show great originality of conception and adaptation, and it is to be hoped that the whole paper will soon be republished in some form accessible to a wide circle of students. Unfortunately, however, so far not even a review of the work has been given to meteorologists. The divisions of No. 5 are as follows: Chapter VIII, Regions of whirls for straight-lined isobars; chapter IX, plurality of whirl formations in the earth's atmosphere; chapter X, motions of the region of whirls itself; chapter XI, change in the wind direction, wind force and the air pressure, for a given exterior point for a double formation of whirls. There is space here only to mention one or two of the results obtained by the author. He finds, for example, that "if two cyclones are formed in the atmosphere they will mutually approach each other, since they rotate in a cyclonal direction about a definite point at rest; while two anti-cyclones on the contrary separate, as they rotate in an anti-cyclonal direction about a definite point." In the last chapter are numerous conclusions that will be of great value if they can be found to hold good in the actual conditions of the atmosphere. (I hope to give an extended review of this whole memoir when I can secure a copy of the first portion.—F. W.).

No. 6.—Professor A. Oberbeck has rendered important service to several branches of physics. His papers on electricity, fluid motion (and other conditions of fluids), and atmospheric mechanics, are all in the front rank of such investigations. In 1882, Prof. Oberbeck published a very important paper in Wiedmann's Annalen with the title, "Ueber die Bewegungen der Luft an der Erdoberfläche," but I think he had not published any other important paper on meteorology until the present contribution appeared; the author, in the meantime, having gone from the university of Halle to that at Griefswald.

In the present paper the author refers to the progress that has been made in the study of atmospheric mechanics during the past ten years, and remarks that although some special points have been satisfactorily treated, as is shown by the excellent résumé given in the *Lehrbuch der Meteorologie*, written by Dr. A. Sprung, yet no complete theory can be deduced until we have a better knowledge of the upper air currents. He says, however, that "The outlines of a rational mechanics of the atmosphere are given in the paper of W. Siemens, "Die Erhaltung der Kräfte in Luftmeere der Erde," (which is No. 1, of the memoirs we are now considering), and thinks it would be well to give a further mathematical development of the theory outlined in that brief paper. On account of the great difficulties to be encountered in any general solution of the problem with all the secondary phenomena, the author limits himself to the computation of the air currents, to the exclusion of such questions as "pressure," distribution, etc. A statement is then made of the various causes of atmospheric motions: temperature, influence of the earth's rotation, friction. Concerning this last, he says that the theories that have heretofore taken into account the friction have not been properly constructed, and that according to his view the law of friction for atmospheric currents is the same as has been developed for fluid motions, *but* the laboratory numerical coefficients cannot be applied without great modification, according to the different conditions to be found in the actual atmosphere. The author's views of the limiting conditions that must be made in the statement of the hydrodynamics of the problem are of the utmost importance. The suggestions concerning the representation of the temperature distribution by means of spherical functions (this was beautifully worked out by Schoch about 1856) should receive the careful consideration of students of meteorology. At the end of the paper is given a general outline of: 1, currents in the case of a spherical earth without rotation; 2, currents arising in consequence of the rotation of the earth.

No. 7.—This is a continuation of the previous paper. In the latter the "pressure" distribution was not considered except incidentally. In this paper he takes up this question and comes to the conclusion that the existing pressure distribution is fully explained by the currents of the atmosphere, and that from the observed values of the pressure, we can draw conclusions as to the intensity of the air currents.

The author then deduces a general view of the pressure distribution at the earth's surface and in elevated regions. The intensity of the rotation currents, both at the earth's surface and up above, is next considered; and this necessitates the introduction of the equation of continuity which plays an important part in the analysis which follows. After stating a formula which represents, with tolerable accuracy, the change of air pressure (at the earth's surface) with the latitude, the author proceeds to calculate the angular velocity of the rotational motion of the air, by means of the formulæ developed by him. After drawing some general conclusions in regard to the actual circulation of the atmosphere, and in which the vertical components receive special attention, the author closes with some most important suggestions concerning the lines for future investigations on this same subject.

No. 8.—This paper is stated by the author to be a popular account of No. 6, and which he prepared at the request of the editor of the "Rundschau." In attempting to make the matter clear, he has entered into such details (which he evidently considered unnecessary in No. 6) that the present paper can hardly be called an abstract of a former one, but must be considered a separate contribution. He has given a short summary of what other workers have done toward creating an atmospheric mechanics, and his ideas deserve special consideration coming as they do from one of the most skillful of the present contributors to the science of mathematical physics. Recognizing that Ferrel was the first to give even an approximate solution of the problem of atmospheric circulation, he goes on to criticize in some respects the method employed as compared with the more finished analysis of the present ideas of fluid and vortex motion. The works of Guldberg and Mohn are also referred to: the author also calling special attention to the estimate Sprung has given, in his "Lehrbuch," of these writers, and particularly of Ferrel's work. Next he gives an outline of the methods used in his own paper (No. 6) and explains with greater clearness the part friction plays in the whole matter of fluid motion. Finally, he gives a rough chart, on the Mercator's projection, of the air currents for the lower layers as deduced by his theory.

No. 9.—Professor von Helmholtz, who has done so much for the advancement of other branches of physics, has at last given some attention to a problem in every way worthy of his consideration, viz: Atmospheric motions. The author's well known investigations on fluid motion have been used as a basis for other contributors to work from, but I believe he has himself published only one other paper, and that of a popular nature, which deals with a specially meteorological topic.

In the present paper the author treats: § 1, The influence of friction on the great circulations of the atmosphere; § 2, Rings of atmosphere having different temperatures and rotation due to the equilibrium; § 3,* Adjacent layers in equilibrium, and having different values of ϑ and Ω; § 4, Gradual changes of equilibrium through friction and warming up.

By aid of the potential, the author derives the equations of fluid motions taking into consideration the friction. The integration of these equations cannot be accomplished until certain constants have been determined. A very neat comparison is made of the two methods of determining the friction constant, viz: in the laboratory, and in nature. There are not data for the latter for high elevations but some valuable ideas are given, which the theory shows must hold good. These relate to change of friction with distance from the ground, differences of pressure and differences of temperature. The author then applies his reasoning to several rings of atmosphere encircling the globe at various latitudes, but finds that other influences must be considered, before the observed facts can be explained. In § 2, the method of determination of the calm belt, toward which the "pressure" increases both from the pole and from the equator, is of great importance. In § 3, the conditions of equilibrium, as determined by the heat capacity of the different layers, are worked out in a very general way; and the form of the layers is shown for various cases. The position is also given of the layers in the case of continual change of the velocity of rotation with the heat capacity. The § 4 contains

* ϑ is the temperature of the air under pressure p_0. Ω is the moment of rotation (which remains constant under certain assumed conditions).

the most practical ideas of the paper, and the author calls attention to several points that will receive the consideration of even the non-mathematical meteorologist. The manner in which the air is gradually warmed up by convection is briefly described, and the effects of a warm layer above (as well as below) are pointed out. The modifying effects of friction where layers of different velocities are mixed are examined; and many of the observed facts connected with the general circulation are briefly accounted for. Special attention is also called to the application of the theory of discontinuous fluid motion which was elaborated by the author in the paper presented to the Berlin Academy in 1868. The importance of the application of these ideas to meteorology has been repeatedly pointed out by several meteorologists, but the advice has been little heeded because it is so difficult a question to handle. The author promises a further treatment of the subject, which will be eagerly watched for.

No. 10.—This is by far the most elaborate contribution Mr. Möller has made to meteorological science, and as it is the result of seven or eight years of study of the questions considered, it deserves a careful reading. The following headings of sections show the great number of special topics treated: Introduction (in which he shows the difficulties in the way of the satisfactory application of general theories like Ferrel's); 1. The deviatory force of the earth's rotation; 2. The surfaces of equal pressure, and the horizontal differences of temperature; 3. The location of the surfaces of equal pressure in the earth's atmosphere; 4. Ferrel's explanation of the cause of a maintenance of steep inclination of surfaces of equal pressure in the temperate and cold zones of the earth's atmosphere; 5. Ferrel's computations; 6. The performance of the work produced by the differences of temperature in the atmosphere; 7. The facts concerning the existing air circulation; *a.* The air circulation of the hot zone in general; *b.* Representation of the air circulation in the hot zone, based on numerical calculations; *c.* The belt of the higher pressure; *d.* The air circulation in the temperate zone for the year, also in the Arctic zone in summer; *e.* Phenomena of changing motions in the atmosphere; *f.* The calm zones at the equator; *g.* The Arctic zone in winter; *h.* The amount of work performed in different upper air layers; *i.* Combination of the results, 8. Closing remarks. Illustrations. A postscript of three pages contains some items omitted from the main paper and also some remarks on Ferrel's and Oberbeck's recent works.

While most of the papers by the writers mentioned in this review have been analytical in character, the present one is synthetical, and the author has necessarily been obliged to give strict attention to the actual facts as observed in nature. He is particularly gratified to find an agreement between some of his views and those given by Oberbeck.

Sections 2, 3 and 6 are of special importance as the topics treated therein are seldom written about. Section 7 presents the author's ideas of the general circulation; and the main interest in the paper, so far as actual results are concerned, will be found centered in this section. The chart of a vertical section of the atmosphere (in the plane of the meridian) in the region of the equator, and extending to a height of 25,000 meters above the sea level, shows with great clearness the author's ideas concerning the circulation in these important regions.

No. 11.—Dr. Vettin of Berlin has long been a special observer of the motions of the atmosphere in the upper layers. As a cloud observer he deserves to rank with Clement Ley, the English observer of whom it is said, he devotes one-third of his entire time to observing the aspects of the clouds. Until the quite recent trigonometrical determinations of cloud elevations and velocities, the long series of observations on the apparent velocities of clouds and their vertical distribution, was the most important carried on by any single observer. The results of these observations have been published in the Österr. Zeits. für Meteorologie, and together with the results of some most interesting experiments relative to the motions of air in a confined space, form the principal earlier meteorological contributions by the author. The present paper is a continuation of some later work published in the Meteor. Zeitsch. in 1887, and while he gives a résumé of his methods of observation and the cloud formations and projected velocities for various elevations as found by him, yet he devotes most of the paper to the consideration of the very important question of the amount of air actually taking part in the in and out flow which takes place in barometric minima and maxima. Very complete tables are given, for summer and winter, in which the sums of the wind velocities as shown by the upper cirrus, the lower cirrus, cloudlets, the rounded clouds, the lower layer of clouds and the wind (anemometrically observed), are given for the 8 octants of both maxima and minima. The same is then presented for the volumes of air (i. e. the product of the times into the velocities). Then follow tables giving these results classified as inflowing or outflowing air. Of special importance are the author's computation of the elevation of the regions of the inflow and outflow of air. This having been previously (so far as I am aware) been made a matter of quite arbitrary assumption in the theoretical considerations made by various writers. The final pages of the paper are given up to a statement of the author's views as to what effect the shifting of the "cold" pole has on the oscillations of the greater currents. A set of 57 diagrams illustrates in a very acceptable manner, the results found by the author.

No. 12.—Professor von Bezold occupies the chair of meteorology at the University of Berlin, and he gives promise of elevating the Prussian Meteorological Institution to as high a rank among the great national meteorological services as that of the Bavarian Institution among the smaller ones of similar aims. Aside from his officially published papers, he has not printed many memoirs on meteorological topics, but those he has given us are of real value.

In the present paper there is considered a question of meteorological physics that is of the very highest importance in connection with the theories of storms, and of the greater cyclonic and anticyclonic atmospheric movements. A number of writers have treated the question of the application of the mechanical theory of heat to atmospheric events, but in nearly every case only such points have been considered as do not take into account the addition or loss of heat during the expansion or compression. Such treatments of the convective equilibrium of the atmosphere, the unstable equilibrium in the case of tornadoes, and the foehn phenomena, have been made on the supposition of adiabatic changes of condition. The author thinks that the method of research which we owe to Clapeyron and Carnot, and which has been so fruitful in the application of the mechanical theory of heat to the study of machines, should likewise be introduced into meteorological analysis.

Hertz, in a paper in the Met. Zeits. 1884, has made a good beginning in the direction in which the author leads us, but he has considered only special cases; and while his application of the graphical method simplifies the question very much, yet it does not take the place of the more general analysis when the wide application of the principle is to be considered. Sprung, also, in his "Lehrbuch" lays stress on the ideas given in Hertz's paper. In the present paper the author explains at length that the cooling and warming up in the case of ascending and descending currents in the atmosphere are to be considered only as a result of the work of expansion and compression, but not the work, which is used in raising the air, and is obtained by the falling, when rising and falling masses did not always belong to a system. The work of expansion and compression must not be omitted from the calculations, as has been done in the computations of Guldburg and Mohn.

The "equations of mixture" are then determined for the four atmospheric stadia, viz: dry stratum, rain stratum, hail stratum, and snow stratum. Then the equations of the characteristic curves are deduced. These are the isothermic, adiabatic, and curves of constant amount of saturation. A short application is then made to the "foehn," and the interchange of air between cyclones and anticyclones in summer.

(There is a considerable literature treating of the matter of convective equilibrium, but I cannot make special mention of it here. I will only mention that in Maxwell's elementary "Theory of Heat" (1880) there is to be found a popular explanation of several important points in this connection.—F. W.)

No. 13.—While this paper is in one sense a continuation of the preceding, yet the introduction of new conceptions, the chief one of which is what Helmholtz has termed "Wärmegehalt," but which, after considering the objections made by von Bezold to this nomenclature, he now prefers to call "potentielle Temperatur." This potential temperature is that absolute temperature which a body assumes when it is brought under the normal pressure without gain or loss of heat—adiabatically or pseudoadiabatically. The graphical determination of potential temperature corresponding to any given condition is very neatly worked out for the dry stadium. In the case of condensation the potential temperature rises and becomes the greater the larger the amount of water lost out. Also "adiabatic changes of condition in the free atmosphere—excluding, however, evaporation—leave the potential temperature either unchanged or they elevate it." The author calls attention to the similarity between this and the theorem of Clausius concerning entropy.

The next section treats of the vertical temperature gradients, and the author emphasizes the fact that the thermodynamic cooling and heating in consequence of the expansion or compression in ascending or descending currents plays a most important part in the vertical motions of the atmosphere. So long as we consider the free atmosphere in which there is little opportunity for the absorption or emission of heat and where only approximate results are expected, we may consider only the adiabatic conditions; but in the neighborhood of the ground and in the regions of cloud or fog the conditions are such that this method is no longer satisfactory.

The author illustrates by a diagram what he calls his "normal plan" of ascending and descending currents; and in it he shows the relation of the ascending current in the dry stadium, its continuation in the stadium of condensation, and finally the curve corresponding to the descending current. The application then shows the practical application to the interchange of air between cyclonic and anti-cyclonic systems, and some more special cases; next follow over half a dozen pages giving the application of the idea of potential temperature to various states of the atmosphere, the deductions of some theorems, and some instances of their use. These theorems are sure to be of the greatest service in perfecting a theory of the vertical interchange of air masses. A couple of pages also are devoted to the subject of compound convection. The author closes with some remarks on the importance of these ideas to any future development of the subject; and he makes some corrections to his first paper (No. 12).

No. 14.—Professor Ferrel's contributions to meteorology are too well known to the readers of this journal to require cataloguing. His book on "Recent Advances in Meteorology," published as Part II of the Chief Signal Officer's Ann. Report for 1885, contains for the most part a connected statement of the results of his meteorological labors during a period of about thirty years. This work was most acceptable to students of meteorology because it gave in a single volume results of the authors researches and the methods by which they were reached, and in addition gave explanations of some points not usually touched on in meteorological treatises.

In the early part of 1886 Professor Ferrel gave a series of forty lectures before a class of Signal Service officers at Washington, and this was the first and only time (so far as I am aware) that he has given a personal systematic explanation of his theories. Recognizing the value of these lectures the Signal Service authorities, I believe, made an unsuccessful attempt to have them written down by a stenographer. A number of Professor Ferrel's friends urged upon him the importance of his giving the substance of these lectures to a wide circle, and in compliance with their requests he prepared the present volume. The contents of the volume are shown by the following chapter headings: I. The constitution and nature of the atmosphere; II. The motions of bodies relative to the earth's surface; III. The general circulation of the atmosphere; IV. Climatic influences of the general circulation; V. Monsoons, and land-and-sea-breezes; VI. Cyclones; VII. Tornadoes; VIII. Thunder storms. Taken as a whole the work gives a connected logical explanation of the cause of the greater and lesser atmospheric motions; and, as only very simple mathematical reasoning is introduced in a few necessary places, the book can be understood by the general reader. Every teacher of physical geography, and of physics in general, should read this volume, and no library should be without it. We must consider it as the best and latest statement of the views of Professor Ferrel, who has probably done more than any other one person toward establishing a science of meteorology.

Cincinnati, Jan. 1890.

P. S.—Since writing the above I have come across the following titles, but have seen only one of the papers:

Pernter, Die allgemeine Circulation der Atmosphäre. Wien. 1889.
Köppen, Ueber die allgemeine Circulation der Atmosphäre. Humboldt, Dec., 1888.
Marchi, Saggio d'Applicazione dei Principii dell' Idraulica alla Teoria delle Correnti dell' Aria. Rome, 1889.
Roth, Der Einfluss der Reibung auf die Ablenkung der Bewegungen längs der Erdoberfläche, Wochens. f. Astron., 1886 (modified by communication written in 1888).

The recent treatises of Blanford and Abercromby should perhaps also be mentioned in this list.

Art. XXXVII.—*Two Methods for the Direct Determination of Chlorine in Mixtures of Alkaline Chlorides and Iodides;* by F. A. Gooch and F. W. Mar.

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

The determination of chlorine associated with iodine in haloid salts is usually accomplished by differential or indirect means: either the two halogens are determined together in a portion of the assay while the iodine alone is estimated in a second portion by one or other of well known methods, the difference between the sum of the halogens and the iodine being the chlorine sought; or, the silver salts of the halogens are weighed together and then converted into a single salt, or the metal, the ratio of chloride to iodide in the original salt being found by simple algebraic processes. If the amounts of iodine involved are minute, it is possible to separate that element by Fresenius's method of treatment with nitrous acid and a solvent like carbon disulphide, and then to determine chlorine directly in the residue; but the manipulation of the process is difficult, and the results inaccurate, when much iodine must be removed. The only method which has been deemed generally applicable to the direct estimation of chlorine associated with iodine in haloid salts is based upon Lassaigne's reaction, by which the iodine is precipitated as palladious iodide; but, the necessity of removing the excess of palladium by hydrogen sulphide before proceeding to precipitate the chlorine is so irksome that, even in this process, it is found to be more convenient to fall back upon the estimation of chlorine as the difference between the iodine found by the palladium process and the sum of the iodine and chlorine obtained by another test in another portion of the material.

A straightforward and easy method for determining the chlorine is obviously desirable, and in the work of which we here give an account we have endeavored to find such an one.

It is a well-known fact* that when an aqueous solution of hydrochloric acid is boiled a point of concentration is reached, by the excessive loss of acid from stronger solutions and of water from weaker ones, at which, for definite barometric pressure, the liquid boils at a constant temperature and distils unchanged in composition. It follows naturally that a degree of dilution may be reached beyond which the loss of the acid must be inappreciable. Indeed, Fleischer justifies his use of hydrochloric acid as a standard in alkalimetric processes upon his observation that decinormal solutions of this acid, and even solutions of twice the strength (7·3 grms. to the liter), do not yield after ten minutes' boiling enough acid to redden blue litmus paper held in the steam. Hydriodic acid behaves similarly to hydrochloric acid in the matter of volatilizing from aqueous solutions; but to the decomposing action of oxidizing agents it is far more sensitive. Our endeavor has been to find conditions under which hydriodic acid may be completely broken up, and its iodine removed from the solution by vaporization, while the hydrochloric is retained without appreciable loss. As a first step toward the solution of this question we initiated a series of experiments upon the volatility of hydrochloric acid in solutions containing sulphuric acid, having fixed upon the latter as the most available means of liberating hydrochloric and hydriodic acids from their compounds with the alkaline metals. After a few preliminary experiments with litmus paper exposed in the steam from boiling solutions, we settled down upon two modes of investigating this point. According to the first, the determination of the chlorine remaining after concentration in solutions made up of water, sulphuric acid, and known amounts of the chloride, by precipitating as silver chloride, filtering the precipitate on asbestos, and weighing, was made the test of volatility of the hydrochloric acid; in the second, the same object was accomplished by estimating the chlorine escaping from the solution, by passing the steam through a condenser and precipitating the acid in the distillate by means of silver nitrate, collecting and weighing the silver chloride as in the former method.

The experiments of Series A to Series F were carried out according to the first method. In them portions of a dilute solution of potassium chloride of known value were measured from a burette into Erlenmeyer flasks of 500 cm^3 capacity, sulphuric acid diluted one-half was added, and the solution was boiled until the flask and contents removed from the flame

* Roscoe and Dittmar, Quart. Jour. Chem., xii, 128.

and placed upon counterpoised scales just tipped the beam. A few trials sufficed to bring the weight to the required point, and the degree of concentration was determined by this means far more accurately than by lowering the level of the liquid to marks placed upon the flasks. The hydrochloric acid remaining after concentration was determined as described, the comparison of the result with the value of the standard solution of chloride indicating, of course, the total loss in the process.

In the experiments of Series A, B, C, D, the effect is traced of increasing proportions of chloride as compared with the same amount of sulphuric acid taken. In those of Series C, E, F, the influence of changing proportions of sulphuric acid, while the amount of chloride remains the same, is brought out. In both sets the evidence is plain that the volatility of the hydrochloric acid is dependent upon the proportion of sulphuric acid as well as upon the amount of the chloride present. It appears likewise that when the amounts of sulphuric acid present are reasonably small the loss of hydrochloric acid is inconsiderable, if the concentration is not pushed to too great an extreme.

SERIES A.

Taken H_2SO_4 [1:1].	Taken KCl = HCl.		Found AgCl = HCl.		Initial volume.	Final volume.	Error.
cm^3	grm.	grm.	grm.	grm.	cm^3	cm^3	grm.
10	0·05	0·0245	0·0963	0·0245	110	65	0·0000
10	0·05	0·0245	0·0957	0·0243	110	45	0·0002—
10	0·05	0·0245	0·0945	0·0240	110	40	0·0005—
10	0·05	0·0245	0·0941	0·0239	110	35	0·0006—
10	0·05	0·0245	0·0871	0·0221	110	30	0·0024—
10	0·05	0·0245	0·0821	0·0209	110	25	0·0036—

SERIES B.

10	0·1	0·0489	0·1910	0·0485	110	65	0·0004—
10	0·1	0·0489	0·1922	0·0488	110	55	0·0001—
10	0·1	0·0489	0·1908	0·0485	110	45	0 0004—
10	0·1	0·0489	0·1894	0·0482	110	35	0·0007—

SERIES C.

10	0·2	0·0978	0·3837	0·0976	110	75	0·0002—
10	0·2	0·0978	0·3838	0·0976	110	65	0·0002—
10	0·2	0·0978	0·3831	0·0974	110	55	0·0004—
10	0·2	0·0978	0·3816	0·0970	110	45	0·0008—
10	0·2	0·0978	0·3746	0·0953	110	35	0·0025—
10	0·2	0·0978	0·3322	0·0845	110	25	0·0133—

SERIES D.

Taken H_2SO_4 [1 : 1].	Taken $KCl=HCl$.		Found $AgCl=HCl$.		Initial volume.	Final volume.	Error.
cm^3	grm.	grm.	grm.	grm.	cm^3	cm^3	grm.
10	0·4	0·1956	0·7690	0·1955	110	60	0·0001—
10	0·4	0·1956	0·7682	0·1954	110	50	0·0002—
10	0·4	0·1956	0·7574	0·1926	110	35	0·0030—

SERIES E.

5	0·2	0·0978	0·3845	0·0978	105	55	0·0000
5	0·2	0·0978	0·3838	0·0976	105	45	0·0002—
5	0·2	0·0978	0·3823	0·0972	105	35	0·0006—
5	0·2	0·0978	0·3788	0·0963	105	25	0·0015—

SERIES F.

20	0·2	0·0978	0·3782	0·0962	120	75	0·0016—
20	0·2	0·0978	0·3602	0·0916	120	65	0·0062—
20	0·2	0·0978	0·3087	0·0785	120	55	0·0193—
20	0·1	0·0978	0·2931	0·0745	120	45	0·0233—

The quantities of chloride dealt with in the preceding experiments are rather smaller than those which would naturally be handled in practical analysis, so that it seemed best to extend the experimentation to solutions of greater dilution and containing larger amounts of chloride. In the experiments of Series G, and subsequently, the second mode of treatment referred to was adopted. The flask was filled as before, but was connected with an ordinary glass condenser so that the distillate might be collected and measured, and the hydrochloric acid condensed with the steam was estimated by precipitation as silver chloride, the last being dried and weighed as such upon asbestos. The details of the experiments are given in the tabular statement.

SERIES G.

Taken H_2SO_4 [1 : 1].	Taken $KCl = HCl$.		Initial volume.	Final volume.	Time in minutes.	Found AgCl.	Loss of HCl.
cm^3	grm.	grm.	cm^3	cm^3		grm.	grm.
10	1	0·4888	400	300	29	0·0005	0·0001
10	1	0·4888	400	300	22	0·0008	0·0002
10	1	0·4888	350	300	10	0·0004	0·0001
10	1	0·4888	350	300	9	0·0005	0·0001
10	1	0·4888	300	200	25	0·0008	0·0002
10	1	0·4888	200	100	27	0·0021	0·0005
10	1	0·4888	100	50	20	0·0037	0·0009

It is obvious from these results that a solution containing 10 cm^3 of the 1 : 1 sulphuric acid, or 5 cm^3 of the strong acid, may be concentrated to 200 cm^3 without significant loss of hydrochloric acid. At a concentration of 100 cm^3 the loss is notable. In later experiments, we found that a small part of the precipitate which we weighed in these experiments must in reality have resulted from the action of the solution upon the rubber stopper and connectors of the apparatus; for the distillate from pure water in the same apparatus yielded a precipitate, probably silver sulphide, which filtered off and weighed, was found to amount to 0·0003 grm. The figures of Series G, therefore, overstate somewhat the volatility of hydrochloric acid under the circumstances, but the misrepresentation is inconsiderable. We fixed upon 300 cm^3 as a convenient volume of liquid to manipulate in future experiments, and one sufficiently dilute to guarantee security against the volatilization of hydrochloric acid when the amount of sulphuric acid does not exceed 5 cm^3 of the strong acid, and when the quantity of potassium chloride present does not exceed 1 grm.

The next point to be considered was the proper mode of breaking up hydriodic acid and volatilizing the iodine thus set free, while leaving the hydrochloric acid fixed.

The use of dihydrogen potassium arseniate, which has been utilized to liberate iodine according to a method recently developed in this laboratory,* is precluded by the necessarily high degree of dilution of the solution employed. The first trials were made, therefore, with ferric alum to act as the oxidizing agent according to the well known reaction of Duflos:

$$2H\text{-}I + Fe_2(SO_4)_3 = 2FeSO_4 + H_2SO_4 + I\text{-}I$$

We found by experiment that from a volume of 300 cm^3 containing 10 cm^3 of sulphuric acid [1:1], 5 grms. of ferric alum, and 0·005 grm. of potassic iodide, every trace of iodine had disappeared so completely after five minutes' boiling that nitrous acid and chloroform collected no color in the cooled liquid. It transpired, however, that when the amount of potassium iodide was increased to 1 grm., iodine was found in considerable amount after boiling for an hour with occasional replacing of the water evaporated, so that the volume should not decrease much below 300 cm^3. The failure of the iron alum to expel the iodine is not attributable to a deficiency in amount; for the 5 grm. present were capable of decomposing more than a gram and a half of potassium iodide were the full effect theoretically possible attained. Furthermore, special tests in which the amount of ferric alum was increased developed the fact that the increase was but little helpful. The apparent explanation of the phenomenon is that here, as in the liberation of iodine by means of dihydrogen potassium arseniate, there

* Gooch and Browning, this Journal, vol. xxxix, p. 188.

occurs a time in the course of action when for a given degree of dilution an equilibrium is established between the tendency of the oxidizer to oxidize and that of the reduced residue to reverse the action. The obvious modes of securing completed action are the concentrating of the liquid and the reinforcing of the oxidizer. Application of the former is precluded by the danger of volatilizing hydrochloric acid; the simplest mode of realizing the latter—and as the result proved, a feasible one—is the re-oxidation of the reduced ferrous sulphate by means of nitric acid.

When a sufficient amount of nitric acid is added to restore the iron to the ferric state, the boiling of the solution resulted in the complete liberation of the iodine. In dilute solutions the amount of nitric acid necessary to oxidize a fixed quantity of ferrous salt is greater than in concentrated solutions. Thus, while 0·1 cm^3 of strong nitric acid should be more than enough to reoxidize the iron reduced by 1 grm. of potassium iodide when the full oxidizing action is brought out, we found it necessary to add to the dilute solutions with which we worked about 2 cm^3 of the acid to complete the action satisfactorily. Incidentally, we found that the nitric acid by itself—that is, without the presence of the iron salt—is not effective in liberating the iodine; for, the successive addition of portions of 1 cm^3 of nitric acid to a solution containing 10 cm^3 of sulphuric acid [1:1], and 1 grm. of potassium iodide in a total volume of 400 cm^3 until the amount of nitric acid reached 5 cm^3, the liquid boiling all the time, liberated but little iodine, while the addition at this point of 2·5 grm. of ferric alum determined the evolution of iodine in dense fumes.

The addition of 2 cm^3, or at the most 3 cm^3, of strong nitric acid to solutions constituted as has been described proved to be sufficient to liberate the entire amount of iodine present. The question as to whether the hydrochloric acid is affected by the addition of so much nitric acid was settled in the experiments of the following series. In these determinations a little sulphurous acid was added to each distillate to insure the complete precipitation of the chlorine by silver nitrate, and sufficient nitric acid was added to re-dissolve the silver sulphite thrown down also at first.

It appears in these results that the ferric salt has no perceptible influence upon the hydrochloric acid, and that the presence of nitric acid within reasonable limits does not sensibly increase the loss of hydrochloric acid which takes place under conditions otherwise similar, strong nitric acid to the amount of 5 cm^3 in a total volume of 300 cm^3 producing no apparent increment of loss from half a gram of hydrochloric acid. The nitric acid itself passes easily into the distillate. That the influence of the sulphuric acid is important, is again demonstrated in the experiments in which 1 cm³ of nitric acid and 1 grm. of potassium chloride were distilled in the one case with, and in the other without, the addition of sulphuric acid.

SERIES H.

Taken H_2SO_4 [1 : 1]	Taken Iron Alum.	Taken HNO_3 Sp. Gr. 1·40	Taken KCl = HCl.		Initial volume.	Final volume.	Time in minutes.	Found AgCl.	Loss of HCl.
grm.	grm.	cm³	grm.	grm.	cm³	cm³		grm.	grm.
--	--	1	1	0·4888	200	100	30	0·0006	0·0002
--	--	1	1	0·4888	100	50	14	0.0010	0·0003
--	--	1	1	0·4888	50	15	10	0·0049	0·0012
10	--	1	1	0·4888	200	100	27	0·0031	0·0008
10	--	1	1	0·4888	100	50	16	0 0116	0·0029
10	5	0·1	1	0·4888	400	300	24	0·0004	0·0001
10	5	0·3	1	0·4888	400	300	30	0·0004	0·0001
10	5	0·5	1	0·4888	400	300	30	0·0004	0·0001
10	5	1	1	0·4888	400	300	27	0·0010	0·0003
10	5	1	1	0·4888	300	200	33	0·0007	0·0002
10	5	1	1	0·4888	200	100	30	0·0025	0·0006
10	5	1	1	0·4888	100	50	15	0·0090	0·0023
10	5	2	1	0·4888	400	300	25	0·0010	0·0003
10	5	3	1	0·4888	400	300	25	0·0010	0·0003
10	5	4	1	0·4888	400	300	30	0·0009	0·0002
10	5	5	1	0·4888	400	300	30	0·0007	0·0002
10	5	10	1	0·4888	400	300	30	0·0018	0·0005

In the indication of these and previous experiments we found warrant for the prosecution of the quantitative tests of the following series:

Weighed portions of a standard solution of potassium chloride (whose value was determined by precipitating with silver nitrate with the usual precautions, collecting in a perforated crucible upon asbestos felt the silver chloride found, and drying and weighing it) were transferred to Erlenmeyer flasks of 500 cm³ capacity, water was added with 10 cm³ of sulphuric acid [1 : 1], 2 grm. of ferric sulphate (either in the form of iron alum or an equivalent amount of ferrous sulphate oxidized in concentrated solution with a sufficiency (0·3 cm³) of nitric acid) and 1 grm. of potassium iodide, were introduced, the whole volume was brought to 400 cm³, and the liquid was boiled with the addition of nitric acid as indicated in the table, 1 cm³ being added after it appeared that all iodine had been expelled.

The color of the ferric salt renders it impossible to tell by the appearance of the solution the exact moment when the iodine has been expelled, and starch paper loses its sensitiveness in hot vapors. We bestowed some attention, therefore, upon means for the detection of small amounts of iodine in hot steam in order to avoid the inconvenience of condensing the distillate and testing it for iodine. We found that red litmus, preferably wet, is a most sensitive agent for the detection of iodine under the circumstances, taking on with exposure to traces of the vapor carrying that element, a distinct gray blue, deepening with exposure to larger amounts into a lavender blue. The addition of 0·005 grm. of iodine to 400 cm³ of boiling water produces immediately upon red litmus paper the characteristic lavender blue color, and the test grows fainter and fainter as fresh test-papers are exposed, until at the end of five minutes, or thereabouts, when the litmus paper shows no color, the cooled solution yields no iodine to nitrous acid and chloroform. This reaction of litmus we found of great value and in no case in which an exposure of two minutes' duration failed to develop the characteristic color were we able to find iodine in the cooled liquid. To prevent mechanical loss of liquid we made use of the trap described in a previous paper from this laboratory, consisting simply of an ordinary two-bulb straight drying tube cut off short and hung with the large end downward in the mouth of the Erlenmeyer flask. The residue in the flask after the expulsion of the iodine was treated with silver nitrate, and the precipitated chloride was determined similarly to that obtained in standardizing the solution of potassium chloride.

Several determinations in blank—that is, experiments from which the iodine was purposely omitted—are included, for the sake of comparison, in the tabular statement.

SERIES I.

H_2SO_4 [1 : 1].	$Fe_2(SO_4)_3$.	HNO_3.	KCl = HCl.		KI.	Initial volume.	Final volume.	Time in Minutes.	AgCl found.	= HCl. found.	Error.
cm³.	grm.	cm³.	grm.	grm.	grm.	cm³.	cm³.		grm.	grm.	grm.
10	2*	--	0·4960	0·2425	--	400	300	40	0·9536	0·2425	0·0000
10	2*	--	0·4970	0·2429	--	400	300	40	0·9534	0·2624	0·0005 —
10	2*	--	0·4942	0·2416	--	400	300	30	0·9509	0·2418	0·0002 +
10	2*	2	0·4969	0·2429	--	400	300	30	0·9559	0·2431	0·0002 +
10	2*	3	0·4956	0·2423	1	400	350	30	0·9546	0·2428	0·0005 +
10	2*	3	0·4969	0·2429	1	400	350	23	0·9662	0·2432	0·0003 +
10	2†	3	0·4949	0·2419	1	400	300	27	0·9523	0·2422	0·0003 +
10	2†	5	0·4970	0·2429	1	400	250	55	0·9559	0·2431	0·0002 +
10	2†	5	0·4955	0·2422	1	400	300	30	0·9524	0·2422	0·0000
10	2†	5	0·4967	0·2428	1	400	300	33	0·9546	0·2428	0·0000
10	2†	6	0·4964	0·2427	1	400	300	30	0·9550	0·2429	0·0002 +

These eminently satisfactory results prove the trustworthiness of the method.

* The iron was added in the form of iron alum.

† The iron was added as $FeSO_4$ oxidized by HNO_3.

The fact that nitric acid appears to affect so little the hydrochloric acid in the solution, suggested the possibility that nitrous acid itself might be turned to account and used in a similar process instead of a ferric salt and nitric acid. Some preliminary experiments were made, therefore, to test the behavior of hydrochloric acid under the action of nitrous acid, and, as they gave favorable indications, the experiments of Series J were undertaken to test the action quantitatively. The general conduct of the test was similar to that followed in Series I. The solution of chloride and iodide containing 10 cm³ of sulphuric acid [1:1] was diluted to 400 cm³, and agitated while the gas developed by the action of sulphuric acid on 2 grm. of sodium nitrite was passed into it. With pure sodium nitrite at hand there is probably no serious objection to introducing that substance directly into the solution, but impurities in the article at our disposal made it desirable to generate the gas outside the solution.

For a generator we used two straight drying tubes connected by a rubber tube and set up after the fashion of the von Babo generator, and regulated the rapidity of the current to a rate of five or six bubbles to the second by changing the relative elevation of the generator tubes. The iodine separates immediately upon the introduction of the nitrous fumes and escapes upon boiling in dense fumes, leaving the solution colorless in a very short time. The litmus test was applied as an additional safeguard to indicate the completion of the removal of the iodine. The results of the experiments as given in the accompanying table are evidently satisfactory.

SERIES J.

H_2SO_4 [1 : 1].	$NaNO_2$ used in generator.	KCl=HCl.		KI.	Initial volume.	Final volume.	Time in minutes.	AgCl found.	HCl. found.	Error.
cm³.	grm.	grm.	grm.	grm.	cm³.	cm³.		grm.	grm.	grm.
10	2	0·4953	0·2421	1	400	350	20	0·9524	0·2422	0·0001 +
10	2	0·4975	0·2432	1	400	350	16	0·9573	0·2434	0·0002 +
10	2	0·4956	0·2423	1	300	250	15	0·9530	0·2423	0·0000
10	2	0·4973	0·2431	1	300	250	15	0·9550	0·2429	0·0002 −
10	2	0·4964	0·2427	1	300	250	15	0·9550	0·2429	0·0002 +
10	2	0·4969	0·2429	1	300	250	15	0·9567	0·2433	0·0004 +

The modes of proceeding to the separation of iodine and the estimation of chlorine according to the processes which we have detailed may be briefly summarized as follows:

First Method.—To the solution of the alkaline chloride and iodide diluted to about 400 cm³ in an Erlenmeyer flask capable of containing a liter, are added 10 cm³ of sulphuric acid of half strength, with 2 grm. of ferric sulphate (either in the form of iron alum, or ferrous sulphate oxidized in concentrated solution by about 0·3 cm^3 of nitric acid), and 3 cm^3 of nitric acid. A trap, of the form described, is hung in the neck of the flask, and the liquid is boiled until the steam which escapes no longer gives to red litmus paper, after two minutes' exposure, the characteristic gray blue due to traces of iodine. Then 1 cm^3 more of nitric acid is added, and the test for iodine again made. When no iodine is found in the escaping vapor, silver nitrate is added in excess to the contents of the flask, the precipitate is settled, collected in a perforated crucible on asbestos, dried, and weighed as silver chloride.

Second Method.—The solution of the chloride and iodide contained in an Erlenmeyer flask is diluted to 400 cm^3; 10 cm^3 of sulphuric acid of half strength are added, and the vapor from 2 grm. of sodium nitrite acted upon by dilute sulphuric acid (preferably in a simple generator, such as is described above) is passed with reasonable rapidity into the agitated solution. The liquid is boiled until colorless, and still further until litmus paper placed in the steam gives no reaction for iodine after an exposure of two minutes. The contents of the flask are treated with silver nitrate, and the precipitated chloride is treated exactly as in the first method.

Both methods are convenient and precise.

Art. XXXVIII.—*On the occurrence of Polycrase, or of an allied species, in both North and South Carolina;* by W. E. Hidden and J. B. Mackintosh.

A few crystals of the mineral here described were brought to the attention of one of us while prospecting in the summer of 1888 for ores of thoria in the zircon region of Henderson County, North Carolina. The new thorium-phosphate (Auerlite)* had lately been discovered in that neighborhood and this yttrium-uranium mineral was considered by its finders to be identical with it. Its yellow exterior alteration bore a great resemblance to auerlite, particularly to that variety found on the Price land, but its form, density, dark interior color, and bright resinous fracture suggested a closer relation to euxenite, polycrase or samarskite. The locality was visited and the work of developing it promptly commenced.

In an announcement of a new occurrence of xenotime-cyrtolite, printed in this Journal (Nov., 1888), the first notice of this

* This Journal, Dec., 1888.

locality is given and the mineral here described is therein referred to as "a member, as yet unidentified, of the samarskite group." No analysis was then attempted, as the material on hand was impure, and insufficient; we hoped for purer and larger masses as the locality became developed. Up to July, 1889, the character of the mineral was not fully determined, and a very considerable amount of labor had been fruitlessly expended in an endeavor to find it and xenotime in commercial quantities. Altogether only about 100 grams had been found, the work being carried on after the manner of placer gold-washing. The locality is on the Davis land, in Henderson Co., North Carolina, at a place on the "old Greenville Road" where it is crossed by a decomposing and low lying granitic formation. It is about four miles from Zirconia (a railroad station), and not far from the South Carolina state line. The associated minerals are zircon, monazite, xenotime, cyrtolite and magnetite. Of the first four of these about one ounce would be found, in the concentrates, upon washing about one cubic yard of the kaolinized granite.

This mineral is invariably found in separate crystals, no massive variety being as yet observed, and they have a type of form greatly resembling figure 434, of polycrase, in Dana's System of Mineralogy. They are always more or less altered on the surface to a pale yellow gummite-like substance, and the line of demarcation from the unaltered to the altered mineral is very sharply defined, no intermediate stages of alteration being evidenced.

No satisfactory measurements of angles were possible. The crystals were small, thin, square flattened prisms, with several terminal planes (in one zone only). One brachydome had an angle of about 133½° on the brachypinacoid. One twin, parallel to the unit brachydome, was observed quite perfectly developed.

The pure mineral is nearly coal-black, with a brownish yellow translucence through thin edges. Its fracture is small conchoidal with a brilliant sub-metallic to resinous luster. No cleavage was noticed. The density as taken on a gram of carefully selected grains of the broken dark internal cores was found to be 4·78. Another determination on a single mass gave 4·724. Its hardness = 5·5. Streak and powder light yellowish brown, approaching to white. When heated it decrepitates slightly and becomes dark brown. It is infusible.

The material analysed was the same as that upon which the higher density was determined and the results were as follows:

				Oxygen ratio.	
Cb_2O_5	48·97	28·52*	?		?
Ta_2O_5		-----			
TiO_2		20·27†			
Y_2O_3, etc.	27·55	At. w't. = 103·8		32·37	52·71
Fe_2O_3	3·19			6·00	
UO_3	13·77			14·34	
H_2O (Ign.)	5·18				28·83
	98·48 %				

The analysis was conducted in general after the method of J. Lawrence Smith, using hydrofluoric acid. The mineral is completely soluble in boiling sulphuric acid when very finely powdered.

An H_2SO_4 solution of both these minerals show, when HCl and metallic zinc are added, at first a faint violet color then momentarily a deep sapphire-blue which changes to greenish and finally to a deep brown. The solution then clears and a muddy precipitate forms. The reactions are quite similar to the behavior of the Hitteroe polycrase.

The foregoing statements comprised our data of this mineral up to the discovery, in September last, of another occurrence of the same species on a more satisfactory scale. Whereas we had formerly a few grams we now have ounces, and where before we had small pieces of impure material we now have large crystals of almost normal purity. The alteration-products are also now available for separate examination, and our present supply of crystals includes many that weigh from 5 to 10 grams each and one of one ounce. All have the same habit as those first described. Some, as before stated, are quite pure, while others are almost wholly changed into a lemon-yellow *gummite* which has Sp. Gr.=3·33+. Hardness=3·5. Loses 11·46 per cent after ignition and becomes dull-brown. When opportunity offers we intend looking into it more thoroughly. Minute radiated tufts of what may prove to be tengerite were also noticed in the clefts of the mineral.

The new material unfortunately does not offer smooth enough surfaces for exact measurement of angles. The crystals present the macro- and brachypinacoids as predominating planes, with the brachypinacoid usually the larger. One brachyprism (i-$\breve{3}$); two brachydomes (1-$\breve{i}$, 2-$\breve{i}$); one brachydiagonal pyramid (1-$\breve{3}$); and one macrodome ($\frac{1}{8}$-$\bar{i}$), which latter is new to the species. Several specimens of a twinning parallel to the new macrodome were observed; this is peculiar for the reason that at the first locality the only twin observed was parallel to

* This gave the blue reduction test with zinc.
† This gave the violet test by reduction with zinc.

the unit brachydome. As the angles were obtained by a hand goniometer and are only approximate they are not considered worthy of record.

With this mineral (of which ten kilos have thus far been mined), we have found only a few small pieces of allanite (Sp. Gr. = 3·54), and one small mass of uraninite (?), having gummite and uranotil as a coating, its density was 7·22, both species of which are not found at the North Carolina locality. The exact situation of the new deposit is, just at this writing, unknown to us, but it is near the "Upper Saluda River," just over into South Carolina, and is distant about twenty miles from the first described locality.

The density of the new crystals varies between 4·925 and 5·038.

The pure mineral was first pulverized and then rubbed very fine, with alcohol, in an agate mortar. It then went into perfect solution when boiled with sulphuric acid. Excepting that it does not decrepitate before the blowpipe it is otherwise very much like the North Carolina mineral. It is slightly harder (6) and its streak and powder are pale snuff-brown, and darker than the North Carolina mineral.

The analysis is as follows:—

				Oxygen ratio.	
Cb_2O_5		14·30			
Ta_2O_5	47·88	----	?		?
TiO_2		33·58			
Y_2O_3, etc.	21·23	At. w't. = 114·1		23·06	
PbO	0·46			0·20	
FeO	2·47			3·43	
Fe_2O_3	0·18			0·33	48·58
UO_3	19·47			20·35	
CaO	0·68			1·21	
H_2O (Ign.)	4·46				24·78
Insoluble	0·12				
SiO_2	1·01				
	97·96				

Both of the analyses show a loss for which we cannot account, though the presence of fluorine was unmistakably detected in the South Carolina mineral. Thoria is absent in both cases.

Our attempts at separation of the metallic acids, contained in both the minerals, were very unsatisfactory. In fact the method by fusion with sodium bisulphate, even when repeated several times, did not give reliable results under our treatment. Until we have separated the metallic acids present, entirely to our satisfaction, we do not propose to offer any conjectural formulæ for these analyses. We will state though that this mineral seems to be very closely allied to, if not identical with, the polycrase from Hitteroe, Norway, analyzed by Rammelsberg; in which he found

Cb_2O_5	20·35
Ta_2O_5	4·00
TiO_2	26·59
Y_2O_3	23·32
Er_2O_3	7·53
Ce_2O_3	2·61
FeO	2·72
UO_2	7·70
H_2O	4·02
	98·84

By calculating the above, without knowing the molecular weight of the Y_2O_3 group but taking it to be 89·5, we arrive at the following approximate formula:

$$Cb_2O_5,\ 4TiO_2,\ 5RO,\ 2\tfrac{1}{2}H_2O,$$
$$\text{or } 2Cb_2O_5,\ 8TiO_2,\ 10RO,\ 5H_2O,$$

which may also represent our mineral when the metallic acids have been accurately separated and their individual molecular weights definitely ascertained; this we propose to do as opportunity offers. In conclusion we call attention to the fact that this is the first occurrence of a columbo-titanate accredited to an American locality.

ART. XXXIX.—*Origin of some Topographic Features of Central Texas;** by RALPH S. TARR.

THE Central Paleozoic area of Texas is a region of older rocks exposed by the removal of the overlying unconformable Cretaceous. The southern portion of this area has since the very earliest times been the seat of extensive denudation as long as any land area remained above the sea. The Potsdam sandstone perhaps derived its sediment from the still older metamorphic rocks. A conglomerate layer in the Lower Carboniferous series contains pebbles from the Silurian rocks. The same is true of the conglomerate in the Upper Carboniferous; and the Trinity beds, the lowest of the Cretaceous system, when conglomeritic, contain, in this region, chiefly Silurian pebbles. The Quaternary drift has the same peculiarity.

* Published by permission of Mr. E. T. Dumble, State Geologist for Texas.

Briefly outlined, geological history, commencing as far back as I have studied it, begins with an old pre-Sub-carboniferous land of Silurian and older rocks. At present this system appears as a patch of very much metamorphosed rock surrounded on three sides by Cretaceous. Little is known of this region. It is plainly a very much degraded mountainous land-area which has furnished thousands of feet of strata for the later formations. As to its former boundaries little can be said; but I have given elsewhere* what I believe to be evidence of a former northward extension. The tract contains marble, sandstones and schists of Lower Silurian and earlier age; but the Upper Silurian and Devonian if they exist at all are mere remnants. The stratigraphy is greatly complicated by faults and folds.

In Lower Carboniferous time a submergence and long continued period of sedimentation permitted the deposition of an extensive series of Lower Carboniferous limestone, several thousand feet of which are still exposed between the Silurian on the south and the overlapping Upper Carboniferous to the north. The old shore line of the Lower Carboniferous sea may be plainly traced in favorable places, and here, particularly in the upper beds, may be seen the varied shore deposits of that time.

A gap of unknown value, accompanied by a tilting and slight crumpling of the Lower Carboniferous limestone series intervened between the close of that period and the beginning of the Upper Carboniferous. The latter beds rest unconformably upon the lower limestone. This series fully 8,000 feet thick consists of the usual alternation of beds so typical of that period.† The upper beds indicate an approach to the Permian condition of an inland sea. What intervened between the Permian and Lower Cretaceous has not yet been made out. That a portion of the Carboniferous had a dry land condition for at least a part of the time is proved by the irregularity of the contour beneath the Cretaceous. It is impossible to say to what extent this land condition was shared by the surrounding areas; but the Carboniferous of the Colorado river valley and the neighboring Silurian shows signs of erosion by the position of the lowest bed of the Cretaceous, the Trinity sands of Hill. The Trinity sands rest on the Carboniferous on the east as low as 1250 feet above the present sea level; but in the western portion they are on the 2000 foot contour line. There is a rise of 750 feet in less than fifty miles. A carefully made map of these beds may reveal to us an interesting history of the immediate pre-Cretaceous land. The Silurian area was

* The American Geologist, forthcoming number.

† See 1st Annual Report Texas Geol. Survey.

then more elevated than the Carboniferous and the rise in the land was from east to west.

The extensive sedimentation of the Cretaceous time completely obliterated all pre-existing topography. The deep sea conditions and accompanying thick deposits, so plainly proved by Prof. R. T. Hill, covered all land with a thick mantle. When this deposit was finally raised above the sea and a new era of erosion began, the large streams which first established themselves commenced to flow without regard to the topographic and geologic features buried beneath the Cretaceous. The Tertiary beds which occupy a large portion of east Texas mark the extension of the oceanic waters many miles farther than at present. It is probable that the Tertiary ocean extended much farther inland than at present indicated and that the beds have been in part removed by later erosion. It is plain from this that the waters of the new drainage systems emptied into an ocean not far removed from the buried Paleozoic area. What were the conditions west of the Paleozoic has not been ascertained. One stream, the ancestor of the present Colorado, established itself in the Southern Carboniferous area, and another, the Brazos, crosses this system farther north. These streams with their tributaries have eroded the Cretaceous from much of the Carboniferous, and the Colorado has in addition removed the Cretaceous from a great area of Silurian.

The history of these operations is not thoroughly plain in every point. The extensive denudation in this Paleozoic area must mean that this was early a region of strong erosion, and that this condition has been continued. It may also mean that this was the highest region of the new land. Be this as it may the fact remains that in this area, by means of two large rivers and several well established tributaries, a great thickness of Cretaceous has been eroded away and some of the Paleozoic removed. This process has established a series of interesting topographic features, some of which throw light upon the later history of the drainage systems.

The Colorado, which rises in the Staked Plains, while well established in its lower and middle course is rapidly extending its drainage area by headwater erosion in the plains. Deep cañons and arroyas mark its new work in this region. Over the Paleozoic it flows with rapid fall and a wonderfully serpentine course without regard to structural features. That it is a superimposed stream is proved by the fact that it is now busy eroding barriers of Silurian and other hard rocks which it has unexpectedly reached after passing through the Cretaceous strata. The larger tributaries flow equally without regard to structural features; but the smaller tributaries of more recent origin have cut valleys in places of structural weakness. This is well shown in the case of the Waldrip coal beds, a series of easily eroded strata, which, for a distance of forty miles, are marked by the presence of small streams and valleys. Similar instances are numerous.

In the erosion, accomplished under such complicated circumstances of accident and geological peculiarity a series of distinct topographic outlines has been evolved. The Silurian, a region of hard rocks, complicated by innumerable folds and probably also retaining a well defined topographic outline evolved in pre-Cretaceous times, is now a hilly country. A portion of the Lower Carboniferous is involved in this region of strong relief but practically the border of the Silurian marks the beginning of the highlands. Once partially rid of its Cretaceous cover, this area would necessarily become a region of strong erosion and this explains the almost complete removal of the Cretaceous from that surface.

The Carboniferous on the other hand is a region of soft rock and gentle dip, and this becomes rapidly degraded. The Carboniferous surface, as shown by the position of the Lower Cretaceous upon it, was when the present drainage systems reached it, considerably below the Silurian; and using this same datum plane, it is evident that very little of the Carboniferous has been since removed. One chief reason for this is that on reaching the Paleozoic the down-cutting of the Colorado has been indefinitely delayed by the hard Silurian and other rocks which it is now engaged in removing. The San Saba river, for instance, for a distance of fifteen miles above its mouth, flows in a flood plain because of the impossibility of eroding deeper until after the Colorado has removed the barriers below. The small streams tributary to the San Saba are similarly affected, and the same is true of other tributaries of the Colorado, as for instance the Pecan Bayou. The chief erosion that is being done in the Carboniferous of the Colorado river is in the headwaters of the small streams, and the material thus removed is deposited lower down in flood plains to be removed when erosion at that point can proceed. A local base-levelling is thus in process relative to the dammed-back Colorado. This process is aided by the peculiarity of rainfall. During the greater part of the year the small creeks either contain no water at all or so little that no work of erosion is done. During some months tumultuous torrents rush down the stream valleys covering the previously dry bed with water twenty feet deep and thirty feet wide. These torrents subside very quickly, but during their brief existence do an immense work of erosion. The Colorado river has a wide channel for ordinary periods of flow; but the high-water channel is two or three times as wide. A terrace twenty-five or thirty feet above the river bed, sometimes on one side sometimes on both, has been cut by the high water. The river sometimes rises forty or even fifty feet, as is strikingly shown by the presence of rafted logs near the top of Pecan trees. Great as are the floods at such time they are incapable of carrying off all the sediment and the flood plains are rapidly growing, at least in the area affected by the dams in the older Paleozoic region. Upright tree trunks, comparatively fresh, are sometimes exposed for a distance of five feet above the roots, and bones of the mastodon are found both in the alluvial deposits of the Colorado and its tributaries.

That there has been a period of very rapid erosion just previous to the present condition is attested to by numerous points of evidence. The Colorado is flowing in a somewhat degraded cañon above the Silurian; and where the rocks are hard enough to resist rapid erosion this cañon character is well preserved. The butte type of erosion so typical of the bordering Cretaceous is also, I believe, an evidence of previous rapid erosion. One example, the Santa Anna Mts. (so called), remains in the center of the Carboniferous. There are two buttes, side by side and divided by headwater erosion, in Coleman county, fully fifteen miles from the nearest notch of Cretaceous. The capping stratum is a compact magnesian limestone, the lowest of the Caprina division of Hill. The lower beds are Trinity sands. The length along the top is a little more than a mile, the height 250 feet. Five distinct large creeks head in the region near these buttes, which are the last remnant of a Cretaceous divide. The hard stratum on the top which permits the retention of the butte outline is one of the several strata which in the bordering Cretaceous gives the topography its benched mesa and butte outline, a topography so characteristic that a person can with safety predict Cretaceous as far as he can see the outline.

The degraded cañon character of the Colorado valley and the sharp benched and butte outline of the Cretaceous seem to indicate a period of hurried erosion of recent date; and the early Quaternary uplift which placed the Tertiary above the sea may very well be correlated with this period.

From this it would seem that the middle Colorado originally starting on the new Cretaceous land is now superimposed upon the older Paleozoic, with which it is engaged in a struggle brought about more quickly by its rejuvenation by elevation. Owing to the vicissitudes then imposed, it is tending to reach a temporary old age in the portion above the barriers and this tendency is being increased by the peculiarities of rainfall.

The combination of geological structure and peculiarity of erosion has given rise to three types of topographic outline. 1st, the rugged hilly topography of the plicated and metamorphosed Silurian rocks, an outline in part descended from an existing pre-Cretaceous topography. 2d, a low hilly Carboniferous area with many broad-topped hills, especially where the Cretaceous has just been removed. On account of the destructibility, this area is being rapidly degraded and the cañon character of the Colorado is therefore rapidly disappearing, thus destroying the evidence of the recent rejuvenation. 3d, the sharp angular outline of the butte and mesa type in the Cretaceous area which is rendered possible by the nearly horizontal nature of the beds and the alternation of hard and soft strata, but which has probably been aided also by the rapid erosion which followed the early Quaternary uplift.

Art. XL.—*On the Formation of Silver Silicate;* by J. Dawson Hawkins.

But very little seems to have been done with regard to the formation of silicate of silver in the wet way. In Gmelin-Kraut's Inorganic Chemistry, vol. iii, p. 970, the following statement is made :—" A solution of Ag_2O in $2(HF)SiF_4$, evaporated to the consistency of a syrup, deposits hydroscopic crystals of $2AgF . SiF_4+4H_2O$. Out of a solution of this compound, ammonia precipitates a yellow basic salt, if added in small quantities. An excess of ammonia precipitates silicate of silver." A like statement is made by Berzelius—Lehrb. d. Chemie; Dresden, 1836, vol. iv, p. 629. With the exception of a paper by Dr. M. W. Iles,* nothing seems to have been done in this direction since then. With regard to the production of silver silicate in the wet way, Dr. Iles merely repeated the above experiment, without making any analysis of the precipitate.

The method I have used is so simple that it seems strange that it has not been used before. The reaction made use of was:

$$Na_2SiO_3+2AgNO_3=Ag_2SiO_3+2NaNO_3.$$

The solution of Na_2SiO_3 was made by fusing together Na_2CO_3 and SiO_2, and dissolving the mass in water. The amount of SiO_2

* Engineering and Mining Journal, April 19, 1884.

used was slightly in excess of the molecular proportion, and the silicate formed was therefore slightly acid. This solution was added to a neutral solution of $AgNO_3$, and a lemon-yellow precipitate was thrown down. This was washed carefully with hot water, and dried. Dried between filter paper, the salt retains its original yellow color, but when completely dried in a bath, the color becomes darker. Two analyses gave the following results:

Ag_2O	77·42	77·41
SiO_2	22·66	22·52
	100·08	99·93

Ag_2SiO_3 requires Ag_2O 79·45, SiO_2 20·55. This salt is, then, slightly acid, which agrees with the conditions of the precipitation, as the meta-silicate of sodium was slightly acid. From this it appears that all that is necessary to prepare a silicate of silver of a certain composition, is the pure corresponding sodium salt, and a neutral silver solution.

The silicate of silver is readily decomposed by all acids, and is perfectly soluble in ammonia. It bears a considerable degree of heat without decomposition, first changing its color to brown red, then back to the original yellow, a red heat, however, resolves it into Ag, O, and SiO_2.

The above is intended merely as a preliminary notice, as I am still engaged in a further study of the salt and will publish my results when they are complete.

Laboratory of the Globe Smelting and Refining Co., Denver, Colorado.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Determination of Vapor Density below the Boiling Point.*—Demuth and V. Meyer have modified the Meyer vapor density method so as to allow the determination to be effected at temperatures below the boiling point of the substance employed. In Hofmann's method this object is attained in consequence of the diminished pressure, as is well known. The author conceived that the same result might be reached by filling the bulb of the Meyer apparatus with hydrogen, a gas lighter than air and also of greater diffusibility. The apparatus used is essentially the same. The material whose vapor-density is to be determined, if

solid, is introduced into the bulb, previously filled with hydrogen, in the form of small cast sticks. If liquid, it is placed in small tubes of Wood's fusible metal when the temperature to be employed is above 60° to 80°, the fusing point of the metal, or in tubes of glass, stoppered, when the temperature is below this; the stopper being shaken out by tapping with the finger. The bulb should have a capacity of about 100^{cc}, and a diameter of three centimeters; and the bottom which must not be too thin, is somewhat flattened to facilitate the volatilization of the substance. The neck is to have a diameter of not over 4 or 5 millimeters; and the quantity of the substance taken should be such as to produce an expulsion of 9 to 11^{cc} of gas from the vessel. It is not desirable with this method of working to cover the bottom with sand or asbestos, since these substances retard the production of vapor; but the bulb may be protected by a small spiral of platinum wire, or some mercury may be placed in it. Results are given, in the paper, of the determination of the vapor-density of xylene at 100°, (40° below its boiling point), of nitrobenzene 23° and 30° below, of naphthalene 35° below and of para-nitrotoluene 33° below the boiling point. Also of ethyl ether at the ordinary temperature of the laboratory, 17°, its boiling point being 35°. These results show the method to give satisfactory results.—*Ber. Berl. Chem. Ges.*, xxiii, 311, Feb., 1890. G. F. B.

2. *On the Vapor-density of Aluminum Chloride.*—In consequence of the results obtained by Friedel and Crafts,* NILSON and PETTERSSON have repeated and extended their experiments on the vapor-density of aluminum chloride. In meeting the criticism of the French chemists upon their method, they observe that for every volatile substance, there exists a certain range of temperature within which the vapor-density is a function not only of the temperature but also of the pressure. Within this interval, which they call a region of gas-dissociation, they concede that the method of Dumas gives the true vapor-density, that of Meyer (or of Dulong, as they call it) giving values which are always too low. But as soon as the temperature is reached at which the density of the vapor becomes constant, the same results are obtained whichever of the two methods be employed. Since the law of Avogadro is true only for bodies in the condition of true gases, and since in the state of a perfect gas the density is independent of the temperature and the pressure, and the two methods then give identical results, it would seem that Friedel and Crafts were hardly justified in giving the preference to one of these methods, rather than to the other. Accordingly the authors undertook a re-determination of the vapor-density of aluminum chloride, employing both methods for the purpose. For the Meyer method they employed a protecting tube of Bayeux porcelain placed in a Perrot furnace for the higher and a tube of Thuringian glass for the lower temperatures. The density obtained, referred to air as

* This Journal, xxxvi, 465, Dec., 1888.

unity, was, in the vapor of sulphur at 440° 7·30, 7·50 and 7·40; in that of phosphoric sulphide at 518°, 7·16 and 7·20; in that of stannous chloride at 606°, 6·34; in the furnace at 758° 4·80; at 835°, 4·54; at 943°, 4·56; at 1117°, 4·27; at 1244°, 4·25; at 1260°, 4·28; about 1400°, 4·26; about 1600°, 4·08. It appears from these results that between 440° and 758° the vapor of aluminum chloride is in a condition of permanent dissociation and that it does not attain a normal gaseous condition until the temperature reaches 800°, when the vapor-density becomes 4·60 and the molecular mass 133·15 corresponding to the formula $AlCl_3$. Between 800° and 1000° there can be no doubt that aluminum chloride has a constant density agreeing with the composition $AlCl_3$. For the Dumas method, the aluminum chloride, formed by passing hydrogen chloride gas over the metal, was sublimed directly into the cylindrical bulb, of about 100^{cc} capacity. After heating so long as vapor was evolved the tube was sealed, cooled and weighed. It was then opened under mercury and the volume of residual gas measured. After washing and drying the tube it was again weighed, the difference being the apparent mass of the aluminum chloride and of the residual gas. It was then filled with dry air, sealed and weighed a third time. The difference between the second and third weighing gave the apparent mass of the air. It was then filled with water and weighed for the purpose of calculating its capacity. The vapors employed for heating were those of nitrobenzene, 209°, engenol, 250°, diphenylamine, 301°, mercury, 357°, antimonous iodide, 401°, and sulphur, 440°. The vapor-densities obtained varied from 9·92 at the lowest temperature to 8·78 at the highest; being 9·62, 9·55, 9·34, and 9·02 at the intermediate ones. These results, therefore, confirm those obtained by Friedel and Crafts as to the general fact that there is a vapor-density of 9·20 within these limits of temperature. But this value is not constant and happens to exist at about the boiling point of mercury; while within a range of 50° above and below this point it varies considerably, and between 209° and 440° it changes by an entire unit. The authors conclude, therefore, (1) that starting from the boiling point, aluminum chloride is continually dissociated as the temperature rises, not becoming a perfect gas until 800° is reached; at which point the vapor-density 4·55 is attained corresponding to the formula $AlCl_3$ and the molecular mass 133·15; (2) that this vapor-density is departed from only very slightly even at the highest temperatures attainable; and (3) that hence aluminum is trivalent.

In the following paper Friedel regards the conclusions of Nilson and Pettersson as too absolute. If there is dissociation between 200° and 400° there must exist a vapor capable of dissociating, and this can be only Al_2Cl_6. Moreover, if curves be constructed representing the results given by the two methods, these curves do not unite with each other to form a single curve. The determination of density between 200° and 400° is regular, as is also that above 600°; while the portion between 440° and 600° appears to have a point of inflexion corresponding to a maximum dissociation. He thinks the most natural conclusion to be that like amylene bromhydrate, aluminum chloride has two vapor-densities; one between 200° and 400° corresponding to the formula Al_2Cl_6, and a second above 800°, corresponding to the formula $AlCl_3$.—*Ann. Chim. Phys.*, VI, xix, 145, 171, February, 1890. G. F. B.

3. *On the Combination of Potassium and Sodium with Ammonia.*—JOANNIS has observed that when an equivalent mass of alkali-metal is dissolved in twenty times the equivalent mass of liquefied ammonia, and the ammonia is gradually removed, the pressure falls very rapidly, becoming after a certain time constant and equal to 170^{mm} at 0°. The residue has the composition $Na + 5{\cdot}3\ NH_3$; but since the proportion of ammonia varies with the temperature, it is probably not a definite compound. As more ammonia is removed, a dark red solid substance, darker even than copper, is deposited from the red solution, the pressure remaining constant. Finally, when one equivalent mass of ammonia to one of metal remains, the liquid has completely disappeared and there is left only solid sodium-ammonium or potassium-ammonium. On reducing the amount of ammonia still further, the free alkali-metal gradually separates, the pressure remaining uniform; a dissociation therefore taking place, the pressure of which is equal to that of the saturated solution.—*C. R.*, cix, 900, Dec., 1889. G. F. B.

4. *On the Preparation of Platinic fluoride.*—MOISSAN has succeeded in preparing anhydrous platinic fluoride by passing a current of fluorine over a bundle of platinum wires contained in a tube of platinum or fluor spar, heated to 500° or 600°, and condensing the product in a dry glass vessel. The fluoride forms a dark-red mass either fused or made up of chamois-colored crystals. It is very hygroscopic and yields a yellow solution with water, which almost instantly decomposes with evolution of heat, yielding platinic hydroxide and hydrogen fluoride. It is thus made evident why platinic fluoride has not been obtained in the wet way. On heating to redness platinic fluoride decomposes readily, yielding pure fluorine and crystallized platinum; thus furnishing the best method of obtaining fluorine pure. Gold treated in a similar way yields a similar fluoride.—*C. R.*, cix, 807, Nov., 1889. G. F. B.

5. *On Xylose or Wood-sugar, a new Penta-glycose.*—WHEELER and TOLLENS have examined the sugar discovered by Koch in wood and called xylose. It was prepared by the hydrolysis of wood-gum, obtained from beech wood. The saw dust from this wood, after extraction with ammonia was digested with a five per cent soda solution for 48 hours and precipitated with 95 per cent alcohol. After washing with acidulated alcohol, the precipitate was treated with ether, and the residue, dried over sulphuric acid, left a porous mass almost colorless. To prepare the xylose 50 grams of this gum were boiled with

400^{cc} water and 20 grams of concentrated sulphuric acid in a flask connected with a vertical cooler. After 11 or 12 hours boiling, the solution was saturated with calcium carbonate, filtered and evaporated to a syrup, then dissolved in strong alcohol, again filtered and evaporated, and treated with absolute alcohol. The evaporated syrup from this solidified to a crystalline mass after a few days. Repeated recrystallization and a treatment with animal charcoal gave a pure white crystallized sugar, fusing at 144° to 145° and giving on analysis the formula $C_nH_{2n}O_n$. It is dextrorotatory, $[\alpha]_D = +18°$ or 19° for a solution which had been made some hours. But it shows the so-called bi-rotation markedly, the rotation five minutes after solution being $[\alpha]_D = +85{\cdot}86°$ or four and a half times that of a solution after 16 hours. From the curve of change it appears that the bi-rotation at the instant of solution must be $+100°$. In its reactions xylose resembles arabinose; both yield with mineral acids furfurol and not lævulinic acid, as do the carbohydrates; and on oxidation, no mucic nor saccharic acid is formed. Treated with phloroglucin and hydrochloric acid, both yield a cherry-red color, the phenyl-osazones of both fusing at 160°. By Raoult's method xylose was proved to be a penta-glycose $C_5H_{10}O_5$ an isomer of arabinose. It yields trioxyglutaric acid and tri-oxybutyric acids on oxidation while arabinose yields tri-oxybutyric acid only.—*Liebig's Annalen*, ccliv, 304; *Ber. Berl. Chem. Ges.*, xxiii, 15 (Ref.), Jan., 1890. G. F. B.

6. *On the Identity of Cerebrose with Galactose.*—THIERFELDER has examined the sugar obtained from the brain by Thudichum and called cerebrose. It was prepared by the action of dilute sulphuric acid on cerebrin. Since it reduces Fehling's solution, yields mucic acid when oxidized with nitric acid, and resembles galactose in its melting point, specific rotation, fermentation, and phenyl-hydrazine compound, the author regards it as identical with this sugar.—*J. Chem. Soc.*, lvii, 57; lviii, 121, February, 1890. G. F. B.

7. *Dust in the Atmosphere.*—At a meeting of the Royal Society, January 27, Mr. JOHN AITKIN expressed his belief that "dust condenses moisture before the air is saturated. For the same number of dust particles per cubic centimeter, the atmospheric transparency depends upon the depression of the wet bulb, being large when the depression is large, but becoming small before the depression vanishes. Increase of temperature also reduces transparency when the number of particles remains the same, for increase of temperature means increase of vapor pressure. As a rule, quantity of dust decreases when the wind increases. When calms occur dust accumulates. This increases the radiating power of the air, so that it cools quickly and fog forms. Thus a fog may be regarded as a suspended dew."—*Nature*, Feb. 20, 1890, p. 382. J. T.

8. *The Sun's Heat.*—K. ANGSTRÖM, in his carefully prepared papers, gives the result of his investigations upon the effect par-

ticularly of the absorption of the sun's radiation by carbonic acid in the earth's atmosphere. The results of Langley are commented upon, and compared with the author's results. A formula is found which expresses the results fairly well. If i represents the heat passing through an atmospheric layer of thickness d, then $i = A_1 \rho_1^d + A_2\rho_2^d$ in which A_1 and ρ_1 represent weak and A_2 and ρ_2 strong carbonic acid absorption. ρ_1 can be taken as the mean value of Langley's coefficient. A very satisfactory agreement is found between the calculated and observed values. To carbonic acid absorption the author attributes the sharp rise in the intensity of radiation with high altitude of sun, which Langley's coefficient does not fully express.—*Ann. der Physik und Chemie*, 1890, No. 2; pp. 267–311. J. T.

9. *Method of rotating mirror.*—A. v. OETTINGEN believes that a plane mirror before a stationary photographic objective is to be preferred to the method of a rotating concave mirror. The images are sharper and there is greater range in the disposition of the apparatus.—*Centralztg f. Opt. u. Mech.*, 8, 1887. *Beiblätter Ann. der Physik und Chem.*, 1890, No. 1, p. 33. J. T.

10. *Thermo-Electricity.*—Dr. DECOUDRES, of Leipzig, has succeeded in detecting a thermo-electric tension between compressed and uncompressed mercury. The compression was produced either hydraulically or by means of its own weight acting through a column of mercury. It was found possible to determine with certainty the direction of the thermo-electric current, and to measure its intensity for given pressures and temperatures.—*Nature*, Feb. 27, 1890. J. T.

11. *Measurement of Electrical resistances.*—At a meeting of the Physical Society of Berlin, Feb. 7, Dr. FEUSSNER spoke of the methods adopted at the Government Physico-Technical Institute for the measurement of electrical resistances. The wires are wound upon metallic cylinders in order to provide for the rapid cooling of the wires as they are warmed by the passage of the current; these are then submerged in petroleum, whose temperature is recorded by a thermometer immersed in the liquid, which is itself kept constantly stirred. German silver wires are unsuitable for standard resistances, since their resistance increases with lapse of time. This tendency was attributed to a gradual crystallization due to the zinc in the alloy. Wires made of an alloy of copper and nickel have been examined. Wires made of this alloy possess a very low temperature coefficient, and were found to be very constant after being heated to 100° C.—*Nature*, Feb. 27, 1890, p. 407. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *Subaerial decay of rocks and Origin of the Red color of certain formations;* by I. C. RUSSELL. Bull. U. S. Geol. Survey, No. 52.—In this paper Mr. Russell treats at length of the amount of decay over the middle and southern parts of the Appalachian border of the United States, dwelling on its extent, its relation to

the kinds of rocks, and its earth-making results. Some of the methods of decay are also considered, especially its dependence on the carbonic and organic acids in the soil and on the moisture and warmth of the climate. The great contrast in depth of decomposition between the northern and southern States is dwelt on; and besides explaining this difference by reference to glacial removal in one region and not in the other, and to difference in climate, he refers to the recent elevation in the former region as having quickened erosion and removal by transportation. The author, moreover, sustains the commonly accepted opinion that subaerial decay is still going on as in the past, with like rate of progress. He also dwells on the prevailing red color of the earth and clays resulting from the decay—*terra rossa*, as a wide-spread deposit is called in Europe. Finally, the red color of red sandstones is attributed to the red iron oxide produced by the decomposition or decay, and not to any subsequent change in the history of the deposits.

The contrast in colors between the northern and southern States is spoken of as "a contrast between a glaciated country and a region in which atmospheric decay has progressed uninterruptedly for ages." Mr. Russell, knowing less of New England than of other parts of the country, does not appreciate, as strongly as Professor Crosby whom he criticizes, the full character of this difference. There is wide decomposition at the north, and its rapid progress in the case of syenites, mica schists, gneisses, granites, and hornblende schists during the past forty years is very strikingly exhibited alongside of many railroad cuts. The fact to be accounted for is that these decompositions over New England, whether in the trap of trap dikes or in metamorphic rocks, produces almost *never* red earth, while at the south red earth predominates. The glacial movements and orographic changes have nothing to do with this. The fact is simply that in New England the result of the iron oxidation attending the decay is limonite, the hydrous yellow-brown iron oxide, and not anhydrous Fe_2O_3. The writer has often tried to discover a reason for the different result at the south; he does not find one in Mr. Russell's excellent paper. The question was brought to the writer's attention long since at the volcanic islands of the Pacific (Samoa among them), where the larger amount of rock decay (as about the East Maui Mountain), produces yellow-brown and reddish brown earths, while dry cinder cones (as in the Maui crater), are often red. The decay of a granitoid gneiss a dozen miles east of New Haven goes on rapidly through the oxidation of the iron of the mica; and it makes the rock brown and comparatively weak to a depth in some places of six inches to a yard, with very little attendant decay of the feldspar. Further, the great blocks thus deeply browned have often a *white* exterior two inches or so deep which had been blanched by surface rainwaters, perhaps with the aid of carbonic or organic acids, and this white crust portion is the granitoid rock with the mica gone, but *the feldspar still sound.* The decayed rock crumbles to the same kind of sand as that out of which the Triassic quartz-feldspar sandstone (arkose) of the region was made.

With regard to the red color of the Triassic sandstone, respecting which the writer is quoted, but misunderstandingly, the fact has been before him that the sands made by decomposition in the region are not incrusted with *red* oxide of iron (hematite), but with brown (limonite); and, accordingly, the condition under which the color became red has been regarded as a subsequent one, as that attending the wide-spread consolidation of the rock. It is explained thus in his Manual of Geology, on page 764 (edition of 1880): "A region invaded by trap eruptions is often also, as a consequent or concurrent fact, a region of steaming fissures and of hot springs, conveying the heated moisture widely through the strata of the region; and thus the sand-beds of the same Mesozoic formations in the Connecticut valley were generally reddened as well as consolidated—the oxidation of iron, when taking place through the agency of hot waters producing the anhydrous red oxide." Under such conditions any limonite present about the grains of the loose sand-beds would have been made red. The sandstone wall-rock of dikes is often of a light gray color, instead of red, because the iron is put by the heat into a silicate condition. Familiar blowpipe experiments illustrate both effects. A touch of the blowpipe-flame will redden most sandstones not already red, from the olive-colored building-stone of New Brunswick to varieties of the white of Ohio; proving, as the writer has stated (1873, 1880), that many great sandstone formations would redden in the early stages of orographic movements, or from heat supplied in any other way. The firm consolidation of a sandstone is, in general, evidence that the needed heat has been present. J. D. D.

2. *Géologie de l' Ancienne Columbie Bolivarienne, Vénézuela, Nouvelle Grenade et Ecuador*; par HERMANN KARSTEN, 62 pp. 4to, with a colored map, two plates of profiles and sections and six plates of fossils. Berlin, 1886 (R. Friedländer & Sohn).—This valuable memoir, on the geology of a large section of northern South America, commences with remarks on the general features of the country under consideration, and a history of previous investigations from the time of Humboldt, ninety years since. The author began his studies of South America in Venezuela and carried them on during the years 1844–47, 1849–56, and his results were the subject of publications between the years 1849 to 1860 and later. The new volume is a collection of all his reports, together with a review of the work of other geologists in the region. The careful descriptions and the colored geological map, together with the paleontological plates and the observations on the volcanoes of the Andes, makes the work one of special importance. The map covers the part of South America west of the meridian of 58½ west and north of the parallel of 5° south. A large area bounded on the north, west

and south by the Orinoco, and Rio Negro is covered by crystalline rocks, which are partly or wholly Archæan. North, west and south of the area the color on the map is that of the Tertiary and Quaternary over a wide region extending to the base of the mountains. Then follows a belt of Cretaceous, either side of narrow ranges of crystalline rocks, with Jurassic beds only over a small area east of Popayan in the U. S. of Colombia (New Grenada). Beyond these crystalline ranges westward there are Quaternary belts along the Magdalena and Cauca Rivers and over a shore region, with intervening belts of crystalline rocks bordered by Cretaceous. No rocks of the Triassic or Carboniferous series, or of any Paleozoic formations, have been recognized, the reports respecting the occurrence of such rocks being errors. The map and the profiles also illustrate the positions of the volcanic cones and areas. The descriptions of the Cretaceous fossils figured were published by the author in the Amtlicher Bericht der Naturforscher-Versammlung in Wien, 1858.

3. *Fossil Sponges and Plants.*—Sir Wm. Dawson has a paper on some remarkable hexactinellid sponges from Little Metis, near Quebec, of the age of the Chazy, in the Transactions of the Royal Society of Canada, iii, 1889, with figures. The paper has notes on the species by Dr. G. P. Hinde. The same volume contains also a paper by the same author giving descriptions of figures of fossil plants from Mackenzie and Bow rivers. The Mackenzie River plants are from the "Upper Laramie or Fort Union Group," "still held by some paleontologists to be Miocene," equivalent of beds in Greenland, Alaska, etc.

4. *Emanations of carbonic acid, sulphurous and other gases at "Death Gulch," Yellowstone Park.*—Mr. W. H. Weed, of the U. S. Geological Survey, has described in Science, of February 15th, 1889, the "Death Gulch" in the extreme northeastern portion of Yellowstone Park, on Cache Creek, two miles above its confluence with Lamar River, five miles from the mail station of Soda Butte. In an opening bordering on Cache Creek occur evidences of former hot springs in geyser-like deposits, a hot spring cone half washed away, a mound of travertine, and a little tepid sulphurous water at the edge of the stream. Besides, there are copious gaseous emanations rising through the waters of the creek "mainly, no doubt, carbonic acid, although containing some sulphuretted hydrogen." Above these is altered and crystalline travertine, besides a bank of sulphur and gravel cemented by travertine. In a lateral gully, the waters of its small stream, sour with sulphuric acid, flow in a channel cut through beds of dark gray volcanic tufa. The only springs now flowing are oozes of water, forming a creamy white deposit about the vents which is largely an alum (alumina sulphate). The odor of sulphur is strong. The bears and other wild animals of the region are often killed by the gases. Dead bears were found in all stages from skeletons to freshly killed, and with them were remains of an elk, squirrels, rock-hares, etc., and many dead butterflies and other insects.

5. *Diatom beds and bogs of the Yellowstone National Park.*—Mr. W. H. Weed, in a paper in the Botanical Gazette, vol. xiv, states that Diatom beds cover many square miles in the vicinity of active and extinct hot-spring vents, and vary from three to six feet in depth. The wagon road leading to the Geyser basins crosses several meadows of this character. Near the Emerald spring, at the Upper Geyser basin of Firehole River, there is a typical marsh of this kind, whose waters encroaching either side, have killed the pines. The larger part of the bog was sparsely covered by brackish water plants, while the drier parts are growing grass. The material in the bog is chiefly a semi-liquid, greenish gray, dirty-looking ooze, consisting, as detected under the microscope, of the shells of Diatoms of the following species, as determined by Mr. F. Wolle: *Denticula valida* (the most abundant), *D. elegans*, *Navicula major*, *N. viridis*, *Epithemia argus*, *E. Hyndmannii*, *Cocconema cymbiformis*, *Achnanthes gibberula*, *Mastigloia Smithii*, a *Fragillaria*. *D. valida*, it is stated, occurs also at the geyser basins of Iceland.

6. *Archæan limestone and other rocks in Norfolk, Connecticut.* — A large region between Winsted and Norfolk, in the western half of northern Connecticut, numbered K 2 in Percival's Report on the Geology of the State, has been supposed to be Archæan. This was the opinion of the writer after his study of the region some years since. In 1885 Mr. R. H. Cornish, then residing at Norfolk, gave the conclusion a better foundation by the discovery of limestone which had characteristic Archæan features. The village of Norfolk is ten miles to the east of Canaan where the rocks are the limestone and schists of the Taconic system. Mr. Cornish states that the limestone ledge is on the land of Mr. Ralph Crissy, near a spring southeast of his house, associated with hard gneiss, granite and some hornblendic rocks, which have in general a high eastward dip; and that it afforded him octahedrons of spinel (some of them half an inch across), together with a little chondrodite. The outcrop is only 75 yards long and 20 wide; and it was difficult to determine its stratigraphic relations to the associated rocks. Apparently it was not conformable to them; but more study is needed for a decision. In a ledge crossing Crissy Hill there is much magnetite; and two and one-half miles east of Norfolk, at the foot of Pine Mountain, and near the cross road leading from the Winsted turnpike to Grants, a large vein has been opened and was for a time worked. J. D. D.

7. *Glacial scratches in the vicinity of Norfolk, Conn.*—Mr. R. H. Cornish obtained for the direction of glacial scratches on Dutton Hill, 1640 feet high above tide level, S. 28° E., the same as on Mt. Everett, 20 miles to the west, which is 1,000 feet higher. The directions in the region, in 25 to 30 observations, varied from S. 24° E. to S. 48° E.; the mean, S. 33° E.

8. *On some Mammalian Remains of Florida and elsewhere;* by J. Leidy. Trans. Wagner Free Institute of Science, Philadel-

phia, vol. vii.—Dr. Leidy reports the discovery, by Mr. Joseph Willcox, in a crevice in Tertiary limestone, at Ocala, Marion Co., Florida, of species of Elephant, Horse, Llama, and a Saber-toothed Tiger. The last is about as large as the existing tiger of Asia, and is named *Machairodus Floridanus.* The Horse is the species *E. fraternus,* or Domestic Horse. The Llama was identified from a tooth, which is larger than the corresponding one of the recent *Auchenia Llama* of South America. The Elephant remains are probably those of *E. primigenius.*

At Peace Creek, according to collections by Mr. Willcox and Mr. T. S. Moorehead, from a sand-bar exposed at low water and explored for phosphates, remains were found of the *Tapirus Americanus* of South America; a Horse, perhaps the domestic horse; a Hippotherium, the 3-toed horse, of the species *H. ingenuum* or *H. plicatile* Leidy; *Bison Americanus,* upper molar; *Cervus Virginianus,* antlers, bones, teeth; American Elephant; a Chlamydotherium, probably *C. Humboldtii* Lund, a species found in the Brazil caverns, the specimens dermal plates; also another Brazilian Glyptodon, which is probably the *Hoplophorus euphractus* Lund, and the *Glyptodon* (*Schistopleurum*) *asper; Megalonyx Jeffersoni,* first phalanx; the Manatee, *Manatus antiquus,* and several Dolphins; *Emys euglypha* Leidy, a Trionyx, and a large Tortoise, *Testudo crassiscutata* Leidy; besides remains of probably the *Alligator Mississippiensis,* and of a number of fishes.

Collections of bones from the Salt Mine of Petite Anse, made by Mr. Wm. Crookes and presented in 1883 to the Smithsonian Institution, include, according to Dr. Leidy, remains of *Mastodon Americanus,* a *Mylodon,* and a Horse, the *Equus major.* A specimen of the teeth of *Equus major* is also reported from a bog on the confines of Bond and Fayette counties, Illinois.

Remains of the Quaternary Peccary, Platygonus compressus, from a gravel bank a few miles from Rochester, N. Y., were obtained by Dr. Leidy from Professor H. A. Ward, of Rochester. Other known localities of the fossil are Galena, Illinois, a cave in Kentucky, near Columbus, Ohio, in Iowa, in Benton Co., Mo., Augusta Co., Va., and Mexico. Dr. Leidy, in his article on the Platygonus, presents the details of a comparison of the skeleton with that of a Dicotyles. Dr. Leidy also states that a large species, *Platygonus vetus* Leidy, has been found in Mifflin county, Pa. Several of the species above mentioned are illustrated on plates I to VIII.

9. *Joseph Willcox on the identity of the modern Fulgur perversus with the Pliocene F. contrarius* Conrad.—In a note published by Dr. Leidy in Trans. Wagner Inst., ii, 51, Mr. Willcox points out the fact that the gradations in specimens from the Miocene to the recent form appear to prove that the former was the precursor of the latter. Mr. Willcox also shows that the non-spinose *Strombus alatus* was probably the original form of *S. pugilis.*

10. *Characteristics of Volcanoes, with Contributions of Facts and Principles from the Hawaiian Islands*, including a historical review of Hawaiian volcanic action for the past sixty-seven years, a discussion of the relations of Volcanic Islands to deep-sea topography, and a chapter on Volcanic Island Denudation, by JAMES D. DANA. 400 pp., 8vo. Illustrated by maps of the islands, a bathymetric map of the Atlantic and Pacific oceans, and views of cones, craters, a lava cascade, lava fountain, etc. New York, 1890. (Dodd, Mead & Co.)—This volume commences with a general account of volcanoes and volcanic phenomena. It illustrates the subject afterward by reviewing the facts afforded by the Hawaiian volcanoes, adding to and rearranging somewhat the descriptions and discussions that have appeared in this Journal. That the importance of the Hawaiian volcanoes to the vulcanologist may be appreciated, we mention here the special points in which they have proved to be the best known source of facts and principles,—citing from the Preface.

Science has learned, from the Hawaiian volcanoes, of volcanic activity unrestricted by altitude up to fourteen thousand feet; of the possibility of two first-class craters working simultaneously within the area of one mountain-dome, and having the loftier the more frequent and the more copious in its outflows, and neither of them ordinarily responsive to the other even when in eruption; and of the outflow of the heaviest of chrysolitic lavas at various altitudes to the very summit.

Science has learned from Hawaii more than it knew of the mobility of liquid basalt; of the consequent range in flow-angle of basalt-lavas, from the lower limit near horizontality to the verticality of a waterfall, and therefore of lava-cones of the lowest angle, and driblet-cones of all angles; of lava-lakes tossing up jets over their fiery surface like the jets of ebullition, and in other cases playing grandly in fountains hundreds of yards in height; and, consequently, of the absence from the craters of large cinder-ejections.

It has further learned of a degree of system in the changes within a crater from one epoch of eruption to a state of readiness for another; of a subsidence, after an eruptive discharge of lava, that has carried down, hundreds of feet, a large part of a crater's floor without a loss of level in its surface; and, following this, of a slow rising of the subsided floor, chiefly through the ascensive or up-thrust action of the lavas of the lava-column, and the lifting force taking advantage of the fault-planes that were made at the subsidence; and also of debris-ridges and of debris-cones, one to two hundred feet in elevation, made, by the lift, out of the talus of the pit-walls.

It has learned that pit-shaped craters are characteristic of true basalt-volcanoes, and a result of the free mobility of the lavas, whether the action in the lava-lakes within be fountain-like or boiling-like; that floating islands of solid lava may exist in the lakes; that a regular oscillation between fusion and cooling takes place at times in the thin crust of lava-lakes; that the solid lava of the margin of a lake may be re-fused, and also even the mass of a floating island, and the blocks of a debris-cone until the cone has wholly disappeared.

It has discovered that solfataric action, or that of the hot vapors in lava-caverns, may include the recrystallizing of basalt, therein making it into long, stony pipe-stem stalactites and stalagmites, having cavities lined with transparent crystals of augite and labradorite, besides octahedrons of magnetite.

It has obtained evidence, also, that the greatest of eruptions may occur without the violence or the noise of an earthquake, and without an increase of activity in the crater; that in place of an increase there may be a sudden extinction of the fires, all light and heat and vapors disappearing as soon as the discharge begins; of the greater frequency of eruptions during the wetter season of the year; of the agency of fresh water from the rains (and snows) in the supplying of steam-power for volcanic action; of the full sufficiency of water from this source without help from the ocean—fresh water being as good as salt for all volcano purposes; and further, of a great augmentation of the activity so produced with the increase in altitude of the working crater.

These are facts from Hawaii—and not all that might be cited—that have not yet been made out from the investigation of other volcanoes, not even the best known, Vesuvius and Etna.

The work closes with a chapter of over twenty-five pages on denudation among volcanic islands in the Pacific, containing also some facts from the author's observations in Australia, taken chiefly from his Geological Report of the Wilkes Exploring Expedition published in 1849.

11. *The Geological Record for* 1880–1884; Edited by WILLIAM TOPLEY and CHARLES DAVIES SHERBORN. Vol. II, Physical and applied Geology, Petrology, Meteorites, Mineralogy, Mineral Waters, Paleontology, General Maps and Sections. 563 pp. 8vo. London, 1889 (Taylor & Francis).—This valuable volume, the contents of which are given in the title, appeared a few months since; with volume I before issued it completes the Geological Record for the five years named. The usefulness of such a work will be appreciated even by those who do not fully understand the amount of labor it has cost.

12. *Tabellarische Uebersicht der Mineralien nach ihren krystallographisch-chemischen Beziehungen geordnet* von P. GROTH, 3d edition, 168 pp. Braunschweig, 1889 (F. Vieweg & Son).—Few works upon Mineralogy have contributed so much to the progress of the science as the Tables of Professor Groth, of which the 3d edition is now issued. They present in clear and comprehensive manner the successive groups of minerals, showing the relation in composition and axial ratio of the individual species belonging to each. The author's profound knowledge and keen mind have enabled him to throw light upon many obscure points and to the advanced worker as well as to the student the Tables are constantly suggestive and helpful.

13. *New localities for Phenacite;* by W. S. YEATES (communicated).—Among a number of mineral specimens collected by me, last June, at the mica mines of Amelia C. H., Va., I have identified crystals of phenacite and topaz, the latter being altered in some instances, to the variety of muscovite known as damourite. I have one quite large pseudomorph of the damourite after topaz. The phenacite is badly cracked, and not, so far as I have seen, in good specimens. I also found galena associated with the albite. The occurrence of these minerals at this locality has not, I believe, been before announced.

I have also received from Mr. Loren B. Merrill, of Paris, Me., for identification, a flat crystal of phenacite from Hebron, Maine. It has a maximum diameter of 14^{mm} and is a combination of the planes, O, i-2, $r\frac{2}{3}$-2, $l\frac{4}{3}$-2 and a rhombohedron of the first order, too small to allow of measurement of its angles. The first mentioned plane is new to the species and a fuller description of the crystal will be published later.

14. *Hybrids in the genus Ranunculus.*—It is well known that certain genera in the Order Ranunculaceæ contain doubtful natural hybrids, while in a few genera of the Order, this tendency to hybridize has been utilized for the production of some of the most attractive plants in general cultivation. FREYN has lately given, in the Botanisches Centralblatt, (1890, 1–6), an interesting account of certain species of Ranunculus, in which, after referring to the investigations of others, he describes a few possible hybrids. *Ranunculus lacerus, Bellardi,* has been regarded as the offspring of *R. aconitifolius* and *R. Pyrenæus*, or more probably, of the former with *R. plantagineus.* But from his researches Freyn concludes that this is not a true hybrid: it is more probably a vigorous form of *R. plantagineus.*

The supposed cross between the two species *R. arvensis* and *R. bulbosus* is reduced by him to a variety of *R. bulbosus* with much divided leaves, the divisions however, falling within the range of form found in *R. bulbosus.*

In the same way, the author reduces the so-called hybrid of *R. bulbosus* and *montanus*, in Heer's Herbarium, to *R. mixtus.* He says that he cannot consider it a hybrid, much less a hybrid in which *R. bulbosus* has had any share.

Certain forms have been described as resulting from the crossing of *R. bulbosus* and *R. nemorosus.* All of the supposed hybrids are brought by the author down to varieties of the species named, or to *R. montanus*, but he recognizes no true hybrids in any of the forms.

The supposed hybrid between *R. bulbosus* and *R. polyanthemos* fares a little better. One from the northern limit of *R. bulbosus*, was described by Schmalhausen (in which the parents as given above are reversed in order) and this is thought to be a hybrid, but a second, described by Lasch, is thrown out.

The plant which has been described as a hybrid of *R. bulbosus* and *R. repens*, is regarded as a form of *R. Philonotis* Ehrh., a synonym of *R. Sardous* Cz.

In the same manner the author is compelled to state that the supposed cross of *R. lanuginosus* and *montanus*, if indeed a hybrid at all, is more likely a hybrid between *nemorosus* and *Villarsii*, or between *nemorosus* and *montanus*.

R. lanuginosus and *nemorosus* hybrids turn out to be merely forms of *R. nemorosus*. The criteria employed by the author are not merely found in the features of the plant, but also in the geographical range of the alleged parents; and by an application of his method, the number of Ranunculus hybrids has been materially reduced.

Attention has been called to this short but interesting communication in the hope that our local botanists will scrutinize the so-called hybrids not only in this but in allied genera with greater care than heretofore, relying not only upon apparent marks of resemblance but giving due weight to the characters drawn from impaired fertility, and from the circumstantial evidence which comes from an examination of the habitat of the supposed parents. G. L. G.

15. *Corals and Coral Islands*; by JAMES D. DANA. 440 pp. 8vo. New York, 1890 (Dodd, Mead & Co.).—A new edition of this work is just now leaving the press. It contains much new matter on the subject, and, in the course of it, a full discussion of the Darwinian and opposing theories of coral reefs. It is illustrated by several new plates and maps, four of the plates being colored plates of corals from the author's Exploring Expedition Report on Zoöphytes, published in 1846.

OBITUARY.

EUGÈNE E. DESLONGCHAMPS of Chateau Mathieu, Caen, formerly Professor of Zoology and Paleontology at the Faculty of Sciences, Caen, Calvados, died in December last. He was the son of the celebrated French paleontologist M. Eudes-Deslongchamps, and had published extensively on paleontological subjects, including a Prodromus of the Teleosaurians of Calvados and "Les Brachiopodes Jurassiques de la France." His "Études critiques sur des Brachiopodes nouveaux ou peu connus," and "Le Jura Normand" were in course of serial publication.

Dr. MELCHIOR NEUMAYR, Professor of Paleontology in the University of Vienna, died on the 29th of January at the age of forty-four. He was one of the ablest and most active of the corps of Austrian geologists, and had written many important memoirs on Paleontology; his early death is a great loss to science.

Dr. VICTOR RITTER VON ZEPHAROVICH, Professor of Mineralogy at Prague, and author of numerous papers, chiefly on crystallographic subjects, died on the 24th of February in his 60th year.

Dr. F. VON QUENSTEDT, the veteran paleontologist and mineralogist of Tübingen, died December last. He was the author of important works on Paleontology, Mineralogy and Crystallography.

CONTENTS.

SCIENTIFIC INTELLIGENCE.

Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

EDITORS
JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS
PROFESSORS JOSIAH P. COOKE, GEORGE L. GOODALE AND JOHN TROWBRIDGE, OF CAMBRIDGE.

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

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XXXIX.—[WHOLE NUMBER, CXXXIX.]

No. 233.—MAY, 1890.

WITH PLATES V–VII.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1890.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

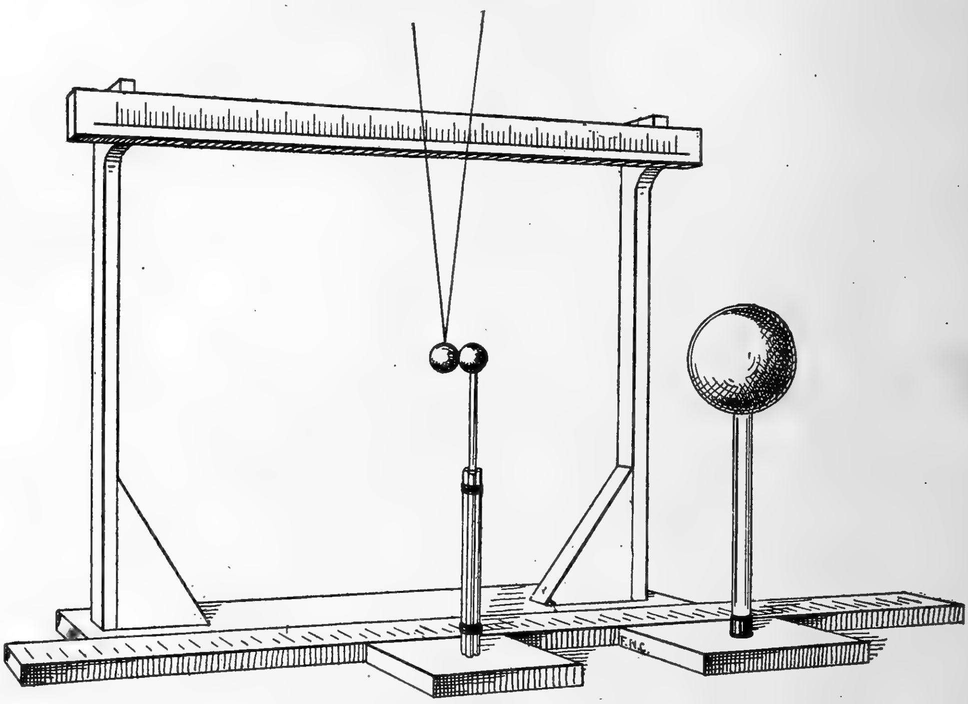
ART. XLI. — *Experiments with a Pendulum-electrometer, illustrating measurements of static Electricity in Absolute Units;* by ALFRED M. MAYER.

Description of Apparatus.—A sphere, accurately turned out of velvet cork to 1 cm. radius, with a smooth surface, was heavily gilt. A staple made of fine wire was driven into this sphere, and a very fine filament prepared from a cocoon of the silk-worm was passed through the staple and the ends of the filament were attached, at a distance of 52 cms. apart, to a support near the ceiling. In this bifilar suspension the effect of torsion is eliminated, for the twist of one length of the thread is opposed to that of the other. The vertical length of the pendulum is 364 cms. or nearly 12 feet.

A scale of millimeters, pasted on a slip of glass, is placed behind the suspending threads and 34 cms. above the center of the suspended sphere. A black band (not shown in figure) is painted along the lower edge of this scale, so that, when the line of sight is in the plane of the two threads of bifilar suspension, we see a fine white line on this black ground. This permits fine readings of deflections along the scale of millimeters.

The force pushing the pendulum from the vertical will be as the weight of the sphere and $\frac{1}{2}$ the weight of suspending thread into the sine of the angle of deflection. The weight of sphere and one half of thread is 990 mgrms., and the force of *one dyne* will give to the pendulum a deflection from the vertical of 3·4 mm. on the scale above the sphere, if we take $g = 980{\cdot}2$ cms. at Hoboken.

As not over 2° of deflection was used in the experiments, it follows that the difference between the sine of the deflection and its chord is just measurable, amounting to only $\frac{1}{6}$ mm. for an angle of deflection of 2°. The scale was inclined to the horizontal so as to coincide with the chord of 2°.



Another sphere of brass of one cm. radius was supported on a rod of glass; the latter coated, while hot, with a film of paraffine. This rod was mounted vertically on a wooden base which slid along a scale of millimeters on a table. This scale and the one before which the pendulum is deflected are so placed that when the suspended cork-sphere and the sphere on the rod are just in contact the threads of suspended sphere read 0 on the upper scale, while the vertical plane through the center of the sliding sphere reads 2 cm. on the lower scale, this being the distance apart of the centers of the spheres.

The ends of the thread, to which the gilded cork-ball is suspended, are passed through small staples in a board fastened to or near the ceiling, and are then joined together and passed around a spool fixed by a screw midway between the staples. By turning the spool the thread is wound on or off it, and thus the height of the pendulum is adjusted so that its center and that of the sphere on the glass rod are in the same horizontal line. When this adjustment has been made the head of the screw is tightened on the spool.

The sphere on the rod is charged and then slid along the scale on the table till it is in contact with the sphere of the pendulum. The charge is thus equally distributed between the spheres: and when the sphere on the rod has been brought to 2 cm. reading on its scale, the deflection on the upper scale plus 2 cm. gives the distance of centers of spheres apart, and the force (f) in dynes in the rate of 3·4 mm. to the dyne; and $f = \frac{qq'}{D^2}$, and since $qq' = q^2$; $q = D\sqrt{f}$, as the sphere, being of 1 cm. radius, has unit capacity.

Influence of the surface of the room and of surrounding objects on the capacity of the sphere.

[If we assume (to be within bounds) that the above influences are equivalent to a sphere of 100 cms. radius, concentric with the suspended sphere, we have $C = \frac{rr'}{r'-r} = \frac{100}{99} = 1·01$. This gives for the effect of the induction of the room in increasing the capacity of the sphere, the same as would be produced by increasing the radius of the sphere by $\frac{1}{10}$ mm.; a quantity too small to be taken into account in experiments with this apparatus, as it is not possible to form the sphere to this degree of precision. We would here remark that this apparatus is not an instrument of extreme precision, though it will measure to $\frac{1}{30}$ of a dyne, and with a sphere of pith, which has $\frac{1}{6}$ of the specific gravity of cork, it may measure to the $\frac{1}{60}$ of a dyne, if the apparatus is guarded from air currents; but this instrument gives the means of readily making electrostatic measurements before a class, and of presenting clear conceptions of the nature of these measurements.

Experiments to determine if apparatus gives the law, $f = \frac{qq'}{D^2}$.

Eight experiments are given in the following table. The first column gives the number of experiment; the second, the deflections in centimeters of the pendulum; the third, the

Exp. 1	$d = 5·25$ $d' = 1·15$	D = 5·25 D′ = 11·15	$\frac{d}{d'} = 4·56$	$\frac{D'^2}{D^2} = 4·51$	Approx. $\frac{1}{91}$
" 2	$d = 5·0$ $d' = 2·4$	D = 5·0 D′ = 7·2	" 2·08	" 2·07	" $\frac{1}{208}$
" 3	$d = 4·8$ $d' = 2·3$	D = 4·8 D′ = 7·0	" 2·08	" 2·12	" $\frac{1}{52}$
" 4	$d = 3·5$ $d' = 2·1$	D = 5·5 D′ = 7·1	" 1·66	" 1·66	" $\frac{1}{\infty}$
" 5	$d = 2·65$ $d' = 0·87$	D = 5·65 D′ = 9·87	" 3·046	" 3·051	" $\frac{1}{609}$
" 6	$d = 2·75$ $d' = 1·5$	D = 4·77 D′ = 6·5	" 1·83	" 1·85	" $\frac{1}{91}$
" 7	$d = 3·02$ $d' = 2·87$	D = 4·86 D′ = 5·02	" 1·052	" 1·066	" $\frac{1}{76}$
" 8	$d = 3·10$ $d' = 2·94$	D = 4·94 D′ = 5·10	" 1·054	" 1·065	" $\frac{1}{96}$

corresponding distances of the centers of the two spheres; the fourth, the direct ratios of the deflections; the fifth, the inverse ratios of the squares of the distances between centers of spheres; the sixth, the approximations to the law of the inverse squares. By approximation we mean $\frac{d}{d'} \div \left(\frac{d}{d'} - \frac{D'}{D}\right)$.

The average approximation is quite close to the law, being $\frac{1}{106}$. One cause of this departure from the law of the inverse squares is the mutual influence of the spheres causing a departure from uniform electrical density over their surfaces.* If we replace the cork ball by one of pith, the approximation to the law is much closer, as the distances of the spheres in the experiments are much greater. A gilded pith ball of 1 cm. radius, made of pieces of pith cemented together, weighs, with one half of the suspending filaments, only ·25 grm., about $\frac{1}{4}$ of the weight of cork ball† and filament; so that, on the pith ball pendulum, a dyne will produce a deflection of 13·3 mms. This pendulum is not suited to class experiments, as it is too readily moved by air currents, and has to be inclosed in a large cage formed of silk fastened to a light wooden frame. When this pith sphere is thus protected and suspended by an exceedingly fine fibre, it gives as close an approximation to the law of inverse squares as does the Coulomb torsion-balance. Another cause of error is the continual loss of electricity during the experiments. This error can be partly corrected by repeating as nearly as possible the first experiment and properly combining this third experiment with the first. This was not done in those given, our object having been to see how close an approximation to the law is reached by methods suited to experiments before a class. The error caused by loss of electricity can be allowed for in measurements of quantity and potential by a determination of this loss by experiments similar to those given below.

Experiments to determine the law of the loss of electricity, per minute, from a sphere of the radius of (1 *cm.*) *the unit of capacity.*

The pendulum sphere was touched by the charged sphere on the rod, and the latter remained in one position during the experiments. The deflections of the pendulum and the distances of the centers of the spheres were read every three minutes.

* On this subject see Sir W. Thomson's papers on Electr. and Mag., p. 86; and Mascart and Joubert's Electr. and Mag., vol. i, p. 153, and vol. ii, p. 173.

† The specific gravity of elder pith, in air, is ·04. This I determined by weighing a right parallelopiped cut out of this substance. The specific gravity of cork is ·24.

At the heads of the columns of following table d stands for the deflections in cms.; D, for the distances apart of the centers of spheres in cms.; f, for force in dynes; q, for units of quantity of electricity.

Times.	d	D	$f=\frac{d}{\cdot 34}$	$\sqrt{f}$	$q = D\sqrt{f}$
0 m.	3·10	5·10	9·1176	3·02	15·4020
3	3·02	5·02	8·8823	2·98	15·9596
6	2·94	4·94	8·6470	2·94	14·5236
9	2·865	4·865	8·4264	2·90	14·1085
12	2·797	4·797	8·2264	2·87	13·7674
15	2·73	4·73	8·0294	2·83	13·3859
18	2·67	4·67	7·8529	2·80	13·0760
21	2·60	4·60	7·6443	2·76	12·6960

Times.	q	Dif. 0 and 3; 3 and 6, etc.	Mean q	Loss per 3 m.	Loss per m.
0 m.	15·4020				
		·4424	15·1808	$\frac{1}{34}$	$\frac{1}{102}$
3	14·9596				
		·4360	14·7416	$\frac{1}{34}$	$\frac{1}{102}$
6	14·5236				
		·4151	14·3160	$\frac{1}{34}$	$\frac{1}{102}$
9	14·1085				
		·3411	13·9370	$\frac{1}{41}$	$\frac{1}{123}$
12	13·7674				
		·3815	13·5766	$\frac{1}{35}$	$\frac{1}{105}$
15	13·3859				
		·3099	13·2309	$\frac{1}{42}$	$\frac{1}{126}$
18	13·0760				
		·3800	12·8860	$\frac{1}{34}$	$\frac{1}{102}$
21	12·6960				

The mean loss per minute is $\frac{1}{108}$ of the charge; and the difference between the maximum and minimum measures is $\frac{1}{535}$. In Coulomb's experiments (Mem. 3d 1785) this difference amounts to $\frac{1}{399}$.

The loss of electricity, as is well known, follows Newton's law of cooling; and these experiments show the operation of this law very closely.

The coefficient thus found is, however, only applicable to experiments made in similar hyrometric and barometric conditions of the air, for the coefficient varies with these conditions.

In the above experiments the barometer was at 30·069 ins.; the force of vapor ·251 ins.; and the relative humidity 31·3. Temperature of air, 73° F.

Experiments on the distribution of electricity on a cylinder, like the one experimented on by Coulomb.

In his sixth paper, of 1788,* Coulomb gives his measurements on the distribution of electricity on a cylinder with hemispheric ends. It was 30 French inches long and 2 French

* Sixième Mémoire sur l'Électricité, Mem. de l'Acad. Sci., 1788, p. 628.

inches in diameter. I made a similar cylinder of wood neatly covered with thick tin-foil. With it I made the following experiments to test the value of the pendulum-electrometer from measurements that could be compared directly with those made by Coulomb with his torsion-balance.

To do this I had first to determine the fraction of the charge lost by this cylinder per minute. This I did by transferring, at intervals of three minutes, a proof-plane from the charged cylinder to the stationary sphere of the pendulum-electrometer, and made a series of experiments similar to those given under "Experiments to determine the law of the loss of electricity, etc." It was found that the charged cylinder lost ·04 of its charge in one minute.

The following experiment, No. 9 of the series given, will show the manner of procedure in making a measure of electric density at a point on the cylinder.

Proof-plane carried from contact with middle of cylinder to stationary sphere of pendulum-electrometer gave a deflection of the pendulum of 3·55 cms., with distance of centers of spheres of 5·55 cms. $\sqrt{3{\cdot}55} \times 5{\cdot}56 = 10{\cdot}43$ = charge on middle of cylinder. After an interval of two minutes the following measure was obtained from charge of proof-plane conveyed to electrical-pendulum from contact with the end of the cylinder:

Deflection of pendulum = 6·7 cms.
Distance of centers of spheres = 8·7 cms.

$$\sqrt{6{\cdot}7} \times 8{\cdot}7 = 22{\cdot}53,\ 22{\cdot}53 + (22{\cdot}53 \times {\cdot}08) = 24{\cdot}33,$$

$$\text{and } \frac{10{\cdot}43}{24{\cdot}33} = 1 : 2{\cdot}33.$$

That is, the ratio between the electric density on the middle of the cylinder to that on the end is as 1 to 2·33.

The following measures were made in the above manner:

	Density on Middle.	Density on End.		Density on Middle.	Density on End.
1	1·00	2·42	7	1·00	2·21
2	"	2·36	8	"	2·31
3	"	2·20	9	"	2·33
4	"	2·22	10	"	2·23
5	"	2·26	11	"	2·26
6	"	2·20	12	"	2·21
	Mean = 1		:		2·27

Coulomb gives for the distribution on this cylinder the following ratios:

At middle of cylinder	1·00
" 2 ins. from end	1·25
" 1 in. " end	1·8
" end	2·3

The mean of our measurements gives for the ratio of densities at middle and at end of cylinder, 1 : 2·27, which is substantially the same as Coulomb's ratio of 1 : 2·3.

Measurements of Quantity and Potential.

The quantity and potential of the charge on a sphere of known radius are readily measured by the pendulum-electrometer, as shown by the following experiments.

The charged sphere, of 1 cm. radius, was brought in contact with the electric pendulum, and the force in dynes exerted on the latter was 7·058. The distance apart of centers of spheres was 7·4 cms. This gives for the quantity (Q) on the pendulum, $Q = \sqrt{7{\cdot}058} \times 7{\cdot}4 = 19{\cdot}7$ units of electricity.

As soon as the readings of the deflection of the pendulum and the distance apart of centers of spheres were obtained, the sphere on the rod, of 1 cm. radius, was removed and a charged sphere of the 4·6 cm. radius was brought opposite the charged pendulum. The deflection of the latter was now 3·5 cms.; the distance of centers of spheres, 28·5 cms., and the force of deflection in dynes, 10·29. The quantity, Q′, on larger sphere is

$$Q' = \frac{fD^2}{Q} = \frac{10{\cdot}28 \times 812{\cdot}25}{19{\cdot}7} = 424{\cdot}26$$

units of quantity.

As the potential (V) of the larger sphere is equal to the quantity (Q′) of its charge divided by its capacity (C), or raaius in centimeters, we have

$$V = \frac{Q'}{C} = \frac{424}{4{\cdot}6} = 92{\cdot}2 \text{ units of potential.}$$

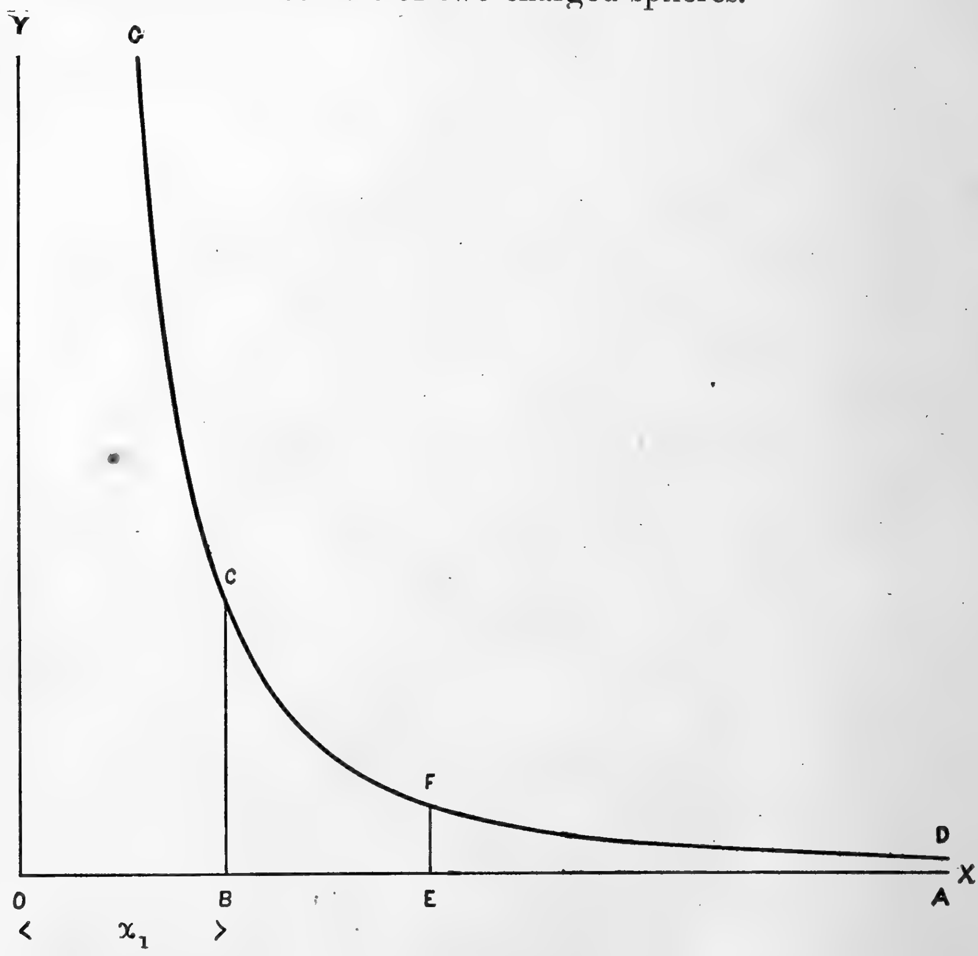
The foregoing experiments show that the pendulum-electrometer gives the law of inverse squares, serves to determine the law of dissipation of electric charge, and with it one may make measures of the electrical distribution on conductors and determine quantity and potential. In short, this simple apparatus affords an inexpensive and ready means of presenting clearly to students the nature of measurements of static electricity, and allows one to make these measures in absolute units before a class with ease and dispatch.

Stevens Institute of Technology, Hoboken, N. J.

ART. XLII.—*On Electric Potential as measured by Work;* by ALFRED M. MAYER.

[Read before the National Academy of Sciences, November 10th, 1887.]

The object of this paper is to give a demonstration of the fact that the potential, $V, = \frac{Q}{d} = \frac{Q}{r} = \frac{Q}{C}$; when Q=quantity, C=capacity, r=radius in cms. of charged sphere, and d=distance in cms. of centers of two charged spheres.



It occurred to me that this problem could be presented in a direct and clear manner by supposing an electrically charged sphere fixed in space with its center at O, (see fig.), and that another sphere charged with a unit of similar electricity is pushed toward O from an infinite distance, along the line OX, and that the electric strain on the moving sphere causes (without work) a vertical rod to slide out of its top in proportion as the stress between the spheres increases. As the sphere progresses along OX it will thus mark at each point of its progress the repulsive force existing between it and the fixed sphere. The end of the sliding rod during the motion of the sphere from X towards O will have traced out the curve D F C G, whose ordinates are as the inverse squares of their distance from O.

Thus we get a trace in a manner similar to that given by the steam-engine indicator, or by one of the many instruments which draw curves, showing the varying effects of pressures, or of stresses.

The potential at any point reached in the progress of the charged body towards O = work done = resistance overcome in pushing body from infinite distance to that point; and this work done is measured by the sum of the resistances at each point of path × the length of path. But this product is equal to the *area* included between the ordinate (say B) of path, the axis of X and the curve, both indefinitely extended; or, say C B A D.

If the body has been moved from infinite distance up to E, a certain amount of work has been done; and it is to be proved that if the body has been moved from infinite distance up to B, = ½ distance OE, that twice the amount of work has been done. In other words, it is to be proved that area C B A D is twice the area F E A D; or, generally, that such areas will vary inversely as the distance of the bounding ordinate (such as F E or C B) from O, the origin of coördinates.

The equation of the curve is

$$y = \frac{a}{x^2}$$

Area A B C D, indefinitely extended =

$$\int_{x_{\prime}}^{\infty} y dx = \int_{x_{\prime}}^{\infty} \frac{a}{x^2} dx = -a \left[\frac{1}{x}\right]_{x_{\prime}}^{\infty} = 0 + \frac{a}{x}, \therefore \propto \frac{1}{x}.$$

Or, area *indefinitely extended*, which represents the work, is inversely as the distance of y (the bounding ordinate of area) from O, or, $V = \frac{Q}{d}$, but also, $V = \frac{Q}{r}$, and as $V = \frac{Q}{C}$, $r = C$; r being expressed in cms.

I had supposed that the mode of presenting this problem and the demonstration based on that conception, as given in this paper, must have occurred to others before it did to me, but Professor B. O. Peirce, of Harvard University, who is better versed in the literature of the subject than I am wrote me as follows: "My experience has taught me that students who have not paid much attention to mathematics almost invariably find it difficult to get any true idea of the meaning of the word "potential" and that they value highly anything which helps to make this meaning clearer. Your graphical illustration of the fact that in the case of two electrified spheres the potential function is a measure of work, is new to me and I feel sure that it will prove helpful to persons who already familiar with indicator diagrams, are struggling to get an idea of the use of the potential function." This opinion of Professor Peirce determined me to publish this paper.

It should be stated that Maxwell also used the indicator diagram in illustration of an electrical problem, though different from the one here considered. Section 27 of his work, "An elementary treatise on electricity," is thus headed "*Indicator diagram of electric work.* The indicator diagram, employed by Watt for measuring the work done by a steam engine, may be made use of in investigating the work done during the charging of a conductor with electricity. . . ."

Stevens Institute of Technology, Hoboken, N. J.

Art. XLIII.—*An elementary proof of the Earth's Rigidity;* by Geo. F. Becker.

Definition of rigidity.—The term rigidity, as used in the theory of elastic bodies and in the theory of the earth, denotes any degree of resistance to change of shape. It must be confessed that the selection of this word to express this quality is not a fortunate one. In ordinary mechanics, as in ordinary life, a rigid body means one which is incapable of change of shape. Such a body would be called by elasticians *infinitely* rigid, and they attribute to every substance which shows elasticity of shape, however small, or in other words to every solid substance, the property of rigidity. Thus both india-rubber and steel are in their language rigid bodies, the difference in this respect being that the "modulus of rigidity" of steel is much greater than that of rubber. From the ambiguity of the term rigid, some geologists who were unfamiliar with his writings have been led to suppose that Sir William Thomson maintained that the earth is incapable of deformation. So far is this from the truth that Thomson was the first physicist who investigated the tidal problem on the hypothesis that the earth undergoes deformation by the attraction of the moon or sun. It is to be understood, then, that the title of this paper may be stated less concisely, but without change of meaning, as "an elementary proof of the earth's resistance to change of shape." It will not be found that the term rigidity, once understood in its special sense, leads to confusion.

Difficulty of Thomson's Problem.—No geologist would think of denying that the question of the earth's solidity is the most important in physical geology, but as it has been treated by physicists, the subject is one of peculiar difficulty. Sir William Thomson has shown that the earth exhibits to the attractive forces of the sun and moon a resistance so great as to imply that it is solid throughout. To reach this conclusion it is necessary to determine separately the resistance to deformation which a solid sphere presents because of the mutual attraction of its parts, and the resistance due to the elastic forces which are called in play when deformation occurs.

The resistance due to gravitation is thoroughly well understood and this portion of the subject is not hard to master. On the other hand, the determination of the elastic resistance is very difficult. The general theory of the statics of elastic bodies is highly complex, and physicists are by no means agreed as to whether the general equations involve 21 or only 15 independent constants.* Both schools accept as the empirical basis of calculation Hooke's law, which experiments show to be only approximately true for small pressures, while for high pressures it is morally certain that the so called constants assume other values, and no physicist professes to be able to obtain results which are strictly accurate excepting for infinitesimal deformations.—On the basis of the general elastic theory, Lamé investigated the equilibrium of an elastic sphere by the method of spherical harmonics. There seems to be no doubt that this investigation is a masterpiece of genius. Thomson's inquiry is based upon Lamé's. He has considerably simplified the discussion, but without rendering it either short or easy; and he has applied it to the case of a homogeneous, isotropic sphere, of the size and mean density of the earth, without mutual gravitation of its parts, but subject to the attraction of a distant external body such as the sun or the moon. That even this application of Lamé's problem is laborious may be inferred from the fact that Thomson himself refers to the "tedious algebraic reductions" which he omits.

The result, so far as the earth is concerned, is an extremely simple formula for the ellipticity of an elastic sphere.

When this formula is once reached, Thomson's argument for the great effective rigidity of the earth presents no difficulty which may not be made intelligible to any geologist. It is not strange, however, that there has been some reluctance in geo-

* B. de Saint-Venant, probably the greatest elastician up to this time (he died in 1886), followed Poisson in maintaining that eolotropic elasticity involves only 15 moduluses and that isotropic elasticity involves but 1 constant. On the other hand, Green, Stokes, Thomson, and others, starting from a different view of the molecular constitution of matter, argue that 21 and 2 moduluses respectively are requisite. Lamé adopted the molecular theory which leads to uniconstant isotropy, but expresses his results by biconstant formulas. These are certainly the more convenient, for they can at once be reduced to uniconstant forms. See Todhunter's History of Elasticity.

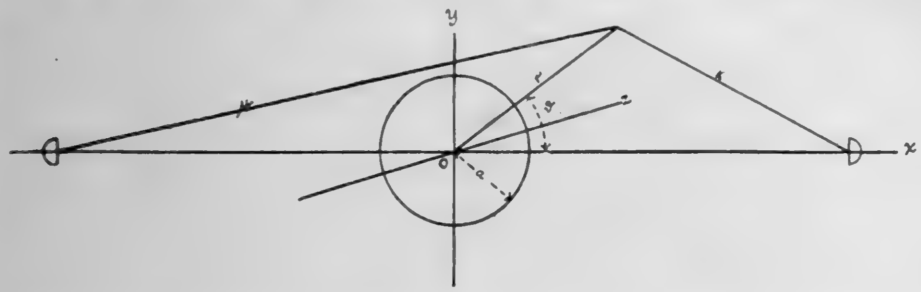
logical circles to admit the necessity of a result the demonstration of which scarcely anyone—perhaps no one—generally classed as a geologist can follow critically.

Possibility of a simplification.—It occurred to me that, since even the result of the Lamé-Thomson investigation is only an approximation for real (or finite) strain there might be some simpler way of reaching another approximation which, though less accurate, would be sufficiently close for a demonstration of the rigidity of the earth. Thomson's result is that the ellipticity of the elastic sphere, under the limitations mentioned above, is $\frac{5}{19}$ of a certain constant. If one could show that this ellipticity were, at all events, greater than $\frac{1}{4}$ of this same constant, it will appear by an examination of Thomson's argument that substantially the same results would follow.

I have succeeded in proving this inequality by a method so simple that no mathematics beyond plane trigonometry is needful to follow it. Besides presenting this proof in the most elementary possible manner to my colleagues, I shall take the occasion to follow out Thomson's argument in the way which seems best adapted to geological readers, for it appears to me certain that on some points he has been very generally misunderstood.

General character of the earth's elastic strain.—The problem of the deformation of an elastic sphere by the attraction of an external body like the moon is closely analogous to the simplest tidal problem. Suppose that the earth were always to present the same face to the moon, just as the moon presents (nearly) the same face to the earth. Then the waters would be drawn upward toward the moon to a definite ellipsoidal surface capable of accurate computation. This ellipsoid would have three unequal axes, of which the longest would be directed toward the moon, while the polar axis would be the shortest. The difference between the polar axis and the shorter of the equatorial axes would be due to the rotation of the earth-moon system, and but for this rotation the two bodies would fall together. This rotation, however, produces an elliptical flattening of the globe, while the attraction of the moon produces a distinct but superimposed elongation of the globe. It is desirable to separate these two effects and this can be done by the following device. The earth may be supposed at rest in space and subjected to the action of two bodies fixed at equal distances from it in opposite directions. If each of these bodies has half the mass of the moon, and if the distance of each of them from the earth's center is equal to the moon's real mean distance, then the deformation will be sensibly the same as that which the real moon would produce irrespective of the effects of rotation. It is the tide found on this hypothesis which is known as the "equilibrium tide."* In the elastic problem, also the globe is supposed subjected to the attraction of two half-moons, but the resistance to deformation is supposed due solely to elastic forces instead of to gravitation.

Form of the stress.—Let the earth's center of inertia be taken as the center of coördinates; let r be the distance of any



point in space from this origin and let ϑ be the angle which r makes with the x axis. Let also μ and $\varkappa$ be the distances of the point from the two portions of the moon, and let M be the mass of the moon and D its mean distance. Then, by the law of gravitation, the forces acting on the point are

$$\frac{M}{2\varkappa^2} \text{ and } -\frac{M}{2\mu^2}$$

and here

$$\varkappa^2 = D^2\left(1 + \frac{r^2}{D^2} - \frac{2r}{D}\cos\vartheta\right);\ \mu^2 = D^2\left(1 + \frac{r^2}{D^2} + \frac{2r}{D}\cos\vartheta\right).$$

These forces can of course be resolved in any direction by simple projections. The resulting formulas can also be simplified without substantial loss of accuracy by neglecting powers of r/D higher than the first. The distance of the moon is 60·3 times the radius of the earth, and the highest value of r^2/D^2 which can occur in this discussion is therefore only 1/3,636.

If the forces are resolved into F_r, the component coinciding in direction with the radius vector, and F_t the component at right angles to the radius it will be found that

$$F_r = \frac{Mr}{D^3}(3\cos^2\vartheta - 1) \text{ and } F_t = \frac{Mr}{D^3}\, 3\sin\vartheta\cos\vartheta.$$

Or if the forces are resolved into components X, Y, Z in the directions of the axes (reckoned as usual per unit volume)

* This system of "moon and anti-moon" is that employed by Laplace, Thomson and others. Prof. G. H. Darwin has given a far more elegant method of dealing with the equilibrium tide (Encycl. Brit., Article Tides, 1888); but though his treatment is very simple, it is less adapted to a paper like this, from which it seems best to exclude the potential.

$$X=\frac{2Mx}{D^3};\quad Y=\frac{My}{D^3};\quad Z=\frac{Mz}{D^3}.$$

These, or equivalent forms, are those used in the theory of the tides and are amply accurate for most problems connected with the subject.

The total values of these forces acting on the earth are easily found. Consider first the hemisphere to the right of the yz plane. The force acting on each particle is simply proportional to its distance from the dividing plane, or to x. Now it is well known that if ξ is the distance of the center of inertia of a mass from a given plane, and if m is the mass of an elementary particle $\xi\Sigma m=\Sigma\,(mx)$. Hence the total force will be proportional to the mass of the hemisphere into the distance of its center of inertia from the origin. For the hemisphere $\xi=3a/8$ where a is the radius, and if w is the mean density, the whole force acting on the basal plane is say

$$\pi a^2 X=\frac{2M}{D^3}\Sigma(mx)=\frac{2M}{D^3}\cdot\frac{3}{8}a\cdot\frac{2}{3}\pi a^3 w=\frac{2M}{D^3}\,\frac{\pi a^4 w}{4}. \qquad (1)$$

In precisely the same way one finds for the sum of the forces affecting the hemisphere which lies above the xz plane

$$\pi a^2 Y=\frac{M}{D^3}\,\frac{\pi a^4 w}{4}$$

and the symmetry of the figure shows that $Z=Y$.

The deformation of an elastic sphere of the size and mean density of the earth by a mass so small as the moon (1/83 of the mass of the earth) and at such a distance from it, is of course very minute. The most probable deformation in fact amounts to an ellipticity of about 1/10,000,000. It may be inferred therefore that the deforming stress on the plane passing through the earth's center of inertia at right angles to the direction of the moon is not very far from uniform. Were this the case the earth would be homogeneously strained, so that each elementary cube would suffer the same distortion.

Simple strain spheroid.—Suppose a cube of isotropic, homogeneous, incompressible matter (like india rubber) subjected to a uniformly distributed tensile stress in the direction of the x axis. Then by Hooke's law the elongation per unit length will be proportional to the force per unit area, say X; and if n is the constant called the modulus of rigidity, this elongation is $X/3n$. If the mass is but little strained and the volume is constant, this elongation is accompanied by a linear lateral contraction in each direction which is equal to half the elongation.*

* If the elongation of the unit cube is α and the linear lateral contraction is β, while the volume remains constant, $1=(1+\alpha)(1-\beta)^2$; and if α^2 and $\alpha\beta$ are so small as to be negligible, this reduces to $\alpha=2\beta$.

Suppose that the cube were also subjected to a compressive force Y acting at right angles to X and to a compressive force Z at right angles to each of the others. Then if the height of the cube is $2a$ and if α, β, γ are the displacements on the three axes, the cube will be elongated in the direction of x by

$$\alpha = \frac{2aX}{3n} + \frac{2aY}{6n} + \frac{2aZ}{6n}$$

and it will be contracted in the direction of y by

$$\beta = \frac{2aX}{6n} + \frac{2aY}{3n} - \frac{2aZ}{6n}$$

and γ will be symmetrical with β.

In a special case let $2Z = 2Y = X$. Then

$$\alpha = \frac{2aX}{2n}; \quad \beta = \gamma = \frac{2aX}{4n}.$$

Now this is precisely the effect which would be produced by a simple tensile force, P in the direction of x, unaccompanied by lateral forces, if

$$P = \frac{3}{2} X. \tag{2}$$

Consider a sphere of radius a inscribed in the cube before the application of the force P. After the mass was strained the sphere would have become an ellipsoid the major semi-axis of which would be

$$a + \frac{\alpha}{2} = a\left(1 + \frac{X}{2n}\right) = a\left(1 + \frac{P}{3n}\right)$$

and the minor semi-axes would be each

$$a - \frac{\beta}{2} = a\left(1 - \frac{X}{4n}\right) = a\left(1 - \frac{P}{6n}.\right)$$

The ellipticity of this ellipsoid would be

$$e = 1 - a\frac{\left(1 - \frac{P}{6n}\right)}{a\left(1 + \frac{P}{3n}\right)} = \frac{P}{2n} \cdot \frac{1}{1 + \frac{P}{3n}}$$

Here P is by supposition a force so small that its square can be neglected and thus

$$(1 + P/3n)^{-1} = 1 - P/3n$$

and hence also

$$e = \frac{P}{2n} \tag{3}$$

First approximation to the earth's bodily tide.—On the hypothesis that the earth is homogeneously strained, I have only to find P of the last formula in terms of the forces applied to the earth. This has really been done in a preceding paragraph. Equations (1), (2) and (3) give

$$P = \frac{3}{2}X = \frac{3}{2}\cdot\frac{2M}{D^3}\cdot\frac{a^2w}{4} = \frac{1}{2}\tau a^2 w$$

where $\tau = 3M/2D^3$ is introduced for brevity; and if e_s is the ellipticity of the earth regarded as a simple strain ellipsoid

$$e_s = \frac{5}{20n}\tau a^2 w.$$

Character of the approximation.—No use can be made of the value e_s unless it can be shown that it is less than the true value. It has been found on the hypothesis that the stress is uniformly distributed and that the mass is incompressible, and neither supposition is strictly correct.

If one considers the true distribution of stress, it is almost self-evident that the applied force will be greater near the major axis than near the periphery of the *yz* section. But this can easily be proved. Suppose a slender cylinder of the elastic spheroid close to its major axis, separated from the surrounding mass as if by a diamond drill. Then the force acting upon this cylinder will be its mass into the distance of its center of inertia from the origin. But this distance is $a/2$ while the center of inertia of the hemisphere is only $3a/8$ from the origin. The cylinder will therefore be much more elongated than it would be if the sphere were homogeneously strained.

When this axial cylinder is connected with the surrounding mass, it will be held back to some extent and cannot be so much elongated as if it were free. But the fact that, when free, it is elongated by more than the average amount per unit length, proves that even when under constraint there is a tendency to greater elongation, which must be operative to some extent.

If the two lateral compressions due to the forces Z and Y are considered, it is clear that these strains will also be more intense near their respective axes than is assumed on the hypothesis of homogeneous strain. Thus the approximation underestimates the longitudinal extension and underestimates the lateral contraction; in short, it underestimates the ellipticity of an incompressible mass.

The famous result of Sir William Thomson for the case of incompressibility is, say,

$$e_r = \frac{5}{19n}\tau a^2 w = 1{\cdot}05 e_s$$

Influence of compressibility.—It will be well to consider first the effect of compressibility on the homogeneously strained spheroid already discussed. If k is the coefficient of compressibility (becoming ∞ when the mass is incompressible) the elongation of a cube of height $2a$ becomes

$$2a\,X\left(\frac{1}{3n}+\frac{1}{9k}\right)$$

and the accompanying lateral contraction is

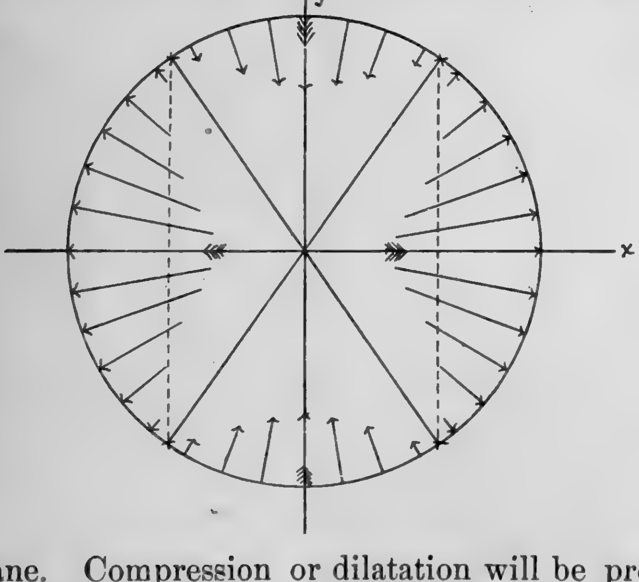
$$2a\,X\left(\frac{1}{6n}-\frac{1}{9k}\right).*$$

The elongations and contractions for Y and Z are of course of the same form. If these values are introduced into the expressions for α, β, γ, it will be found that the terms in k cancel, and that the ellipticity is exactly the same as for the case of incompressibility.

To find the effect of compressibility upon the sphere when the distribution of strains is the real one, it is more convenient to deal with the polar components of the forces or

$$F_r=\frac{Mr}{D^3}\left(3\cos^2\vartheta-1\right);\ F_t=\frac{Mr}{D^3}3\sin\vartheta\cos\vartheta.$$

The latter or tangential component will have no effect upon the volume. The forces of this form will form couples tending to increase the angle which each diameter originally made with



the yz plane. Compression or dilatation will be produced by the component which is directed toward or from the center, or

* For the very simple method by which these formulas are established, see Thomson and Tait, Natural Philosophy, § 683, or Thomson's article on Elasticity, in the Encycl. Brit.

by F_r. This force vanishes when $3\cos^2\vartheta=1$ or when $\vartheta=54° 44'$, nearly. The lines of no compressive force form a cone of two sheets, the axis of which coincides with the line connecting the two halves of the moon. Within this cone the forces F_r are directed from the center and tend to produce dilatation of the mass, and F_r is a maximum on the axis where it has the value $2\frac{Mr}{D^3}$. Between the sheets of the cone is an annular mass bounded on the surface by a zone. Within this mass the forces are directed inward, and tend to produce compression. The compressive force is maximum when $\vartheta=90$ and thus has the value Mr/D^3.

This distribution is illustrated in the diagram on page 343, where an arbitrary length is assumed as equal to the value of the force on the x-axis and the other forces are exhibited in the true proportion to it.*

When strains are small, they may be supposed to take place successively. Thus one may arrive at the distortion of a compressible sphere by supposing it first deformed as if it were incompressible, and that it then becomes compressible. If this course is adopted in the present case, the incompressible sphere would be distorted to an ellipsoid of the same volume, in which the compressive stresses exhibited in the diagram would exist, but would be inoperative. If compressibility now supervenes, it is clear that dilatation will take place along the major axis and compression at right angles to it.

General result for elastic spheroid.—Hence compressibility must increase the ellipticity which an elastic sphere assumes under a tide-generating stress. Hence also the ellipticity is always greater than $\tau wa^2/4n$, and any conclusions which can be

* It is a noteworthy fact that *all* ellipsoids of infinitesimal ellipticity and constant volume intersect the surface of the unstrained sphere at the circles of no force. One way of proving this is as follows: Let the semi-axes of the ellipse be $a(1+\delta)$ and $a(1-\delta/2)$ where δ is so small that its square can be neglected. Then, the volume being constant,

$$a^3 = a(1+\delta)\,.\,a^2(1-\delta/2)^2$$

and the equation of the ellipse is

$$\frac{x^2}{(1+\delta)^2}+\frac{y^2}{(1-\delta/2)^2}=a^2=x^2(1-2\delta)+y^2(1+\delta)$$

when this ellipse cuts the circle, $a^2=x^2+y^2$, and

$$2x^2=y^2 \text{ or } \tan^2\vartheta=2 \text{ and } \cos^2\vartheta=\frac{1}{3}$$

irrespective of the spherical value of δ.

The equipotential surfaces are hyperboloids of revolution asymptotic to the cone mentioned in the text, and the equation of the potential is simply

$$\int F_r\, dr = V = \frac{Mr^2}{2D^3}(3\cos^2\vartheta-1)$$

drawn as to the rigidity of the earth by taking as a minimum value of the distortion

$$e_s = \frac{1}{4}\ \frac{\tau w a^2}{n}$$

are perfectly safe.

If $3k = 5n$, as is the case for the theoretical, uniconstant, isotropic solid, and at least approximately also for glass and iron, the result reached by the beautiful, but laborious, method of Lamé and Thomson is, say

$$e_c = \frac{5}{19}\ \frac{\tau w a^2}{n}\left(1+\tfrac{2}{55}\right) = 1{\cdot}09\ e_s$$

so that one is very safe indeed in taking the ellipticity as at least e_s.

Ellipticity of a fluid sphere.—Having considered the elastic resistance of the earth apart from the influence which the mutual attraction of its elements produces, it is next necessary to consider the effect of this attraction apart from the rigidity, or as if the mass were a fluid. Later it will appear how the results are to be combined so as to include both elasticity of form and attraction toward the center.

It is very easy indeed to prove that if the earth were a homogeneous, incompressible fluid of mean density 5·5, and if the attraction were directed to a single, central point; the ellipticity of the equilibrium tide would be $a\tau/g$, where g is the acceleration of pure gravitation.* It is somewhat more difficult to prove that the mutual attraction of the fluid in its deformed state would augment this ellipticity by 5/2. But these are familiar propositions of analytical mechanics, which no one doubts and which geologists are safe in accepting.

The ellipticity of an incompressible homogeneous fluid earth would then be, say,

$$e_g = \frac{5}{2}\ \frac{a\tau}{g} = 162\times 10^4\tau.$$

* The forces acting on a fluid sphere by the equilibrium theory are $\frac{M}{2\mu^2}$, $\frac{M}{2\kappa^2}$, and gravitation which is expressed by $\frac{E}{a^2}$ where E is the earth's mass. This leads to a value of the major semi-axis expressed by $r = a\left(1+\frac{Ma^3}{ED^3}\right)$. It is also readily proved that, for any ellipsoid closely approaching the sphere, the major semi-axis is $a\left(1+\frac{2}{3}e\right)$. Hence $e = \frac{3Ma^3}{2ED^3}$. (In Nat. Phil., § 804 this ellipticity is erroneously stated at twice this quantity). The ordinary meaning of g is the resultant of gravitation and centrifugal force; but on the equilibrium theory there is no rotation of the globe, and g is then equal to E/a^2. Substituting this and the value of τ, the equation becomes $e = a\tau/g$.

If the fluid supposed at first incompressible were to become compressible, it is clear that a would decrease and that g, being inversely proportional to the square of the distance from the earth's center, would increase. Thus the resistance to deformation by the attraction of the moon would increase and the deformation measured by the ellipticity would decrease. It can also be shown in detail that if the increase in density took place in any manner capable of approximate expression by Laplace's law (that the increase of the square of the density is proportional to the increase of the pressure) compressibility would decrease the ellipticity; but even infinite compressibility would only reduce the ellipticity by a moderate fraction of its value for the case of incompressibility.* Beyond a knowledge of the sense in which compressibility would affect the ellipticity of the fluid sphere it is really not worth while to inquire, for it is not at all probable that the so-called constants of elasticity, n and k, would exhibit invariability if we could experiment with pressures of hundreds of thousands of pounds to the square inch; indeed there is good evidence of great changes in rigidity even at pressures which have been experimentally applied.

Comparison of results.—In the following table I have collected the various ellipticities mentioned above with numerical expressions for spheres of the mean density of the earth, but with the rigidity of glass, brass and steel. Thomson gave figures for glass and steel, and I have added those for brass. I

* Centrifugal force is equivalent to a simple repulsion from a line, and if ω is the angular velocity, the measure of this force is $\omega^2 r$. Tide-generating force is equivalent to repulsion from a plane as appears from the manner in which it was deduced above and its measure is $2\tau x$. Hence the formulas for the two cases are convertible by the substitution of one of these forces for the other, bearing in mind that centrifugal spheroids are oblate and that tidal ellipsoids are prolate. See Nat. Phil., § 834, page 432.—If E is the mass of the earth, and if f is the ratio which the mean density of a sphere bears to its surface density, the ellipticity of a rotating spheroid in which there is a small increase in density from the surface downward, may be expressed by

$$e = \frac{5}{2} \frac{\omega^2 a^3}{\mathrm{E}} \cdot \frac{1}{2(1+4(f-1))}$$

(Cf. Nat. Phil., §§ 824′ and 800). In the case of the equilibrium tide, real and apparent gravitation coincide and therefore $g = \mathrm{E}/a^2$. Introducing also the value of τ this becomes

$$e = \frac{5}{2} \cdot \frac{\tau a}{g} \cdot \frac{1}{1+4(f-1)}$$

Similarly § 824′(2) gives for the case in which the surface density is infinitesimal as compared with the density at the center

$$e = \frac{6}{\pi^2} \cdot \frac{5}{2} \frac{a\tau\omega}{g} = \text{nearly } \frac{6}{10} \cdot \frac{5}{2} \cdot \frac{a\tau\omega}{g}$$

For the reasons stated in the text these formulas are of no use excepting to show that progressive increase of density decreases the ellipticity of a fluid sphere.

may note that, judging from the value of "Young's modulus," cast iron and phosphorus bronze have a rigidity nearly the same as that of brass. The rigidity of brass is from a determination by Everett. In the table n/g is the value of n in grams weight per square centimeter; e_s is the ellipticity of a homogeneously strained sphere, treated in this paper as affording a rough approximation; e_r is the ellipticity as given by Thomson's formula for the case of incompressibility; e_c is the value given by his formula for the case of compressibility if $3k = 5n$, or if isotropy involve but a single constant. Finally S and R, which will be of use presently, are given by

$$S = \frac{e_s}{e_g + e_s} \text{ and } R = \frac{e_r}{e_g + e_r}$$

ELLIPTICITIES OF ELASTIC, NON-GRAVITATING SPHEROIDS.

	n/g	e_s	e_r	e_c	S	R
Glass	244×10^6	$235 \times 10^4\tau$	$248 \times 10^4\tau$	$257 \times 10^4\tau$	0·591	0·606
Brass	373×10^6	$153 \times 10^4\tau$	$161 \times 10^4\tau$	$167 \times 10^4\tau$	0·485	0·498
Steel	780×10^6	$72 \times 10^4\tau$	$77 \times 10^4\tau$	$80 \times 10^4\tau$	0·311	0·322

Comparing these ellipticities with that for a fluid sphere, $e_g = 162 \times 10^4\tau$, it appears that in a globe of the size of the earth, the mutual attraction of parts is much more powerful than the elasticity of figure if the rigidity is that of glass; that these two resistances to deformation are substantially equal if the rigidity is that of brass; and that gravitation is less than half as powerful as elasticity of figure if the rigidity is that of steel.*

Combination of resistances.—The ellipticity of a deformed sphere varies directly as the applied force and inversely as the resistance. Thus if W is the resistance one may write

$$\frac{1}{e} = \frac{W}{\tau}$$

In the cases of an elastic incompressible sphere and a fluid sphere this equation takes the forms

$$\frac{1}{e_r} = \frac{19n}{5a^2w} \cdot \frac{1}{\tau} = \frac{\mathfrak{r}}{\tau} \text{ and } \frac{1}{e_g} = \frac{2g}{5a} \cdot \frac{1}{\tau} = \frac{\mathfrak{g}}{\tau}$$

where the Old English letters are introduced for brevity. In the case of a sphere in which gravitation and elasticity co-operate, $W = \mathfrak{g} + \mathfrak{r}$ and the ellipticity is expressed by

* In the first sentence of Nat. Phil., § 840, it seems to me certain that Sir William Thomson must have meant to write glass instead of steel, for he has just shown that the attraction of the moon deforms a fluid sphere much more than it does a steel sphere in which there is no mutual attraction of parts.

$$\frac{1}{e_r} = \frac{\mathfrak{g}+\mathfrak{r}}{\tau} = \frac{1}{e_g} + \frac{1}{e_r}$$

or

$$e = \frac{\tau/\mathfrak{g}}{\mathfrak{r}/\mathfrak{g}+1} = e_g \cdot \frac{e_r}{e_g + e_r} = e_g \mathrm{R}$$

where R is the fraction given in the table. If instead of taking Thomson's value for the ellipticity of the elastic spheroid, or e_r, my rough approximation, e_s, is substituted, e simply becomes e_gS. In the table R and S are given in decimals in order to show how far they differ. Excepting for this purpose the third decimal is of no value whatever, indeed the second decimal is also nearly if not quite worthless. Now for glass S=0·98 R and consequently is substantially identical with R.

Both R and S are in fact underestimated; for the earth is certainly compressible to some extent and, as has been shown above, compressibility increases e_r and decreases e_g. Hence the deformation of the solid globe as compared with a fluid one of the same mean density is distinctly understated in the above formulas or in other words the globe is really more rigid than the formulas imply.* The extent to which the rigidity of the earth is understated by the formulas however must be quite insignificant, unless indeed the earth contains ellipsoidal shells exhibiting a higher degree of compressibility than is shown by ordinary solids and liquids.†

Whether R or S is used in the formulas one may thus safely state that, if the earth had the same rigidity as glass, it would yield to the deforming influence of the moon and sun 3/5 as much as if it were fluid and that if it possessed the rigidity of brass it would yield 1/2 as much as if it were fluid. Even in the case of steel S=0·97 R and the difference between R and S is far within the limits of error of any knowledge which we can ever hope to reach as to the actual rigidity of the earth. Thus for steel R or S may be taken at about 1/3, and all these values, which follow from the investigations of Lamé and Thomson are also deducible from the inequality $e > \frac{1}{4}a^2\tau w$ itself deduced by the most elementary methods.

* The Rev. Osmond Fisher has attempted to reconcile the hypothesis of a fluid substratum with the effective rigidity of the earth (Physics of the Earth's Crust, 2d edition, chapter v). If I understand him correctly, he misunderstands Henry's law on which his argument is based. He seems to suppose that the amount of gas which a fluid will dissolve is proportional to the sum of the pressures of the gas and the fluid. Henry's law shows the proportionality between the pressure of the gas alone and the amount of gas which the fluid will dissolve. Water from great oceanic depths contains no more gas in solution than that from the surface.

† Thomson after calculating the effect of the compressibility of the uniconstant solid on the ellipticity of an elastic spheroid, says "we see that the compressibility of the elastic solid exercises very little influence on the result." § 837.

Apparent oceanic tides.—If the earth were a fluid of density 5·5 and the ocean rested upon the heavier liquid, both would yield to the attraction of the moon almost equally and there would be no considerable apparent tide. If the earth were a perfectly rigid mass and always turned the same exposure toward the moon, the water directly under the moon would rise $\frac{5}{2} \cdot 1\frac{3}{4}$ feet or $4\frac{3}{8}$ feet higher than it would stand at an angular distance of 90° from the moon. The solar tides are about 1/2 of the lunar tides. The actual total amplitude of the tides at oceanic ports is usually from 2 to 3 feet. Were the actual tides equal to the equilibrium tides, it would be perfectly easy to state the approximate rigidity of the earth. The real tides are greatly affected by the rotation of the earth, the obstruction of the continents, and the inequalities of the bottom. They are not static but dynamic. Nevertheless the fact that these are apparent tides shows that the earth possesses some rigidity, and the fact their amplitude is so considerable compared with the equilibrium amplitude shows that this rigidity is great. Thus if the globe were as rigid as glass, the apparent tides would be only 2/5 of the real tides or in other words perfect rigidity would then increase the apparent tides to 5/2 of their present amplitude, so that the amplitude of the tides at oceanic stations would increase to from 5 to $8\frac{1}{2}$ feet and would be much greater than the lunar equilibrium tides. If the rigidity is really that of brass, infinite rigidity would raise the oceanic tides to from 4 to 6 feet. If the earth were as strong as steel these tides would be raised by perfect rigidity to from $2\frac{1}{2}$ to $4\frac{1}{4}$ feet.

Messrs. Thomson and Darwin have examined the tidal theories and observations with especial reference to the question of rigidity. In 1888, the latter wrote, "it cannot be admitted that perfect rigidity of the earth would augment the tides in the proportion of 5 to 2, although they might perhaps be augmented in the proportion of 4 to 3."* The context shows that Darwin includes tides of short period as well as those of long period in this statement.

Rigidity of the earth.—The conditions affecting the tides of short period are so complex that no more information can be derived from them than is contained in the above quotation, which amounts to the statement that the earth's modulus of rigidity must exceed 24,400 kilograms per square centimeter by some indefinite amount. But the tides of long period must conform much more nearly to the equilibrium values than do those of short period. Were the period so long that the kinetic energy of the ebb and flow currents would be sensibly dissipated, or were the waters practically motionless at high

* Encyc. Brit., Article Tides.

water and low water, the long period tides would coincide with those of equilibrium and then observation would give a reasonably accurate value of the rigidity of the earth. Laplace supposed that the fortnightly tides did sensibly coincide with the equilibrium heights. On this hypothesis Darwin discussed the observations and found that the amplitude of the lunar fortnightly and monthly tides is about 2/3 of the equilibrium height. This would correspond to the rigidity of steel. Later however he came to the conclusion that these periods are too short to bring the waters to rest and that the result is thus vitiated.

It is certain, however, as Mr. Darwin wrote me in November, 1889, "that these tides will not be large on a rigid earth and hence the investigation remains as a general confirmation of the rigidity of the earth, without giving any quantitative evaluation of its amount."*

If the earth had the rigidity of brass the semidiurnal rise and fall of the land would be half the amplitude of the real tides and would equal the apparent tides. Were the continents uniform in lithological composition and elevation the tidal wave might pass under our feet unnoticed, as it does under a ship at sea. But it seems to me that at points near abrupt changes of density, as along the foot of a great mountain range or near the edge of a great oceanic abyss such as lies close to the Pacific Coast, a semidiurnal rise and fall of two or three feet would surely manifest itself in differential displacements.

Solidity of the earth.—The earth is thus a very rigid body. It does not follow as a matter of logical necessity that it is solid, because under certain circumstances a fluid in motion may act like a rigid mass toward certain external forces. On this subject it can only be said that, though the matter has been considered, physicists have thus far been unable to devise any system which will account for the effective rigidity of the earth as displayed in the tidal phenomena in this manner. No such explanation would be satisfactory unless the fluid were treated as viscous.

* Mr. Osmond Fisher quotes Mr. Love in the Proc. London Math. Soc., vol. xix, 1888, p. 206, as reaching the result that only the fortnightly tides can settle the question. If there is such a tide "we shall be entitled to say that the tidal effective rigidity of the earth is too great to allow us to suppose it to consist of a liquid mass covered with a thin solid crust." But, he says, "the Tidal Committee of the British Association appears to be still doubtful whether there really is an appreciable fortnightly tide." Mr. Darwin is or has been a member of the Brit. Assoc. committees on tides (excepting one to promote tidal observations in Canada) and has usually written the reports of these committees. I can find no evidence in these reports of any such doubt as is mentioned. Darwin speaks of these tides as "distinctly sensible" in Proc. R. S., Nov. 25, 1886, and as being 2/3 of the equilibrium height in Encyc. Brit., Art. Tides, 1888. That he is still confident of their existence is clear from the extract from his letter given in the text.

The average rigidity of the rocks exposed at the surface of the earth is certainly much less than that which a continuous mass of glass or brass would exhibit and there is thus a distinct difficulty in accounting for so high a rigidity as the earth evinces, even on the theory that the globe is solid. On this point, however, certain experimental results of Dr. William Hallock are very instructive. He subjected wax and paraffin to a pressure of 96,000 pounds per square inch in a horizontal steel cylinder; and on the top of these substances he placed small silver coins. The coins were forced against the tube with such violence as to leave in the steel impressions which could be felt as well as seen.* Thus substances which at one atmosphere show trifling rigidity, may develop a rigidity comparable with that of steel at pressures such as are to be found at about 15 miles below the surface of the earth.

On the other hand it is at first surprising to learn that a globe of the size of the earth and as rigid as the best drawn brass, would yield to the attraction of a distant body half as freely as if it were fluid. But it is a matter of common observation that bodies of large dimensions are not so strong as small ones in proportion to their size. Thus a bar of steel of the size of a needle held horizontally by one end does not bend even sensibly and the strain is far within the elastic limit; while a bar of the same relative dimensions, but 1000 feet long, evidently could not be supported in a similar manner. In fact, when two bodies are geometrically similar, the strength varies as the squares of the corresponding dimensions, while the mass varies as the cubes of these dimensions. When we come to deal with a mass like the earth, containing about 11×10^{20} cubic metres each weighing 5,500 kilograms, it therefore is not strange after all that it presents but a feeble resistance to external forces.

The opposition which some geologists have made to the theory of the solidity of the earth is of course based upon the hypothesis that geological phenomena cannot be accounted for on the theory of solidity. So far as the contortion of strata is concerned, there is no conflict between geology and physics. Time enters into the expression of viscosity; and the fact that the earth behaves as a rigid mass to a force which changes its direction by 360° in 24 hours is not inconsistent with great plasticity under the action of small forces which maintain their direction for ages. For a considerable number of years I have constantly had the theory of the earth's solidity in mind while making field observations on upheaval and subsidence, with the result that to my thinking, the phenomena

* This Journal, vol. xxxiv, 1887, p. 277.

are capable of much more satisfactory explanation on a solid globe than on an encrusted fluid one

The only considerable novelty in the foregoing paper is the proof that a simple strain spheroid affords an approximation to the deformation of an elastic globe sufficiently close to serve as a basis for Sir William Thomson's demonstration of the rigidity of the earth; but an endeavor has also been made to present the whole subject in a clear and elementary manner.

U. S. Geol. Survey, Washington, Feb. 1890.

ART. XLIV.—*On the Hornblende of St. Lawrence County, N. Y., and its Gliding Planes;* by GEORGE H. WILLIAMS.

A PERFECT cross-parting due to intercalated twinning lamellæ has been incidentally referred to by the writer* and by the late Professor vom Rath† as occurring on certain crystals of brown hornblende from Pierrepont, St. Lawrence County, N. Y. The phenomenon is altogether analogous to the basal parting much more commonly observed on pyroxene; and, on account of the general interest attaching to the gliding or structure planes of crystals, it seems deserving of further study.

Hornblende is one of the important silicates whose occurrence in the great belts of crystalline limestone in northern New York has rendered St. Lawrence County a well-known mineral locality. From its composition this hornblende is to be referred to *actinolite*. It presents two well marked varieties, which however differ in hardly any other respect than

	(I)	(II)
SiO_2	56·54	56·44
TiO_2	----	·11
Al_2O_3	1·10	1·77
Fe_2O_3	·69	·84
FeO	2·36	·73
MnO	----	·11
CaO	13·69	11·83
MgO	24·42	22·98
Na_2O	1·15	2·13
K_2O	----	·75
Ignition	----	2·46
	99·95	100·15

color. The one of these is green and comes principally from the neighborhood of Russell; while the other is brown and

* This Journal, III, vol. xxix, p. 486, June, 1885.
† Sitzungsber. d. niederrh. Ges. f. Natur- und Heilkunde, Juli 7, 1886.

occurs most abundantly near Pierrepont. Their chemical similarity may be gathered from the preceding analyses: I being an average of two analyses of the green variety made by Dr. W. M. Burton formerly of the Johns Hopkins University; and II, an analysis of the brown variety made by Dr. T. M. Chatard of the U. S. Geological Survey.

In habit these hornblende crystals are usually short and stout, though sometimes much elongated. Their terminal planes are few and rough, while the faces of the prismatic zone are numerous and glistening. Indeed, certain of the green crystals from Russell possess an unparalleled development of prismatic forms, showing six faces between the pinacoids whose symbols are as follows: $\infty P\grave{7}$ (170), $\infty P\grave{5}$ (150), $\infty P\grave{3}$ (130), ∞P (110), $\infty P\bar{2}$ (210), $\infty P\bar{3}$ (310).* Of these forms, all except the first have also been identified on the brown crystals from Pierrepont.

It was on certain small brown hornblende crystals of simple prismatic habit, ∞P (110) and $\infty P\grave{\infty}$ (010), from South Pierrepont that the transverse parting with parallel twinning lamellæ was first observed. Subsequent search for more material showed that, although the parting itself occurred quite frequently on both the brown and green hornblende from northern New York, twinning lamellæ parallel to the parting, which were of sufficient breadth to allow of their optical orientation, were apparently confined to such simple brown crystals as those above mentioned.†

Crystals of both the green and brown hornblende, where the parting is present without visible twinning lamellæ, often yield, on separating, a surface of high luster which allows of an exact location of the parting plane. A number of measurements of its inclination to the faces of the fundamental prism, clearly showed this plane to be parallel, not to the form usually assumed as the basal pinacoid for hornblende, as at first surmised by vom Rath and myself, but to the unit orthodome, $P\bar{\infty}$ ($\bar{1}01$), which has nearly the same inclination to the vertical axis. The angles obtained on one large crystal of brown hornblende from South Pierrepont against the four faces of the unit prism are as follows:

$$\left.\begin{array}{l}\bar{1}01:110 = 104^\circ\ 12' \\ \bar{1}01:1\bar{1}0 = 104^\circ\ 10'\end{array}\right\}\ 104^\circ\ 7'\ 26''\ \text{(calc. v. Koksch.)}$$

$$\left.\begin{array}{l}\bar{1}01:\bar{1}\bar{1}0 = 75^\circ\ 49' \\ \bar{1}01:\bar{1}10 = 75^\circ\ 46'\end{array}\right\}\ 75^\circ\ 52'\ 34''\ \text{(calc. v. Koksch.)}$$

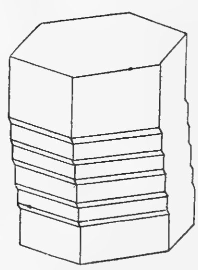
* Neues Jahrbuch für Min., etc., 1885, II, p. 175, where this hornblende was wrongly designated as *pargasite*.

† For their kindness in willingly furnishing hornblende material for this investigation, the writer desires to express his obligation to the following gentlemen: J. H. Caswell, Esq., of New York; Messrs. C. E. Bement and Joseph Wilcox of Philadelphia, C. D. Nims of St. Lawrence County, N. Y., Dr. Whitman Cross of Washington, Prof. S. L. Penfield of New Haven, and the authorities of the U. S. Geological Survey

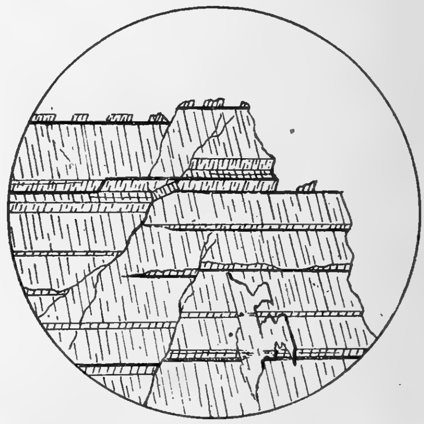
This result is quite in accord with the position of a similar transverse parting as determined by Cross* for hornblende in certain dioritic rocks from Brittany, and by Mügge† for analogous cases from Arendal.

Upon the simpler crystals from South Pierrepont, which show distinct twinning lamellæ parallel to the parting, this plane is itself always dull, so that no certain result can be obtained from its reflections. That its position, however, is the same as that of the above determined plane, $P\bar{\infty}(\bar{1}01)$, is proved both by the optical orientation of the lamellæ and by the angle between the prismatic faces of the lamellæ and those of the principal individual. The appearance of such a crystal is represented in fig. 1; and the transverse lamellæ, although

1.



2.



much narrower than those here depicted, are broad enough to yield distinct prismatic reflections. These gave the angles:

$$(110) : (\bar{1}\bar{1}0)' = 147^\circ\ 38'$$
$$(1\bar{1}0) : (\bar{1}10)' = 147^\circ\ 44'$$

while 147° 56′ 26″ is required by von Kokscharof on the supposition that the twinning axis is the normal to $P\bar{\infty}(\bar{1}01)$.

These narrow twinning lamellæ parallel to the transverse parting in the Pierrepont hornblende vary in width and are not always continuous across the crystal. Their maximum breadth is less than $0{\cdot}04^{mm}$, but under the microscope they nevertheless come out with a distinctness which allows of their complete optical orientation. The appearance of a portion of a thin section, cut parallel to the clinopinacoid and magnified about eighty diameters, is represented in fig. 2. In ordinary light the twinning lamellæ appear as a series of parallel bands,

* Tschermak's Min. und Petrogr. Mitth., III, p. 386, 1881. The first observation of such a transverse parting in hornblende was made, as far as I know, by Jeremejew in 1872. Neues Jahrbuch für Min., etc, 1872, p. 405.

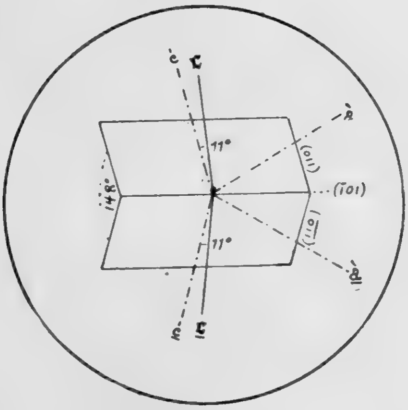
† Neues Jahrbuch für Min., etc., 1889, I, p. 243.

across which the cleavage lines are inclined 32° to those of the main crystals. Very often a thin film of calcite lies on one side of the twinning band; and, in some cases, this may be seen to cross from the lower to the upper side, as indicated in fig. 2. The width of these bands is very variable, as is also that of different portions of the same band. Within the hornblende are irregularly shaped intercalations of another mineral of a somewhat darker brown color than the hornblende and with a parallel extinction. It is a mica, probably phlogopite, which is regularly grown with the hornblende in such a way that their cleavages are parallel; although, in some cases, its position is wholly independent of that of the hornblende. Across large areas of this mica the twinning lamellæ do not pass, but they have evidently created more or less disturbance in the mineral where they could not produce a gliding (fig. 2). Very narrow bits of the mica are, however, displaced by the gliding of the hornblende (fig. 3).

In some cases the lamellæ die out gradually in the hornblende, while in others they terminate abruptly at a crack, beyond which they may be continued at a different level. Their microscopic character bears strong witness to the secondary and dynamic origin of these twinning bands. Within them the cleavage cracks are much more abundant than in the undisturbed hornblende substance. Along their edge the

3.

4.



hornblende is slightly frayed out and bent, as though by a forcible shoving; and, in certain parts of the lamellæ, the little fibers are twisted across the whole width of the band, so as to produce an irregular or undulatory extinction. In still other cases, along the line of a fissure, small parts of the band are displaced from their normal direction, as shown in fig. 2.

Fig. 3 shows the highly magnified detail of lamellæ in their passage of a mica area and crack.

When viewed between crossed Nicol prisms, a section like that shown in fig. 2, displays the twinning lamellæ with a distinctness equal to that of calcite. The obtuse bisectrix, c, is inclined to the vertical axis, as indicated by the cleavage lines, about 11°. It also lies in what is usually considered the acute angle β for hornblende; and hence, while the cleavage lines of the twinning bands and the principal crystal are inclined ca. 32° to each other, their extinction directions make an angle of only 10° (fig. 4). This optical orientation is in entire accord with the measured angles as indicating $P\bar{\infty}$ ($\bar{1}01$) to be the twinning plane for these intercalated lamellæ.

Aside from the intrinsic interest attaching to the discovery of secondary transverse twinning lamellæ in hornblende, identical in character with those already well known in pyroxene, these lamellæ and their attendant parting planes are important indications of the correct crystallographic orientation of these two closely related minerals. The positions now generally employed for crystals of hornblende and pyroxene are arbitrary while they lack uniformity. I shall attempt to briefly indicate the reasons why the position commonly selected for hornblende should be so altered as to make its present orthodome $P\bar{\infty}$ ($\bar{1}01$) the basal pinacoid. No such important change should be advocated without abundant evidence in its favor, inasmuch as it modifies a long established usage on a common mineral. Nevertheless, if this usage does violence to natural relationships, such a change is warranted.

As is well known, both pyroxene and hornblende possess two planes in their orthodiagonal zones which have nearly the same inclination to the vertical axis. Assuming that the position usually adopted for pyroxene is correct, since it makes so important a direction as the gliding plane the basal pinacoid, then the arguments for reversing the common usage for hornblende are of four kinds, which are based upon

1. relative inclinations of the planes,
2. optical orientation,
3. structure planes,
4. parallel growths.

1. As they are now usually placed, the *steeper* of the two nearly equally inclined faces of the orthodiagonal zone is made the base on pyroxene, while on hornblende the *flatter* of the two is thus employed. Hence, if the positions of orthodome and basal pinacoid were reversed on hornblende, there would be uniformity established in this respect.

2. With the present orientation, the axis of elasticity c, which is nearest to the vertical axis, lies with pyroxene in the *obtuse*, but with hornblende in the *acute* angle β. If, however, such an alteration as that above mentioned were made, there would also be uniformity established here.

3. The practical identity in character of the gliding planes and secondary lamellæ in the case of hornblende and pyroxene has already been emphasized; and yet, with the present usage, we must make one of these parallel to $P\bar{\infty}$ ($\bar{1}01$), and the other parallel to 0P (001). The importance of being able to assign to them the same crystallographic symbol is at once apparent, and it has already been insisted upon by Mügge.*

4. Much the strongest argument for reversing the symbols of the orthodome and basal pinacoid of hornblende is, however, to be derived from nature's usage. As far as I have been able to extend my observations, all the many parallel growths of pyroxene and hornblende, whether original or produced by secondary paramorphism, are such that the two species have their vertical and orthodiagonal axes in common, while the basal plane of the former is as nearly as possible parallel to the orthodome of the latter. This certainly indicates the crystallographic homology of these two faces, and is alone ample reason for giving them the same symbol.

Long before gliding planes had been recognized on either pyroxene or hornblende, vom Rath described and figured parallel growths from Vesuvius like those above mentioned,† and gave them as sufficient ground for reversing the accepted symbols of one of the two minerals. He suggested that the change be made on pyroxene, but in this he has not been followed, nor should he be, since it is desirable to keep so important a face as the gliding plane for the basal pinacoid.

I have examined a large number of parallel growths of pyroxene and hornblende in rocks, and have found the lesser extinction angle for both minerals to lie on the same side of the vertical axis. This indicates an orientation similar to that observed by vom Rath.

In this connection some of the material from St. Lawrence County is particularly instructive. The brown hornblende from Pierrepont is associated with pale green salite and white albite of a lenticular habit. Parallel growths of the hornblende and salite are not uncommon. Fig. 5 represents a thin section of such a growth, cut parallel to the clinopinacoid, which is common to both minerals. The section shows that the vertical axes of both are also parallel, while the position of the extinction directions proves that the planes commonly known as the basal pinacoid for pyroxene and as the orthodome for hornblende, are nearly parallel. In the former mineral the transverse parting and twinning are well developed. In this specimen of hornblende these are absent, but we can

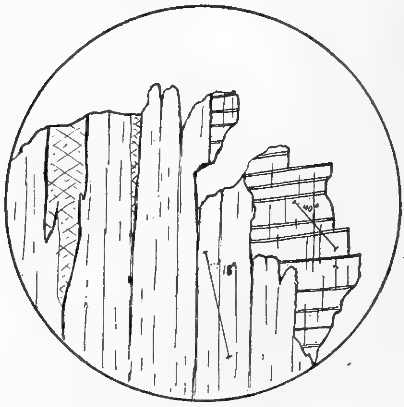
* Neues Jahrbuch für Min., etc., 1889, i. p. 244.

† Verhandl. Naturhist. Vereins d. preuss. Rheinl. u. Westfalens xxxiv, 5 Folge. Vol. iv. Neues Jahrb. für Min., etc., 1876, p. 391, pl. viii, figs. 5 and 6.

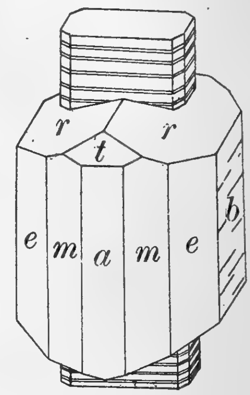
see that, if they were present, they must form nearly a continuation of the pyroxene parting. On the left of the figure inclusions of calcite in the hornblende are indicated.

Fig. 6 shows a remarkable growth of dark green hornblende from Russell, St. Lawrence County, around a crystal of pale green salite. Both crystals have their clinopinacoids parallel,

5.



6.



while the parting planes, which are here present in both, are as nearly as possible parallel. This specimen is about three inches in length, and belongs to the collection of Mr. Clarence Bement, in Philadelphia.

Another long crystal of green hornblende from Somerville, St. Lawrence County, loaned by Mr. Joseph Wilcox, of Philadelphia, is a twin, according to the common law (twinning-plane the orthopinacoid), and has the transverse parting well developed in both individuals parallel to the face $P\overline{\infty}(\bar{1}01)$. Both surfaces give good reflections, and the angle between them was found to be 150° 10′ (calc. v. Koksch., 150° 4′). This specimen offers strong evidence against the possibility of a gliding in hornblende parallel to *both* the planes, 0P (001), and $P\overline{\infty}(\bar{1}01)$, whose inclinations to the vertical axis are nearly the same.

In view of all this evidence we must, therefore, conclude that an alteration of the symbols for the terminal planes of hornblende is necessary to show its analogy to pyroxene; furthermore that this change must be made in accordance with the assumption that the gliding plane, now called the orthodome, $P\overline{\infty}(\bar{1}01)$, is the basal pinacoid, 0P (001), as first suggested by Tschermak in his Lehrbuch der Mineralogie, in 1884.

Petrographical Laboratory of the Johns Hopkins University,
Baltimore, Feb., 1890.

ART. XLV.—*Note on some secondary minerals of the Amphibole and Pyroxene groups;* by WHITMAN CROSS.

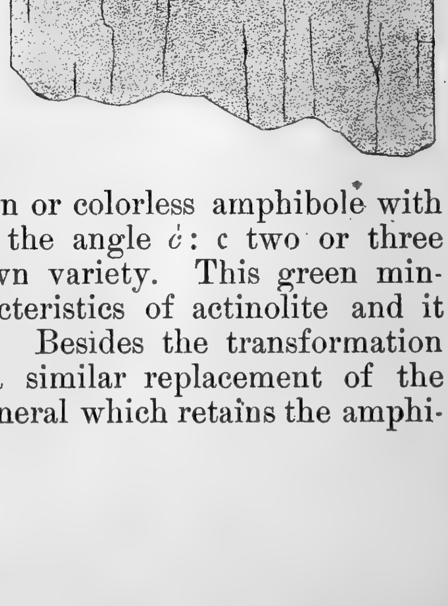
IN the course of the microscopical examination of some rocks from Custer County, Colorado, the writer has observed two peculiar minerals of secondary origin, one an amphibole and the other a pyroxene, which are of interest on account of their unusual properties, relationships and mode of formation. One of the observed minerals is a clear blue amphibole occurring as a pseudomorphic replacement of common hornblende or of augite, and also as enlargements of the same, with a pleochroism much like that of glaucophane, while the orientation of the ellipsoid of elasticity brings the variety into close relationship with the new species riebeckite. The pyroxene is of a bright green color and seems at first to be orthorhombic in crystal form, but it is thought more probable that it is related to ægirite, in which there is a close approximation to the optical orientation of an orthorhombic species.

The blue amphibole appears most prominently in a dike rock cutting sharply across upturned Archæan gneisses, and best seen at the northern base of the eruptive Rosita hills, about five miles east of the mining town of Silver Cliff. This dike rock is completely decomposed at its outcrop and the product, which is a mixture of calcite, quartz, barite, limonite, etc., with local impregnations of galena and other metallic sulphides, has been considered a mineral vein and several mining claims have been located upon it. It is known for a distance of about one mile with a course northwest to southeast. Prospect shafts on this "vein" have usually passed into a hard and apparently fresh rock at depths of less than fifty feet. This material is dense and tough, of apparent porphyritic structure, showing many bright green grains of pyroxene often more than one cm. in diameter, and smaller glistening prisms of brown hornblende, both being imbedded in a bluish gray matrix which usually makes up about half the rock mass. The microscope shows the matrix to consist of quartz and calcite with minute blue or green amphibole needles penetrating and coloring it. The pyroxene and hornblende are often regularly intergrown and these two are the only primary constituents of this rock now remaining, for there is no indication of the character of the mineral or minerals replaced by the quartz-calcite mass. This decomposition has already attacked the pyroxene grains and they rarely show crystal outlines, but the hornblende is better preserved and even the terminations are sometimes distinct.

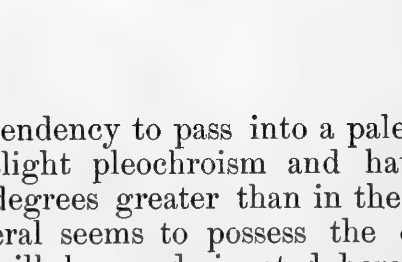
The pyroxene appears almost colorless in thin sections and is not visibly pleochroic. In optical orientation it corresponds with diopside or augite, and chemical analysis shows it to belong to the aluminous variety. The material for analysis was obtained by dissolving the calcite cement and separating the pyroxene from quartz by the Thoulet solution. This examination was carried out by Mr. L. G. Eakins in the laboratory of the U. S. Geological Survey and yielded the following results: SiO_2 54·87, Al_2O_3 6·34, Fe_2O_3 2·88, FeO 4·61, MnO 0·14, CaO 15·87, MgO 14·47, Na_2O 0·28, H_2O 0·31,=99·77. There was a small amount of quartz attached to some of the grains, which explains the high silica percentage, and some brown hornblende with its alteration products was included with the pyroxene, but these latter impurities cannot have materially influenced the result.

The original hornblende associated with the augite is dark brown in color, strongly pleochroic, showing: a=pale yellow, b= reddish brown, c= almost chestnut-brown in rather thick sections. The angle ć : c is at least 13°. Small particles of the normal brown hornblende are included in the larger augite grains, usually with the *c* axis in common, and some of the hornblende prisms, on the other hand, are regularly intergrown with or include small augite prisms. As a rule the hornblende prisms are less than 1mm in diameter and they are frequently terminated by the usual planes. The brown hornblende exhibits in nearly all crystals a more or less marked

2.



1



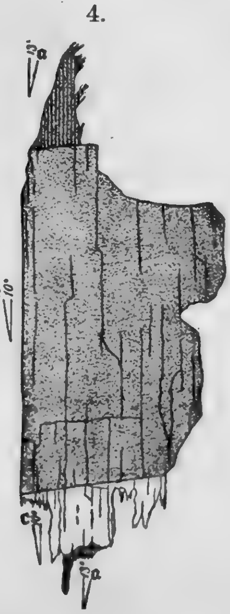
tendency to pass into a pale green or colorless amphibole with slight pleochroism and having the angle ć : c two or three degrees greater than in the brown variety. This green mineral seems to possess the characteristics of actinolite and it will be so designated hereafter. Besides the transformation into actinolite there is often a similar replacement of the original hornblende by a blue mineral which retains the amphibole cleavage and is unquestionably a member of this group. The change to the blue amphibole may take place directly or through the intermediate actinolite, while a change of the blue into the actinolite does not occur. The blue amphibole and the the actinolite occur most prominently as enlargements of the primary hornblende crystals, being added as a rule to the clinopinacoidal or terminal planes. By means of the accompanying figures, drawn with the aid of the camera lucida, the characteristic relationships will be most clearly shown.

Fig. 1 represents a cross section of brown hornblende of entirely normal character. Upon the clinopinacoidal faces are oriented additions of blue amphibole possessing a cleavage plainly parallel to that of the brown, and to the boundaries of the new growth. The two minerals are sharply defined by their pleochroism, being of very nearly the same pale yellow color parallel to the shorter diagonal of the prism, while the one is brown and the other a deep blue parallel to the longer diagonal.*

In fig. 2 is given a section nearly parallel to the clinopinacoid of a hornblende crystal with the blue amphibole added in flame-like forms upon the terminal planes. These two figures give the characteristic outlines assumed by the added blue amphibole in nearly all cases. The delicacy of the termina-

.3

4.



tions of the growths is not accurately represented by figure 2, for the ends of the spires are often made up of tufts of needles not perfectly orientated and blue fibers are attached to the

* In all figures of this article the stippled portion represents brown hornblende; the stippled with black lines, blue amphibole or allied forms; with white lines, augite; and the white areas, actinolite, unless otherwise stated.

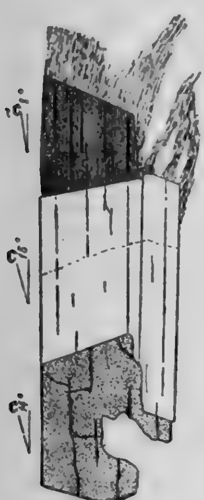
sides in many cases. The illustrations give the form of the massive material with strictly uniform orientation. Sharp pointed spires without attached needles are seen. In fig. 2 the brown hornblende extinguishes at 9° 35′ to the left of the $\dot{c}$ axis, which is indicated by cleavage, while the blue extinguishes at 12° 45′ to the right. These are not maximum values, hence the section is clearly somewhat inclined to the plane of symmetry.

In fig. 3 is represented a section more nearly parallel to the clinopinacoid of a brown hornblende prism which has been partially replaced by blue amphibole at the lower end and by actinolite at the upper. In this section the brown hornblende extinguishes at 10° 40′ to the left of the cleavage line and the blue at 13° to the right. Certain cleavage lines run uninterruptedly through both minerals, and, as proven by all orientated sections, the axes $\dot{c}$ and $\bar{b}$ are plainly common to the two varieties. Fig. 4 gives a representation of a brown hornblende crystal to one end of which the blue amphibole has been added, while on the other end actinolite of pale grass-green color forms a similar extension and is itself tipped by the blue variety. The spire of blue amphibole is fringed by imperfectly oriented needles of the same substance in a manner very roughly represented by the figure and the bounding surfaces do not appear to be regular crystal planes. In optical orientation the blue portions of the two extremities are plainly identical, extinguishing at 13° to the right of the cleavage lines of the main hornblende crystal, while the latter and the added actinolite extinguish in common at 10° to the left. Fig. 5 represents a crystal of amphibole, cut nearly parallel to the clinopinacoid, in which three substances are sharply distinguished. At the lower end is the normal brown hornblende, extinguishing at 14° 30′ to the left of the axis $\dot{c}$. Adjoining this is actinolite, the line between the two being straight in part and apparently representing a crystal plane. This actinolite extinguishes at 15° 30′ to the left of $\dot{c}$, and while the part near the brown is grass-green the upper portion is colorless, the line between being sharp and parallel to the same apparent crystal planes as the other change. On the upper end of the crystal is an area of dark chestnut-brown color extinguishing at about 8° to the left from the cleavage lines, some of which run uninterruptedly through both the actinolite and the brown mineral. Absorption is very strong near the axis $\dot{c}$, so that the angle of extinction cannot be closely measured Beyond this peculiar brown mineral there are tufts of fine blue needles some of which are orientated parallel to the vertical axis of the large crystal. They spring from the actinolite as well as from the brown amphibole, and also lie free in the calcite surrounding the crystal. While these needles do not show uniform orientation the parts of the aggregate nearest the large crystal extinguish to the right of the vertical axis of the latter.

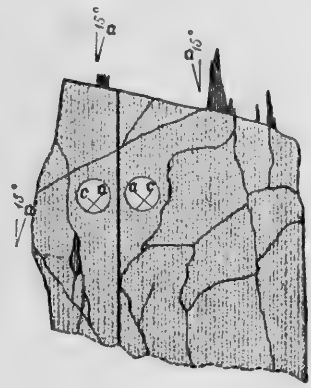
From the relationships observed in studying several sections of this rock the writer concludes that the actinolite of the crystal shown in fig. 5 replaces primary brown hornblende, and that the dark chestnut-brown portion is an added growth. Taken by themselves the sharp boundaries might well be considered as indicating original intergrowths of three varieties. The probable character of the added brown material will be spoken of below.

The augite of this dike rock is more strongly attacked than the hornblende by that decomposition which has resulted in the production of calcite and quartz, but it gives way to the influences which have produced the blue amphibole far less readily. Yet alteration very similar to uralitization may be

5.



6.



seen progressing from the irregular fissures in the augite. The fibrous product is sometimes pale green and sometimes blue, and whenever the latter is developed so as to give homogeneous optical action it can be seen to be identical in its properties with that form already described, while the green is probably actinolite.

The blue amphibole is also added to augite grains, as illustrated in figure 6. Such occurrences are comparatively rare but they are sometimes very distinct. In the case figured the augite is twinned parallel to $\infty P\bar{\infty}$ and the particles of blue amphibole added to the two parts are correspondingly orientated, as is also a small fibrous mass within the augite grain. Nearly every grain of hornblende and many of augite exhibit the blue amphibole regularly implanted upon or replacing the primary mineral in the ways represented by the figures. Fissures traversing several distinct grains will be bridged over by blue fibers which possess the crystallographic orientation of the enclosing grain. Small particles of brown hornblende included in augite grains suffer the changes noticed and the new minerals seem in some cases to have induced a similar alteration of the augite itself. The blue variety is much more common as an enlargement than is the actinolite, but they frequently occur side by side, with sharp boundaries between them.

From the study of many sections of the blue amphibole it appears as its most peculiar property that the axis of greatest elasticity, $\mathfrak{a}$, lies near the vertical crystallographic axis and on the opposite side from the position of $\mathfrak{c}$ in glaucophane, common hornblende, actinolite, etc. This is clearly shown by using the quartz wedge as a compensator in the well known manner. The axis of least elasticity, $\mathfrak{c}$, is also in the plane of symmetry, which thus remains the plane of the optic axes as for other amphiboles. The angle $\dot{c}$: $\mathfrak{a}$ is 13° to 15°. The optic angle is large and in consequence the optical character of the mineral could not be satisfactorily determined. Pleochroism : $\mathfrak{a}$=deep blue, $\mathfrak{b}$=purple to violet, $\mathfrak{c}$=pale yellow. Absorption : $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$.

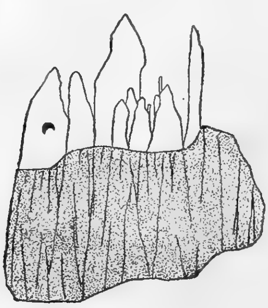
The second material in which the blue amphibole has been observed occurs half a mile north of the dike above described, and is of problematic origin. In a region of fresh Archæan outcrops some prospector found a peculiar exposure and explored it by a shaft 15 feet deep. Nothing is known of the formation beyond the data afforded by this shaft. The material passed through is structurally a conglomerate, the greater part composed of pebbles less than one cm. in diameter, which are dull olive-green in color and seem macroscopically homogeneous throughout. They are imbedded in a similar green matrix which contains however many particles of feldspar, hornblende, biotite, and quartz, the gravelly debris of the adjacent gneisses. In parts of the mass are larger pebbles of gneiss or granite and a few of diorite. The surface outline of this mass is obscured but it does not extend more than a few yards from the shaft in any direction, and it seems probable that the material is the filling of a crevice or hole in the Archæan by waterworn particles. Nothing resembling it was found elsewhere. As far as the present paper is concerned it is only important to show that the rock is markedly a secondary formation and also entirely different in origin from that above described. Microscopical study shows the dull green pebbles and the green part of the groundmass to consist largely of calcite and quartz, and the green color to come from minerals of secondary origin, to be referred to again below. The grains of green or brownish hornblende of common characteristics lying in the matrix, are seen in all stages of alteration to blue amphibole identical in properties with that described from the dike-rock. Additional growths are not developed in this case.

It does not seem necessary to illustrate the relationship between these amphiboles in order to establish the secondary character of the blue variety. There can scarcely be any more typical examples of the passage of one mineral into another of allied character by gradual molecular replacement, than are afforded by the change in question. It is not spoken of as paramorphosis, because identity of chemical composition is not at all probable, but the outward appearance of transition is directly comparable to the change, often seen, from brown to green hornblende. All quantitative stages of the replacement of the common hornblende by the blue may be observed to the point where the former has wholly disappeared, and beyond this to the replacement of the blue amphibole itself by calcite and quartz, or by the green pyroxene to be described.

The mineral which has been referred to as green pyroxene occurs as an alteration product of the blue amphibole, and as a new formation in small prisms and needles in feldspar, or in the secondary calcite and quartz grains. Further, it appears in the small olive-green pebbles as a decomposition product of an unknown, yellow mineral, occurring in fibrous strings similar to the forms often assumed by chlorite. Its secondary origin is also most clearly shown in a pebble of hornblende-diorite which is traversed by narrow fissures mainly filled by calcite and quartz, but also containing prisms of the green pyroxene, appearing as oriented extensions of hornblende prisms crossed by the crack, and in needles lying free in the calcite grains. The designation of this mineral as a pyroxene rests upon the visible crystallographic orientation with regard to the blue and green amphiboles, its crystal form as seen in free individuals, and its close agreement in properties with certain members of the pyroxene group. In cross sections of blue amphibole and the green mineral the latter is seen to have two cleavages of equal prominence, intersecting at an angle of about 87°, and related to the axes of the amphibole as would be normal for an intergrown pyroxene. In length sections the traces of the cleavage planes are parallel to the vertical axis, $\dot{c}$. Free prisms of the mineral do not exhibit pinacoidal planes and the terminations are sharp pointed combinations of pyramids, with orthodomes in some cases at least. The color of the mineral is clear emerald-green in prisms $0{\cdot}03^{mm}$ in thickness. The axis of greatest elasticity, $\mathfrak{a}$, is within a very few degrees of the vertical axis, $\dot{c}$; that of least elasticity, $\mathfrak{c}$, is also in the plane of symmetry, assuming the orientation to be that indicated by the intergrowth with amphibole. The pleochroism is quite strong: $\mathfrak{a}$=green (bluish-green in thick sections), $\mathfrak{b}$=clear green, $\mathfrak{c}$=yellow. Absorption: $\mathfrak{a} > \mathfrak{b} > \mathfrak{c}$. Owing to the strong absorption near $\mathfrak{a}$ the position of this axis cannot be accurately located, and the mineral seems to extinguish parallel to its vertical axis. Sections cut normal to the prism show the optic angle to be large, but the exits of the axes are much plainer than in sections seemingly near to $\infty P\bar{\infty}$, hence the mineral is probably *negative* in optical character.

The change from blue amphibole takes place with no intermediate stage. It occurs mainly along the borders, and in less degree from fissures. In either case the alteration proceeds most rapidly from the starting point parallel to the vertical axis, producing columns of the new substance. While additions to the original amphibole grain do not appear, the pyroxene substance often assumes it proper terminal form when adjoined by calcite or quartz, and in case the latter minerals have eaten into the side of the amphibole grain the pyroxene substance may project in terminated crystal points into the area of calcite or quartz, as illustrated by fig. 7, in which the stippled area represents blue amphibole. The boundary between the minerals is in this case a cloudy zone and the amphibole is evidently giving way to calcite and quartz. There seem to be pyramidal planes on the central

7.



8.

crystal, but the others have rough faces. The section cuts nearly parallel to $\infty P\breve{\infty}$, as shown by pleochroism. The needles or sharp and spine-like crystals of the same pyroxene when found free in calcite have the forms shown in fig. 8. Some of them seem to have pyramidal terminations with distinct planes (*a*), while the majority are like crystals *b*, and have apparently curved faces. Some crystals $0{\cdot}4^{mm}$ long by $0{\cdot}15^{mm}$ thick were isolated which are doubly terminated and then show, when lying on a prism face, the monosymmetry represented in fig. 8, *c*. This symmetry appears only where the pleochroism indicates an approach to the position of the clinopinacoid, and this fact is the strongest observable evidence for referring the mineral to the monosymmetric system. Oblique extinction in such sections cannot always be made out.

The peculiar minerals which have been described in the preceding pages are of interest from several different standpoints. In the first place, as to the identity of the varieties observed, it seems clear, either, that they represent a group of known, allied forms, occurring here under quite new and remarkable conditions, or, they constitute an equally interesting group of new varieties. The former alternative seems the more probable, and the blue amphibole is to be compared with *riebeckite*, the new species recently described by Sauer,* while the green pyroxene is apparently *ægirite*, or the closely related form *acmite*. It is also suggested that the dark brown amphibole, rarely appearing with the blue, may be *barkevicite*.

The blue amphibole agrees very closely with glaucophane in pleochroism but the colors of $\mathfrak{a}$ and $\mathfrak{c}$ are interchanged, corresponding to their different positions. With riebeckite the agreement in optical characters is more nearly complete. The angle $\dot{c}:\mathfrak{a}$ in the blue amphibole is 13°–15° in front of $\dot{c}$ (referred to the usual orientation of the group), while for riebeckite† $\dot{c}:\mathfrak{a}=5°–7°$, but neither Sauer nor Rosenbusch state whether the axis $\mathfrak{a}$ is in front of $\dot{c}$ or not. From the considerations presented below it is probable that it is inclined in the same direction as in the blue amphibole here described, and in that case the difference in orientation is but 7°–10°. Otherwise the minerals differ in intensity of color, pleochroism and absorption.‡

In his "Hülfstabellen" Rosenbusch gives the optical orientation of arfvedsonite, "$\dot{c}:\mathfrak{c}(?)=14°$ vorn." As $\bar{b}=\mathfrak{b}$ the query indicates that it may be the axis $\mathfrak{a}$ of elasticity which is near c, and if this were true, the orientation of the blue amphibole and of arfvedsonite would be nearly identical. This orientation for arfvedsonite seems the natural one in view of the relationships to be presented.§

In the dike rock there are certain individuals of dark blue color in which absorption is so strong that they seem black when $\mathfrak{b}$ or the axis near $\dot{c}$ is parallel to the principal section of the Nicol. This dark material occurs in several places as an addition to actinolite, very much like that of the chestnut-brown mineral in fig. 5, but it is also found associated with the lighter blue amphibole in the same crystal or in separate but adjacent ones. This extremely dark variety would seem to agree fully with riebeckite, and its presence in company with

* Zeitschrift der deutsch. geol. Gesellschaft, xl, 138, 1888.

† Sauer, loc. cit. Rosenbusch, Hülfstabellen zur mikr. Mineralbestimmung, 1888.

‡ While reading the proof of this article the writer's attention was drawn to the observations of A. Lacroix on the optical properties of crocidolite (Bull. Soc. Fr. de Minéralogie, xiii, p. 10, Jan., 1890), showing that mineral to be very closely related to riebeckite and to the blue amphibole here described.

§ Lacroix has stated (Comptes Rendus, etc., cix, 39) that the amphibole from near Pike's Peak, hitherto considered to be arfvedsonite on the ground of König's analysis, has the optical orientation of riebeckite.

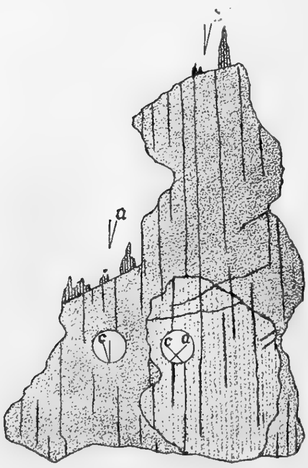
the other amphibole indicates that the latter has a somewhat different composition, though doubtless near that of riebeckite. Considering the similarity existing between these minerals and the group of soda-iron amphiboles and pyroxenes it is most natural to suspect that the dark-brown amphibole represented in fig. 5 may correspond to barkevicite, another form in which the molecule $Na_2Fe_2Si_4O_{12}$ is known to occur predominantly, according to the latest tables of Groth* and Rosenbusch.† In the crystal of fig. 5 it could not be clearly determined whether the axis near $\dot{c}$ is $\mathfrak{a}$ or $\mathfrak{c}$, but the direction of extinction, being on the same side of the vertical axis as in the actinolite and hornblende, indicates that it is $\mathfrak{c}$.

The green pyroxene occurring in the conglomerate resembles ægirite in color, pleochroism, absorption, and optical orientation. It differs from it as the blue amphibole differs from riebeckite, in the intensity of its pleochroism and absorption, while it has a purer green color than is usual for ægirite. In the characteristic development of steep terminal planes this mineral contrasts strongly with the habit of ægirite of other occurrences, but its development is just that observed in acmite, a variety now commonly united with ægirite by mineralogists.

Repeated efforts have been made to isolate the blue amphibole and the green pyroxene for chemical analysis, but without success. The particles of pure material are so very small and are so intimately associated with brown or green hornblende or with the unknown yellowish mineral, that separations by specific gravity could not be effected. A few grains treated with hydrofluosilicic acid yielded microscopic crystals of soda and iron salts in characteristic forms.

In studying such a number of associated amphiboles and pyroxenes the writer's attention was naturally called to the character of the variations in the position of the ellipsoid of elasticity within the group of the amphiboles, and to a comparison of the variations presented by the two groups. One of the first points observed in studying the primary intergrowths of hornblende and augite in the dike rock was that the axes $\mathfrak{a}$ and $\mathfrak{c}$ of elasticity in the two species were always in *similar* quadrants relative to the common vertical axis, instead of in *opposite* ones as would be the case were the minerals intergrown with the basal planes of the commonly adopted orientations inclined in the same direction. Fig. 9 illus-

9.



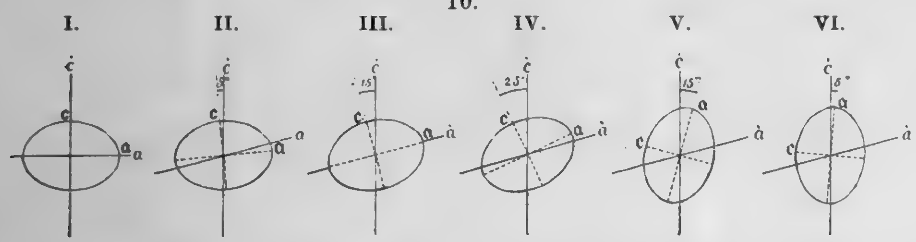
* Tabellarische Uebersicht der Mineralien, 1889.

† Hülfstabellen zur mikr. Mineralbestimmung in Gesteinen, 1888.

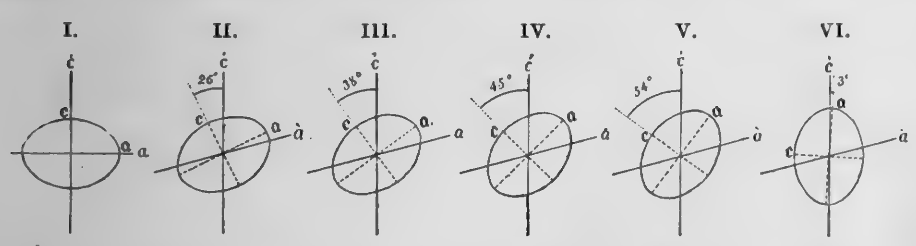
trates the orientation observed in a typical section near the clinopinacoid, showing augite surrounded by brown hornblende, with blue amphibole added to the latter. This orientation agrees fully with the observations recorded by Dr. G. H. Williams in the article preceding this, which have led him to the conclusion that in the monosymmetric amphiboles the plane $P\bar{\infty}$ of the usually adopted orientation should be taken as the basal plane 0P. As Dr. Williams clearly shows, this orientation better expresses the remarkable harmony existing between these groups in regard to several physical properties as well as to the purely crystallographical. The change has been advocated on the latter ground by various authors and the facts here presented seem to form a strong argument in the same direction.

In fig. 10 are presented a number of diagrams expressing the range of the variations in optical orientation within the two groups, the amphiboles being drawn in the new position. It will be seen at a glance that in this way the relationships of the groups are made clear. Riebeckite has been drawn in the position naturally indicated for it by analogy with ægirite and

10.



I. Anthophyllite. II. Glaucophane. III. Tremolite, etc. IV. Brown hornblende. V. Blue amphibole (Silver Cliff). VI. Riebeckite (?)



I. Enstatite, etc. II. Spodumene. III. Diopside, etc. IV. Augite. V. Augite. VI. Ægirite.

the blue amphibole of Silver Cliff. Arfvedsonite will have the position assigned to the blue amphibole or one at right angles to it, according as $\mathfrak{a}$ or $\mathfrak{c}$ is near $\dot{c}$. The latter position would be unique among the amphiboles. Barkevicite, if its orientation is correctly given by Rosenbusch, will be near glaucophane. Should it be proven for either of these minerals that the axis of least elasticity lies near c then we plainly cannot put that emphasis on the influence of chemical composition in determining the optical orientation which is at once suggested by the noteworthy correspondence of riebeckite and ægirite.

The minerals ægirite, acmite, arfvedsonite and barkevicite have been described mainly from eruptive rocks rich in alkalies, such as elæolite-syenite, phonolite, leucitite, etc. Riebeckite occurs in a much altered granite, in large distinct prisms and in microlites included in feldspar. The larger free prisms are regarded by Sauer* as primary, and the latter as secondary, in origin. The occurrences here described suggest the query whether the large individuals of riebeckite in the Socotra granite may not have been originally common hornblende, which were replaced by riebeckite at the time the secondary needles were formed. The only other occurrence of probable riebeckite known to the writer is in a quartz-porphyry of Wales, described by A. Harker.† Although this rock has undergone structural metamorphosis the blue amphibole is considered to be primary riebeckite.

If the minerals which have been described be considered as ægirite, riebeckite, etc., then they appear in novel associations and were clearly formed under conditions quite different from those attending their origin in other known occurrences. Whatever the minerals in question are held to be there are many interesting points illustrated by their relationships. Perhaps none is more striking than that a pyroxene should be formed in such a manner from the decomposition of an amphibole, or that it should be formed at all, as an apparent end product of decomposition, in company with calcite and quartz. The occurrences show plainly that we have much to learn regarding the physical properties, the chemical composition, the genetic relationships, and the conditions of formation of the members of the geologically and mineralogically important groups of the amphiboles and pyroxenes.

Art. XLVI.—*On Spangolite, a new Copper Mineral;* by S. L. Penfield.

During the summer of 1889, while visiting Mr. Norman Spang of Etna, Allegheny County, Pa., my attention was called by him to a very beautifully crystallized specimen of an unknown mineral which he had obtained from a man living near Tombstone, Arizona. The original owner had a small

* Loc. cit.

† Notes on the Geology of Mynydd Mawr and the Nantle Valley, Geol. Mag., v, 1888, p. 221 and p. 455.

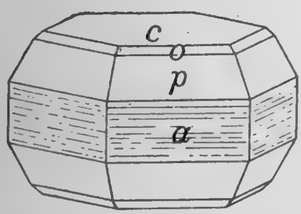
collection of minerals which he had gathered together within a radius of about two hundred miles, but he had no idea of just where he had found the specimen, though he thought it was from the Globe District. Mr. Spang had forgotten the name of the man from whom he had secured it, so that until other specimens are found uncertainty must exist about the exact locality and mode of occurrence. On expressing a desire to investigate the mineral, Mr. Spang very generously lent me the specimen and has since presented me with it, and it is now deposited in the collection of Professor Geo. J. Brush, at New Haven.

A preliminary blow-pipe examination showed that the mineral was undoubtedly a new species and essentially a hydrated sulphate and chloride of copper, and I take pleasure in not only expressing at this time my thanks to Mr. Spang for his kindness but also in naming the mineral, which as will be shown, is of unusual interest, *Spangolite* after him.

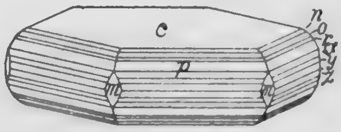
The original specimen, which was about the size of a small hen's egg, consisted of a rounded mass of impure cuprite which was mostly covered with hexagonal crystals of spangolite, associated with a few crystals of azurite and some slender pris matic crystals of a copper mineral containing chlorine, probably atacamite.

The crystallization of spangolite is hexagonal, rhombohedral. The habit of the crystals does not vary much as they all show a prominent hexagonal basal plane and a series of apparently holohedral hexagonal pyramids, which as will be shown must be taken as pyramids of the second order. Some of the crystals have the habit of fig. 1 showing a prism, which is always so dull and striated that it gives no reflection of light, associated with pyramids and a basal plane. Others are flatter, figure 2, and show a large series of pyramids which oscillate

1.



2.



with one another, giving rise to prominent striations which run horizontally about the crystal and make the identification of the pyramids a difficult matter. On the crystals we occasionally find a prism of the first order, m, which is small but gives good reflections. The material which could be used for the investigation was limited, but great care was taken to select only the best and purest crystals for making the crystallographic and chemical investigation. A number of small crystals were selected which were measured in the prominent pyramidal zones between the basal planes. The basal planes usually gave very good reflections of the signal but on turning the crystal on the goniometer, after the pyramids came into a position to reflect light, there usually followed an unbroken band of signals reflected from these faces owing to their striations and oscillatory combinations. In this band of reflections prominent parts could usually be located which indicated the position of distinct pyramidal faces. On measuring fifteen independent pyramidal zones on five different crystals, only one crystal was found, which we will designate as No. 1, that gave sharp reflections from the pyramidal faces; from this an angle was obtained of $c \wedge p$, $0001 \wedge 2\bar{1}\bar{1}2 = 63° 32'$. Still better results were obtained on measuring from pyramid to pyramid when the reflections of the signal are not so much disturbed by the striations and the value given below, which will be accepted as the fundamental measurement, was obtained

$$p \wedge p', \ 2\bar{1}\bar{1}2 \wedge 11\bar{2}2 = 53° \ 11' \ 30''$$

from which we calculate the length of the vertical axis $c = 2{\cdot}0108$.

The largest of all the crystals, which we will designate as No. 2, was fortunately so situated that it could be measured without detaching it from the specimen. It was very symmetrical and had the habit shown in fig. 1; it measured about 8^mm^ in diameter and was $5\frac{1}{2}$^mm^ high. Five out of the six pyramidal faces p at one end of the crystal were quite perfect, being only slightly distorted by the horizontal striations. Some of the faces were so situated that reflections could not be obtained from them without detaching the crystal, but a number of very satisfactory measurements were made which are given below. The accompanying table contains a summary of the measurements which were made on the two best crystals from the faces c, 0001, O; p, $2\bar{1}\bar{1}2$, 1–2; o, $2\bar{1}\bar{1}4$, $\frac{1}{2}$–2 and m, $10\bar{1}0$, I; all of which gave sharp reflections of the signal. The measurements were made on a Fuess goniometer, using the signal and the ocular β of Websky. The one marked with an asterisk was taken as fundamental.

TABLE I.

		Crystal No. 1.	Crystal No. 2.	Calculated.
$p \wedge p'$,	$2\bar{1}\bar{1}2 \wedge 11\bar{2}2$	53° 11′ 30″*	53° 13′ 45″	53° 11′ 30″
$p' \wedge p''$,	$11\bar{2}2 \wedge .2\bar{1}2$		53° 11′ 45″	“
$p'' \wedge p'''$,	$\bar{1}2\bar{1}2 \wedge \bar{2}112$		53° 14′	“
$p \wedge p^{iv}$,	$2\bar{1}.2 \wedge .\bar{1}22$		101° 43′	101° 41′
$p \wedge o^{v}$,	$2\bar{1}\bar{1}2 \wedge 1\bar{2}14$	50° 48′	50° 51′	50° 51′
$p \wedge c$,	$2..2 \wedge 0001$	63° 32′		63° 33′ 30″
$p \wedge m$,	$2\bar{1}\bar{1}2 \wedge 10\bar{1}0$	39° 4′		39° 9′

In the above table we find a very satisfactory agreement between the measured and calculated angles from which we may conclude that the measurement which we have accepted as fundamental is very nearly correct.

When all of the approximate measurements, which were obtained from fifteen different zones measuring from the basal plane above over the pyramids on the base below, are tabulated it is found that with few exceptions they fall into groups indicating the existence of a series of pyramids, among which we may safely assume the following, in addition to those which have already been mentioned: *k*, $2\bar{1}\bar{1}8$, $\frac{1}{4}$–2; *n*, $2\bar{1}\bar{1}6$, $\frac{1}{3}$–2; *r*, $6\bar{3}\bar{3}8$, $\frac{3}{4}$–2; *l*, $6\bar{3}\bar{3}7$, $\frac{6}{7}$–2; *x*, $6\bar{3}\bar{3}4$, $\frac{3}{2}$–2; *y*, $2\bar{1}\bar{1}1$, 2–2; *z*, $6\bar{3}\bar{3}2$, 3–2.

The following table contains a summary of the measurements which can be referred to the definite pyramids just mentioned.

TABLE II.

	No. of times observed.	Limiting measurements.	Average.	Calculated.
c ∧ *k*, 0001 ∧ $2\bar{1}\bar{1}8$	3	25° 48′–26° 7′	25° 55′	26° 41′
c ∧ *n*, 0001 ∧ $2\bar{1}\bar{1}6$	6	33 54 –34 46	34 26	33 50
c ∧ *o*, 0001 ∧ $2\bar{1}\bar{1}4$	19	44 19 –46	45 3	45 9
c ∧ *r*, 0001 ∧ $6\bar{3}\bar{3}8$	3	55 46 –56 53	56 18	56 27
c ∧ *l*, 0001 ∧ $6\bar{3}\bar{3}7$	5	59 10 –60 33	59 50	59 53
c ∧ *p*, 0001 ∧ $2\bar{1}\bar{1}2$	22	63 12 –63 46	63 30	63 33½
c ∧ *x*, 0001 ∧ $6\bar{3}\bar{3}4$	6	71 17 –72 30	71 51	71 39
c ∧ *y*, 0001 ∧ $2\bar{1}\bar{1}1$	4	76 48 –75 36	76 13	76 2
c ∧ *z*, 0001 ∧ $6\bar{3}\bar{3}2$	7	79 17 –80 39	80 4	80 35

An examination of the above table will give an idea of the frequency of occurrence of the different pyramids and the accuracy of the determination.

All of the measurements which have not already been given in Tables I and II are collected together in the following table where they are again arranged into groups, which indicate the occurrence of vicinal faces agreeing nearly with simple forms.

TABLE III.

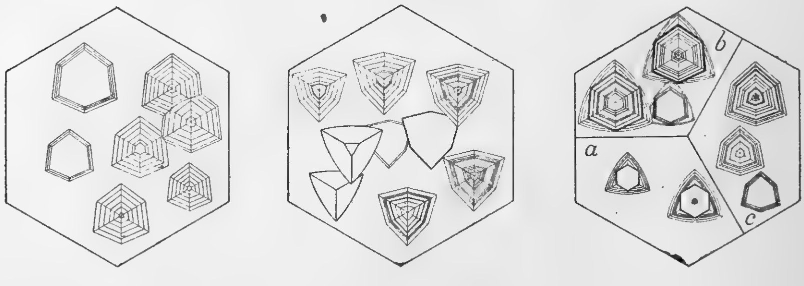
Mean angle on the base.	Limiting measurement.	No. of these observed.	Simple form to which they approximate.
23°		1	$2\bar{1}\bar{1}10$, $\frac{1}{5}$–2
35 44′	35° 30′–36°	6	*n*, $2\bar{1}\bar{1}6$, $\frac{1}{3}$–2
43 40	43 15 –44	5	*o*, $2\bar{1}\bar{1}4$, $\frac{1}{2}$–2
57 40	57 26 –57 53′	2	*r*, $6\bar{3}\bar{3}8$, $\frac{3}{4}$–2
61 37	60 47 –62 41	4	*p*, $2\bar{1}\bar{1}2$, 1–2
73 2	73 –73 5	2	*x*, $6\bar{3}\bar{3}4$, $\frac{3}{2}$–2
77 53	77 5 –78 53	4	*y*, $2\bar{1}\bar{1}1$, 2–2
88 15		1	*a*, $2\bar{1}\bar{1}0$, *i*–2

In all of the zones which were measured there was no indication of any hemihedral development of the pyramids.

Cleavage.—The cleavage of spangolite is very perfect parallel to the base; this was a great help in studying the crystals, as many of the measurements recorded in Tables II and III, were obtained from cleavage-planes. Inclined to the base the crystals usually broke with a conchoidal fracture; in only one case a distinct cleavage was observed parallel to the pyramid *p*, the angle of the cleavage measured on to the base being 63° 28′, calculated 63° 33½′. Thin plates of the mineral are non-elastic and brittle.

Etching.—Experiments made by etching the mineral with acids gave results which add very much to a proper understanding of the crystals. It is readily soluble in dilute mineral acids and the perfect basal cleavage makes it easy to obtain orientated sections suitable for etching. The figures differed both with the character and strength of the acid, but always showed a decided hemihedral and rhombohedral symmetry. Fig. 3 represents the character of some etchings produced by dilute sulphuric acid. The figures which are very perfect are about ·066^{mm} in diameter and have the shape of a section across a scalenohedron. Some of the depressions are bounded below by a basal plane, others taper to a point while the scalenohedrons oscillate and give rise to delicate striations which are beautifully brought out under the microscope by a slight change of focus. The obtuse angle of the scalenohedron section measured under the microscope was about 133°, from which we calculate that its relation to the lateral axis is $a : \frac{5}{3}a : \frac{5}{2}a$, which requires an angle of 133° 10′. Fig. 4 represents some etchings produced by very dilute sulphuric acid: 1^{cc} of concentrated H_2SO_4 diluted with 80^{cc} of water. These also have a scalenohedral cross section and are about ·06^{mm} in diameter.

3. 4. 5.



The obtuse angle of the cross sections measures about 152°, from which its relation on the lateral axes $a : \frac{4}{3}a : 4a$ can be calculated, which requires an angle of 152° 12′. There are also some steep rhombohedral depressions, with somewhat curved contours developed on this section. Some of the etchings produced by hydrochloric acid are shown in fig. 5, where the hexagon is divided into three parts. The figures shown in part *a* represent deep hexagonal depressions whose cross section is that of a pyramid of the second order, these have a diameter of about ·035^{mm} and are surrounded above with shallow and very delicate rhombohedral depressions with curved contours. In part *b* we have again scalenohedral, surrounded by shallow and more delicate rhombohedral, depressions. The obtuse angle of the scalenohedral sections measured 129°, from which its relation on the lateral axes $a : \frac{7}{4}a : \frac{7}{3}a$ can be calculated, which requires an angle of 129° 26′. In part *c* we have again represented simple scalenohedron depressions which are about ·025^{mm} in diameter and were produced by a very dilute acid, 1^{cc} concentrated HCl diluted with 160^{cc} of water. The obtuse angle of the scalenohedron measured about 142°, indicating a relation on the lateral axes of $a : \frac{3}{2}a : 3a$, which requires an angle of 141° 48′. With nitric acid the figures are very similar to those produced by hydrochloric; in all cases it was observed that with very dilute acids there was a tendency to form scalenohedral and with stronger rhombohedral depressions. When we compare the position of these rhombohedral and scalenohedral etchings to the outer hexagon, which in figs. 3, 4 and 5 indicates the outline of the crystal section, we see at once that the pyramids on the mineral must be of the second order. It should be stated here that the etchings were of very great beauty and perfection, the outline of the scalenohedral cross sections being in almost all cases very distinct and free from distortions of any kind, so that the angles could be measured with comparative accuracy.

Optical properties.—The color of the mineral by reflected light is dark green, cleavage plates by transmitted light are light green. Prof. H. L. Wells examined a basal section of the mineral ·4^{mm} thick with the spectroscope. When the slit was very narrow the light transmitted by the mineral gave a narrow spectrum with a maximum of light in the green at about λ 525. There was a total absorption of the red and yellow, running well into the yellowish-green. At the other end of the spectrum there was a decided absorption of the blue and a total absorption of the violet. Pleochroism is not very marked. The ordinary ray is green while the extraordinary is a decided bluish green. Cleavage plates show perfectly normal optical properties In convergent polarized light they yield a black cross surrounded by rings which are bordered by green and blue. The double refraction is quite strong and negative. Considerable difficulty was obtained in making a prism from a small crystal of the mineral with its edge at right angles to the perfect basal cleavage, but a small one was obtained, with an angle of 37° 48′, from which the indices of refraction were determined. The prism was opaque to the red and yellow lights of lithia and soda flames, even to the yellowish-green light of a thallium flame. With an ordinary kerosene flame the prism yielded two narrow green spectra with a minimum deviation of 26° 25′ for the extraordinary and 28° 46′ for the ordinary, measuring from the brightest part of the spectra, which from the spectroscopic examination we have located at about λ 525, and we obtain for the two indices of refraction ω 1·694, ϵ 1·641.

Other physical properties.—The hardness of the mineral on the basal plane is about 2, on the pyramidal faces nearly 3. The specific gravity was taken very carefully with a chemical balance on the purest material, which was selected for chemical examination. After boiling the crystals in water, to expel any air, three separate portions weighing respectively 0·2143, 0·1787 and 0·1538 grams gave 3·147, 3·133 and 3·142, an average of 3·141 as the specific gravity.

Chemical composition.—More than three grams of exceptionally pure material were readily obtained by sacrificing about one-half of the crystals on the specimen. As the material was somewhat limited a method of analysis was adopted by which nothing could well escape detection and a qualitative and quantitative analysis was carried on with a single sample, the results of which are given below. The fourth analysis was made on an entirely different sample from that which yielded the figures in the first three columns.

	I.	II.	III.	IV.	Average.	Ratio.		Calculated for Cu_6Al $ClSO_{10}9H_2O$
SO_3	----	10·08	10·11	10·14	10·11	·126	1·01	10·03
Cl	4·12	----	4·10	4·11	4·11	·116	0·93	4·45
Al_2O_3	6·59	----	6·51	6·70	6·60	·064	0·51	6·45
CuO	59·57	----	59·47	59·50	59·51	·7495	6·00	59·75
H_2O	----	20·32	----	20·49	20·41	1·134	9·07	20·32
					100·74			101·00
O, equivalent of Cl					·92			1·00
					99·82			100·00

The analysis yields a ratio of $SO_3 : Cl : Al_2O_3 : CuO : H_2O$ = 1·01 : 0·93 : 0·51 : 6·0 : 9·07 or very nearly 1 : 1 : ·5 : 6 : 9, from which we obtain a rather complicated and remarkable formula, $Cu_6AlClSO_{10}, 9H_2O$. No doubt can however exist concerning this formula; not only was the material beautifully crystallized and of unusual purity, but the analysis of two separate samples are identical within the error of analysis and the ratio is throughout very sharp; moreover the calculated composition agrees very well with the results of analysis. A slight deficiency in chlorine may result from a partial replacement of that element by hydroxyl, which, if true, would diminish somewhat the slight excess of water. The method of analysis was as follows: A weighed quantity of the mineral lost water slowly by standing in a desiccator over sulphuric acid, amounting to 0·30 per cent in thirty-six hours, but it regained almost all of this loss by standing uncovered in the air. Heated for an hour at 100° C. it lost about 0·49 per cent, but also regained this by standing in the air. The analyses were all made on air-dry powder. Water was determined by heating the mineral, weighed in a platinum boat, in a hard glass tube containing a loose plug of sodium carbonate at one end, through which the water vapors were conducted before absorption in a weighed chloride of calcium tube. A good deal of chloride of copper distilled off from the mineral. In some cases the contents of the boat was dissolved in nitric acid, the tube cleaned out carefully and a complete analysis made on one portion. A new portion being taken it was dissolved in nitric acid and the chlorine precipitated with silver nitrate. The weighed silver chloride when tested was found to contain no bromine or iodine and when ignited in hydrogen gas yielded a weight of metallic silver agreeing with the composition AgCl. After removing the excess of the silver from the solution with hydrochloric acid the SO_3 was precipitated with $BaCl_2$, care being taken to avoid a loss owing to the solubility of $BaSO_4$ in the aqua regia which was present in the analysis. After separating the excess of barium with sulphuric acid the solution was evaporated to expel the nitric acid after which the copper was precipitated with hydrogen sulphide and weighed after ignition in hydrogen gas as Cu_2S. A portion of the copper precipitate was carefully tested for other metals, but none were found. The filtrate from the copper sulphide, when evaporated to dryness and ignited left a residue which proved to be sulphate of alumina; this was dissolved in acid, precipitated in ammonia and weighed as Al_2O_3. A weighed quantity of the oxide was carefully tested for beryllium, but none was found, and after conversion into sulphate and evaporation with the right quantity of K_2SO_4 it yielded alum crystals. The filtrate from the alumina yielded no perceptible residue when evaporated to dryness proving that everything had been separated from the solution.

Pyrognostic and chemical tests.—Before the blowpipe the mineral fuses at about 3 to a black slaggy mass, coloring the flame green. On charcoal with soda in reducing flame it yields globules of metallic copper. Heated in the closed tube gives abundant water which has a strong acid reaction. Insoluble in water, but readily soluble in dilute acids.

There is at present no known mineral similar to spangolite in composition; the very rare connellite from Cornwall, England, whose chemical composition has never been determined, is the nearest approach to it, as it contains, according to Connel, copper in combination with sulphuric and hydrochloric acids, but the crystalline form and physical properties of the two minerals are entirely distinct. As far as can be found these two minerals and sulphohalite, $3Na_2SO_4$, $2NaCl$; Caracolite Na_2SO_4, $Pb[OH]Cl$ and Kainite $MgSO_3$, KCl, $3H_2O$ are the only mineral occurrences of sulphate and chloride in combination. The occurrence of small quantities of alumina in a copper mineral, although not unknown, is certainly very unusual. It is also interesting to note that the alumina in the formula, one atom, is just sufficient to satisfy the quantivalence of the total acids $[AlCl]SO_4$, leaving six molecules of cupric oxide basic.

Before closing the author desires to express the hope that some one living in the neighborhood of Tombstone, Arizona, will take an interest in examining both the collections and ores of that region so as to secure, if possible, an abundant supply of this mineral.

Mineralogical Laboratory of the Sheffield Scientific School,
New Haven, March, 1890.

ART. XLVII.—*Archæan axes of Eastern North America;* by JAMES D. DANA.

IN my paper read before the Geological Society of America at its Toronto meeting in August last, and since published by the Society, after speaking of the Archæan range or series of ridges along the course of the Appalachian Chain from Canada through Vermont to Georgia as the Appalachian *protaxis*, I briefly mentioned the parallel ranges east of the protaxis in New England and Canada, and referred to the geological importance of the included troughs or basins. I return to the subject to make some additional explanations.

The Appalachian protaxis, the earliest line of heights in the history of the mountain chain, extends, with interruptions, after a long course between the New England boundary and the river St. Lawrence, through the eastern half of Vermont, eastern Berkshire, northwestern Connecticut, Putnam, Orange and Rockland counties in New York, northwestern New Jersey, South Mountain in eastern Pennsylvania, and thence southwestward through Virginia and beyond to South Carolina and Georgia—in all over 1250 miles. The parallel eastern ranges, having a general N.E.–S.W. trend, are continued into Newfoundland, range succeeding range quite to the farthest extremity of this great continental promontory. These ranges, it should be understood, like that of the protaxis, are not simple continuous lines, but broken lines, with often parallel subdivisions, they having the composite style of all mountain ranges.

Why there should be so large an Archæan-ribbed projection of the continent north of the parallel of 42°, and little corresponding to it farther south awaits explanation. It may be connected with the fact that the continental margin north of 42° is backed so closely by the eastern arm of the V-shaped Archæan nucleus, which is here made up of the Adirondacks and the hills just north of the St. Lawrence. And the *landward* bend of the protaxis and Alleganies south of lat. 42° N. (to a west-southwest course) across central Pennsylvania (and paralleled in the coast-line) may have the reverse cause.* The trough between the Adirondacks-and-Canada Archæan and the protaxis—the St. Lawrence-Champlain trough—is not fifty miles in mean width. This trough was an open channel to the Interior Continental sea receiving thick rock deposits until the close of the Lower Silurian; but at this epoch the Lake Champlain portion ceased rock-making cotemporaneously with the formation of the Taconic Mountains and the general uplift of the Green Mountain area along the western New England border, not to resume it again except temporarily.

The Ranges.—The ranges, partly or wholly Archæan, lying to the east of the Protaxial Range are the following—numbering the protaxis I, as it is the first in the series:

II. The New Hampshire Range: extending from the borders of Maine and Canada through New Hampshire and Massachusetts into Connecticut, making the east side of the Connecticut Valley.

III. The Mount Desert Range: commencing near Chaleur Bay, on the Gulf of St. Lawrence, and continued southwestward through New Brunswick to the coast of Maine, where it includes the Mt. Desert region, and thence into eastern Massachusetts between Boston and Worcester, and probably into Connecticut.

IV. The Acadian Range: commencing in the western part of northern Newfoundland, east of White Bay and extending thence to St. George Bay and Cape Ray in southwestern, and beyond over eastern Nova Scotia; and thence, probably, beneath the sea along the course of shallow soundings, as sustained by Professor W. O. Crosby, to Plymouth and Cape Cod in eastern Massachusetts.

The Archæan ridge of the long northwestern arm of Newfoundland, north of the Bay of Islands, making the northern part of the so-called "Long Range," is a more western range than the preceding; it is separated from the Archæan region of Labrador by the Belleile strait or channel.

* The landward bend of the Rocky Mountain protaxis (Archæan) in Montana and Idaho (to the east-southeast) between the parallels of 42° and 45° may have a like origin—the bend *like that on the Atlantic side*, being opposite the southern extremity of the nucleal V.

V. The Central-Newfoundland Range: extending over a broad region east of the Exploits River Valley, to the east side of Exploits Bay.

Besides these ranges there appear to be two other more or less complete ranges separating pairs of bays that head together, and then, the easternmost, that of Ferryland.

The Troughs.—The troughs into which the country is topographically divided by these ranges were the rock-making troughs or basins of Paleozoic time, and partly of Mesozoic, and were more or less independent in their geological history, especially after the Lower Silurian era. The Lower Silurian and Cambrian beds often spread from one of these troughs to another, and across the protaxis, over portions that were then submerged. But the mountain-making disturbances at the close of the Lower Silurian ended in giving greater height and breadth, and Siluro-Cambrian annexations, to the Archæan, not only in the Green Mountain region, but also, as evidence from unconformabilities proves, in the Mt. Desert and Acadian ranges; and probably in others.

The troughs or areas between the ranges above enumerated, are the following.

A. Between Ranges I and II, The Connecticut Valley Trough: containing, Lower Silurian, Upper Silurian and Devonian beds in the state of metamorphic schists (mica, hornblendic, chloritic) and crystalline limestones, but nevertheless affording fossils of each of the eras for their identification; and containing also, the Connecticut Valley Sandstone or Jura-Trias beds, which are uncrystalline and fossiliferous.

B. Between Ranges II and III, the Gaspé-Worcester Trough: extending from Gaspé, on the Bay of St. Lawrence, over much of northern New Brunswick and central Maine, and continued to Worcester, Mass. and possibly beyond; and containing Cambrian? Lower Silurian, Upper Silurian, Devonian and Carboniferous beds. The rocks are unaltered at Gaspé, but become more or less metamorphic in southwestern Maine and graphitic slates and mica schists of Carboniferous age at Worcester, these last being identified by fossil plants.

C. Between Ranges III and IV, the Acadian Trough: beginning in northern Newfoundland west of the northern part of Long Range and extending to St. George Bay and Cape Ray, in southwestern; passing thence over the region of the Magdalen Islands, in the Bay of St. Lawrence to Nova Scotia and New Brunswick on either side of the Bay of Fundy; and thence to the region of Boston and Massachusetts Bay, and to that of Narragansett Bay in Rhode Island; and including rocks from the Cambrian to the Jura-Trias as identified by fossils. The rocks are metamorphic to the south. Strata from the Cambrian to the Carboniferous are identified by fossils for 300 miles in Newfoundland* (the Carboniferous through the southern half of the 300 miles), and also, for the western margin of the trough, in New Brunswick–Maine and in Massachusetts–Rhode Island; the outcrops of Lower Silurian to Devonian extending along the coast region of Maine for fifty miles or more, or at least to Narraguagas Bay in Millbridge.†

The length of the Acadian trough between the limits stated is about 1000 miles, and between the most northern and southern localities of coal over 800 miles. It was probably therefore, a great feature in the Carboniferous history of Paleozoic North America; and it is a relatively small one in existing coal areas only because of the vast amount of erosion which has since taken place—a large part of it, probably, after the epoch of disturbance at the close of Paleozoic time.

The continuation of the Coal measures and associated rocks from southern Newfoundland in a line toward White Bay proves that the Acadian trough extends by the east side of the northern section of "Long Range," and that the country on the west side is not its proper continuation. The latter becomes to the north the Belleile Straits or trough, and in it the rocks are Lower Silurian and older, like those of the lower part of the St. Lawrence trough.

D. Between Ranges IV and V, The EXPLOITS RIVER TROUGH, extending along Exploits River across Newfoundland, southwestward, to La Poile Bay and White Bear River, the length 200 miles, containing rocks reported by the Canadian Survey to the Upper Silurian.

There may be, also, the partially independent (E) Trinity—Placentia and (F) Conception—St. Mary troughs, the borders of which have afforded Cambrian fossils; and perhaps a subordinate Fortune Bay trough.

In view of the great extent of the Newfoundland Banks, and the possibilities attributable to erosion, our knowledge is very uncertain as to the loss in size and in fossiliferous strata which may have taken place in eastern Newfoundland. The shallow water area to the southeast, out to the 100-fathom line, is much larger than all Newfoundland, and the distance is 250 miles to the 50-fathom line, the outline of the Banks proper.

* Murray mentions in his Report of 1866, the discovery of *Olenellus Vermontanus* on the west coast at the entrance to Long Arm, of Canada Bay, (about latitude 50° 45′), with Devonian beds (containing *Psilophyton. Lepidodendron Chemungense*, etc., as identified by Dawson) just north, at Cape Rouge Harbor. The localities are near the west margin of the trough, the only part there extant. Mr. Murray, formerly of the Geological Survey of Canada, is the chief source of our knowledge of Newfoundland geology.

† C. H. Hitchcock, Agric. and Geol. of Maine, 1861, 1863; and on the vicinity of Cobscook Bay, N. S. Shaler, Am. J. Sci., xxxii, 35, 1886.

The troughs are areas, for the most part, of independent geological work.—It is of great geological interest that subsequent to the Lower Silurian era, if not also before, these troughs were, for the most part if not wholly, areas of independent geological work, and that in them all the geological formations of this part of North America, up to and including the Jura-Trias, were made. This is apparent from the facts respecting the rocks and fossils of the troughs already mentioned.

The thickness of the Silurian and Devonian rocks of the Connecticut Valley trough is not known; but it is certain that the Jura-Trias rocks of the southern half of the valley have a thickness of at least 5000 feet; and this proves that subsidence to this large amount took place in the valley at so late a date in geological history.

The Acadian trough has its thick Silurian and Devonian formations yet unmeasured; and then, some 16,000 feet of Carboniferous rocks, and later, a great thickness of Jura-Trias—as great probably as in the Connecticut valley; moreover the Newfoundland part of the trough has, according to estimates made, some 6000 feet of Carboniferous beds near St. George Bay. 20,000 feet of subsidence is thus recorded for parts of the Acadian trough after the Devonian era. And probably as much took place before the Carboniferous era.

The other troughs bear evidence of like subsidence and work; but we have no definite estimates as to the thickness of the deposits.

Further, we find that the Connecticut valley trough was in its southern half, through a long period, that of the Jura-Trias, a fresh or brackish water trough. Again, the Gaspé-Worcester trough became a trough of fresh-water marshes in its southern part during the Carboniferous era. The Acadian trough, passed from a salt-water channel to a condition of great fresh-water marshes and estuaries after the Carboniferous period had set in; and this may possibly have been its condition for a length of 800 miles. It was while in this state that the trough in part of Nova Scotia sunk 13,000 out of the 16,000 feet. And after the Carboniferous era of fresh-water marshes, alternating with fresh or brackish water estuary conditions, during deep subsidence, had passed, and after also the mountain-making events which closed Paleozoic time in Nova Scotia as well as the Continental Interior, the trough still existed and in some parts continued its work through another long period of deep deposition and subsidence,—that of the Jura-Trias.*

* The broad margin of the continent south of New York had its troughs in the Jura-Trias. But each of the troughs contains Jura-Trias rocks alone; the beds rest on the crystalline Archæan, or on Lower Silurian rocks crystalline or uncrys-

In each case it appears that geological work went forward as long as subsidence was continued; and that stoppage of subsidence was stoppage of work, in accordance with a general geological law. Some would put it—Stoppage of work of deposition was genetically stoppage of subsidence; but the question is not yet so settled. Moreover, the deposits in each trough were thickest along some axial line in the trough, or more than one, where its subsidence was greatest.

The facts illustrate strikingly the great truth that the earth's features even to many minor details were defined in Archæan time, and consequently that Archæan conditions exercised a special and even detailed control over future continental growth. The extension of North America to the most eastern point of Newfoundland, and beyond it, was determined in this beginning time; and likewise, that of the European Continent to the Hebrides, in front of the Scandinavian Archæan area.

Art. XLVIII.—*On the Metamorphic Strata of Southeastern New York*; by Frederick J. H. Merrill.

Of the strata comprised in the metamorphic terrane of southeastern New York there are two principal divisions.

First, in Rockland, Orange, Putnam and Dutchess counties, the granitoid gneisses and granulites of the Highlands, which, with their continuation in New Jersey, can be shown stratigraphically to be pre-Cambrian, since they underlie unconformably in southern Dutchess County, N. Y., and at several points in New Jersey, a basal Paleozoic quartzite of Potsdam or Lower Cambrian age.

Secondly, in Westchester and New York Counties the gneissoid quartzites and arkoses overlain by crystalline limestones and mica schists, which border the rocks of the first division on the southeast and have been regarded as altered Paleozoic rocks of Ordovician or Cambrian age by Professors W. W. Mather and J. D. Dana.

The metamorphic rocks of the New Jersey Highlands were first definitely classified by Dr. N. L. Britton as a result of his studies in 1885 and 1886.* In this terrane he identified three groups: first; a Massive Group, devoid of bedding planes,

talline. The facts are of interest here; for the troughs are all parallel to the courses of the Appalachian Mountains, curving with all their long curves; and at the same time, as is true also for the Nova Scotia and Connecticut valley areas, the deep subsidence went forward in each—2000 to 5000 feet—without giving access to salt-water. The troughs were kept filled with sediments.

* Annual Report Geol. Survey of New Jersey, 1885–1886.

described by him as being the oldest formation exposed in that state, and almost entirely composed of "hornblendic granite": second, an Iron-bearing Group, resting conformably on the preceding, well stratified, and comprising bedded granulites and magnetite deposits, above the latter being crystalline limestones containing magnesian silicates in various stages of alteration: third and uppermost, a "Schistose Group," composed of micaceous gneisses, of mica schists sometimes containing graphite, and hornblendic and pyroxenic schists of varied composition. The basal Paleozoic quartzite has not yet been found to rest on strata of the third group, and the relative age of the latter remains in doubt.

In the study of the metamorphic rocks of the New Jersey Highlands and in a preliminary examination of the Hudson River section, the writer was associated with Dr. Britton and has since made a more extended study of the latter. The facts there observed corroborate the general results of Dr. Britton's stratigraphical work in New Jersey.

The basal member of the pre-Cambrian terrane of southeastern New York and New Jersey, is a granitoid hornblende-gneiss consisting chiefly of quartz, orthoclase, plagioclase and hornblende. Magnetite and zircon sometimes occur as accessories. As stated by Dr. Britton the rock is devoid of bedding planes and has only a parallel arrangement of its minerals to denote macroscopically its sedimentary origin. Its microscopic structure, however, also suggests its detrital and metamorphic character.

This rock is not a granite although usually called by that name. In addition to the parallel arrangement of its minerals which would differentiate it from the normal granites, its structure shows that it never attained that condition of molecular freedom which would be necessary to enable its mineral components to assume a crystalline form. The quartzes and feldspars occur in irregular masses interlocking at their margins and in no case show crystalline boundaries. The hornblende, which is *allotriomorphic* and fills the irregular interstices between the other mineral particles, has probably been developed in the process of metamorphism from aluminous mud containing iron, lime and magnesia. As in rocks which have been developed from the plastic or fluid state the magnesia-iron silicates according to Rosenbusch, are *idiomorphic* with respect to the feldspars and the latter are idiomorphic with respect to the quartzes, the structure of the rock in question seems to demonstrate that its component minerals are not developed from a magma but are merely the fragmental particles of a sedimentary rock and that during metamorphism only a slight degree of molecular freedom was attained by them.

The thickness of the basal member is at present indeterminate, as nothing has been found beneath it, and in the Hudson River section it is seen to descend below tide-level. The maximum thickness exposed is in Breakneck Mountain, of which the summit is said to be 1787 feet above tide. Whatever be the true height of the mountain, its central mass from tide-level to the summit consists of hornblende-gneiss, and whether it be anticlinal or monoclinal in structure, an equivalent thickness of this rock is exposed.

The second member or Iron-bearing Group, as Dr. Britton has stated, consists essentially of granulites, this name being used by him and the present writer to describe subcrystalline, well stratified metamorphic rocks composed principally of detrital quartz and feldspar. They are highly metamorphosed arkoses, and differ essentially from the under-lying formation in the absence of magnesia-iron silicates such as hornblende and biotite. The comparative absence of silicate minerals containing iron is indeed the conspicuous feature of this member taken as a whole. In some places, as at Garrisons, a pale yellowish mica is present, giving the rock the semblance of a granite, under which name it is quarried, and in close proximity to some of the magnetite beds in New Jersey, biotite and hornblende are quite abundant. This formation is at least 500 feet thick.

The beds of magnetite appear to occur at various levels in the second group and offer little evidence of their origin. If, however, it were known that the rock which furnished the detritus out of which these granulites were formed, contained magnetite distributed through it in any appreciable quantity there would be good reason for the conclusion that the magnetite beds of this horizon originated as beds of magnetic sand concentrated by wave action. There is no indication that they originated as bog ores. They are simply lenticular beds enclosed by a stratified metamorphic rock formed of quartz and feldspar sand and there is no adjoining rock of which the composition would suggest that it is a metamorphosed soil. There is, besides, no indication of a former land surface on which these beds might have been formed. The only suggestion of organic agency is in the apatite which occurs with the iron ores at some of the mines and this, if it were organic, could have been derived from marine organisms as well as from terrestrial. It is not, however, by any means certain that this apatite is organic, since the mineral is a frequent accessory in various eruptive rocks.

The strata of Dr. Britton's schistose group and the limestones which, according to him, occur near the top of the second member are found near the Hudson River, in Orange County at Fort Montgomery, and in Putnam County between

Highlands and Garrisons. It has not yet been determined whether they should be regarded as part of the system to which the two lowest groups or members belong, nor have their relations been determined with respect to the Manhattan Group (hereafter defined). As before stated, no Ordovician or Cambrian Rocks have been found to rest upon them and hence their pre-Cambrian age cannot, as yet, be predicated with certainty.

The thickness of the pre-Cambrian rocks in the Hudson River Valley may, therefore, be stated as between 2300 and 2800 feet. As to their age, it is difficult to predicate anything on account of their isolated position. The "upper member," or granulitic group may or may not be the equivalent of the Huronian. There is nothing but its unconformable position immediately below the Cambrian quartzite to suggest such equivalence, and as it seems to be conformable to the "basal member" that would have to be included in the same horizon.

The magnetite beds of this region have been compared by Dr. Britton to those of the Grenville series in Canada, and they may be equivalent but until the Laurentian of Eastern Canada has been studied and classified with the aid of modern methods of research any attempt at correlation will be unsatisfactory.

The stratigraphy of the Highland region as displayed in the section along the Hudson River is very simple. A small number of anticlinal ridges, 900 to 1700 feet in height, with a northeasterly trend, are intersected by the Hudson River valley. Along the lines of these the basal member of the Archæan is exposed and resting on their flanks and in the synclinal troughs the rocks of the Iron-bearing Group appear.

The most northern axis is that of the Fishkill range which is probably a continuation of the Wawayanda Mountain axis of Northern New Jersey, along which line in Orange Co. N. Y. occur a number of isolated hills of gneissic rock known as Sugar Loaf Mountain, Goose-Pond Mountain, Peddler Hill, Rainer Hill, Mosquito Hill, Round Hill and Woodcock Hill.

Second is that of Storm King and Breakneck Mountains, closely related orographically to the axis of Crow Nest Mountain and Bull Hill or, as the latter is sometimes called, Mt. Taurus. There is probably a fault line between these two axes and nearly parallel to them, but the structural details have not been accurately determined. A fourth axis is that which crosses the Hudson at West Point. A group of axes crosses the Hudson along the lines of Fort Hill, Sugar Loaf Mountain, Anthony's Nose and Bear Hill and finally the anticlinal of Manitou Mountain and the Dunderberg closes the succession. These folds generally pitch steeply to the S.W. In this respect the most noticeable are those of Anthony's Nose and Sugar Loaf, the latter of which exhibits this peculiarity by its profile to the most careless observer.

On the southeastern flank of Dunderberg and Manitou Mountains the stratified granulites again appear and these are succeeded after a drift-covered interval near Peekskill and Jones Pt. by slightly metamorphosed sandstones, limestones and slate, presumably of Paleozoic age, the relation of which to the sub-crystalline rocks of Westchester and New York Counties is still an interesting problem.

Younger Rocks.—The metamorphic strata of New York and Westchester Counties have long attracted the attention of geologists and several attempts have been made to solve the problems of their age and history. The extended researches of Prof. Jas. D. Dana on the relations of the limestone belts in the vicinity of Manhattan Island have furnished a clue to the stratigraphy, and, after a careful study of a portion of the terrane to which those limestones belong, the writer is enabled to announce the following general results. As Prof. Dana has noted (Am. Jour. Sci., III, vol. xxi, p. 439), the beds underlying the limestones of New York County are highly quartzose, while those overlying them are chiefly micaceous. Throughout Westchester County south of the latitude of Sing Sing, an area of about one hundred square miles, the writer has found this lithological difference to prevail. The exact relation of the lower beds to the granitoid gneisses and granulites of the Highlands of Rockland, Orange and Putnam Counties has not yet been determined by the writer, but his investigations have satisfied him that the former, with the exception of the limestones, are distinctly detrital rocks in which are preserved the fragmental character of the quartz and feldspar which they contain. The mica, chiefly biotite, is of metamorphic origin, having been developed from aluminous mud rich in potash, iron and magnesia.

As the limestones of the region under consideration contain no organic traces, so far as we know, there is no direct clue to their origin, but in the absence of evidence to the contrary we may believe that the carbonate of lime was separated by organic agencies from the sea water which held it in solution. The well known chemical theory of Dr. Hunt accounts very satisfactorily for the presence of bicarbonate of lime in sea water, but it does not account so well for the separation of the carbonate from solution, and as this separation is effected very extensively at the present time by various marine organisms and as the cases of chemical separation of carbonate of lime from solution in sea water are very few, we are justified in believing that the former process was in operation as far back in the earth's history as the sea water was inhabited by creatures possessing skeletons of carbonate of lime. The source of the magnesia so abundant in the limestone is yet undetermined.

The lowest stratum yet recognized among the Westchester County rocks is a reddish gneiss which forms the central mass of some of the hills in Yonkers where it is well exposed, and consists of small grains of detrital quartz with fragments of reddish orthoclase and a few crystals of biotite which have developed during the process of metamorphism. From its macroscopical characters the rock would be called a gneiss. From its microscopic structure it would be called a metamorphosed sandstone or arkose. As the name quartzite gneiss has been applied in Germany to rocks of analogous structure, it is proposed to designate the rock in question as an *arkose gneiss.* It may be objected that all gneisses were quartzites or arkoses previous to their metamorphism, but there is an evident necessity for the use of some descriptive term which will convey the idea of comparatively unaltered detrital structure and differentiate such a rock as this from the pre-Cambrian granitoid gneisses of Putnam County.

The thickness of the red gneiss referred to has not been determined, as no section has been found which shows its relations to the formation beneath it, but it is believed to rest upon the stratified granulites which form the second or upper member of the pre-Cambrian formation. Since the best exposures of the red gneiss have been found within the limits of Yonkers and its relations to the overlying stratum are well shown within the limits of that city, it is proposed to call it the *Yonkers gneiss.* Outcrops of this rock are frequent along the shores of the Hudson and good exposures may be found at Hastings, on the property of Dr. Draper; on the river near the southern border of Tarrytown; between Scarborough and Sing Sing stations near the railroad; along the southeast shore of the mouth of Croton Bay on the property of Orlando B. Potter, Esq.; and a little south of Oscawana Station, on Oscawana Island; it also probably occurs in the ridge which separates Annsville Cove from the valley of Peekskill village. The best exposures are in Yonkers, on and near Jerome avenue, a little north of the New York City line.

With regard to the variations in the composition and structure of the Yonkers gneiss, the most important are an increase in the proportion and size of the feldspar fragments in approaching the Laurentian Highlands.

Overlying the reddish Yonkers gneiss and beneath the crystalline limestone is a stratum of thinly bedded gray quartzite gneiss. This contains but little feldspar and its component beds vary in composition from almost pure quartz to a mixture of quartz and biotite or hornblende. Occasionally, layers of pure biotite schist, an inch or two in thickness, are intercalated with white, coarsely granular quartzite. This rock forms the summit and eastern slope of the ridge which separates the Sawmill River valley from that of the Hudson and also occurs in that on the east side of the Hudson between Yonkers and Spuyten Duyvil. It forms, as well, the anticlinal ridge of Fordham Heights which borders the east shore of the Harlem River and of which the southern extremity forms the long narrow hill by the northern end of Seventh avenue and which separates the latter from the Boulevard.

In general terms this quartzite gneiss is the gray rock used for a building stone in southern Westchester County. The Yonkers gneiss is also used for building, but not so extensively and is characterized by its reddish color. No section has yet been found which shows accurately the thickness of this gray gneiss. It is at least two hundred feet thick and, in many exposures, has an aggregate thickness of half a mile, but in these it is apparently repeated many times by folding. As in most cases the folds are isoclinal and their arches have been removed by erosion, there is little stratigraphical evidence of the thickness of the stratum thus folded.

Since this rock is well exposed and its stratigraphical relations are well shown in the Fordham Heights it is proposed to call it the *Fordham gneiss.*

The Fordham gneiss varies widely from the normal type, in places, through the presence of hornblende and garnet and an increase in the amount of feldspar and mica, but the localities of variation are comparatively few.

Between the Fordham gneiss and the crystalline limestone of the Hastings Quarry and in Yonkers at the south end of the railroad trestle near the Lowerre Race Track, a stratum of thinly bedded quartzite from five to ten feet thick is found. It seems probable that this is of wide distribution but on account of its slight thickness it is very rarely preserved when the limestone which rested upon it has been removed by erosion.

At Tuckahoe this quartzose stratum next beneath the limestone contains numerous flakes of biotite.

The position and stratigraphy of the limestone areas of Westchester County have been carefully studied by Professor Dana. My only contribution to the geology of these beds has been to determine the relations and character of the associated rocks, to note a few unrecorded outcrops and in a few cases to extend the limits of those previously known.

Professor Dana has estimated the thickness of the bed occurring in Tremont and the Harlem River valley at from six hundred to seven hundred and fifty feet. The measurements of the writer would indicate that the thickness varies from six hundred to eight hundred feet, it being apparently greater on New York Island than in Morrisania. The eastern bed at Tuckahoe is but one hundred and fifty feet thick. For this rock I propose the name of *Inwood limestone*, from the locality on New York Island in the vicinity of which it is well exposed.

The rocks which overlie the limestone are highly schistose and consist largely of mica with a small proportion of quartz and usually little or no feldspar. Garnet, staurolite, fibrolite and cyanite are the chief accessories. There are some beds of gneiss among them, but these are very small and the studies of the writer enable him to state positively that mica preponderates in the rocks above the limestone beds. No sections have yet been found which would warrant an expression of opinion as to the *exact* thickness of these schists, but it probably exceeds one thousand feet.

The mica schist formation which belongs above the limestone is of very limited extent in Westchester County. A synclinal ridge of this rock extends from Park Hill, in Yonkers, northward along the east bank of the Saw Mill River and has been traced to Elmsford.

North of Croton landing the mica schist containing garnet and staurolite extends along the bank of the Hudson for about a mile and east to the norite area of the Cortlandt Series. Near Crugers the schists have been described by Professor Dana.

Between the Bronx River and Long Island Sound, in Southern Westchester County, there is a considerable extent of mica schist but its limits are not determined. In Eastchester village, on the west shore of Eastchester Creek the rock is a gneissoid quartzite. At New Rochelle the rock along the shore of the Sound probably belongs below the limestone. The same rock, essentially a gneissoid quartzite, occurs on the shore of Mamaroneck Harbor, while Milton Point in Rye township seems to be composed of the mica schists. On the Hudson River shore, in general, the limestone areas are succeeded to the north by mica schists and to the south by the arkose gneisses.

As these uppermost beds are well exposed on Manhattan Island of which they constitute the principal rock formation they may well be called the *Manhattan schists.*

The name Manhattan Group was proposed in 1868 by R. P. Stevens, Esq., to include the rocks of New York Island and it seems proper that it should, for the present, be retained, including in it, with the Manhattan schists, the Inwood limestone and the Fordham gneiss, the Yonkers gneiss which though not found on Manhattan Island, is evidently a part of the same littoral deposit to which the Fordham gneiss belongs. The Manhattan schists are the only beds now to be found on New York Island with the exception of the limestone areas described and mapped by Professor Dana and the small area of Fordham gneiss at the north end of Seventh avenue.

If in time this group be correlated with some other which has been previously described, the names here suggested may be unnecessary, but until the question is indisputably settled they are of use in referring to the formation and its subdivisions.

Intercalated with the Manhattan schists and also with the beds of the Fordham gneiss we find at a great number of localities, hornblendic and augitic strata of limited thickness, usually only a few feet. In composition these rocks resemble diorites and diabases, and in structure they are granular, but their present well stratified condition renders it difficult to say whether they are originally eruptive rocks or not. Whatever their origin they are now metamorphic rocks and as such may be called amphibolites and pyroxenites according to the terminology of Kalkowsky. It is probable that to rocks of this character we are indebted for some of our serpentines, notably that of 60th street near 10th avenue, New York City, for as originally suggested by Dana and lately demonstrated by Gratacap it is derived from the alteration of amphibole, and on 61st street near 11th avenue, a bed of amphibolite occurs, of which the line of strike passes through the well known and interesting serpentine above mentioned and which lies about 250 feet southeast.

Age of the Manhattan Group.—It is not yet in the power of the writer to contribute any positive information on this important question He has not yet found any decisive evidence of the age of the rocks in question. All the suggestive evidence, however, favors the view taken by Professor W. W. Mather and subsequently elaborated by Professor J. D. Dana, viz: that the rocks of the Manhattan Group are the metamorphosed equivalents of the Paleozoic beds of Southern Dutchess County.

After a careful study of the stratigraphy in the vicinity of Peekskill which seems to be the index of this geological chapter, and at other points along the northern margin of the Manhattan terrane, the writer concludes that if this group is pre-Cambrian, its identity as such has been obscured by a series of stratigraphic vicissitudes so complicated that it is beyond his powers, at present, to conceive them.

A fact which may be of much significance, is that, the Potsdam or Lower Cambrian sandstone of Southern Dutchess County lies unconformably on the second or granulitic member of the pre-Cambrian formation, and it is upon the same second member that the basal beds of the Manhattan Group rest. No unconformability has yet been found between the Manhattan Group and the underlying pre-Cambrian beds, and it is chiefly this lack of positive evidence that leaves the writer in doubt as to the geological equivalence of the former. Of equal significance, however, is the lack of unconformability between the Lower Silurian strata of Peekskill Hollow, Tompkins Cove, and Verplank's Point, which are but partially metamorphosed, and the metamorphic beds of the Manhattan Group which adjoins them.

The crystalline limestones of the Manhattan Group are, as already stated, highly magnesian and in this respect they correspond in composition to the Calciferous limestones of New Jersey which according to Professor Geo. H. Cook (Geology of New Jersey 1868) contain from seventeen to twenty per cent of magnesia.

In this abstract it has not been possible to give in detail the evidence upon which the writer's conclusions are based. A complete discussion of the evidence must therefore be reserved for future publication.

ART. XLIX.—*The Radiant Energy of the Standard Candle; Mass of Meteors*; by C. C. HUTCHINS.

THE following investigation was undertaken with the primary object of finding, if possible, more trustworthy data for determining the mass of shooting stars; but a reliable determination of the radiation of the standard candle cannot fail to be of value for other purposes.

The apparatus employed in making the measurements was my thermograph,* the constant of which was found in the two following ways.

First method.—A copper Leslie cube, holding about 3 kilos. of water, was placed behind an opening of 16 sq. cm. in a wooden screen, which opening was closed by a movable shutter, by opening which the thermograph, one meter distant, could be exposed to the radiation from the cube.

The following quantities were then determined: dimensions of cube; weight of water contained in cube; water equivalent of cube; mean of the galvanometer deflections taken dur-

* Proc. American Academy, 1889.

ing the interval that the cube and its contents were falling 5° from a temperature about 65° above that of the air; time in seconds occupied by the cube in falling the 5° as above.

Knowing these quantities we can evidently compute in ergs per second the radiant energy passing through the sq. cm. of surface containing the thermal junction, and such that it will produce a deflection of one division of the galvanometer scale. A number of trials showed that 16·9 ergs per second was the quantity required.

Second method.—The constant was found by passing the rays of the sun through openings of 0·394 and 0·23 cm. diameter and observing the galvanometer deflections when the thermograph was exposed in the divergent beam at a point where the diameter of the beam was 4·2 cm. and then computing the deflection for the undiminished sunlight. Simultaneously with the above measures the radiation of the sun was observed with Pouillet's pyrheliometer.

The mean of several sets of measures by this method gave the constant 17·02; agreeing better than could have been expected with the results of the first method. The candle employed was the ordinary sperm candle, six to the pound. It burned in still air, without snuffing, 7·37 gm. per hour. The radiation of the candle was measured by placing it behind the screen in place of the cube employed in finding the instrumental constant, the exposures being made in the same manner as for the cube. The deflection given varied very much with the length of the wick of the candle, constantly increasing for a half hour or more after lighting. It therefore was necessary to observe the deflection at what was considered to be an average condition of the candle flame, that is, about 15 minutes after lighting, when a deflection of 75 scale divisions was obtained.

This number multiplied by the constant previously found gives the radiant energy which from the candle passes through each sq. cm. of a surface everywhere one meter from the candle, provided we assume that the candle radiates equally in every direction. To find the total radiant energy, we must, as a first step, know the area of cross section of the candle flame in a plane perpendicular to the direction of the flame to the opening of the thermograph. To learn this, an image of the flame was projected upon 400 sq. cm. of paper, taking care to have the projecting lens midway between the candle and paper. It was then easy to trace about the image of the flame with a pen, and this having been done ten times upon the same sheet, the whole sheet was weighed and then the tracings cut from it and also weighed. In this manner the section of the candle-flame was found equal to 1·303 sq. cm.

We now have the whole radiant energy of the candle—

$$\varepsilon = \frac{4\pi \times \overline{100}^2 \times 75 \times 17}{1 \cdot 303} = 1 \cdot 23 \times 10^8 \text{ ergs per second.}$$

To find what portion of this total energy lies in the visible spectrum could be satisfactorily accomplished only by measures made in every part of the spectrum of the candle. Such measures have been made by Langley* in the spectrum of an argand gas-lamp with a glass chimney. He finds 2·4 per cent of the total radiant energy to be visible. It is easy to compare the candle with such a lamp. At a certain distance from the thermograph an argand lamp, whose light was that of ten candles, gave a deflection of 238 scale divisions. When the lamp was replaced by the candle the deflection was 29. Hence we see that very nearly 2 per cent of the radiant energy of the candle is visible; or the visible part is $2 \cdot 46 \times 10^6$ ergs per second; about 10·9 ft. lbs. per minute.

We may now proceed to find the mass of a meteor, first upon the supposition that its rays have the same ratio of visible to total energy as do those of the candle, and later, correct, if possible, the value thus found.

Let the meteor at a distance of 50 miles have a light equal to that of Vega; let it continue for 2 seconds with a velocity of 25 miles per second. From the best data we find that if the meteor were at 1 meter distance the log of its candle power would be 3·9851. Hence to find the energy ε, we have:

log candle power	3·9851
log energy of candle	8·0899
log 2	0·3010
log ε	12·3760

We have for the mass, $m = \frac{2\varepsilon}{v^2}$, and employing the data assumed above we find $m = 0 \cdot 2936$ gm.

If the meteor in burning produce, for a given expenditure of energy, more light than does the candle, then a less mass than the one found would serve to produce the light given by the meteor. From what has been observed of the spectra of meteors, it is safe to conclude that their light is mainly due to incandescent vapors of the materials composing the meteors. It is also known that the spectra of these substances remain unchanged throughout very considerable changes of temperature, and we may therefore be permitted to draw conclusions from laboratory experiments upon these substances in the state of vapor.

* Science, vol. i, p. 482.

A lump of the Emmett Co., Iowa, iron meteorite was placed upon the lower carbon of an arc lamp and vaporized by the passage of the current. The light given by the meteor vapor was found, on the average, equal to that of 40 candles. The galvanometer deflection by the meteor at a certain distance from the thermograph was 223·2 scale divisions. At the same distance the candle gave a deflection of 55·4 divisions. From this we see that for a given expenditure of energy the arc of meteor vapor gives 10 times the light of the candle. Dividing the value of m obtained above by 10, we have $m = 0·029$ gm. for the mass of a meteor giving the light of a star of the first magnitude, moving with nearly the parabolic velocity and lasting for 2 seconds.

Bowdoin College, March 12, 1890.

Art. L.—*Meteoric Iron from North Carolina;* by L. G. Eakins.

The iron here described was found in the latter part of 1880 on a farm near Ellenboro', Rutherford Co., N. C., and its nature remained unknown until February, 1890, when it was brought for examination to Mr. Stuart W. Cramer of the U. S. Assay office at Charlotte, N. C., who ascertained that it was a meteorite and secured half of the mass. This portion was sent by Mr. Cramer to the U. S. National Museum for description, and the iron was cut and divided between the Museum collection and that of the Assay office.

The weight of the original mass, as near as can be determined, was about 2,200 grams; in shape it was roughly two globular ends with a connecting bar, the total length being about 150^{mm}, with end diameters of 75^{mm}, and 50^{mm} in the middle.

The iron is very tough and highly crystalline, the Widmanstätten figure showing distinctly on a polished, unetched face, and after etching they are unusually strong. Small, irregularly distributed patches of troilite are visible and schreibersite also seems to be present. On account of the small amount of material that could be secured for analysis no attempt was made to determine carbon, and the sulphur found shows that very little troilite happened to be included in the material analyzed, which, of course, in such highly crystalline material could not represent the actual average composition without cutting up a large part of the mass.

The analysis is as follows:

Fe	88·05
Ni	10·37
Co	·68
Cu	·04
P	·21
S	·08
Si	·02
	99·45

Laboratory U. S. Geological Survey, March, 1890.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Determination of Gas volumes by Direct Reading.*—A very simple apparatus has been contrived by Lunge which he calls a "gas-volumeter," by means of which the volume at normal pressure and temperature of the gas set free in any reaction can be read directly without requiring reduction. In its complete form, the apparatus consists of three tubes called respectively the measuring tube, the reduction tube, and the pressure tube. The measuring tube is graduated, and is closed at top by a two-way tap, one opening being to the air and the other into a lateral tube connected with the gas evolution apparatus. The reduction tube is enlarged at the upper end and is closed by a well fitting tap. The pressure tube is open above. All these tubes are drawn out below, so that strong rubber tubes can be slipped over them. By means of a Y-tube of glass the pressure tube is connected with the other tubes. The two taps being open, mercury is poured into the pressure tube, previously moistened, which of course rises in the other tubes. The barometer and thermometer are then noted, the height of the barometer corrected for the temperature and the pressure of aqueous vapor, and the volume which 100 c. c. of air would occupy at the resulting pressure and temperature is calculated. The pressure tube is then so adjusted in height that the mercury in the reduction tube (graduated for this purpose from 110 to 130 c. c.) stands at the division which represents the volume of 100 c. c. at the actually corrected pressure and temperature, when the tap on the reduction tube is closed. This tube is thus made to enclose once for all a quantity of air such that when the temperature is 0° and the pressure 760^{mm}, the air being dry, it shall occupy 100 c. c. By raising the pressure tube the measuring tube is filled with mercury and the evolution of gas into it is proceeded with as usual. To measure it, after the apparatus has acquired the temperature of the room, the division 100 on the reduction tube is made some-

what higher than the mercury level in the measuring tube, and the pressure tube is raised until the mercury in the reduction tube exactly reaches the 100 mark. If now the measuring tube be raised until the mercury within it is at exactly the same level as that in the reduction tube, it is evident that the gas it contains occupies the volume which it would have at 0° and under 760^{mm} pressure, since this is the condition of the air in the reduction tube which communicates with it. Hence the corrected volume can be read off at once on the measuring tube. Various modifications of the form of the apparatus for special cases are described. —*Ber. Berl. Chem. Ges.*, xxiii, 440, March, 1890. G. F. B.

2. *On the Nature of Solutions.*—PICKERING has published an extended paper on the nature of solutions, as elucidated by a study of the density, electric conductivity, heat-capacity, heat of dissolution and expansion by heat of sulphuric acid solutions, following the suggestion of Mendeléeff that by plotting the rate of change, i. e., the first differential coefficient of the density, conductivity, etc., of the solution as a function of the percentage composition, any sudden alterations in the curvature might be more satisfactorily established. But the statement of Mendeléeff that the derivative yielded a straight line or a series of straight lines, was found to be true not of the first but only of the second derivative. The curves for example which represent the first differential coefficient of the densities of sulphuric acid solutions, though continuous, are made up of a series of separate curves which on further differentiation yield a series of straight lines. So if the contractions obtained on mixing sulphuric acid and water be plotted instead of the densities, while a curve totally unlike that of the densities is obtained, yielding a first derivative curve also unlike that of the densities, the second derivative yields a right line closely resembling the second derivative of the densities and indicating the existence of changes at the same points. In the same way the electric conductivities, heat-capacities, heats of dilution, and expansions are represented by curves which split up by two differentiations into a series of straight lines, showing changes at the same points. These points correspond to simple and definite hydrates of sulphuric acid amounting to as many as 17, the mono-hydrate being at one extreme and a hydrate with 5,000 H_2O being at the other. "The main facts elucidated by this work," the author says, "afford absolute proof that the properties of solutions do not vary regularly with their composition, and that the nature of the solution is therefore not merely physical. There can be no doubt but that solutions consist of hydrates of a definite composition, though these may always be in a state of partial dissociation."—*J. Chem. Soc.*, lvii, 64, March, 1890. G. F. B.

3. *On the Density of Fluorine.*—By using a larger apparatus in the preparation of fluorine by electrolysis and by purifying the gas from hydrogen fluoride by passing it first through a platinum worm cooled to —50° by means of methyl chloride and then through a

platinum tube containing anhydrous sodium fluoride (since it is not hygroscopic is preferable to the potassium salt), MOISSAN has been able to determine the density of fluorine. The pure gas was collected in platinum flasks of about 100 c. c. capacity, previously filled with nitrogen. After weighing, the fluorine was brought in contact with water and the evolved gases were measured and analyzed, a correction being made for any remaining nitrogen. The mean density found was 1·265, while that required by theory ($F=19$) is 1·316.—*C. R.*, cix, 861; *J. Chem. Soc.*, lviii, 201, March, 1890. G. F. B.

4. *On the Determination of Oxygen dissolved in Water.*—THRESH has proposed a new method of determining the oxygen which is dissolved in water, founded on the fact that a very minute quantity of a nitrite is able to cause the liberation of a very large amount of iodine when to a water containing it and oxygen, potassium iodide and sulphuric acid are added; the nitrogen oxide seeming to act as a carrier. Since the iodine thus set free is capable of accurate estimation, the oxygen dissolved in a drinking water may be very rapidly determined in this way and with great precision. For this purpose it is necessary simply to add to a known volume of the water a definite quantity of sodium nitrite together with an excess of potassium iodide and sulphuric acid, and, avoiding access of air, to determine volumetrically the amount of iodine liberated. Deducting the quantity corresponding to the nitrite used, the remainder represents the oxygen dissolved in the water. The strength of the solutions used and the apparatus employed in the determination are noted in the paper.—*J. Chem. Soc.*, lvii, 185, March, 1890. G. F. B.

5. *On a Method of distinguishing Hydrogen Arsenide from Hydrogen Antimonide.*—BRUNN has observed that hydrogen sulphide and hydrogen arsenide do not act on each other in the absence of air either in the gaseous state or in solution in water, even on exposure to direct sunlight; but that on the admission of air, arsenous sulphide is at once produced, and in both cases, a mixture of hydrogen arsenide and air in a flask over water deposited a brown-black precipitate; thus confirming the observation of Janowsky. But the author shows that this precipitate varies in its composition according to the amount of oxygen present. With an excess of air the hydrogen arsenide is oxidized to black metallic arsenic; while if only a small quantity of air be mixed with the gas, it is oxidized only to brown solid hydrogen arsenide. Hence it would appear that the above reaction of H_2S upon H_3As takes place in two stages; the H_3As being oxidized to arsenic in the first; and in the second the arsenic being converted into sulphide. On heating a mixture of hydrogen arsenide and hydrogen sulphide, however, to 230°, even when absolutely free of air, decomposition takes place and arsenous sulphide is deposited. Further experiment showed that hydrogen arsenide is itself decomposed at about this temperature, and that therefore the formation of arsenous sulphide is a secondary

reaction. Hydrogen antimonide, on the other hand, is at once decomposed by hydrogen sulphide even when both air and light are absent. If hydrogen antimonide be heated alone it begins to dissociate at about 150°. This fact the author proposes to use for the detection of traces of hydrogen antimonide occurring with hydrogen arsenide in hydrogen or other gases. For this purpose, the mixture of gases is to be passed through a tube about a meter long, heated to 208°–210°; in a liquid having this boiling point. No arsenic whatever is deposited, while all the antimony is thrown down. The mirror obtained may be examined in the usual way.—*Ber. Berl. Chem. Ges.*, xxii, 3202, Jan., 1890; *J. Chem. Soc.*, lviii, 209, March, 1890. G. F. B.

6. *On the Atomic Mass of Gold.*—Mallet's final paper on the atomic mass of gold has been presented to the Royal Society. The gold employed consisted (1) of material purified by himself, the final reduction being effected with formic acid; (2) of material furnished from the Philadelphia mint; (3) of material obtained from the New York assay office; and (4) of material sent to him from the British mint. The results appear to have been sensibly the same by each method for all the gold used. Seven series of experiments are described. In the first, auric chloride was precipitated with sulphurous acid and the gold weighed; and, in the resulting solution, the chlorine was determined. In the second, auric bromide was similarly treated. In the third, a potassium auri-bromide solution was divided into two equal parts, in one of which the gold was precipitated and weighed and in the other the bromine was determined. In the fourth, tri-methyl-ammonium auri-chloride was ignited and the metallic residue weighed. In the fifth, an attempt was made to determine the ratio between the weights of metallic gold and metallic silver deposited by the passage of the same electric current through their solutions. In the sixth, the electro-deposited gold was compared with the hydrogen set free by the same current. And in the seventh, the gold was precipitated by metallic zinc, and weighed, the hydrogen evolved by the excess of zinc being noted. The mean of the first series is 196·722; 2d, 196·790; 3d, 196·775; 4th, 197·225; 5th, 196·823; 6th, 197·137; and 7th, 196·897; the general mean being 196·910.—*Phil. Trans.*, clxxx, A. 395, November, 1889. G. F. B.

7. *On Musical Tones by means of unlike formed Waves.*—Dr. Rudolph König shows, by a series of rotating wheels, in which the intervals between the teeth are the same but of different form, that the tones produced by the rotation of these teeth against a suitable vibrator are musical and do not obliterate the fundamental tone produced by the main serrations of the wheel, and can produce a musical note as long as the dissimilarity in form does not change the amplitude of the fundamental waves. A number of diagrams of the serrated wheels accompany the paper.— *Wied. Ann. der Physik und Chemie*, No. 3, 1890, pp. 403–411. J. T.

8. *Electrical Vibrations in rarefied air without Electrodes.*—JAMES MOSER gives the following results of his experiments:—A glass tube which contained a gas of constant rarefaction was surrounded by a wider tube, and the rarefaction varied in this by means of the air pump. The following results were obtained:—

(*a.*) At the ordinary atmospheric pressure in the outer tube the inner tube becomes luminous.

(*b.*) With a sufficient rarefaction of the outer tube the phenomenon is reversed: the inner tube becomes dark and the outer one luminous. Here there is a screening action.

(*c.*) The rarefaction was pushed further, the outer tube became dark, the inner one luminous, so that to the eye the third stage was like the first one.

The more perfect vacuum gives, therefore, no screening action. It has lost the power of conducting the electrical current.—*Phil. Mag.*, April, 1890, p. 375. J. T.

9. *Magnetization in strong fields at different temperatures.*—H. E. J. G. DUBOIS believes that his experiments show that all doubts that have occasionally arisen in regard to the existence of a limit of magnetization will be dissipated. He agrees with the results of M. Goldhammer, that "magnetization affects all physical properties of metals in a way generally depending on its direction. Whenever the ensuing changes are odd functions of the magnetization (both simultaneously reversing their sign), they are simply proportional to it. In the case of even functions (always having the same sign), they are simply proportional to its square.—*Phil. Mag.*, April, 1890, pp. 293–306. J. T.

10. *On the structure of the Line Spectra of the Chemical Elements.*—J. R. RYDBERG, of the University of Lund, gives the following as the results of his study:

(1.) The long lines of the spectra form doublets or triplets, in which the difference (ν) of wave numbers of their corresponding components is a constant for each element.

(2.) The corresponding components of the doublets form series of which the terms are functions of the consecutive integers. Each series is expressed approximately by an equation of the form $n = n_0 - \frac{N_0}{(m+\mu)^2}$, where n is the wave number, m any positive integer (the number of the term), N_0, n_0 and μ constants peculiar to the series.

The wave length (and the wave numbers) of corresponding lines, as well as the values of the constants ν, n_0, μ of corresponding series of different elements, are periodical functions of the atomic weight.—*Phil. Mag.*, April, 1890, pp. 331–337. J. T.

11. *Velocity of the Propagation of Gravitation.*—M. J. VAN HEPPERGER, in a paper read before the Vienna Academy of Sciences, has assigned an inferior limit to the velocity of propagation of gravitation. It results from this limit that the time taken by gravitation to travel the radius of the earth's orbit does not exceed a second.—*Nature*, March 20, 1890, p. 472. J. T.

12. *Electricity in Modern Life;* by G. W. DE TUNZELMANN. 272 pp. 8vo. London, 1889. (Walter Scott.)—The widespread interest in electricity and its applications during the past decade or two has called out a large number of books, of varying scope and method, devoted to the different parts of the subject. The present volume starts with the design to present the matter in such a form as to be attractive and intelligible to the ordinary reader with little or no scientific training, and this plan is carried through with satisfactory success. On many topics, such as the telegraph, the telephone and telephone exchanges, electric lighting, etc., the reader will find information of interest here, which is not always easily accessible elsewhere.

II. GEOLOGY.

1. *The Coal formation in southeastern England.*—Professor W. BOYD-DAWKINS has recently reported on the results of a boring at Dover, opposite Calais, which was commenced in 1886, on his recommendation, by the South-Eastern Railway and Channel Tunnel Company. The coal measures were reached at a depth of 1204 feet, and good coal was found 20 feet below. Much is expected from further exploration. At Calais, the coal-measures had previously been reached at a depth of 1104 feet. The coal area extends thence along the boundary of France and Belgium. The Westphalian field is 7218 feet thick and contains 117 coal beds yielding 294 feet of workable coal; at Liège the thickness is 7600 feet, the number of coal beds 86, the thickness of good coal 212 feet; at Monz these figures are 9400, 110, 250; in Somersetshire southeast of South Wales, 8400 feet, 55 and 98; in South Wales, 1100, 75 and 120. The coal-measures are represented as upturned and lying unconformably beneath the Oölitic and Cretaceous strata.

The probable existence of the coal-measures in southeastern England was first urged by Godwin-Austen in 1856, who showed that the coal fields of South Wales in North Somerset and the Belgian were characterized by long, narrow, east and west folds and lay in nearly the same line; and pointed out the Thames Valley and the Weald of Kent and Sussex as places where they possibly might be discovered. Professor Prestwich, of the Coal-commission of 1856–71, reported in favor of this conclusion, and with full details as to the probable facts. A well was consequently bored in 1871 by the Sub-Wealden Exploration Committee at Netherfield, in the Wealden region; but at a depth of 1905 feet it was stopped after passing only 60 feet into the Oxford clay. Eleven years later an anticlinal of Devonian and Silurian was found in a boring in the area of London at Ware at a depth of about 800 feet, and near Richmond at a depth of 1289 feet, with the oolite unconformably superposed only 87 feet thick, indicating as Professor Boyd-Dawkins states, that coal should be looked for in the synclinal band farther south; and there it was found.

2. *Geological Society of America.*—The publication of the papers read before the Geological Society at its December meeting has been going forward, and already have appeared papers by I. C. Russell, the Surface Geology of Alaska; A. C. Lawson, Canada Archæan surfaces and taxonomy; W. M. Davis, structure and origin of Glacial Sand-plains; C. R. VanHise, the pre-Cambrian of the Black Hills; S. F. Emmons, Orographic movements in the Rocky Mountains; R. Bell, Glacial phenomena in Canada; Sir W. Dawson and D. P. Penhallow, the Pleistocene flora of Canada; C. D. Walcott, the value of the term Hudson River group in geological nomenclature; A. Winchell, Some results of Archæan studies.

3. *Quaternary History of Mono Valley, California*, by Israel C. Russell. 126 pp. large 8vo. 8th Ann. Rep. Director U. S. Geol. Survey for 1866-67 (yet unpublished).—Mr. Russell's extensive explorations over the Great Basin, as shown in his Reports on Lake Lahontan Basin, and the Glaciers of the Sierras, had well prepared him for his later work on the Quaternary history of the Mono Valley. This valley of Mono Lake is situated on the southwestern part of the basin, 6,380 feet above the sea. In Mr. Russell's account of the region, he first describes its general features, those of the present time and of the Quaternary, its remarkable tufa towers and other deposits, and the chemistry of its waters; and then takes up, and treats with much instructive and interesting detail its glacial history. Among the facts mentioned, he states that the basin of Lake Mono is rock-bound on all sides, and therefore must have been excavated by glacial abrasion; the bottom is now fifty-one feet below the surface of the lake. Next the volcanic history is discussed. Scores of recent craters of basalt, andesite and more recent lavas are described as occurring along the base of the Sierra in the vicinity of Lake Mono; and not far distant to the eastward are mountain ranges of "more ancient volcanic rocks;" but no such cones occur in the adjoining part of the Sierra. Feeble fumaroles and springs of heated water occur at Hot Spring Cove on the eastern side of Paoha Island as the only remains of former activity.

The region described is one of the most interesting on the Pacific side of the Continent, as shown some years since by Prof. LeConte's descriptions. The fuller details and judicious discussions of Mr. Russell's memoir bring the fact strongly to view. This is made the more manifest by the many excellent maps and views.

4. *Catalogue of British Fossil Vertebrata;* by Woodward and Sherborn. (Communicated.)—Some months since Mr. Arthur Smith Woodward published the first part of a Catalogue of the fossil fishes in the British Museum, forming a volume of nearly 500 pages, octavo, with 17 plates. This volume contained only the Elasmobranchii; and we may soon expect another which shall include the Placoderms, Ganoids and Teleosts. Much conscientious labor was bestowed upon this work by Mr. Wood-

ward, and containing as it does complete synonymy and copious reference to authorities in addition to the enumeration of the specimens in the British Museum, it cannot fail to be of great utility not only to the frequenters of the Museum but to students of fossil Ichthyology in all countries.

Now, Mr. Woodward, with the coöperation of Charles Davies Sherborn, has issued a smaller volume which is a *Catalogue raisonné* of all the fossil vertebrates up to the present time found in the British Islands. The introduction to the volume includes much useful and interesting information in regard to their geographical and stratigraphical distribution, with tables of the dates of the different parts of the "Poissons Fossiles" of Agassiz and of the "Odontography" of Professor Owen. The catalogue which follows give not only full synonymy, but a bibliography which must have cost the authors much time and trouble. It also attempts a revision of the genera, which on the whole is judicious and will be a great help to the student, and yet in some repects is too revolutionary and will tend to confuse where it aims to make clear. This is specially true of the references to American genera, which would have been more satisfactory if the authors had been in possession of good specimens, and had not trusted to necessarily imperfect figures and descriptions. It is natural and unavoidable that those who are reviewing genera and species of fossils found in other countries should err in considering forms allied to those with which they are familiar at home as identical or mere varieties; the material under their eyes attaching to itself the solitary or scattered specimens floating through foreign literature by an attraction which is directly as the mass. Hence a safe and satisfactory comparison can only be made when approximately equal amounts of foreign material have been studied with that of home origin, and the prevailing and characteristic features of each group are given their due weight. Fortunately, Mr. Woodward is soon to be in America, where he comes to see with his own eyes the fossil fishes found in this country to which he has made reference in the works referred to above. We may fairly expect that with the things themselves before him he will modify somewhat the opinions he has formed simply from figures and descriptions; and it will be not only a gratification to his American co-laborers but a decided gain to science when with his keen observation and great knowledge he shall pass their material in review. J. S. N.

5. *The Mammalia of the Uinta formation.* 112 pp. 4to. Trans. Amer. Phil. Soc., 1889. *On the Geological and Faunal relations, and on the Creadonta, Rodentia and Artiodactyla;* by Wm. B. Scott, of Princeton; *and on the Perissodactyla and the Evolution of the Ungulate foot;* by H. F. Osborn, of Princeton.—Professor Scott discusses the stratigraphical relations of the Uinta and other Eocene formations of the Rocky Mountain summit region, and concludes that this group (so named, not by Mr. King to whom it is credited but by Professor Marsh) is, as generally believed,

the most recent. From the Bridger Fauna it differs in the absence of Dinocerata and Tillodonts. The authors describe several new species of fossil Mammals from the Uinta beds, and illustrate them by a number of plates of excellent figures.

6. *On the Lower Carboniferous limestone series in Central Texas;* by R. S. Tarr.—Mr. Tarr, in a recent communication to the editors, gives an account of his study of a Paleozoic region in Central Texas which was reported upon by Dr. F. Roemer in 1848 as affording fossils like those of the Carboniferous limestones of the Mississippi Valley. The fossils described were from San Saba County. Mr. Tarr reports that the Paleozoic area covers part of Llano, Mason, Southern San Saba and McCulloch Counties. The older rocks in it are much upturned and flexed; and the Silurian limestones are chiefly marble, and have lost most of their fossils by metamorphism. Carboniferous limestones and shales overlie these beds unconformably, and the Upper Carboniferous consisting of sandstones, shales, clays and limestone, "attain a thickness in one section of 8,000 feet."

7. *The Geographic Development of Northern New Jersey,* by Wm. M. Davis and J. Walter Wood, Jr. (Proc. Boston Soc. N. Hist., 60 pp. 8vo. 1889.)—This paper is a valuable study in the subject of the development of drainage channels and areas and of topographic features.

8. *The Intrusive and Extrusive Trap sheets of the Connecticut Valley;* by Wm. M. Davis and C. L. Whittle. (Bull. Mus. Comp. Zool., xvi, No. 6, Dec., 1889).—The authors here treat of the means of distinguishing Intrusions and Extrusions, and their general features in Connecticut, and describe in detail some of the more important localities. To those who have read the paper of E. O. Hovey in the number of this Journal for last November (a month earlier in time of publication) and desire the most recent views of Prof. Davis on the general question and help as to methods of further investigation, this paper will have special interest.

9. *Underground Water in the Western Districts of New South Wales;* by H. C. Russell, F.R.S.—With reference to the remarkable supply of underground water in the interior of Australia, Mr. Russell states that Darling River, one of the largest of the rivers, whose drainage-area receives 22·14 inches of rain (mean result of ten years) discharges only $1\frac{1}{2}$ per cent of the amount. This remarkably small proportion is due to the porous character of the rocks, through which the water becomes subterranean. Lake George, a lake 5×16 miles in area at high water, situated in a depression in the mountains about 2200 feet above mean tide-level, receives by drainage from the hills around but 2 to 3·64 per cent of the rain-fall. The great porosity of the rocks is here again demonstrated.—*Journ. Proc. R. Soc. N. S. Wales*, xxiii, 57, 1889.

10. *Genesis and Chemical Composition of the Italian Volcanic soils;* by Dr. Leonardo Ricciardi, Prof. Chim. Accad. Agricolt.

di Torino. 150 pp. 8vo. Florence, 1889.—Dr. Ricciardi here treats of the various volcanic rocks of Italy, gives their chemical composition, distribution, the results of their decomposition and the character of the soils they afford. He discusses the effects of atmospheric agents in producing decomposition and among them those of vegetation, the Lichens, Diatoms, and Bacteria. One of the most characteristic lichens of volcanic regions, the *Stereocaulon Vesuvianum*, afforded in two analyses, one of them of specimens from the Leucitic lava of Vesuvius:

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	P_2O_5
1.	46·40	11·13	....	20·40	2·51	14·78	....	2·28	tr. = 97·49
2.	46·41	19·67	6·88	4·17	5·28	10·53	2·02	4·09	= 99·00

The amount of ash is stated to be 11·16 p. c. of the dried lichen. Special soils of various localities are next described in detail and their origin considered.

11. *Fauna der Gaskohle, etc., Der Permformation Bohmens.* Band ii, Heft 4. Prague, 1889. Dr. Ant. Fritsch.—Dr. Fritsch's work on the Vertebrate fossils of the Permian or Upper Carboniferous of Bohemia has long been favorably known to geologists. The earlier parts, on the Batrachians of the order *Stegocephala* and its allies, have added very much to our knowledge of this group, and the later parts on the fishes prove equally interesting, as illustrating some of these in a much more perfect manner than has hitherto been possible. Vol. ii, pt. 3, published in 1848, describes the *Dipnoi*, and in part 4, just issued, the author is enabled to restore a species of *Ctenodus* (*C. tardus*) in such a manner as to bring out very distinctly its remarkable resemblance to the modern Barramunda of Australia (*Ceratodus*). It is most interesting to see these fish, hitherto mostly known by detached teeth, thus restored and compared in their details with their more modern relatives, as well as with those of the Devonian and Silurian. The figures also throw much light on curious bones and scales found with the *Ctenodus* teeth, with which collectors in the Carboniferous are familiar.

Part 4 is devoted principally to another group, the sharks of the genus *Orthacanthus* Agassiz, a genus established by the great worker in Paleozoic fishes for a group of straight, striated spines often with denticles near their points, but which it now appears is synonymous with the genus *Diplodus* of the same author founded on the teeth. Egerton, Newberry, Cope and others have remarked on the probable identity of the two genera, from the occurrence of *Orthacanthus* spines and *Diplodus* teeth in the same beds. The writer, before knowing anything of the views of these authors, stated in 1869 a similar conclusion from the frequent association of the spines and teeth on the shales of the Pictou coal field in Nova Scotia.*

Fritsch now presents us with illustrations of specimens in which the cartilaginous skull and jaws are in great part preserved,

* Second edition of Acadian Geology, p. 211.

and the rows of small teeth and the great nuchal spine are seen in place or nearly so; and we see that the teeth lie flat on the jaw in successive rows as in modern sharks. We see also that there were bands of very small teeth on the gill-arches quite different in form from those of the jaws, and that the latter are of different forms in different parts of the mouth, so that if found separated they might be referred to distinct species.

These specimens enable true species to be established, as distinguished from those founded merely on detached teeth and spines, and of these four are described and figured, besides a doubtful one, and spines of the allied genera, *Tubulacanthus* and *Brachyacanthus*, etc.

These Carboniferous sharks, of moderate size and armed with sharp teeth, must have devoured the smaller ganoids of the estuaries and lagoons, and probably also the larvæ of Batrachians, and the smaller aquatic species of these animals. *Coprolites* which are found in the same beds are usually filled with the scales of small ganoids. Both in America and in Europe the abundance of spines and teeth in some of the coal shales testifies to the numbers of these predaceous fishes, and the presence of their teeth in the roofs of coal beds, and even in some cases in the coal itself, shows that they ventured into fresh water and even into the shallower ponds of the coal swamps.

Fritsch deserves the utmost credit for his painstaking and careful work on these fossils, and his work should be in the hands of all students of Carboniferous batrachians and fishes. J. W. D.

12. *On fossil plants collected by Mr. R. A. McConnell on Mackenzie River and by Mr. T. C. Weston on Bow River;* by Sir J. William Dawson. Trans. Roy. Soc. Canada, vol. vii, sect. iv, 1889.—Twelve species are here enumerated, two of which are new, the remainder having been found in some of the Arctic localities. Of the remainder, seven have previously been found in the Mackenzie River region, all but one of which are also common to the Fort Union series along the 49th parallel, pointing strongly to the close relationship between the Mackenzie River beds and those of the Fort Union group.

The fine oak leaf collected by Mr. Weston at Calgary (Fort Union) is probably correctly referred to *Quercus platania;* but the specimen figured by Professor Lesquereux in his "Tertiary Flora," which comes from Carbon, Wyoming, is probably not that species, being a palminerved leaf. In this paper Sir William Dawson manifests a willingness to regard the Fort Union group as belonging to the Tertiary system, while admitting that it forms a part of the Laramie series in general, the lower portion of which is conceded to be Cretaceous. L. F. W.

13. *The Bala Volcanic Rocks of Caernarvonshire and associated rocks,* being the Sedgwick prize essay for 1888, by Alfred Harker, M.A., F.G.S., Demonstrator in Geology (Petrology) in the University of Cambridge. 130 pp., 8vo.—This memoir contains the results of a careful stratigraphical and petrological study

of the rocks referred to in the title. The rocks are rhyolytes, augite-andesytes, diabase, gabbro, hornblende-diabases, hornblende-picryte, and others. Their origin, the nature of the crust-movements leading to the volcanic irruptions, the following of the lighter acidic lavas by the heavier basic, are among the subjects discussed.

14. *Scapolite Rock.*—Professor F. L. NASON, of New Brunswick, N. J., states in a letter of April 5th, that he has found, associated with the crystalline limestone of Vernon, Franklin Furnace, and Sparta, New Jersey, a Scapolite rock, consisting of scapolite, hornblende, pyroxene and orthoclase. The rock is usually well foliated. Titanite is rather abundant in the rock.

III. BOTANY AND ZOOLOGY.

1. *Histology as a Basis for Classification.*—At the Botanical Congress held in Paris, on the 24th of August, and now pretty fully reported in the Bulletin de la Société Botanique de France, there was an elaborate paper by Vesque, in which he supported by additional instances the claims of Microscopic Anatomy as a factor in Systematic Botany. The positions taken by Vesque were contested by many disputants, one of the more important opposing communications being from Cornu. G. L. G.

2. *On the Stem Structure of Iodes Tomentilla;* by B. L. ROBINSON. (Ann. du Jardin Botanique de Buitenzorg., vol. VIII, p. 95).—In this interesting paper Mr. Robinson treats of the anomalous histological features of the species mentioned in the heading, and takes up also certain other members of the Order *Phytocreneæ* to which it belongs. Some of the morphological features are elucidated with much skill. G. L. G.

3. *Garnsey's Translation of Sachs's History of Botany.*—When the German edition of this interesting work appeared, we took occasion to give in this Journal an extended review of its chief features. It is therefore unnecessary to go over the same outlines again. It is, however, due to the translators to say that his work has been remarkably well done and that it brings out clearly the attractive style of the German teacher. Some slight mistakes which were attributable to careless proof-reading or transcription in the original have been carefully corrected, and the English edition is uncommonly free from errors. The naïve preface by Professor Sachs to this translation is well worth giving almost in full, since it sums up well a few of the changes which his views experienced after the publication of the works of Darwin on the movements of plants, and certain other treatises which controverted positions held by him.

"On questions connected with times long gone by, the decision of the experts has in most cases been already given, though I myself found to my surprise that older authors had for centuries been regarded as the founders of views which they had distinctly repudiated as absurd, showing how necessary it is that the works of our predecessors should from time to time be carefully read and compared together. But in the majority of cases there is no dispute at the present day respecting the historical value, that is the operative influence on posterity, of works written three hundred or even one hundred years ago.

"But it is a very different matter when the author of a book like mine ventures, as I have done for sufficient reasons, but at the same time with regret, to sit in judgment on the works of men of research and experts, who belong to our own time, and who exert a lively influence on their generation. In this case the author can no longer appeal to the consentient opinion of his contemporaries; he finds them divided into parties, and involuntarily belongs to a party himself. But it is a still more weighty consideration that he may subsequently change his own point of view, and may arrive at a more profound insight into the value of the works which he has criticised; continued study and maturer years may teach him that he overestimated some things fifteen or twenty years ago, and perhaps undervalued others, and facts, once assumed to be well established, may now be acknowledged to be incorrect.

"Thus it has happened in my own case also in some but not in many instances, in which I have had to express an opinion respecting the character of works which appeared after 1860, and which to some extent influenced my judgment on the years immediately preceding them. But this was from fifteen to eighteen years ago when I was working at my History. It might perhaps be expected that I should remove all such expressions of opinion from the work before it is translated. In some few cases, in which this could be effected by simply drawing the pen through a few lines, I have so done; but it appeared to me that to alter with anxious care every sentence which I should put into a different form at the present day would serve no good purpose, for I came to the conclusion that my book itself may be regarded as a historical fact, and that the kindly and indulgent reader may even be glad to know what one, who has lived wholly in the science and taken an interest in everything in it old and new, thought from fifteen to eighteen years ago of the then reigning theories, representing as he did the view of the majority of his fellow botanists.

"However these remarks relate only to two famous writers on the subjects with which this History is concerned. If the work had been brought to a close with the year 1850 instead of 1860 I should have hardly found it necessary to give them so prominent a position in it. Their names are Charles Darwin and Karl Nägeli. I would desire that whoever reads what I have written on Charles Darwin in the present work should consider that it contains a large infusion of youthful enthusiasm still remaining from the year 1859 when the Origin of Species delivered us from the unlucky dogma of constancy.

"Darwin's later writings have not inspired me with the like feeling. So it has been with regard to Nägeli. He, like Hugo von Mohl, was one of the first among German botanists who introduced into the study that strict method of thought which had long prevailed in physics, chemistry, and astronomy; but the researches of the last ten or twelve years have unfortunately shown that Nägeli's method has been applied to facts which, as facts, were inaccurately observed. Darwin collected innumerable facts from the literature in support of an idea, Nägeli applied his strict logic to observations which were in part untrustworthy. The services which each of these men rendered to the science are still acknowledged; but my estimate of their importance for its advance would differ materially at the present moment from that contained in my History of Botany. At the same time I rejoice in being able to say that I may sometimes have overrated the merits of distinguished men, but have never knowingly underestimated them." G. L. G.

4. *On the Compound eyes of the Arthropoda;* by J. M. Clarke. (Communication dated Albany, March 1st, 1890.)—The recent (February, 1890), number of *Studies from the Biological Laboratory* of the Johns Hopkins University contains a very interesting paper by Dr. S. Watase on the morphology of the compound eyes in the Arthropoda. The developmental and mature characters of the optical unit or ommatidium are shown for Serolis, Talorchestia, Cambarus, Callinectes and Limulus (lateral eyes). In the last named, the ommatidia are covered by a simple layer of integumentary chitin, the cornea, which is thickened over the opening of each eyelet, forming a simple dioptric organ or lens. Thus the inner surface of the cornea of Limulus is covered by a multitude of minute elevations, corresponding numerically to the ommatidial cavities. In Serolis, representing the Isopod type of compound eye, a discrete portion of the chitin is enclosed within the ommatidial cavity forming a subspherical crystalline cone. Dr. Watase suggests in a foot-note that the structure of the eye in Phacops, which I endeavored to elaborate in the Journal of Morphology, vol. ii, No. 2, appears to correspond more closely with that of Serolis and the Isopods than with that of Limulus. After reading this admirable paper I have no longer any doubt that the type of trilobite-eye which was termed by me *holochroal* (exemplified by Asaphus, Proëtus, and in fact nearly all trilobites except the Phacopidæ and Harpidæ), is essentially identical with that of Limulus; but I am not prepared to concede the similarity between the *schizochroal* eye (Phacops) and that of Serolis. It would simplify the correlation of what is known in regard to the schizochroal trilobite-eye if we were entitled to assume, as does Dr. Watase and as was done by Quenstedt and Burmeister, that a chitinous envelope originally covered the entire visual surface but has invariably been lost; this, however, I do not believe is any longer a legimate assumption. No trace or evidence of such a continuous corneal envelope has ever been seen, though these fossils have been under the most careful scrutiny for over fifty years. I have myself exam-

ined a vast number of specimens in almost every variety of preservation, with the very purpose of determining the question of its existence, and I am satisfied that the cornea never existed save as discrete, hollow corneal lenses, for however tenuous an additional continuous layer may have been it would not have been so delicate as to have escaped preservation in some of the conditions observed. Again, it must not be overlooked that in the compound eye of Phacops are continuous patches of scleral integument between the ommatidia, a fact which finds no homology among recent Arthropod eyes nor in the holochroal trilobites. The eyelets are absolutely and widely discrete, while in Serolis, Limulus they are in the closest apposition. More evidence is needed to prove that the schizachroal type of compound eye is still extant. An interesting suggestion bearing upon its genesis, and one which may fruitfully be followed up, is that (as remarked in a foot-note to my paper referred to) an extremely young individual of Calymene (holochroal) showed remarkably large corneal lenses and an interlensar sclera developed to such a degree as I have never observed among mature holochroal eyes.

J. M. C.

5. *Prodromus Faunæ Mediterraneæ, sive Descriptio Animalium Maris Mediterranei Incolarum, etc., congessit* J. V. CARUS, vol. ii, Pars I, BRACHIOSTOMATA, MOLLUSCA. Stuttgart, 1889. [E. Schweizerbartsche Verlagshandlung, E. Koch.]—This first part of the second volume of Dr. Carus's work on the Mediterranean Fauna extends to the close of p. 272. The Brachiostomata include Class 1, containing the Bryozoa, which occupy 54 pages, and Class 2, the Brachiopoda, covering 7 pages. The Brachiopoda include 3 species of Terebratula, 2 of Terebratulina, 2 of Waldheimia, 1 of Megerlia, 2 of Platydia, 3 of Argiope, 5 of Cistella, 1 of Thecidea, 1 of Rhynchonella, and 3 of Crania. After these, descriptions of the Mollusca follow, commencing with the Pelecypoda or Lamellibranchiates.

6. *Corals and Coral Islands;* by J. D. DANA. 3d edition. New York: Dodd, Mead & Co.—This new edition of the Corals and Coral Islands, announced on page 326, has now been published. The map of the Louisiade Archipelago will be found to be a very complete argument in favor of the Darwinian theory of subsidence. The size of the barrier reef—150 miles long—the great interior sea, and the fragment-like deeply indented islands and islets within, appear to admit of no other explanation. In the discussion of opposing arguments, Dr. Guppy's current theory is shown to be inapplicable to the largest of coral island archipelagos, because the needed currents do not exist. A map of part of southern Oahu, showing the positions of the artesian borings and the accompanying descriptions give the basis now available for conclusions with regard to the origin of the great thickness of the shore reefs. The great coral-reef sand-accumulations of Florida, the Bahamas and the Bermudas, reaching a height of 230 feet in the latter region, which all recent observers

describe as made of drifted sands, and which contrast strikingly with facts in the Central Pacific, are explained by reference to the positions of the areas within the cyclone belt of the ocean. A copy of the map of these regions by the Hydrographic department, making Plate XI, gives all the soundings of the adjoining seas. The four new colored plates, one representing Actiniæ, and the others, species of living corals, are from the author's Zoophyte Atlas.

IV. Astronomy.

1. *The Diurnal Variation of Terrestrial Magnetism;* by Arthur Schuster.—Prof. Schuster, in a memoir read before the Royal Philosophical Society of London, has discussed the Diurnal Variation of Terrestrial Magnetism, by the methods of Spherical Harmonics. For this he has used the observations for 1870 made at four stations, Greenwich, Lisbon, St. Petersburg and Bombay. He thus sums up the principal results obtained in his paper:—

(1.) The principal part of the diurnal variation is due to causes outside the Earth's surface, and probably to electric currents in our atmosphere.

(2.) Currents are induced in the Earth by the diurnal variation which produce a sensible effect chiefly in reducing the amplitude of the vertical component and increasing the amplitude of the horizontal component.

(3.) As regards the currents induced by the diurnal variation, the Earth does not behave as a uniformly-conducting sphere, but the upper layers must conduct less than the inner layers.

(4.) The horizontal movements in the atmosphere which must accompany a tidal action of the Sun or Moon, or any periodic variation of the barometer such as is actually observed, would produce electric currents in the atmosphere having magnetic effects similar in character to the observed daily variation.

(5.) If the variation is actually produced by the suggested cause, the atmosphere must be in that sensitive state in which, according to the author's experiments, there is no lower limit to the electromotive force producing a current.

2. *Bibliographie Générale de l'Astronomie;* by J. C. Houzeau and A. Lancaster.—The second volume of this large and very valuable Bibliography appeared several years ago (see this Journal, vol. xxi, p. 253, and vol. xxiv, p. 76). Two parts of vol. i have since been issued, the first in 1887, and the second in 1889. The first part contains an extended history of Astronomy (325 pages) by M. Houzeau. The history of the science in its earlier developments is more particularly dwelt upon. The remainder of this part is given to the Bibliography of the History of Astronomy and to Astrological Books. There are of these 5415 entries. A large number of these are manuscripts. When there are second editions, or translations, or detailed reviews of printed books, the titles of or references to them follow the first entry.

Before the appearance of the second part of the Bibliography M. Houzeau died, and an interesting biography of him by Mr. Lancaster is given as introduction thereto. M. Houzeau's life in this country in 1858–1866 and his life in Jamaica form portions of Mr. Lancaster's story. The subjects covered by this part are Biography and Correspondence; Didactic and general works; Spherical Astronomy; Theoretic Astronomy.

The third part of vol. I, which is in press, will contain Celestial Mechanics; Astronomical Physics; Practical Astronomy; Descriptive Astronomy; Systems. The second volume (already published) contained the bibliography of Memoirs and Notices; the third volume will be devoted to Observations.

V. Miscellaneous Scientific Intelligence.

1. *National Academy of Sciences.*—Papers entered to be read at the April meeting, 1890.

H. C. Wood: Effects of the inhalation of nitrogen, nitrous oxide, oxygen, and carbonic acid upon the circulation: with special reference to the nitrous oxides, anæsthesia and asphyxia.

A. A. Michelson: Application of interference methods to astronomical measurements.

S. H. Scudder: Physiognomy of American Tertiary Hemiptera.

D. P. Todd: Totality of the eclipse of 1889, December 22.

W. K. Brooks: The budding of Salpa considered in relation to the question of the inheritance of acquired characters.

G. Brown Goode and Tarleton H. Bean: Recent advances toward a knowledge of the fishes of the great oceanic depths.

S. C. Chandler: A system of classification of variable stars.

H. A. Rowland: On the spectrum of metals.

S. P. Langley: On the cheapest light.

R. Pumpelly: Relation of secular disintegration to certain crystalline and transitional schists; Structure of the Green Mountains.

T. Gill: The interrelationships of the Ichthyopsida; the Notacanthoid Fishes as representatives of a peculiar order; the Halosauroid Fishes typical of a special order.

Ira Remsen: Researches on the double halides; researches on the sulphinides.

2. *Great depth in the South Pacific Ocean.*—The bathymetric map published in the writer's work on Volcanoes, registers the depth of 4428 fathoms just south of the Friendly Islands. A bulletin from the Hydrographic Department of the Admiralty dated January, 1890, contains among the soundings of H. M. S. Egeria in 1889, one of 4530 fathoms to the southeast of that of 4428 fathoms, which is thus far the deepest found in the South Pacific. The records are as follows:

		Fathoms.	Temp. at bottom.	
Lat. 19° 31′ S.	173° 40′ W.	2235	34·6	volcanic mud.
19 16	173 38	1795	35·0	Globig. ooze.
18 24	173 02	2525	34·5	chocolate clay; Radiolarian ooze, pumice.
17 56¾	172 42½	3092	34·5	chocolate clay.
17 04	172 14½	4530	wire parted.	

Between the Phœnix and Union Groups, the following soundings were obtained:

Lat. 5° 21′ S.	171° 38¼′ W.	3312 fath.	Bottom temp.	34·5
5 58	171 23¾	3100	"	34·5
6 45	171 17¼	2956	"	34·5
7 52	171 01½	2766	"	34·0
8 30¼	171 07½	2518	"	34·5
10 24½	171 20¼	2680	"	33·5

The first of the above soundings—nearly 20,000 feet—was obtained about 60 miles southwest of Sydney Island; and the last about half way between Fakaafo and Swain's Island.

Pteropod ooze was found in a number of soundings between the Friendly Islands and the Feejees, or near 179° W. and 20° to 21° S., at depths of 300 to 700 fathoms. J. D. D.

3. *Transactions of the Kansas Academy of Science*, 1887–88, vol. xi, 130 pp. 8vo.—This volume contains geological papers as follows: Robert Hay, on the horizon of the Dakota Lignite of Middle Kansas; E. N. S. Bailey, on the newly-discovered salt beds in Ellsworth Co., Kansas; E. Jameson, Geology of the Leavenworth Prospect Well; R. Hay, The Triassic Rocks of Kansas; Prof. F. H. Snow, on reported (not actual) Nickel Mines in Logan Co.; E. N. S. Bailey, Composition of Kansas Coals. The beds of rock salt reported on by Mr. Bailey occur at a depth of 730 feet in two layers, 50 and 90 feet in thickness, with 5 feet of gray slate intervening. An analysis proves it to contain 95 p. c. of pure salt. A similar bed has been struck at Hutchinson and brines are abundant from many borings.

4. *Loubat Prize of the Academy "Des Inscriptions et Belles-Lettres" of the Institut of France.*—This prize is established on a gift to the Academy by Mr. Loubat, of the New York Historical Society. The foundation affords an annual income of 1,000 francs for a prize of 3,000 francs, to be given triennially, for the best published work on the history, geography, archæology, ethnography, linguistics, numismatics, of North America. The extreme limit of time fixed by the Academy for the matters treated in the works submitted to the council is the date of 1776. The prize will be given first in 1892. Works published in Latin, French, English, Spanish and Italian after July, 1889, will be accepted. Two copies must be sent to the Secretāry of the Institute before the 31st of December, 1891. Two other copies must be contributed by the "laureate" to the Academy under whose auspices the work is made a success, one to Columbia College, New York, and one to the Historical Society of the same city.

5. *Essays of an Americanist;* by Daniel G. Brinton. 490 pp. 8vo. Philadelphia, 1890. (Porter & Coates.)—These essays, based on Archæological American history have the headings: 1. Ethnologic and Archæologic; 2. Mythology and Folk lore; 3. Graphic Systems and Literature; 4. Linguistic. The discussions of the learned author extend to the questions of the origin of language, and the origin of the American people and their mythology.

Catalogue of Fossil Reptilia and Amphibia in the British Museum. Part III, containing the order Chelonia; by R. Lydekker. 239 pp. 8vo. London, 1889.

Index to the Reports of the Chief of Engineers, U. S. A., 1880–1887. 622 pp.

The topography of Florida by N. S. Shaler, Bull. Mus. Comp. Zool., Cambridge, vol. xvi. No. 7. 1890.

Studies on Lepidosteus, by E. L. Mark; 128 pp. 8vo, with nine fine plates. Ibid., vol. xix, No. 1, 1890.

History of Niagara River, by G. K. Gilbert. 24 pp. 8vo. Ann. Rep. Comm. State Reserv. Niagara for 1889.

Physical History of the Boston Basin, by W. O. Crosby. Boston, 1889.

Geology of the Lassen Peak District; by J. S. Diller. 8th Ann. Rep. Director U. S. Geol. Survey. 32 pp. large 8vo. 1889.

Fossil Butterflies of Florissant; by S. H. Scudder, ibid. 32 pp. 8vo. 1889.—Mr. Scudder here describes and figures several new species, making the number from Florissant seven, which is nearly half of all the fossil species known.

Annals of the Astronomical Observatory of Harvard College, Edward C. Pickering, Director, vol. xxii: Meteorological Observations made on the summit of Pike's Peak (the height 14,434 feet), Colorado, Jan., 1874, to Jan., 1888, under the direction of the Chief Signal Officer, U. S. A., 476 pp. 4to.

Memoirs of the National Academy of Sciences.—Vol. iv; Part 2, just issued contains Contributions to Meteorology by E. Loomis (pp. 7–79); on the determination of Elliptic Orbits from three observations, by J. Willard Gibbs; the temperature of the moon, by S. P. Langley; the Lucayan Indians, by W. K. Brooks.

Bulletin of the American Museum of Natural History, Vol. ii, Nos. 3, 4, contains several papers on new or described mammals of America, by F. M. Chapman; Birds and Mammals, by J. A. Allen; Mammals of New Mexico, by E. A. Mearns.

Richard Owen.—Professor Richard Owen died suddenly, at New Harmony, Indiana, on the 31st of March. He was born in Lanarkshire, Scotland in 1810 and was nearly three years younger than his brother, David Dale Owen, who died about 30 years since. With his father and brother, he came to New Harmony in 1828. He served under General Zachary Taylor, as captain in the Mexican war, during the years 1847–48. In 1849 he joined his brother in the geological survey of Minnesota, and also became Professor of the Natural Sciences at Nashville; and while there, in 1857, published "A Key to the Geology of the Globe." In 1859, he was associated with his brother in the survey of Indiana, the report on which by him, appeared in 1862, after the death of his brother, and also after his having joined in the Civil War. During the year 1861, he was made Lieutenant Colonel of the 15th Indiana Volunteers, and in the autumn of that year colonel of the 60th regiment. In November of 1865 he resigned his commission as colonel at New Iberia, Louisiana (as stated in volume xlii of this Journal, 1866), and having heard of the rock salt deposit of La Petite Anse, 12 miles distant, went and investigated it, and made the first report on it to the Academy of Sciences at St. Louis. In 1865, he became Professor of the Natural Sciences in the Western Military Institute of Kentucky (afterward, changed to the University of Nashville), and held the position until the autumn of 1879. Professor Owen also devoted himself in later years to meteorology.

Professor Owen's Key to the Geology of the Globe, of 1857, exhibits the man in his science, which while practical, tended strongly toward the speculative, and also in his relations to young students, who, from his deep interest in them, drew out some pages of advice on temperance and other virtues.

APPENDIX.

ART. LI.—*Distinctive Characters of the order Hallopoda;* by O. C MARSH.

IN 1877, the writer described a small reptile from the Jurassic of Colorado, and referred it to the *Dinosauria.** On further investigation, it was found to be distinct from all the known members of that group, and in 1881, it was made the type of a new sub-order, the *Hallopoda.*† One of the most distinctive characters, which separated it widely from all known Dinosaurs, was seen in the tarsus, which had the calcaneum much produced backward. This feature, in connection with the greatly elongated metatarsals, suggested the generic name *Hallopus*, or leaping foot.

The general structure of the pelvis, especially of the ilium and pubis, as well as the proportions of the entire hind limb, suggested an affinity with *Compsognathus*, from the Jurassic of Bavaria, and the writer, in his classification of the Dinosaurs, in 1882, placed the *Hallopoda* next to the sub-order *Compsognatha*, which belongs in the great group of carnivorous Dinosaurs, the *Theropoda.*‡

Quite recently, the writer has reëxamined the type specimen, and had various parts of it uncovered, so far as the hard matrix of red sandstone would permit. This has brought to light other portions of the skeleton, so that now many of the more important characters of the order can be determined with certainty.

In its present condition, the specimen shows both the fore and hind limbs in good preservation, portions of the scapular arch, and apparently the entire pelvis, and sacrum, various vertebræ, ribs, and other parts of the skeleton. It is at present doubtful if any portions of the skull are sufficiently well preserved for determination.

* This Journal, vol. xiv, p. 255, September, 1877.
† Ibid, vol. xxi, pp. 422, 423, May, 1881.
‡ Ibid., vol. xxiii, p. 85, January, 1882.

In size, the animal was about as large as a rabbit, but the fore limbs were proportionately much smaller. As the present specimen is the only one known, it is important to place on record its distinctive characters.

The scapula is of moderate length, and its upper portion broad and thin. The humerus is slender, with a strong radial crest. The shaft is very hollow, with thin walls, and the cavity extends almost to the distal end. The latter is but little expanded transversely. The radius and ulna are short, and were closely applied to each other. There were but four digits in the manus, the first being short and stout, and the others slender.

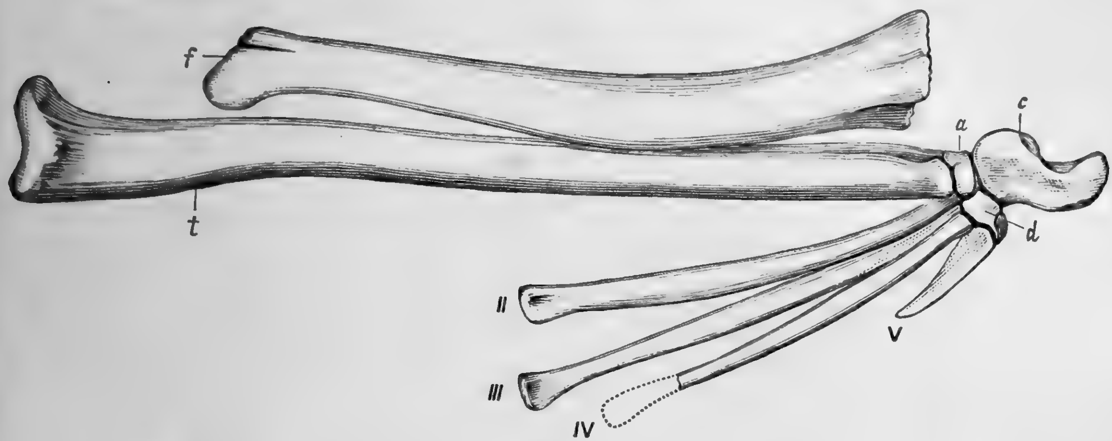
All three pelvic bones aided in forming the acetabulum, as in typical Dinosaurs. The ilia are of the carnivorous type, and resemble in form those of *Megalosaurus*. The pubes are rod-like, and projected downward and forward. The distal ends are closely applied to each other, but not materially expanded, and in the present specimen are not coössified with each other. The ischia projected downward and backward, and their distal extremities are expanded, somewhat as in the *Crocodilia*.

The femur is comparatively short, with the shaft curved and very hollow. The tibia is nearly straight, much longer than the femur, and its shaft equally hollow. The fibula was slender and complete, but tapered much from above downward. Its position was not in front of the tibia below, as in all known Dinosaurs, but its lower extremity was outside, and apparently somewhat behind, the tibia.

The astragalus is large, and covered the entire end of the tibia, but was not coössified with it. The calcaneum is compressed transversely, and much produced backward. It was closely applied to the outside of the astragalus, and although agreeing in general form with that of a crocodile, strongly resembles the corresponding bone in some mammals. The tarsal joint was below the astragalus and calcaneum. There appears to be but a single bone in the second tarsal row, although this may be composed of two or more elements.

There were but three functional digits in the hind foot, and their metatarsals are greatly elongated. The first digit was entirely wanting, and the fifth is represented only by a remnant of the metatarsal. The posterior limbs, as a whole, were especially adapted for leaping, and are more slender than in almost any other known reptile.

The main characters of the posterior limbs are shown in the figure below, which represents the bones of the left leg and foot, natural size, in the position in which they lay when uncovered. All the bones figured are still firmly embedded in the matrix.



Left leg and foot of *Hallopus victor*, Marsh; natural size; side view. *a*, astragalus; *c*, calcaneum; *d*, tarsal; *f*, femur; *t*, tibia; II, second metatarsal; V, remnant of fifth metatarsal.

There are but two vertebræ in the sacrum. The other vertebræ preserved have their articular faces bi-concave. The chevrons are slender and very elongate.

Taken together, the known characters of *Hallopus* indicate Dinosaurian affinities rather than those of any other group of reptiles, and if the *Dinosauria* are considered a sub-class, the *Hallopoda* at present may be regarded as an order of Dinosaurs standing more apart from typical forms than any other.

The characters which now indicate the position of the *Hallopoda* among the *Reptilia*, living and extinct, are given below. The discovery of more perfect specimens, however, especially of the skull, must be awaited before their nearer affinities can be determined.

DINOSAURIA ?

Order HALLOPODA (Leaping Foot). Carnivorous.

Feet digitigrade, unguiculate. Fore limbs very small, with four digits in manus. Hind limbs very long, with three digits in pes, and metatarsals greatly elongated. Calcaneum much produced backward. Vertebræ and limb bones hollow. Two vertebræ in sacrum. Acetabulum formed by ilium, pubis, and ischium. Pubes rod-like, projecting downward, but not coössified distally. No post-pubis. Ischia with distal ends expanded, meeting below on median line.

New Haven, Conn., April 21st, 1890.

ART. LII.—*Additional Characters of the Ceratopsidæ, with notice of New Cretaceous Dinosaurs;* by O. C. MARSH. (With Plates V–VII.)

THE gigantic horned Dinosaurs from the Laramie, which have already been described by the writer, in this Journal,* are still under investigation, and many new points in their structure have recently been brought to light. Some of these are here placed on record for the first time, and taken in connection with those previously made known by the writer, indicate that the group is a very distinct one, worthy to be called a sub-order, which may be termed the *Ceratopsia.*

Some of the main characters of this group are shown in the specimens figured in the accompanying plates, and others will be fully represented in the illustrations of the memoir now in preparation.

The new forms described make it still more evident that the Cretaceous Dinosaurs, of which so little has hitherto been known, are quite as remarkable as their allies from the Jurassic.

Skull of Triceratops.

In addition to the armature of the skull of *Triceratops*, already described, another ossification has been found attached to the lower extremity of the jugal bone. This is a separate element, like the epoccipital bones, but in very old animals, it is coössified with the jugal, on which it rests. The external surface is rugose, indicating that it was covered with horn. It formed an anterior extension of the lateral series of ossifications on the squamosal, and served to protect the side of the head. This element may be called the epijugal bone. Its form and position are shown in Plate V, fig. 1, *d*.

The pterygoid bones and their position have already been described by the writer. The palatine bones are much smaller than the pterygoids. They are vertical, curved plates, outside, and in front of the pterygoids, and uniting firmly with the maxillaries. The vomers join the pterygoids in front, where they appear as thin bones, closely applied to each other.

* This Journal, vol. xxxvi, p. 477, December, 1888; vol. xxxvii, p. 334, April, 1889; vol. xxxviii, p. 173, August, 1889, p. 501, December, 1889; and vol. xxxix, p. 81, January, 1890.

The transverse bones give a weak support to the maxillaries, which are strengthened by close union with the pterygoids. They meet the pterygoids behind, and the palatines in front.

The Brain.

The brain of *Triceratops* appears to have been smaller in proportion to the entire skull, than in any known vertebrate. Its position and relative size are shown in Plate V, fig. 1, *f.* A side view of the brain-cast of another specimen is shown in Plate V, fig. 2, one-half natural size.

The position of the brain in the skull does not correspond to the axis of the latter, the front being elevated at an angle of about thirty degrees, or somewhat more than is indicated in Plate V, fig. 2.

The brain-case is well ossified in front, and in old animals, there is a strong septum separating the olfactory lobes.

Rostral Bone.

This bone, which has already been described by the writer, is well shown in Plate V, figs. 3, 4 and 5. Although firmly coössified with the premaxillaries in this specimen, the suture uniting them is quite distinct. In this species, the rostral bone is very large, and unusually sharp in front. The pre-dentary bone that meets it below is also very sharp, with corresponding massive dimensions.

Nasal Horn-core.

This protuberance is a separate ossification, and is free in young animals. It varies much in shape and position, in different species. In *Triceratops prorsus*, it is directed nearly forward, as shown in Plate V, figs. 3 and 4. In adult animals, it unites with the nasals, and slightly with the premaxillaries, and in old animals, the suture is entirely obliterated, as in the present specimen.

Teeth of Triceratops.

The teeth of *Triceratops* and its near allies are very remarkable in having two distinct roots. This is true of both the upper and lower series. These roots are placed transversely in the jaw, and there is a separate cavity, more or less distinct, for each of them. One of these teeth from the upper jaw is shown in Plate VI, figs. 1–4.

The teeth form a single series only in each jaw. The upper and lower teeth are similar, but the grinding face is reversed, being on the inner side of the upper series, and on the outer side of the lower series. The sculptured surface in each series is on the opposite side from that in use.

The teeth in this family are entirely confined to the maxillary and dentary bones. The rostral bone, the premaxillaries, and the pre-dentary, are entirely edentulous.

Cervical Vertebræ.

The atlas and axis of *Triceratops* are coössified with each other, and at least one other vertebra is firmly united with them. These form a solid mass, well adapted to support the enormous head.

The cup for the occipital condyle is nearly round, and very deep, as shown in Plate VI, fig. 6, *a*. In fig. 5, the same specimen is shown, seen from the side, with the fourth vertebra in position, but free. In this specimen, the rib of the second vertebra is coössified with it. On the fourth vertebra, the rib had a free articulation.

Scapular Arch and Limbs.

The scapula is massive, especially below. The shaft is narrow, sigmoid above, with a thin edge in front, and very thick posterior margin.

The humerus is large and robust, and similar in form to that of *Stegosaurus*. It is nearly as long as the femur in one individual, proving that the animal walked on all four feet. The radius and ulna are comparatively short and stout, and the latter has a very large olecranon process. The digits were terminated by broad hoof-like phalanges, one of which is shown on Plate VI, figures 7–9.

The femur is short, with the great trochanter well developed. The shaft is comparatively slender, and the distal end much expanded. The tibia is of moderate length, and resembles that of *Stegosaurus*. In one individual, at least, the astragalus is firmly coössified with the distal end of the tibia, as in *Stegosaurus*. The limb bones and other parts of the skeleton are nearly or quite solid.

The Pelvis.

The pelvis in this group is very characteristic, and the three bones, ilium, ischium, and pubis, all take a prominent part in forming the acetabulum. The relative size and position of these are shown in Plate VII, fig. 1, which represents the pelvic elements as nearly in the same plane as their form will allow, while retaining essentially their relative position in life.

The ilium is much elongated, and differs widely from that in any of the known groups of the *Dinosauria*. The portion in front of the acetabulum forms a broad, horizontal plate, which is continued backward over the acetabulum, and narrowed in the elongated, posterior extension. Seen from above, the ilium, as a whole, appears as a nearly horizontal, sigmoid plate. From the outside, as shown in the figure, the edge of this broad plate is seen.

The protuberance for the support of the pubis is comparatively small, and elongated. The face for the ischium is much larger, and but little produced. The acetabular face of the ilium is quite narrow.

The pubis is massive, much compressed transversely, with its distal end widely expanded, as shown in the figure. There is no post-pubis. The pubis itself projects forward, outward, and downward. Its union with the ilium is not a strong one, and is similar to that seen in the pubis of *Stegosaurus*, as represented in the diagram on Plate VII, fig. 2.

The ischium is smaller than the pubis, but more elongate. Its shaft is much curved downward and inward, and in this respect, it resembles somewhat the corresponding part of the pubis of the ostrich. There is no indication that the two ischia met closely at their distal ends, and they were probably united only by cartilage.

A comparison of this pelvis with that of *Stegosaurus* shows some points of resemblance, but a wide difference in each of the elements. The pubis corresponds very closely, in its essential features, to the pre-pubis of *Stegosaurus*, but the post-pubis is entirely wanting in the specimen figured.

The characters which separate the *Ceratopsia* from the other known orders of the *Dinosauria* may be briefly stated, as follows:

(1) The skull surmounted by massive horn-cores.
(2) A rostral bone forming a sharp, cutting beak.
(3) The teeth with two distinct roots.
(4) The anterior cervical vertebræ coössified with each other.
(5) The pubis projecting in front, and no post-pubis.

There are various other characters, more or less distinctive, but not of ordinal importance.

For the discovery of the specimens here described, belonging to this order, science is mainly indebted to the writer's able assistant, J. B. Hatcher, whose genius has done so much to bring to light the rare fossil vertebrates of the West.

New Cretaceous Dinosaurs.

Triceratops sulcatus, sp. nov.

One of the largest skulls of *Triceratops* secured during the past season was not in good preservation, although nearly the whole was recovered, and with it various vertebræ and other portions of the skeleton. The animal was fully adult, as shown by the ossification of the epoccipital and epijugal bones with the portions of the skull on which they rest. The epijugal bones are especially prominent and rugose, and the sutures uniting them with the jugals are nearly obliterated.

The most distinctive character of the skull is seen in the horn-cores of the frontal region, which are very large and elongate. On the posterior surface of the upper half of each horn-core, there is a deep groove, which has suggested the specific name. The horn-cores are narrow in front, and in the upper portion become distinctly ridged.

The antero-posterior diameter of the horn-cores at the base is about nine inches, and above, where the groove begins, about four and a half inches.

The caudal vertebræ in this species are unusually short, and the median caudals have a deep longitudinal groove on the bottom of the centra.

This type specimen was found in the Ceratops beds, in Wyoming, by Mr. J. B. Hatcher.

Trachodon longiceps, sp. nov.

In the same horizon with the *Ceratopsidæ*, remains of other gigantic Dinosaurs are found, but as yet only detached portions of the skull and skeleton have been secured. One of the largest of these specimens is a right dentary bone, nearly perfect, which surpasses in size the corresponding part of any of the *Ceratopsidæ* hitherto found. This dentary bone is fairly well preserved, and now measures over thirty-eight inches in length. When complete, it must have been fully three and one-half feet long. The front part, extending back eighteen inches, is edentulous. The alveolar portion is of equal length, and the border shows depressions for fifty-one teeth in a continuous series. These teeth had only a single root, and in general form, resemble those of *Hadrosaurus*. On the outer side of this dentary bone, there is a strong, rounded ridge, extending from the base of the coronoid process to the front, as now preserved. The dentary bone, as a whole, is slender, quite unlike any hitherto described, and represents a well-marked species.

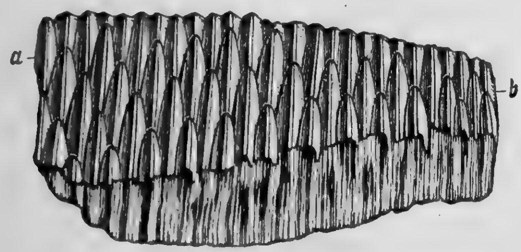
The type specimen of the present species was found by Mr. J. B. Hatcher, in the Laramie of Wyoming.

Hadrosaurus breviceps.

Additional remains of the present species, or one nearly allied to it, have been secured since the description of the type specimen.* The latter has now been completely removed from the matrix, and on comparison with more perfect material proves to be a portion of the right dentary bone. The remarkable character of the teeth is well shown in the cuts below, figures 1 and 2.

There were at least five distinct series of teeth in place at once, but only two or three rows were in use at the same time.

1.



2.

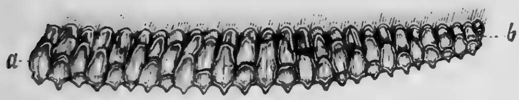


FIGURE 1.—Portion of right dentary of *Hadrosaurus breviceps*, Marsh; side view; one-fourth natural size.
FIGURE 2.—The same; seen from above. *a*, anterior; *b*, posterior.

Claosaurus agilis, gen. nov.

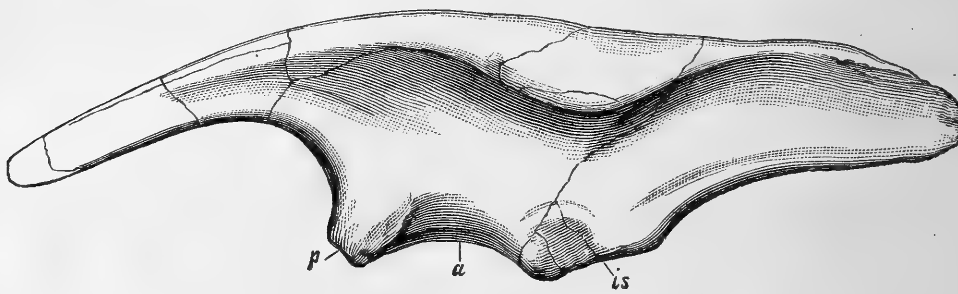
The small dinosaur described by the writer, in 1872, as *Hadrosaurus agilis*,† proves on investigation to represent a distinct genus, which may be called *Claosaurus.* The remains of this reptile were found by the writer, in the Pteranodon beds of the Cretaceous, near the Smoky Hill River in western Kansas. After the species was described, the writer again visited the locality, and secured other portions of the skeleton, so that now the more important parts are available for comparison.

The teeth are of the *Hadrosaurus* type, but, apparently, only a single row was in use at one time. The cervical vertebræ are very short, and strongly opisthocœlian. The fore limbs were very small. There are seven vertebræ in the sacrum, firmly coössified. The caudals are longer than wide, and the tail was quite elongate.

* This Journal, vol. xxxvii, p. 335, April, 1889.
† Ibid., vol. iii, p. 301, April, 1872.

The astragalus was closely applied to the end of the tibia, but not coössified with it. The fibula is strong and complete, with both ends nearly equal in size. There were three functional digits in the pes, with their metatarsals moderately elongate. The terminal phalanges are broad, and ungulate in form.

The ilium is intermediate in form between that of *Hadrosaurus* and *Stegosaurus*, and its general characters are shown in the cut below. The portion in front of the acetabulum is very slender, and elongate. The face for the pubis is much smaller than that for the ischium.



Ilium of *Claosaurus agilis*, Marsh; side view; one-sixth natural size. *a*, acetabulum; *is*, surface for ischium; *p*, surface for pubis.

The present genus is very distinct from *Nodosaurus*, which was described by the writer from a higher horizon of the Cretaceous. The present animal had apparently no dermal armor, and was of much more slender proportions. When alive, it was probably not more than fifteen feet in length.

The American Cretaceous Dinosaurs now known represent several well-marked families, which may be arranged as follows:

Order *Theropoda*. Carnivorous.

(1) The *Dryptosauridæ*, including the large carnivorous forms, of which only imperfect specimens have been found, but sufficient to indicate that they are distinct from the *Megalosauridæ* of the European Jurassic. Limb bones hollow. Fore limbs very small. Feet digitigrade, with prehensile claws.

Order *Ornithopoda*. Herbivorous.

(2) The *Trachodontidæ*, herbivorous forms of large size, with teeth of the *Hadrosaurus* type, in many rows. Cervical vertebræ opisthocœlian. Limb bones hollow. Fore limbs small. Feet digitigrade.

(3) The *Claosauridæ.* Only a single row of teeth in use. Cervical vertebræ opisthocœlian. Limb bones solid. Fore limbs small, and feet ungulate.

(4) The *Ornithomimidæ.* Limb bones hollow. Fore limbs very small; hind limbs of avian type. Feet digitigrade, and unguiculate.

Order *Ceratopsia.* Herbivorous.

(5) The *Ceratopsidæ*, highly specialized forms fully defined above.

(6) The *Nodosauridæ.* Heavy dermal armor. Bones solid. Fore limbs large. Feet ungulate.

No *Sauropoda* are known from the American Cretaceous.

New Haven, Conn., April 22d, 1890.

EXPLANATION OF PLATES.

Plate V.

Figure 1.—Skull and brain-cast of *Triceratops flabellatus*, Marsh; seen from above; one-twentieth natural size.

c, supra-temporal fossa; *d*, epijugal bone; *e*, epoccipital bone; *f*, brain-cast; *h*, horn-core; *h′*, nasal horn-core; *n*, nasal bone; *p*, parietal; *r*, rostral bone; *s*, squamosal.

Figure 2.—Brain-cast of *Triceratops serratus*, Marsh; side view; one-half natural size.

c, cerebral hemispheres; *cb*, cerebellum; *m*, medulla; *ol*, olfactory lobe; *on*, optic nerve; *p*, pituitary body.

Figure 3.—Anterior part of skull of *Triceratops prorsus*, Marsh; side view; one-eighth natural size.

Figure 4.—Front view of same.

Figure 5.—The same; seen from below.

h′, nasal horn-core; *n*, nasal bone; *na*, narial aperture; *pm*, pre-maxillary; *r*, rostral bone.

Plate VI.

Figure 1.—Maxillary tooth of *Triceratops serratus*, Marsh; outer view; natural size.

Figure 2.—The same tooth; side view.

Figure 3.—The same tooth; inner view.

Figure 4.—The same tooth; seen from below.

Figure 5.—Anterior cervical vertebræ of *Triceratops prorsus*, Marsh; side view; one-eighth natural size.

Figure 6.—The same; front view.

a, anterior face of atlas; *d*, diapophysis; *p*, posterior face of fourth vertebra; *r*, rib; *s*, neural spine of axis; *s′*, neural spine of third vertebra; *s″*, neural spine of fourth vertebra; *z′*, posterior zygapophysis.

Figure 7.—Ungual phalanx of *Triceratops horridus*, Marsh; front view; one-fourth natural size.

Figure 8.—The same bone; side view.

Figure 9.—The same; posterior view.

Plate VII.

Figure 1.—Pelvis of *Triceratops flabellatus*, Marsh; side view; one-twelfth natural size.

Figure 2.—Pelvis of *Stegosaurus stenops*, Marsh; side view; one-tenth natural size.

a, acetabulum; *il*, ilium; *is*, ischium; *p*, pubis; *p′*, post-pubis.

CONTENTS.

VOL. XXXIX. JUNE, 1890.

Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

EDITORS

JAMES D. AND EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS JOSIAH P. COOKE, GEORGE L. GOODALE AND JOHN TROWBRIDGE, OF CAMBRIDGE.

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

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

THIRD SERIES.

VOL. XXXIX.—[WHOLE NUMBER, CXXXIX.]

No. 234.—JUNE, 1890.

WITH ONE PLATE.

NEW HAVEN, CONN.: J. D. & E. S. DANA.
1890.

TUTTLE, MOREHOUSE & TAYLOR, PRINTERS, 371 STATE STREET.

Published monthly. Six dollars per year (postage prepaid). $6.40 to foreign subscribers of countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks.

Elias Loomis

PROFESSOR OF NATURAL PHILOSOPHY AND ASTRONOMY

C.D. WALCOTT.

THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. LIII.—Professor Elias Loomis.

A Memorial Address prepared at the request of the President and Fellows of Yale College, by H. A. Newton, and delivered in Osborn Hall, April 11th, 1890.

Elias Loomis was born in the little hamlet of Willington, Conn., August 7th, 1811. His father, the Rev. Hubbell Loomis, was pastor in that country parish from 1804 to 1828. He was a man possessed of considerable scholarship, of positive convictions, and of a willingness to follow at all hazards wherever truth and duty, as he conceived them, might lead. He had studied at Union College, in the class of 1799, though apparently he did not finish the college course with his class. He is enrolled with that class in Union College, and he also received, in 1812, the honorary degree of Master of Arts from Yale College. At a later date he went to Illinois, and there was instrumental in founding the institution which afterwards became Shurtleff College.

Although the boy inherited from his father a mathematical taste, yet his love for the languages also was shown at a very early age. At an age at which many bright boys are still struggling with the reading of English, he is reported to have been reading with ease the New Testament in the original Greek. He prepared for college almost entirely under the instruction of his father. He was, for a single winter only, at the Academy at Monson, Mass. Owing in part to feeble health he was more disposed, in those early years, to keep to his books than to roam with other boys over the Willington hills. In later life he frequently said that in his early days he never had a thought of asking what subjects he was most fond of, but studied what he was told to study.

At the age of fourteen he was examined and was admitted to Yale College, but owing to feeble health he waited another year before actually entering a class. In college he appears to have been about equally proficient in all of the studies, taking a good rank as a scholar, and maintaining it through his college course. President Porter remembers well the retiring demeanor of the young student, and his concise and often monosyllabic expressions, peculiarities which he retained through life. During his Junior and Senior years he roomed with Alfred E. Perkins whose bequest was the first large endowment of the College Library. He graduated in 1830.

A few weeks before graduation he left New Haven and entered a school, Mount Hope Institute near Baltimore, to teach mathematics, and he remained there for a year and a term. One of his classmates, the late Mr. Cone of Hartford, said that Mr. Loomis had intended to spend his life in teaching, and that it surprised him when he heard that this purpose was abandoned, and that Mr Loomis had gone, in the Autumn of 1831, to the Andover Theological Seminary with the distinct expectation of becoming a preacher. This new purpose was, however, again changed when a year later he was appointed Tutor in Yale College. A vacancy in the Tutorship occurred in the May following (1833), and while not yet twenty-two years of age he returned to New Haven and entered upon the duties of the office. Here he remained for three years and one term. In the spring of 1836 he received the appointment to the chair of Mathematics and Natural Philosophy in Western Reserve College, at Hudson, Ohio. He was allowed to spend the first year in Europe. He was, therefore, during the larger part of the year 1836–7 in Paris attending the lectures of Biot, Poisson, Arago, Dulong, Pouillet and others. He did not visit Germany because of want of money. A long series of letters written by him at this time appeared in the Ohio Observer, and the contrast between England and France as he saw them, and the same places as seen by the tourist to-day is decidedly interesting.

He purchased in London and Paris apparatus for his professorship, and the outfit for a small observatory, and in the Autumn of 1837 began his labors at Hudson. Here he remained for seven years, maintaining with unflagging perseverance both his work in teaching and his scientific labors. In judging of this work at Hudson we must remember that he was not with perfect surroundings. He was without an assistant and without the counsel and encouragement of associates in his own branches of science. The financial troubles which culminated in this country in 1837 were peculiarly severe upon the young and struggling College. Money was almost unknown in business circles in Ohio, trade being almost entirely in barter. In this way principally was paid so much of the promised salary of $600 per annum as was not in arrears. In one of his letters he congratulates himself that all of his bills that were more than two years old had been paid. In another he says that there was not enough money in the college treasury to take him out of the state. When he left Hudson the College offered to pay at once the arrears of his salary by deeding to him some of its unimproved lands.

In 1844 he was offered, and he accepted, the office of Professor of Mathematics and Natural Philosophy in the University of New York. In this new position he undertook the preparation of a series of text books in the Mathematics, and for some years a large part of the time which he could spare from his regular college work was given to the preparation of these books.

When Professor Henry resigned his professorship at Princeton in order to accept the office of Secretary of the Smithsonian Institution, Professor Loomis was offered the vacant chair. He went to Princeton and remained there during one year, at the end of which he was induced to return again to his old place in the University of New York. Here he continued until 1860, when he was elected to the Professorship in Yale College made vacant by the death of Professor Olmsted. For the last twenty-nine years of his life, he here labored for the

College and for science, passing away on the 15th of August, 1889.

Let us look now in succession at the different lines of his activity during these fifty-six years,—four here in the tutorship and in Europe; seven at Hudson, Ohio; sixteen in New York City and Princeton; and twenty-nine in New Haven.

For the first year on returning from Andover to New Haven, he was tutor in Latin, although it seems that he might, had he chosen it, have been tutor of Mathematics. I believe that at the beginning his mind was not yet definitely turned toward the exact sciences. In his childhood he had taken specially to Greek. In college he was equally proficient in all of his studies. He is represented to have led his class at Andover in Hebrew, and now on entering the tutorship he chose to teach the Latin language and literature. During the second year he taught Mathematics, and the third year Natural Philosophy. His later success in scientific work was, I believe, in no small measure due to his earlier broad and thorough study of language.

I have made some inquiry in order to learn what it was that turned his attention and tastes toward science. One of his colleagues in the tutorship, the Rev. Dr. Davenport, says that he recollects very distinctly the first indication to his own mind that Tutor Loomis was turning his thoughts in this direction. The great meteoric shower of 1833 came early in the period of his tutorship, and the views of Professor Twining and Professor Olmsted about the astronomical character and origin of these interesting and mysterious bodies were a common topic of conversation among scientific men in the College, especially whenever Professor Olmsted was present. The tutors were accustomed to meet as a club from time to time in the tutors' rooms in turn, and Dr. Davenport well recollects the occasion when Tutor Loomis brought in a globe and discussed before the club the new theories about these bodies. Up to this time Tutor Loomis had seemed to him to have given his thoughts and study to language rather than to science.

In January, 1834, there were constituted in the Connecticut Academy of Arts and Sciences twelve committees representing the several departments of knowledge, and Tutor Loomis was put on the Committee on Mathematics and Natural Philosophy. These are the only signs of scientific taste or activity which I have detected earlier than the autumn of 1834, after he had been a year and a term in the tutorship. From this time on to the end of his life, he gave his time and energies to several subjects that are enough distinct one from the other to make it convenient to disregard a strictly chronological account of his labors, and consider his work in each subject by itself.

A subject of which he early undertook the investigation was *Terrestrial Magnetism.* We often use the rhetorical phrase "True as the needle to the pole," but, looked at carefully, the magnetic needle is anything but constant in direction; like the weather vane on the steeple, it is ever in motion, swinging back and forth, in motions minute and slow it is true, but still always swinging. It has fitfully irregular motions;—it has motions with a daily period;—motions with an annual period; and motions whose oscillations require centuries for completion.

The *daily* motions of the magnetic needle were those which Tutor Loomis first studied. At the beginning of the second year of his tutorship he set up by the north window of his room in North College a heavy wooden block, and on it the variation compass that belongs to the College. Here for over thirteen months, he observed the position of the needle at hourly intervals in the day time, his observations usually being for seventeen successive hours of each day.

The results of these observations, together with a special discussion of the extraordinary cases of disturbance, were published in the American Journal of Science in 1836. No similar observations of the kind made in this country had at that time been published. So far as I am aware, none made before 1834 have since been published, except ten days observations made by Professor Bache in 1832. In fact, I know of only one or two like series of hourly observations made in Europe earlier than these by Tutor Loomis. He also at this time formed the purpose of collecting all the observations of magnetic declination that had been hitherto made in the United States, and of constructing from them a magnetic chart of the country. He appealed successfully to the Connecticut

Academy of Arts and Sciences for its sympathy and aid. The work of collecting facts was so far advanced before leaving New Haven that when he had been a few months Professor at Hudson, he forwarded to the American Journal of Science a discussion of the observations thus far obtained, and with them a map of the United States, with the lines of equal deviation of the needle drawn upon it. Two years later he published additional observations and a revised edition of this map.

These were the first published magnetic charts of the United States, and though the materials for their construction were not numerous, and in many cases those obtainable were not entirely trustworthy, yet sixteen years later, when a map was made by the United States Coast Survey from later and more numerous data, Professor Bache declared that between his own new map and that of Professor Loomis, when proper allowance had been made for the secular changes, the "*agreement was remarkable.*"

The northern end of a perfectly balanced magnetic needle turns downward, and the angle it makes with the horizon is called the magnetic *dip*. This angle is an important one, and is observed with accuracy only by using an expensive instrument, and taking unusual pains in observing. Hence only a few observations of this element were found by Professor Loomis. From these, however, he ventured to put on his first magnetic map a few lines that exhibited the amount of the *dip*.

While he was in Europe he purchased a first class dipping needle, for Western Reserve College, and at Hudson and the neighborhood in term time, and at other places in vacation, he made observations with this needle. Some of these observations were made before his second magnetic chart was published, and upon this map were now given tolerably good positions of the lines of equal magnetic dip. But he continued his observations for several years, determining the dip at over seventy stations, spread over thirteen states, each determination being the mean of from 160 to over 4,000 readings. These observations were published in several successive papers in the transactions of the American Philosophical Society at Philadelphia.

Various papers on terrestrial magnetism, in continuation of his earlier investigations, appeared in 1842, in 1844, in 1847, and in 1859, but movements in Germany, England and Russia had meanwhile been inaugurated which led to the establishment by governments of a score of well equipped magnetic observatories, and this subject passed largely out of private hands.

Closely connected with terrestrial magnetism, and to be considered with it, is the *Aurora Borealis.* In the week that covered the end of August and the beginning of September, 1859, there occurred an exceedingly brilliant display of the Northern Lights. Believing that an exhaustive discussion of a single aurora promised to do more for the promotion of science than an imperfect study of an indefinite number of them, Professor Loomis undertook at once to collect and to collate accounts of this display. A large number of such accounts were secured from North America, from Europe, from Asia, and from places in the Southern Hemisphere; especially all the reports from the Smithsonian observers and correspondents, were placed in his hands by the Secretary, Professor Henry.

These observations and the discussions of them were given to the public during the following two years, in a series of nine papers in the American Journal of Science.

Few, if any, displays on record were as remarkable as was this one for brilliancy and for geographical extent. Certainly about no aurora have there been collected so many facts. The display continued for a week. The luminous region entirely encircled the North Pole of the earth. It extended on this continent on the 2d of September as far south as Cuba, and to an unknown distance to the north. In altitude the bases of the columns of light were about fifty miles above the earth's surface, and the streamers shot up at times to a height of five hundred miles. Thus over a broad belt on both continents this large region above the lower atmosphere was filled with masses of luminous material. A display similar to this, and possibly of equal brilliancy, was at the same time witnessed in the Southern Hemisphere.

The nine papers were mainly devoted to the statements of observers. Professor Loomis, however, went on to collect facts about other auroras, and to make inductions from the whole of the material thus brought together. He showed that there was good reason for believing that not only was this display represented by a corresponding one in the Southern Hemisphere, but that all remarkable displays in either hemisphere are accompanied by corresponding ones in the other.

He showed also that all the principal phenomena of electricity were developed during the auroral display of 1859; that light was developed in passing from one conductor to another, that heat in poor conductors, that the peculiar electric shock to the animal system, the excitement of magnetism in irons, the deflection of the magnetic needle, the decomposition of chemical solutions, each and all were produced during the Auroral storm, and evidently by its agency. There were also in America effects upon the telegraph that were entirely consistent with the assumption previously made by Walker for England, that currents of electricity moved from northeast to southwest across the country. From the observations of the motion of auroral beams, he showed that they also moved from north-northeast to south-southwest, there being thus a general correspondence in motion between the electrical currents and the motion of the beams.

When there is a special magnetic disturbance at any place, there is usually a similar one at all other neighboring places. But these disturbances do not occur at the several places at the same instant of time. Professor Loomis showed that in the United States they take place in succession as we go from northeast to southwest, the velocity of the wave of disturbance being over one hundred miles per minute. The waves of magnetic irregularities were thus connected with the electrical current and with the drifting motions of the streamers in the auroral display.

As incident to this discussion, he collected all available observations of auroras, and he deduced from them the annual number of auroras visible at each place of observation. These numbers, when written upon a chart of the Northern Hemisphere, showed that auroras were by no means equally distributed over the earth's surface. It was found that the region in which they occurred most frequently was a belt or zone of moderate breadth and of oval form, enclosing the North Pole of the earth, and also the North Magnetic Pole. It was therefore much farther south in the Western hemisphere than in the Eastern. Along the central line of this belt there are more than eighty auroras annually, but on going either north or south from the central line of that belt the number diminishes.

In 1870 Professor Loomis published a paper of importance relating to terrestrial magnetism, in which he showed its connection and that of the aurora with spots on the sun. That the spots on the sun had periods of maximum and minimum development had long been known. Lamont had noticed a periodicity in the magnetic diurnal variations. Sabine and Wolf and Gauthier had noticed that the two periodicities were allied. The connection of the period of solar spots with conjunction and opposition of certain planets had been shown by De La Rue and Stewart. Professor Loomis undertook an exhaustive examination of the facts that tended to confirm or refute the propositions that had been advanced. He confirmed and added to the conclusions of Messrs. De La Rue and Stewart. He also brought together such facts as were relevant to the question, and he showed that the regular diurnal variation of the magnetic needle was entirely independent of the solar spots, but that those disturbances that were excessive in amount were almost exactly proportional to the spotted surface of the sun. He also showed that great disturbances of the earth's magnetism are accompanied by unusual disturbances on the sun's surface on the very day of the storm.

Various forms of periodicity in the aurora have frequently been suggested. Professor Loomis, from all available accounts of the aurora, was able to show that while in the center of the zone of greatest auroral frequency auroras might be visible nearly every night, and hence that periodicity could not easily be shown by means of numbers of auroras recorded in such places, yet that such periodicity was distinctly traceable at places where the average number seen was about twenty or twenty-five a year. The times of maxima and minima of the solar spots were seen to correspond in a remarkable manner with the maxima and minima in the frequency of auroral displays in these middle latitudes. Also from the daily observations made by Messrs. Herrick and Bradley at New Haven during seventeen years, he concluded that auroral displays in the middle latitudes of America are generally accompanied by an unusual disturbance of the sun's surface on the very day of the aurora. The magnetism of the earth, the Aurora Borealis, and the spots on the sun, have thus all three a causal connection, and apparently that connection is closely related to the conjunctions and oppositions of certain planets.

Shortly after the publication of this memoir, Professor Lovering published his extensive catalogue of auroras. A further discussion of the periodicity of the auroras was undertaken by Professor Loomis and published in 1873. In this he made use of all the auroras recorded in Professor Lovering's catalogue. They confirmed his previous conclusions, only slight modifications being required by the new facts presented, and by their more systematic collation.

In these papers, as in most of his papers upon other subjects, Professor Loomis was ever intent upon answering the questions: What are the laws of nature? What do the phenomena teach us? To establish laws which had been already formulated by others, but which still needed confirmation, was to him equally important with the formulation and proof of laws entirely new.

Let us now turn to another important line of Professor Loomis's work,—*Astronomy.* As I have said, he was early interested in the shooting stars. In October, 1834, he read a paper before the Connecticut Academy of Arts and Sciences upon this subject, probably in substance that which was shortly afterward published in this Journal. The published paper is principally a restatement of the observations made in Germany in 1823 by Brandes in concert with his pupils for determining the paths of the stars through the atmosphere, together with methods of computation. From the results of Brandes' observations, however, he deduces an argument for the cosmic character of the shooting stars. One month after reading this paper to the Connecticut Academy he engaged in similar concerted observations with Professor Twining, who was then residing near West Point, N. Y. These were only moderately successful, but they were the first observations of the kind undertaken in America.

During the senior year of his college course there arrived at New Haven the five-inch telescope, given to the college by Mr. Sheldon Clark, constructed by Dolland. This instrument was much larger than any telescope then in the country. It was temporarily placed in the Athenæum tower, where it was mounted on castors and wheeled to the windows for use. This temporary abode it occupied, however, for over thirty years. In spite of its miserable location it was, in the decade following its instalment, a power in the development of the study of astronomy in the college. The lives and works of Barnard, and Loomis, and Mason, and Herrick, and Lyman, and Chauvenet, and Hubbard, and of other graduates of the college prove this. What rich returns for Mr. Sheldon Clark's twelve-hundred-dollar investment!

In 1835 the return of Halley's comet had been predicted, and its appearance was eagerly expected by astronomers and the public: Professor Olmsted and Tutor Loomis first in this country caught sight of the stranger, and throughout its course they noted its physical appearances. With such means as he had at command, Mr. Loomis observed the body's place, and computed from his observations the orbit.

The latitude and longitude of an observatory are constants to be early determined. These were measured by President Day for Yale College in 1811. In the summer of 1835 Tutor Loomis, with such instruments as the college possessed, a sextant and a small portable transit, made numerous observations of Polaris for latitude, and several moon culminations for longitude. From these he computed the latitude and longitude of the Athenæum tower. The longitude from Greenwich though obtained from a small number of observations, differs less than two seconds of time from our best determinations to-day.

While in Europe in 1836–37 Professor Loomis, as I have said, bought for Western Reserve College the instruments for an observatory. These were a four-inch equatorial, a transit instrument and an astronomical clock. On his return he erected, in 1837, a small observatory at Hudson, and in September, 1838, began to use the instruments. He had no assistant, and by day had a full allotment of college work. Two hundred and sixty moon culminations and sixteen occultations observed for longitude, sixty-nine culminations of Polaris for latitude, along with observations on five comets, sufficiently extended for a computation of their orbits; these attested his activity outside of his required duties. Some years later, when the corresponding European observations were made public, he prepared an elaborate discussion of these longitude observations, and published it in *Gould's Astronomical Journal.* A sixth comet was observed by him at Hudson in 1850.

It may not seem a very large output of work in six years' time to have determined the location of the Observatory, and to have observed five comets. But we must recollect that the telegraph had not then been invented, that the exact determination of the longitude of a single point in the western country had a higher value then than it can have now, and that it could be obtained only by slow and tedious methods. These were, moreover, days of small things in astronomy in this country. At Yale College we had a telescope but not an observatory. At Williamstown an observatory had been constructed, but it was used for instruction, not for original work. At Washington Lieutenant Gilliss, and at Dorchester Mr. Bond, were commissioned by the government in 1838 to observe moon culminations in correspondence with the observers in the Wilkes exploring expedition for determining their longitude. These two prospective sets of observations, both of them under government auspices and pay, were the only signs of systematic astronomical activity in the United States outside of Hudson, when in 1838 Professor Loomis began his observing there. In his Inaugural Address he asks: "Where now is our American Observatory? Where throughout this rich and powerful nation do you find a single spot where astronomical observations are regularly and systematically made? There is no such spot." When he left Hudson in 1844 the situation was not largely changed. Mr. Bond had removed his instruments and work to Cambridge. The High School Observatory at Philadelphia had been erected and Messrs. Walker and

Kendall were using its instruments. Professor Bartlett had built the observatory at West Point, and had begun to observe there. Lieutenant Gilliss after years of excellent work in the little establishment on Capitol Hill had just finished the present Naval Observatory building at Washington, Professor Mitchel had begun to build the Cincinnati Observatory, and the Georgetown Observatory building had been erected. Professor Loomis's work at Hudson should be measured by what others were doing at the time, rather than by the larger performance of to-day.

In the summer of 1844, the year in which Professor Loomis came to New York, a new method in Astronomy had its first beginnings. The telegraph line had just been built between Baltimore and Washington, and Captain Wilkes at Baltimore compared his chronometer by telegraph with one at Washington, and so determined the difference of longitude of the two places.

Professor Bache was now Superintendent of the Coast Survey, and he determined at once to use the new method for the purposes of the survey. To Mr. Sears C. Walker was committed the direction of the work, but scarcely less important were the services of Professor Loomis, who for three campaigns had charge of the end of the lines in Jersey City and New York. Their first partially successful efforts were made in 1846, but the practical difficulties were overcome and entire success was obtained by them in 1847 and 1848. In these years the differences of longitude of Washington, Philadelphia, New York and Cambridge were thus determined with an accuracy far greater than any previous similar determination whatsoever.

The next summer, that of 1849, Professor Loomis assisted in a like work to connect Hudson, Ohio, with the eastern stations. His observations of moon culminations at Hudson were thus available equally with those made at Philadelphia, Washington, Dorchester and Cambridge for determining the absolute longitudes of Atlantic stations from Greenwich. It was not until 1852 that European astronomers began to use these telegraphic methods in measuring longitudes.

In 1850 Professor Loomis published a volume on the *Recent*

Progress of Astronomy, especially in the United States. A first and a second edition were soon exhausted, and in 1856 the volume was entirely rewritten and very much enlarged. Some of the topics in these volumes were the subjects of articles communicated from time to time to the public in this Journal, *Harper's Magazine*, and other periodicals. Another important contribution to astronomy appeared in 1865, that is, his *Introduction to Practical Astronomy.* Eminent astronomers in England and America have expressed in the highest terms their praise of this book. Though it is now thirty-five years since its first appearance, and many treatises on the same subject, some elaborate and some elementary, have since been published, yet for an introduction to practical work I believe that a student will find this volume better than any other for his uses at the beginning of his course.

The increase of our knowledge in astronomy was, from first to last, an object of special interest to Professor Loomis. Before he left New York the income from his text-books enabled him to make to Yale College the generous offer of coming to New Haven and working in an observatory at his own charges, provided a suitable observatory should be constructed and equipped for him. Unfortunately, the college was not able, although it was greatly desirous of doing it, to avail itself of his generous offer. Near the same time he joined with public spirited citizens of New York in an effort to establish an astronomical observatory in or near that city, and for that purpose an act of incorporation was obtained from the New York State Legislature. After coming to New Haven, he always took the warmest interest in the plans of Mr. Winchester for the establishment of an observatory in connection with Yale University. His counsel and assistance have been instrumental, more than the public could know, in producing and preserving whatever of value has been developed in that observatory.

The science of *Meteorology* has, however, been that in which Professor Loomis has made the most important contributions to human knowledge.

Shortly after his graduation in 1830 and before he entered upon the tutorship, there appeared the first of a long series of papers by Mr. Redfield, of New York City, upon the theory of storms. In the last year of his tutorship there appeared also the first of a like remarkable series of papers on the same subject by Professor Espy of Philadelphia. Two rival theories were advocated by these two men, and these theories became the subject of no little discussion in scientific meetings, and in scientific journals, for a long period of years. Professor Loomis had, from their very inception, taken a warm interest in these discussions, and the subject of meteorology, and in particular its central problem the theory of storms, held in his thought and work the first place from that time to the day of his death.

In his visit to Europe the year before he went to Hudson, he purchased a set of meteorological instruments, and for several years in Hudson he steadily performed the naturally irksome task of making twice each day a complete set of meteorological observations. A few weeks after he entered upon his professorship in Hudson a tornado passed five miles from that place, and he went out immediately to examine the track and learn what facts he could that should bear upon the theory of the tornado. The results were valuable, but he was not altogether satisfied with them. They led him, however, to undertake the discussion of one of the large storms that covered the whole United States.

For this purpose he selected the storm which had occurred near the 20th of December, 1836. Sir John Herschel had recommended that hourly observations be taken by all meteorological observers on four term days in the year, that is, observations for thirty-six successive hours at each equinox and each solstice. This storm fell partly upon one of these term days. Professor Loomis set to work to collect all the meteorological observations made during the week of the storm that he could obtain from all parts of the United States, and from some stations in Canada. The discussion resulting therefrom was read in March, 1840, before the American Philosophical Society at Philadelphia.

Let us for a little while consider the amount of knowledge of the facts about storms in our possession in 1840, the date when this memoir was read and an abstract of it published in Philadelphia. Franklin had noted the motion of storms from southwest to northeast. He said:* "Our northeast storms in North America begin first in point of time in the southwest parts, that is to say, the air in Georgia, the farthest of our colonies to the southwest, begins to move southwesterly before the air of Carolina, which is the next colony northeastward; the air of Carolina has the same motion before the air of Virginia, which lies still more northeastward; and so on northeasterly through Pennsylvania, New York, New England, etc., quite to Newfoundland." Redfield had traced several storms along the West India Islands northwesterly until about in the latitude of 30° their course was turned quite abruptly and they swept off northeasterly along the Atlantic coast toward and even past Newfoundland. Espy found some storms moving easterly or south of east from the Mississippi to the Atlantic.

Brandes had announced as a law that the wind in storms blows inward toward a center; but his law was an induction from a small number of observations. Dove had contended for a whirling motion; Redfield advanced facts to show that the winds blew in circles anti-clockwise around a center that advanced in the direction of the prevalent winds, and with him agreed Reid, Piddington and others. Espy, agreeing with Brandes, claimed that the observations in the various storms showed a centripetal motion of the winds, toward a center if the region covered by the storm was round, and toward a central line if the storm region was longer in one direction than in another. Espy's conclusions were intimately connected with his theory that in the center of the storm there was an upward motion of the air, and that the condensation of vapor into rain furnished the energy needed for the continuation of the storm. The rival theories of Redfield and Espy were in sharp contest on several points, but the main contention was around this central question: Do the winds blow in circular whirls, or do they blow in toward a center? New York State was collecting observations from the Academies. The American Philosophical Society and the Franklin Insti-

* Letter to Alexander Small, May 12, 1760.

tute, aided by an appropriation from the State of Pennsylvania, had united in an effort to learn the facts and the true theory of storms.

Under such circumstances the thorough discussion of a single violent storm was likely to add materially to our knowledge. The treatment of this storm by Professor Loomis was probably more complete than that of any previous one, and the methods which he employed were better fitted to elicit the truth than any earlier methods. But the storm was a very large one, extending from the Gulf of Mexico to an unknown distance north, and having its center apparently to the north of all the observers. The results which he was able to secure did not sustain either of the two rival theories, but rather tended to prove some features in each of them. Professor Loomis was not himself satisfied with them, and he therefore waited for another storm that should be better fitted for examination.

In the month of February, 1842, a second tornado passed over northeastern Ohio, and Professor Loomis with one of his colleagues again started out for the examination of the track. The tornado passed over a piece of woods, and hence the positions of the prostrate trees showed clearly the motion of the wind in the passing tornado, and threw much light upon the character of this kind of storm. But the tornado was a single feature of a large storm that covered the whole country, and a second storm of great intensity was also experienced in the same month.

The discussion of these two storms was now undertaken by him. The paper giving the results of that discussion was sent to Professor Bache, and read by him at the centennial meeting of the American Philosophical Society, in May, 1843, and created, as Professor Bache wrote, a great sensation. It was at the time important for the light which it threw upon the rival contending theories of Espy and of Redfield, but it was more important by far by reason of the new method of investigation then for the first time employed.

In the paper upon the storm of 1836 Professor Loomis had made some advance upon previous methods of representing the facts about storms. But even the method he then used was entirely unfitted to give answers to the questions which meteorologists were asking. Some of those questions were stated in circulars issued by the joint committee of the American Philosophical Society and the Franklin Institute: What are the phases of the great storms of rain and snow that traverse our continent; what their shape and size; in what direction, and with what velocity do their centers move along the surface of the earth; are they round, or oblong, or irregular in shape; do they move in different directions in different seasons of the year?

The graphic representation by Professor Loomis on the map of the United States of the storm of 1836 had been a series of lines drawn joining the places where at a given hour the barometer was at its lowest point. That line would so far as the barometer was concerned mark for that hour the central line of the storm. The progress of the line from hour to hour on the map showed, quite imperfectly, how the storm had traveled. Some arrows added showed to the eye also certain facts about the movements of the air.

Professor Espy adopted and thereafter adhered to a modification of this method of representing storm phenomena, and I think meteorologists will agree with me in my opinion that Professor Espy's four Reports from 1842 to 1854 though they contained an immense accumulation of facts, were because of this radical defect of presentation almost useless to meteorological science.

In the discussion of the storms of 1842, instead of the line of minimum depression of the barometer, Professor Loomis drew on the map a series of lines of equal barometric pressure, or rather of equal deviations from the normal average pressure for each place. A series of maps representing the storm at successive intervals of twelve hours were thus constructed, upon each of which was drawn a line through all places where the barometer stood at its normal or average height. A second line was drawn through all places where the barometer stood $\frac{2}{10}$ of an inch below the normal; and other lines through points where the barometer was $\frac{4}{10}$ below, $\frac{6}{10}$ below, $\frac{8}{10}$ below, etc.; also lines were drawn through those points where the barometer stood $\frac{2}{10}$, $\frac{4}{10}$, $\frac{6}{10}$, etc. above its normal height. The deviations of the barometric pressure from the normal were thus made prominent, and all other phenomena of the storm were regarded as related to those barometric lines. A series of colors represented respectively the places where the sky was clear, where the sky was overcast, and where rain or snow was falling. A series of lines represented the places at which the temperature was at the normal, or was 10 or 20 or 30 degrees above the normal, or below the normal. Arrows of proper direction and length represented the direction and the intensity of the winds at the different stations. These successive maps for the three or four days of the storm furnished to the eye all its phenomena in a simple and most effective manner.

You have no doubt, most of you, already recognized in this description the charts, which to-day are so common, issued by the United States Signal Service, and by weather service Bureaus in other countries. The method seems so natural that it should occur to any person who has the subject of a storm under consideration. But the greatest inventions are ofttimes the simplest, and I am inclined to believe that the introduction of this single method of representing and discussing the phenomena of a storm was the greatest of the services which our colleague rendered to science. This method is at the foundation of what is sometimes called "the new meteorology," and the paper which contains its first presentation stands forth, I am convinced, as the most important paper in the history of that science. I regret that I cannot aid my memory by quoting the exact words, but I remember distinctly what seemed to me an almost despairing expression made many years ago by one who had high responsibility in the matter of meteorological work, as he looked out upon the confused mass of observations already made, and felt unable to say in what direction progress was to be expected. With this I contrast the buoyant expressions of another officer charged with like responsibility, as he showed me, one or two decades later (in 1869), charts constructed like those of Professor Loomis, and said, "I care not for the mass of observations made in the usual form. What I want is the power and the material for making such charts as these." These two expressions of Sir George Airy and of LeVerrier mark the progress and the direction of progress in meteorology developed by Professor Loomis's memoir.

What was his own judgment of the method at the time of its publication and its value in meteorology, can be seen from his words at the close of the memoir, which I beg permission to quote.

"It appears to me that if the course of investigations adopted with respect to the two storms of February, 1842, was systematically pursued we should soon have some settled principles in meteorology. If we could be furnished with two meteorological charts of the United States daily for one year, charts showing the state of the barometer, thermometer, winds, sky, etc., for every part of the country, it would settle forever the laws of storms. No false theory could stand against such an array of testimony. Such a set of maps would be worth more than all which has been hitherto done in meteorology. Moreover, the subject would be well nigh exhausted. But one year's observation would be needed. The storms of one year are probably but a repetition of those of the preceding. Instead then of the guerilla warfare which has been maintained for centuries with indifferent success, although at the expense of great self-devotion on the part of individual chiefs, is it not time to embark in a general meteorological crusade? A well arranged system of observations spread over the country, would accomplish more in one year, than observations at a few insulated posts, however accurate and complete, continued to the end of time. The United States are favorably situated for such an enterprise. Observations spread over a smaller territory would be inadequate, as they would not show the extent of any large storm. If we take a survey of the entire globe, we shall search in vain for more than one equal area which could be occupied by the same number of trusty observers. In Europe there is opportunity for a like organization, but with this incumbrance, that it must needs embrace several nations of different languages and governments. The United States then afford decidedly the most hopeful field for such an enterprise. Shall we hesitate to embark in it; or shall we grope timidly along as in former years? There are but few questions of science which can be prosecuted in this country to the same advantage as in Europe. Here is one where the advantage is in our favor. Would it not be wise to devote our main strength to the reduction of this fortress? We need observers spread over the entire country at distances from each other not more than fifty miles. This would require five or six hundred observers for the United States. About half this number of registers are now kept in one shape or another, and the number by suitable efforts might probably be doubled. Supervision is needed to introduce uniformity throughout, and to render some of the registers more complete. Is not such an enterprise worthy of the American Philosophical Society? The general government has for more than twenty years done something, and has lately manifested a disposition to do more for this object. If private zeal could be more generally enlisted, the war might soon be ended, and men would cease to ridicule the idea of our being able to predict an approaching storm."

This plan of a systematic meteorological campaign was cordially seconded by Professors Bache and Peirce. At a somewhat later date the American Academy of Sciences of Boston appointed a committee, of which Professor Loomis was chairman, to urge upon the proper authorities the execution of the plan. The American Philosophical Society of Philadelphia united its voice with that of the Academy. About this time Professor Henry was made Secretary of the Smithsonian Institution. He determined to make American meteorology one of the leading subjects of investigation to be aided by the Institution. At Professor Henry's request Professor Loomis prepared a report upon the meteorology of the United States, in which he showed what advantages society might expect from the study of the phenomena of storms; what had been done in this country toward making the necessary observations, and toward deducing from them general laws; and finally, what encouragement there was to a further prosecution of the same researches. He then presented in detail a practicable plan for securing the hoped-for advantages in their fullest extent.

This plan looked to a unifying of all the work done by existing observers, a systematic supervision, a supplementing of it by new observers at needed points, a securing of the coöperation of the British government and the Hudson's Bay Company in the regions to the north of us, and finally a thorough discussion of the observations collected. A siege of three years was contemplated. In the history of the several steps that finally led to the establishment of the United States Signal Service, this report has an important place.

The scheme laid down by Professor Loomis was in part followed out by the Institution. But the fragmentary character of the observations, the want of systematic distribution of the places of the observers, and the imperfections of the barometers, made the material collected difficult of discussion. Professor Loomis waited in hopes of some better system.

In 1854, Professor Loomis undertook a rediscussion of the storm of 1836, using the new methods introduced for treating the storms of 1842. A visit to Europe shortly after enabled him to collect a large number of observations upon a storm or series of storms that occurred in Europe about a week later than that American storm. He had long been anxious to connect, if possible, these two storms, as he said, "stepping across the Atlantic." The European and the American storms, however, not only proved to be distinct one from the other, but the discussion showed clearly that many of the laws of American storms were radically different from those of the European storms. The results of the whole discussion were published in 1859 by the Smithsonian Institution.

Upon coming to New Haven, in 1860, he commenced the collection of all the meteorological observations that had been made in New Haven and the immediate vicinity, and succeeded in finding sets which, when brought together, made up a nearly continuous record through 86 years. The results of these observations formed the subject of a memoir published by the Connecticut Academy of Arts and Sciences in 1866.

It became part of his duties in college to deliver a course of lectures upon the subject of meteorology. In preparation for these he caused to be printed in very limited numbers the outlines of a treatise upon meteorology, to be used as the basis of his series of lectures. In 1868 he developed this outline into a treatise suited to use in college classes and in private study.

This treatise, notwithstanding the rapid advances of the science during more than twenty years, is still indispensable to the student of meteorology.

The better system of observing, for which Professor Loomis had been long waiting, came when the United States Signal Service was established in 1871. The daily maps of the weather published by the Bureau were constructed essentially after the plan which Professor Loomis had, thirty years before, invented for the treatment of the storms of 1842. As soon as these maps had been been published for the two years 1872 and 1873, Professor Loomis commenced in earnest to deduce from them the lessons which they taught us respecting the nature and the phenomena of United States storms. To this investigation he gave nearly all his energies during the remaining fifteen years of his life.

For several years he employed and paid for the services of assistants whose time was given to the preparation of material for use in his studies. The aggregate cost of this assistance was of itself a very large contribution to science. Beginning in April, 1874, he presented regularly at eighteen successive meetings of the National Academy of Sciences in April and in October of each year, a paper entitled "Contributions to Meteorology." These were at first based upon the publications of the Signal Service alone, but as years went by like publications appeared in Europe that were useful for his work. These papers were published in July and January following the Academy meeting, and they regularly formed the first and leading article in eighteen successive volumes of the American Journal of Science. Gradually, one after another of his college duties were committed to others that he might give his whole strength to these investigations.

An attack of malaria interrupted the regularity of the series. His advancing years and diminishing strength warned him that the end of his investigations could not be far distant. The number of hours in which he could work each day was slowly diminishing. Five more papers followed at somewhat less regular intervals.

In 1884 he began a revision of the whole series of papers. They had been presented without much regard to systematic order in the subjects investigated, and new material had accumulated from time to time, so that a thorough, systematic revision seemed absolutely necessary.

In 1885 he presented to the Academy of Sciences the first chapter of this revision, in which he discussed the areas of low pressure—their form, their size, their motions, and the phenomena attending them. Two years later, in 1887, the second chapter of the revision appeared, in which he discussed the areas of high pressure, their form, magnitude, direction and velocity of movement, and their relation to areas of low pressure. Gradually his physical strength was failing, though his mind was as bright and clear as ever. To this work, the only work which he was now doing, he was able to give two or three hours a day. Anxiously he husbanded his strength, slowly and painfully preparing the diagrams and the tables for the third chapter upon rain areas, the phenomena of rainfall in its connection with areas of low pressure, and the varied phenomena of unusual rainfall. "I see," he said to a friend, "not the end of this subject, but where I must stop. I hope I shall have strength to finish this work, and then I shall be ready to die."

This third and finishing chapter was finally passed through the printer's hands and some advance copies distributed to correspondents abroad in the summer months of 1889. His work upon the theory of storms he felt was finished. As he paid the bill of the printer, he said to him: "When I return at the close of the vacation I expect to put into your hands for printing a new edition of the *Loomis Genealogy*." Before the close of the vacation he died.

These three chapters of his revised edition of *Contributions to Meteorology* constitute the full and ripe fruitage of his work in his favorite science. They will for a long time to come be the basis of facts by which writers in theoretical meteorology must test their formulas. They cover all the important points taken up in the twenty-three earlier memoirs,—with one important exception, the relation of mountain observations to those made on the plains below. The laws connecting these two are not yet clearly indicated; much remains to be learned about them, and they are of the utmost importance in theoretical meteorology. He felt most deeply the backward steps taken by the United States Signal Service when mountain observations and the publication of the *International Bulletin* were discontinued. "The National Academy of Sciences," he said, "ought at once to take up the subject and use all its influence to secure the restoration of these two services."

Professor Loomis at various times studied certain other questions in physics and astronomy that were more or less allied with the subjects to which he gave the principal part of his time, and he published the results of his studies. He made a series of experiments on currents of electricity generated by a plate of zinc buried in the earth. He examined the electrical phenomena in certain houses in New York; the curious phenomena of optical moving figures; the vibrations sent out from waterfalls as the water flows over certain dams; the orbits of the satellites of Uranus; the temperature of the planets; the variations of light of the stars η Argus and Algol; and the comet of 1861.

The subject of family *Genealogy* has a peculiar fascination to many minds. It would be an interesting study to determine practically by a collection of facts what are the elements in a man's character which lead him to engage in this peculiar study. Certain it is that men of most diverse disposition are led into it. I should not have thought it likely that Professor Loomis would have taken up the subject very seriously. Others have expressed to me the same thought, and he himself says that he did not think it strange that others should be surprised at his devoting so much time to this subject, for he was surprised at it himself. He became interested in the subject early in life, and that interest remained unbroken to his last days. For near forty years before his first publication he collected from time to time materials for a list of the descendants of his ancestor, Joseph Loomis, who came from Braintree, England, in the year 1638, and settled in Windsor, Connecticut, in 1639. In each of his four visits to Europe he extended his inquiries to his ancestor's earlier history in England. The materials thus collected were put in type in 1870. He published a list containing 4,340 descendants of

Joseph Loomis bearing the Loomis name. He regarded it as entirely provisional, printed to help himself in making further researches, and to excite interest in others of the name, who would thus be led to give additional information, or correction of errors.

Finding that to a limited extent only could he hope by correspondence to gain the information desired, he now undertook in his vacations to canvass the country by personal visits. He collected lists of names from every available source, from catalogues of every description, from city directories, county directories, county maps and county tax lists, and he compiled from these sources lists of all the Loomis names he could find. Arranging these names by counties he undertook to visit each family personally. In this way he made a pretty thorough canvass of every part of New England and New York State, of nearly every part of New Jersey and Pennsylvania, of the northern part of Ohio, and of some of the western cities.

After five years of these researches he published the second edition of the *Loomis Genealogy*, in which were given 8,686 names of persons that bore the Loomis name, descendants of Joseph Loomis in the male branches.

Five years later, in 1880, Professor Loomis printed in two additional volumes a provisional list of 19,000 descendants of Joseph Loomis in the female branches. Large as was this list, he did not regard it as more than a first outline of a census of the descendants of the original emigrant, and he hoped in the near future to publish an additional volume. For this he has left in manuscript many corrections and large additions that will be of use to the future Loomis Genealogist.

Am I tarrying too long upon the vacation work of Professor Loomis? If so, I plead on this occasion that among these direct descendants of Joseph Loomis there were enrolled more than 200 graduates of Yale College, and nearly 100 more of our graduates have married members of this numerous family.

Professor Loomis was doubtless more widely known as the author of mathematical text-books than as a worker in new fields in science. Shortly after coming to New York, he prepared a text-book in Algebra. The market was ready for good book of this kind, and the work prepared for it was a good one. It was followed the next year by a Geometry. This was an attempt, and if judged by its reception and sale, it was a successful attempt to combine in a school-book the rigid demonstrations of Euclid with the courses of thought in Legendre and in modern science. The task is one of peculiar difficulty, as the existence and activities of the English Society for the Improvement of Geometric Teaching now for near twenty years illustrates. Other books followed the Geometry from year to year, the whole forming a connected series from Arithmetic upward, so that the list of his works finally numbered near twenty volumes. His experience in teaching, his rare skill in language, his clear conception of what was important, and his unwearied painstaking, combined to produce text-books which met the wants of teachers. About 600,000 volumes have been sold, benefiting the schools and colleges, and bringing to the author a liberal and well merited pecuniary return.

We ought not on this academic occasion to omit to speak of the teacher. College graduates who have been under his instruction will probably retain a more positive impression of the personal traits and the character of Professor Loomis than of most of their other teachers. His crisp sentences, lucid thought, exactness of language and steadiness of requirement, more than made up for any apparent coldness and real reserve. These characteristics of his riper years were peculiar to him from the beginning of his life as a teacher. During his tutorship he was thought to be strict as a disciplinarian, and this may have unfavorably affected his influence with some members of the class of 1837, of which he was tutor. It was not so with all of them. Some of you will recall what was said by a member of that class as he came to Commencement a few years since, occupying at the time the highest office which a lawyer in the line of his profession can in this country secure:—"If I have been successful in life," said Chief Justice Waite, "I owe that success to the influence of Tutor Loomis more than to any other cause whatever."

There was in Professor Loomis so much of reserve that to many persons he seemed cold and without interest in the lives of others. But this was mainly due to appearances only. The tear would at times come unbidden to his eye. His correspondence with his classmates in the years immediately following graduation shows warm interest in all that concerned them. From Hudson he wrote often to Mr. Herrick, and complained much of isolation, but more especially of isolation from scientific companions and books.

In 1840 he married Miss Julia E. Upson, of Talmadge, Ohio, a lady about whom those who knew her have spoken to me only in terms of praise, and for whose memory Professor Loomis cherished a tender reverence. She died in 1854, leaving two sons. From this time Professor Loomis lived in apartments, surrounded by his books and devoted to his studies. His sons after passing their school and college days went to their own fields of work. During many years of his New Haven life he was unable to receive visitors in the evening. He made very few new friends, and one after another of his old ones passed away. To his work he was able to give undivided his time and his strength. His mind did not seem to require the excitement of social intercourse for its full and healthful activity. Isolated though he was there was in him no trace whatever of selfish or morbid feeling. In council his advice was always marked by his clear judgment of what was important, and at the same time what was practicable. Whatever he himself had the right to decide was promptly decided by a yes or a no. and few persons cared to question the finality of his decision. But when his colleagues, or others, had the right to decide he accepted their decision without questioning or subsequent murmur. Upon being told that his letters to Mr. Herrick had come to the College Library, and that he could, if he chose, examine them and see whether there were among them any which he would prefer not to leave in this *quasi* public place, he promptly replied: "No, I never wrote a letter which I should be ashamed to see published."

After coming to New York he had a generous income from his books, besides his salary as professor. The amount he saved from his income was carefully and prudently invested, and before his death the savings with their accumulations were a large estate, how large only he and his banker knew.

One of his college classmates told me that Mr. Loomis left college with the definitely expressed purpose that the world should be better for his living in it. The central proposition in his Inaugural Address at Hudson in 1838 was: "That it is essential to the best interests of society that there should be a certain class of men devoted exclusively to the cultivation of abstract science without any regard to its practical applications; and consequently that such men instead of being a dead weight upon society are to be ranked among the greatest benefactors of their race." He chose this for his principal work for man, and he steadily kept to the chosen work. To establish an Astronomical Observatory had been through life a cherished object. He entered into and aided heartily the plans of Mr. Winchester, both before and after Mr. Winchester asked his Trustees to transfer his magnificent endowment to the University. Professor Loomis looked forward to a large institution in the future on the observatory site. To endow this public service, after making liberal provision for his two sons, he bequeathed his estate. The income from more than $300,000 will eventually be available to continue the work of his life. With clear judgment of what was most important he limited the use of that income to the payment of salaries of persons whose time should be exclusively devoted to the making of observations for the promotion of the science of astronomy, or to the reduction of astronomical observations, and to defraying the expenses of publication. He knew that if he provided observers, other benefactors would furnish buildings, and instruments, and the costs of supervision and maintenance.

A university has an organic life, with its past and its future. The wealth of a university consists mainly in its men;—not so much in those men who are its active members now, as in those who have lived themselves into its life in the past, and have made it a home of scholarship, of truth and of devotion to duty, a place fit for the development of the nobler elements of character. The life and work of Elias Loomis form no mean portion of the wealth of Yale University.

ART. LIV.—*The Magnetic Field in the Jefferson Physical Laboratory.* Part II; by R. W. WILLSON.

IN the February number of this Journal I have given an account of some observations made upon the variations of the Horizontal Intensity in different parts of the Jefferson Physical Laboratory in 1886–7, and upon the disturbance in the magnetic field produced by the presence of iron steam pipes and other iron masses. I have recently received a copy of the dissertation of Dr. Gustav Rasch of Aix-la-Chapelle* giving the results of similar observations upon the effect of the heating apparatus in the Physical Laboratory at Würzburg and of passing railway trains, etc.

During the past summer an iron water-pipe six inches in diameter was laid for some hundreds of feet, nearly parallel with the west wall of the Jefferson Laboratory and passing it at a distance of about twenty feet. The question was raised whether this would produce any serious change in the magnetic conditions previously observed in the building, and at the request of the Director, Professor Trowbridge, I have made a re-examination of the variations of the Horizontal Intensity at the points observed in 1887. A further interest in the results lies in the fact that since the former observations were made both the stove and iron table top, to which I attributed certain disturbances, have been removed, and it may now be seen whether the disturbances have disappeared with their assumed causes. Whether there has been any change in the absolute value of H, about 0·170 C. G. S. units, I have not attempted to determine.

Rooms 12 and 17, were not included in the observations on account of the great variations caused by the proximity of the steam-pipes at A, B, C, F, near the east wall (fig. 4).

The same instrument was used and mounted upon the same stand, a small high table carrying the variometer, five feet from the floor and resting on three very easy casters. Attached to the stand at about two and a half feet from the floor is a magnetometer with mirror and scale which serves for the rapid orientation of the stand at each new station. The distance between the variometer and magnetometer is such that neither has any appreciable influence upon the readings of the other, and at no point of observation was their difference of meridian (from local disturbances, such as proximity of the magnetometer to the piers) sufficient to cause an error so great as $\frac{1}{20,000}$ in the concluded value of H.

* Magnetische Untersuchungen. Würzburg, 1888.

It will be remembered that the plane of observation was originally fixed at five feet from the floor to avoid any possible disturbance due to the brick-work of the piers. A few preliminary observations had seemed to show such an effect, amounting to about 1–1000 H, in the case of one pier, when the instrument was very near the brick-work; while observations taken at various points upon one of the piers in room 17 showed no apparent magnetic effect comparable with that due

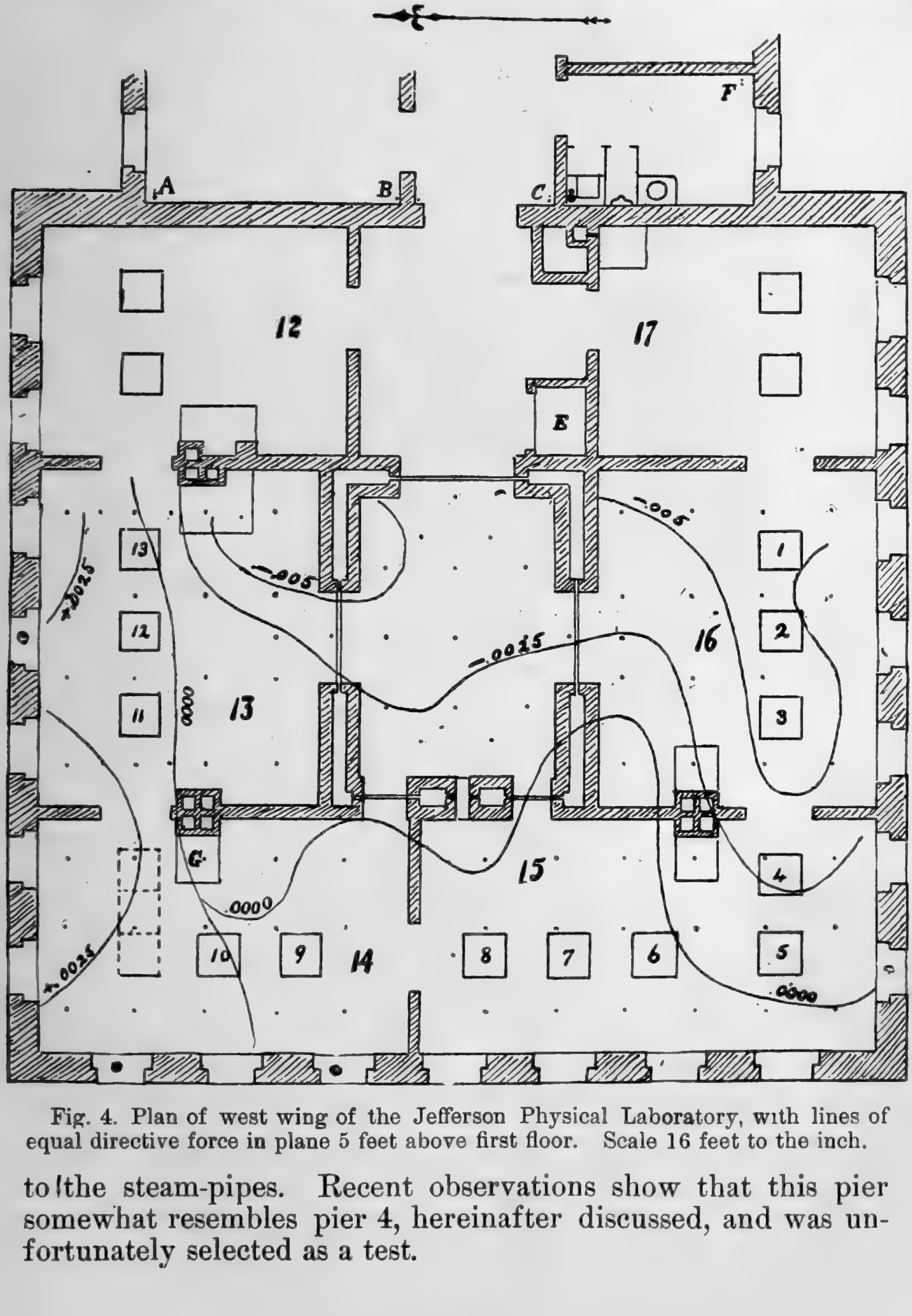


Fig. 4. Plan of west wing of the Jefferson Physical Laboratory, with lines of equal directive force in plane 5 feet above first floor. Scale 16 feet to the inch.

to the steam-pipes. Recent observations show that this pier somewhat resembles pier 4, hereinafter discussed, and was unfortunately selected as a test.

The observations upon the magnetic declination at various levels in the elevator shaft, described on page 90, were originally made in order to see if any considerable amount of free magnetism was present in the walls of the central tower. The results showed a far greater effect due to the steam-pipes than any that could be ascribed to the brick-work, and it was this which first led to a careful examination of the pipes and a just estimation of their effect upon the magnetic field. These results are here noted to explain why the very considerable

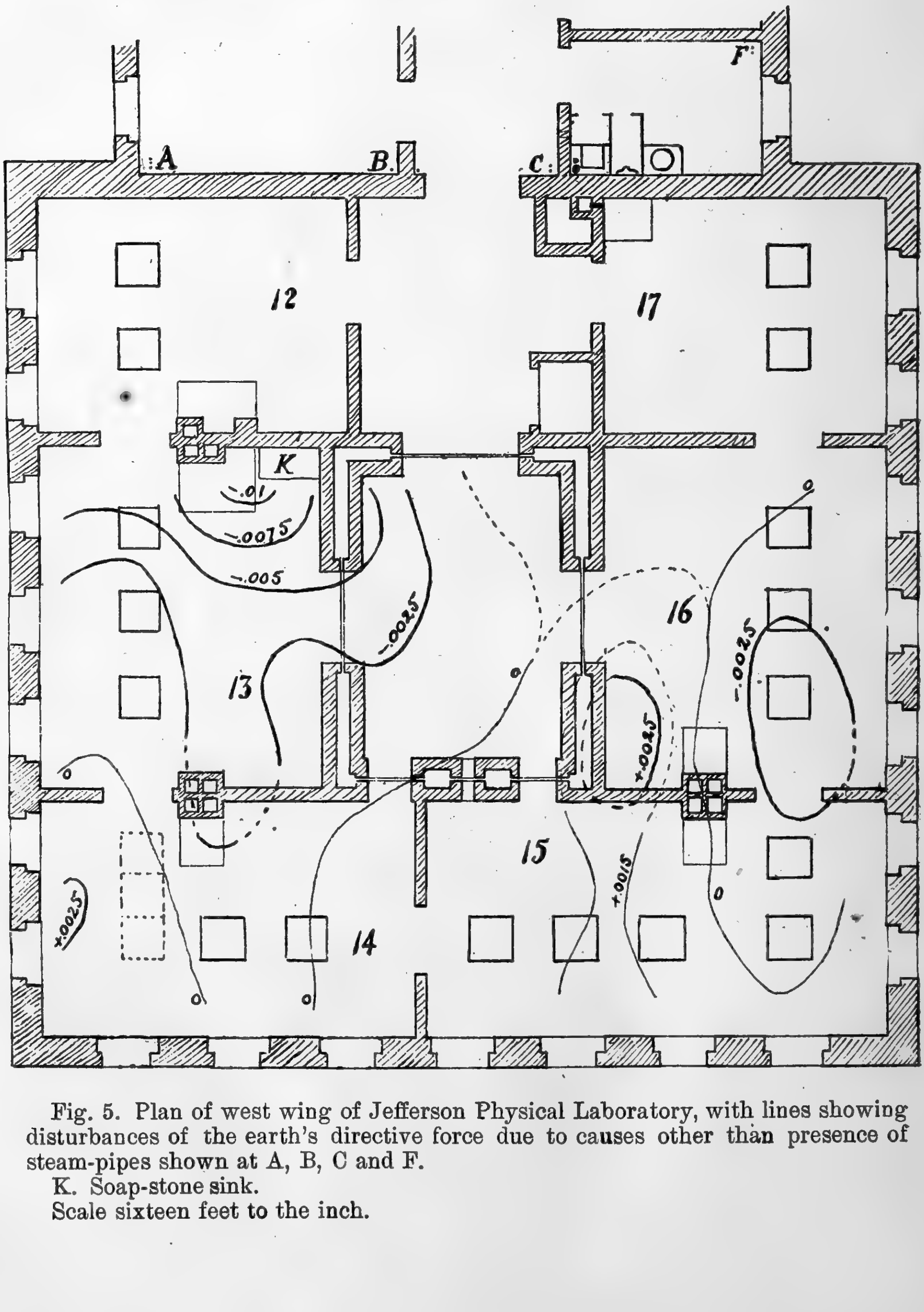


Fig. 5. Plan of west wing of Jefferson Physical Laboratory, with lines showing disturbances of the earth's directive force due to causes other than presence of steam-pipes shown at A, B, C and F.

K. Soap-stone sink.

Scale sixteen feet to the inch.

effect due to the general magnetization of the bricks, soon to be recorded, should have escaped even a very superficial examination.

The result of the general survey undertaken to determine what change in the field may have been produced by the laying of the water-pipe mentioned above is exhibited in figs. 4 and 5.

Fig. 4 gives the lines of equal horizontal intensity recently determined and is to be compared with fig. 1, p. 88. These lines connect points at which the horizontal intensity is the same, the values at points in adjacent lines differing by ·0025 H. It is evident that there is no change in the general character of the field except that due to the removal of the stove above G. This will be more evident on consulting fig. 5, which gives the results obtained by correcting the observed values for the disturbance due to the steam-pipes at A, B, C and F by the method explained on page 91 (fig. 5 may be compared with fig. 3, p. 92).

The disturbance in room 13 being unchanged although the iron table top to which it was ascribed has been removed, some other cause must be sought for this disturbance.

The observations upon which the system of lines depend were made at points distant five feet from each other and only the general features of the system can be thus determined. In order to settle definitely the cause of the disturbance in room 13, observations have recently been made at distances of one foot apart in the eastern part of the room, and the lines of equal directive force thus much more accurately drawn. As the object was simply to determine the position of the disturbing body, the plane five feet from the floor was abandoned in these observations, and the arrangement adopted which had been used in the examination of the piers, which greatly lessens the labor and increases the accuracy of observations made at points very near together. The results of this examination pointed unmistakably to a soap-stone sink, shown at K, fig. 5, as the *main* cause of the disturbance. (This sink showed a considerable free south magnetism on its upper surface, tending to decrease H at points north and above; some further account of this will be given later.)

The only disturbances remaining unaccounted for are that in room 15–16 and that in room 14; which I now believe to be almost entirely due to magnetic action of the bricks of the piers and walls of the building itself. If this is the case, the whole system of lines of figs. 4 and 5 must be looked upon as giving only the most prominent characteristics* of the field,

* Compare with fig. 10, which gives a portion of the field more in detail, but for a different plane.

since many of the points observed are so near the piers as to be unduly affected by their presence. As the magnetic effect of the mass of the building upon the Horizontal Intensity at any point is too complex to admit of estimation, I have confined myself principally to an investigation of the effect of the piers.

To facilitate these observations a board 28 feet long, and 8 inches wide was carefully smoothed and brought to a straight edge and wooden horses, put together with copper nails, were prepared of just the height of the piers; a sliding piece 15 inches long with a guide bearing upon the edge of the board, carried the variometer with its needle in a plane seven inches above the top of the piers and 3 feet 3 inches above the floor.

The long board being brought into position, supported by the piers or horses, the variation at different points could be rapidly observed without any sacrifice in point of accuracy, the instrument being slid from one point to another with very slight derangement in level and azimuth, so that the latter adjustment was made once for all while the former was very quickly accomplished. The changes of temperature are also less troublesome factors than when the observations extend over considerable periods of time. Variations of the horizontal intensity during the observations have usually been determined and corrected for by occasional observations at the same reference point.

The piers consist of rectangular columns of brickwork laid in Portland cement. They are 3 feet by 2 feet at the base, tapering to 2 feet square at the first floor, above which they rise 2 feet 4 inches, and are capped by slabs of blue stone 3 feet square and 4 inches thick. The foundations are 5 feet below the basement floor and the total height of the column is about 18 feet. As the building faces within 2½ degrees of the magnetic South, and as the sides of the piers are parallel to the walls of the building, it will be sufficiently accurate in describing their magnetic effect to speak of either as if exactly oriented.

If the brick of which the piers are made contains magnetic material we should expect to find indications of a magnetic distribution depending upon the inductive action of the earth and the form and position of the piers, independent of any permanent magnetism existing in the bricks previous to their being placed in their present places, and which, on account of its random distribution, in so large a number of bricks, would have no effect except in causing small very local disturbances easily recognizable as such.

The effect of the earth's induction upon the piers would produce, on the whole, free south magnetism on the upper surface of each pier, and owing to the length of the piers and the very considerable dip, 72 degrees,* the distribution would

Dist. from south wall.	Nov. 22.	Nov. 21.	Nov. 23.	East Edge.	West Edge.	
4	+0003	—0001	--------	+0001	0000	
4½	+0012	+0009	--------	+0005	------	
5	+0029	+0025	--------	+0011	+0014	
5½	+0034	+0029	--------	+0009	+0018	
6	+0008	+0004	--------	—0008	+0003	
6½	—0020	—0027	--------	—0025	—0024	over pier 5.
7	—0050	—0055	--------	—0032	—0032	
7½	—0066	—0067	--------	—0040	—0037	
8	—0051	—0053	--------	—0033	—0036	
8½	—0034	—0033	--------	------	------	
9	—0021	—0023	--------	—0015	—0017	
9½	—0015	—0014	--------	------	------	
10	—0010	—0009	--------	—0008	—0006	
10½	—0007	—0006	--------	------	------	
11	—0004	—0002	--------	—0003	—0009	
11½	+0001	+0002	--------	------	------	
12	+0004	+0007	--------	+0006	+0002	
12½	+0008	+0013	--------	------	------	
13	+0012	+0016	--------	+0013	+0008	
13½	+0017	+0021	--------	------	------	
14	+0022	+0024	+0020	+0012	+0012	
14½	+0014	+0018	+0013	------	------	
15	—0001	--------	0000	0000	+0001	
15½	—0005	--------	—0008	------	------	over pier 6.
16	—0001	--------	+0001	+0006	—0001	
16½	—0004	--------	—0003	------	------	
17	—0010	--------	—0010	+0001	—0005	
17½	—0009	--------	—0008	------	------	
18	—0004	--------	—0001	+0006	—0001	
18½	+0002	--------	+0007	------	------	
19	+0009	--------	+0015	+0014	+0007	
19½	+0017	--------	+0021	------	------	
20	+0022	--------	+0025	+0023	+0015	
20½	+0023	--------	+0027	------	------	
21	+0019	--------	+0023	+0011	+0009	
21½	+0004	--------	+0008	------	------	over pier 7.
22	—0008	--------	—0006	+0004	+0010	
22½	—0009	--------	—0005	------	------	
23	—0002	--------	+0002	+0009	+0007	
23½	+0005	--------	--------	------	------	
24	+0011	--------	--------	+0017	+0017	
24½	+0018	--------	--------	------	------	
25	+0024	--------	--------	+0023	+0027	
25½	+0035	--------	--------	--------	--------	
26	+0051	--------	--------	--------	--------	
26½	+0069	--------	--------	--------	--------	
27	+0060	--------	--------	--------	--------	
27½	+0021	--------	--------	--------	--------	over pier 8.
28	—0008	--------	--------	--------	--------	
28½	—0006	--------	--------	--------	--------	
29	+0014	--------	--------	--------	--------	
29½	+0030	--------	--------	--------	--------	
30	+0039	--------	--------	--------	--------	
30½	+0044	--------	--------	--------	--------	

* Erroneously given in my last paper as 60 degrees.

be nearly uniform. The result would be that at points north of the center the field would be weakened and at points south strengthened, while in a line east and west through the center of the pier the field would be undisturbed by its presence.

The preceding table shows the variations of the Horizontal Force actually observed along a horizontal line passing 7 inches above the centers and edges of the piers 5, 6, 7, 8 in room 15, fig. 4.

Column 1 gives the distance of the point of observation from the south wall. Columns 2, 3 and 4 the corresponding difference in decimal parts of H, from its value assumed as normal in those parts of the room farthest removed from the influence of the piers. Columns 5 and 6 give the corresponding values on parallel lines 14 inches east and west of the central line. Columns 3 and 4 are introduced to furnish a means of judging of the accuracy of the individual observations, each of which rests upon *a single* reading of the instrument in each of the positions, N. pole east and N. pole west.

Although the differences on different dates amount in the maximum to ·0007 H, owing to uncertainty in the diurnal variation of H, which has been assumed to be uniform during the time of observation, it will be noticed that the difference between consecutive points (upon which the important features of the disturbance depend) as observed on various dates, is the same for 32 out of 39 points, within ·0002 H, which is practical identity, since any observation may be in error in either direction by ·0001 H. In four cases the difference is ·0003 H, in two cases ·0004 H and in one case ·0005 H. This is remarkable testimony to the accuracy of the instrument when it is remembered that each determination required but little over two minutes for its completion.*

The results of column 1 are best exhibited to the eye by fig. 6, in which the abscissas represent distances from the south wall in feet while the ordinates give the corresponding differences from the normal undisturbed value of H for the whole room. The places of the piers are as indicated below.

It appears that in passing from south to north the value of H increases as we approach the pier 5 to a maximum almost exactly over the edge of the brick-work and six inches inside of the bluestone, then rapidly decreases to a minimum almost exactly over the northern edge of the brick-work, from which it increases, reaching the average value for the room at a point about half way to the next pier. Beyond this it still increases to a maximum over the edge of pier 6 and follows the same

* For a detailed account of the method of observation see the paper by F. Kohlrausch, Wied. Ann., vol. xix, p. 130. As my instrument was adjusted a difference of one division in the reading of $n_1 - n_2$ corresponds to ·00025 H.

general course for that and for each of the other piers. The curves corresponding to the values in columns 4 and 5, observed nearly over the eastern and western edges of the brick-work, show maxima and minima at the same points but of about half the values reached on the center lines, the values being very nearly the same for each edge.

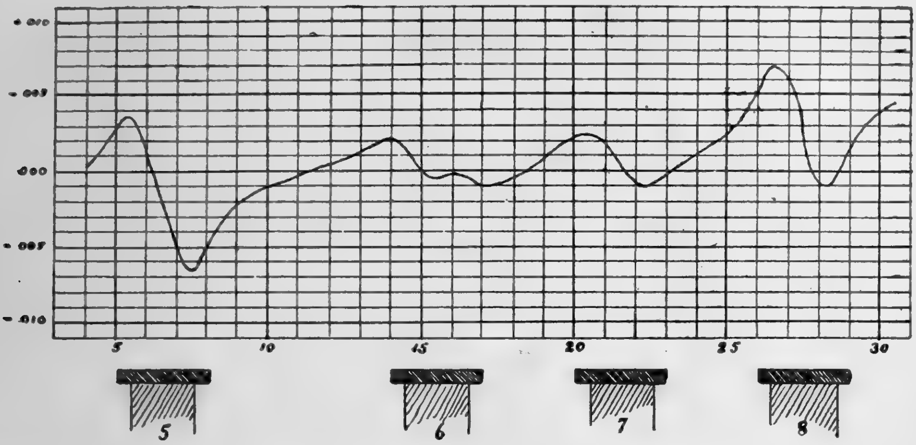


Fig. 6. Variations of the Horizontal Intensity in a line seven inches above piers.

The general form of the curve is accounted for by the assumption that free south magnetism is distributed nearly uniformly over the upper surface of each of the piers, strengthening the field on the south side and weakening it on the north as before described, while over the center the Horizontal Force has nearly its normal value.

The fact that the values of the maxima over the edges are about half those in the central line strengthens this assumption of a uniform distribution of the magnetism over the surface, since, if the pier be supposed divided by a vertical plane passed meridionally through the center, the half of the pier farthest removed contributes but little to the disturbance over the edge, while if transferred parallel to itself so that the two edges coincide, each half would be similarly situated with respect to the points observed, and the effect would be doubled and should obviously give the same value of the disturbance as that actually observed on the central line.

The double maximum observed in the case of pier 6 appears to be owing to an irregularity in the distribution of the magnetism, perhaps due to a single brick or bricks near the surface of the pier possessing permanent magnetism, not produced by the induction of the earth upon it in its present position.

Such permanent polarity has been observed in varying degree in many bricks and portions of bricks of the same manufacture. With this exception the magnetism shown by the piers is exactly what might be expected to result from the effect of the earth's nearly vertical induction upon a mass containing a relatively small amount of magnetic matter in the form of isolated particles, disseminated through a non-magnetic shaft nearly 20 feet high and of relatively small diameter.

The nearly uniform distribution of the magnetism is further confirmed by observations of the other piers, the results of which are shown in figs. 7 and 9.

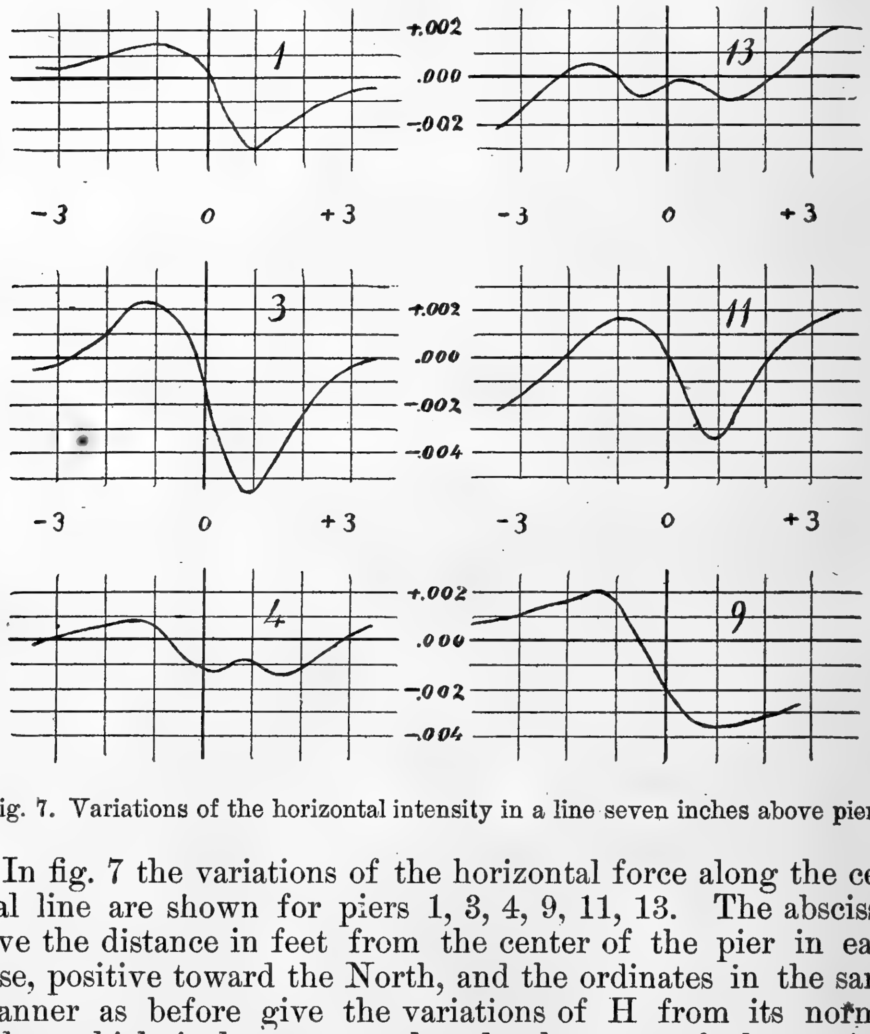


Fig. 7. Variations of the horizontal intensity in a line seven inches above piers.

In fig. 7 the variations of the horizontal force along the central line are shown for piers 1, 3, 4, 9, 11, 13. The abscissas give the distance in feet from the center of the pier in each case, positive toward the North, and the ordinates in the same manner as before give the variations of H from its normal value, which is here assumed to be the mean of observations North and South at a distance of 3 feet from the center.

Let $2l$ be the length in centimeters of the side of a square pier, σ the density per sq. cm. of the magnetism uniformly distributed over its upper surface. Then a unit pole h cm. above the pier, and in its meridian plane at a distance x_0 cm. from the axis, is urged horizontally toward the axis by a force in C. G. S. units

$$F=2\sigma \log_e \frac{(l+\sqrt{(x_0-l)^2+h^2+l^2})\ ((x_0+l)^2+h^2)}{(l+\sqrt{(x_0+l)^2+h^2+l^2})\ ((x_0-l)^2+h^2)}.$$

For our piers $l=30^{cm}$, and $h=28^{cm}$.

The value of F for different values of x_0 computed from the above expression is given in the following table:

x_0	F.	x_0	F.
0 cm	0·000 σ	30cm	2·698 σ
5	0·570 σ	35	2·833 σ
10	1·114 σ	40	2·856 σ
15	1·626 σ	45	2·796 σ
20	2·080 σ	50	2·682 σ
25	2·446 σ	60	2·390 σ

Plotting the coefficients of σ we obtain a curve very similar to that of pier 5, fig. 6, showing that the assumption of uniform distribution agrees well with the observed values.

The maximum observed value is about ·005 H=·00085 absolute units and corresponds to the computed value 2·8 σ; hence σ=·0003 and the total amount of free magnetism on the surface of the piers, 3600 sq. cm., is 1·08 C. G. S. units.

Pier 5.

Distance North of Center. (inches.)	Distance East of Center (inches).							
	−14	−10	−6	−2	+2	+6	+10	+14
+18	−0012	−0023	−0023	−0026	−0026	−0021	−0020	−0016
+14	−0018	−0029	−0033	−0038	−0037	−0032	−0031	−0019
+10	−0016	−0026	−0034	−0038	−0038	−0034	−0029	−0024
+ 6	−0012	−0022	−0028	−0026	−0028	−0024	−0021	−0013
+ 2	−0004	−0008	−0009	−0007	−0011	−0007	−0010	−0009
− 2	+0010	+0008	+0011	+0012	+0007	+0006	+0002	−0001
− 6	+0025	+0025	+0031	+0033	+0029	+0025	+0017	+0011
−10	+0038	+0042	+0049	+0052	+0051	+0045	+0037	+0022
−14	+0042	+0048	+0055	+0057	+0059	+0052	+0046	+0026
−18	+0036	+0041	+0047	+0048	+0049	+0046	+0043	+0027

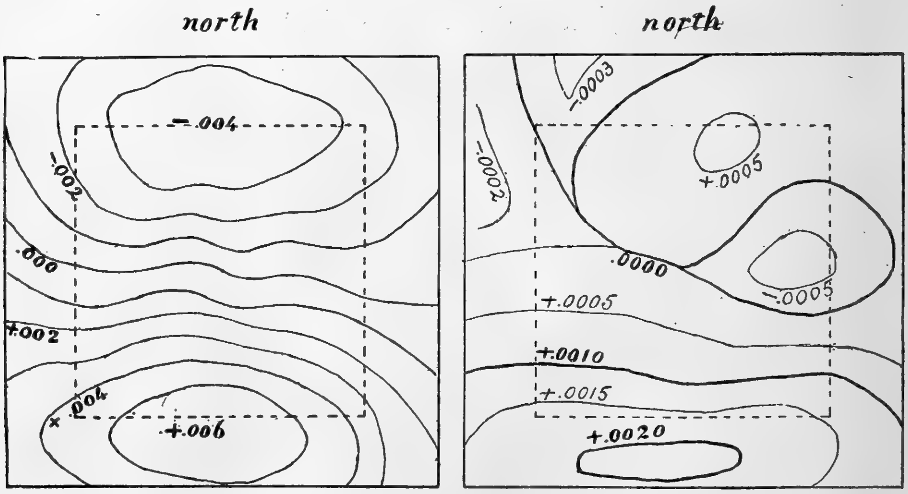
Pier 4.

Distance North of Center. (inches.)	Distance East of Center (inches).					
	−15	−9	−3	+3	+9	+15
+18	−·00005	−00040	+·00010	−·00005	+·00020	+00025
12	−·00025	−00020	+·00030	+·00065	+·00030	+00020
6	−·00025	00000	+·00040	+·00040	−·00020	+00010
0	+·00010	+00020	+·00020	−·00020	−·00090	−00020
− 6	+·00080	+00075	+·00060	+·00050	+·00050	+00040
12	+·00160	+00170	+·00160	+·00160	+·00170	+00130
18	+·00170	+00190	+·00195	+·00190	+·00155	+00140

The length of the pier being about 6 meters, this corresponds to a magnetic moment of 6500 C. G. S. units or rather more than that which may be readily given to a hard steel magnet of 1 sq. cm. section and 20 cm. long.

Piers 1, 2, 3, 5, 7, 8, 9, 11, 12, figs. 6, 7 and 9 show variations nearly as described for a typical pier; while 4 and 13 show the same irregularity as 6*. I may here note that the pier in room 17, which was superficially examined in 1887 for the purpose of detecting local influences was of this class, the variation over a large part of its surface being very small.

The nature of this deviation from this normal type is made more striking by comparison of the adjacent piers 4 and 5, the former presenting the case of least and the latter of greatest local effect of piers. The variations of H from its value at the center are given in the preceding tables, and fig. 8 shows the lines of equal horizontal force in a plane seven inches above each pier. The field above 4 although the extreme variation amounts to but ·0025 H, indicates a distribution of magnetism far from uniform. The existence near the northeast corner of free north magnetism would account for the observed variations. In the case of pier 5 the effect of the pier, though large, is quite symmetrical, indicating a very uniform distribution.



Pier 5. Pier 4.

Fig. 8. Lines of equal directive force in a plane seven inches above piers 4 and 5.

The magnitude of the disturbance is noteworthy. Above pier 5, for instance, the Horizontal Force at the two edges varies by one per cent, while a change of one tenth of one per cent is caused by passing over two inches near the center, so

* Pier No. 10 has been omitted being covered with a heavy stone. Piers in rooms 11 and 17 are not included for reasons before given.

that the position of an instrument must be determined with considerable precision to ensure even ordinary accuracy. Moreover all of the points observed are distant at least 11 inches from the nearest brick-work. It is plain then that the observations made 5 feet from the floor and 2 feet 8 inches above the brick-work of the piers are by no means unaffected by the presence of the latter.

The effect of the walls too may extend to points at some distance. The magnetism due to the earth's induction pro-

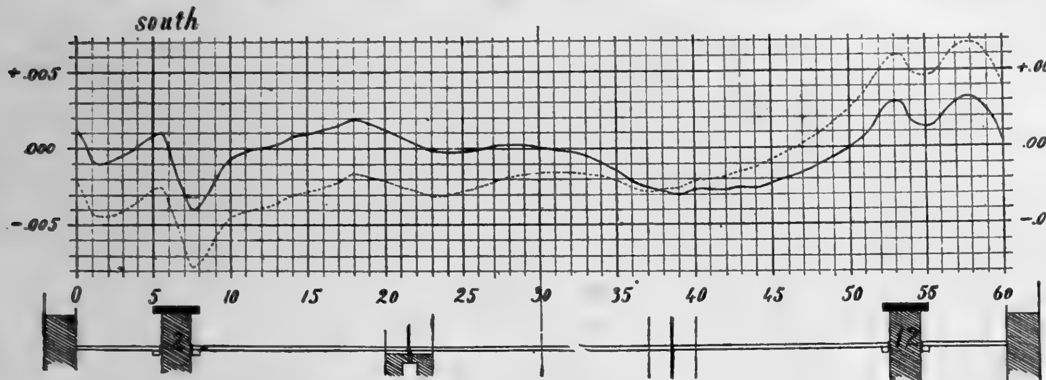


Fig. 9. Variations of the Horizontal Intensity on a line seven inches above piers 2 and 12.

duces disturbances in the neighborhood of openings in the brick-work, such as doors and windows, where free magnetism appears, and the local effect of permanent magnetism in the single bricks can be in many places detected. The first point appears in the observations represented in fig. 9 which shows the variations along a line passing above the piers 2 and 12 and through the center of the wing.

The dotted curve gives in the same manner as before the variations of H from its normal value at the center of the wing, the position of the walls, piers and door-ways being indicated as on fig. 6. The line of observation passes 11 inches above the brick-work of the piers, 12 inches above that of the window sills, and 3½ feet above the lower brick-work of the door opening in the tower wall. The door openings are 10 feet high and the instrument is therefore much nearer to the bricks below than to those above. The general increase of H toward the north shown in the dotted curve is due to the influence of the iron steam-pipes. Correcting the observed values for this effect the full line curve is obtained. Both curves show south magnetism in the vicinity of the walls and piers, the earth's induction producing free south magnetism in the lower surfaces of the window and door openings through which the line of observation passes. This results in a strengthening of the field on the south in the immediate vicinity of the openings and a weakening on the north, as in the case of the piers. (The point of maximum disturbance is

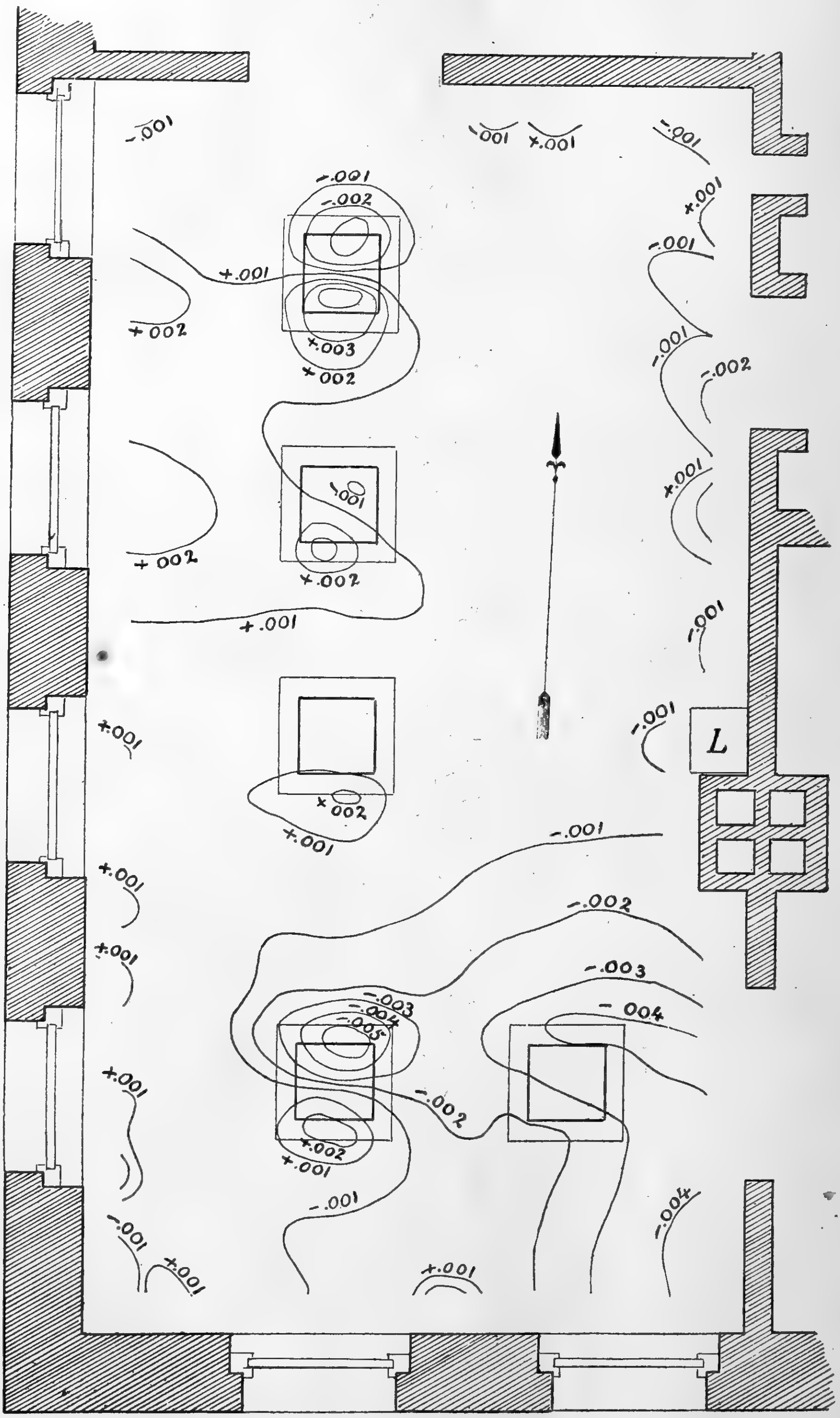


Fig. 10. Lines of equal directive force in room 15, plane seven inches above piers. Scale, six feet to the inch.

not over the edge of the brick-work as in the case of the piers, owing to the different form of the surface, and in the case of the door, to the greater distance of the plane of observation.) The absence of local disturbance in the north doorway of the tower is due to the fact that there is on that side a corresponding doorway in the basement, and the opening in the brick-work extends to the ground level.

The amount of irregular disturbance arising from nearness to walls is shown in fig. 10, which gives the lines of equal directive force in room 15 in a plane 7 inches above the piers, plotted from a very careful survey in which observations were made at points one foot apart over the whole room.

This shows the same general features as the former survey 5 feet above the floor.

This detailed observation, however, enabling a much more accurate determination of the lines brings out very clearly the connection of the piers with these disturbances.

The effect of the individual bricks is so great when the points are within 6 inches of the wall that I have only continued the lines within one foot of the bricks, although many observations were made within that limit to determine more accurately the position of the lines. It is worthy of notice that no considerable disturbance is produced by the small soapstone sink near the chimney at L.

The normal value assumed is the mean of the values observed at 96 points taken in a parallelogram 15 feet × 5 feet about the arrow, fig. 10, no point being less than three feet removed from the nearest bricks.

Within this space the deviations though less than ·001 H from the mean are plainly discriminated by the variometer, and it may be fairly said that there is no point in the room where the magnetic effects of the brick-work is not an easily measurable quantity.

It is hardly worth while to multiply observations or to treat of such points as the effect of change of temperature, since the magnetic effect of the bricks is so great. A few facts are, however, of interest. Bricks similar to those used in the Laboratory Building have been found to be in various degrees permanently magnetic, and to show the alterations in their temporary magnetism produced by change of position with respect to the earth's field, two or three specimens of brick from other sources show magnetic effects comparable with these.

Portions chipped from the piers and crushed to coarse powder delivered to a 2 oz. magnet many magnetic particles, which when examined under a microscope were seen to contain among their number octahedra of magnetite. Magnetic particles were separated in the same manner from the cement, as well as from the clay of the brick-yard where the bricks were made.

Far more striking results were obtained on examining the soap-stone sink which is connected with the disturbance in room 13, and which shows upon the upper surface and edges of its slabs free south magnetism of sufficient amount to deflect a compass needle several degrees when brought within an inch of its mass.

Sixteen grams of dust scraped with glass from the under side of the base gave 1 gram of dark *strongly* magnetic particles consisting mainly of magnetite in octahedra up to 1-2^{mm} in diameter, which were disseminated through the mass with considerable uniformity. Pencils cut from a similar slab and hung by a thread were strongly attracted by a magnet, though they received no permanent polarity. A chip of the same weighing over one third of a gram was lifted bodily by a one pound magnet with poles approaching each other within $\frac{1}{8}$ of an inch.

I am not aware that any observation has been previously made of so great a disturbance of the magnetic field from brick-work. In the magnetic observatory at Würzburg the brick for which was selected with great care, a variation of ·00025 H has been noted.* Lamont† remarks upon a difference of 2′ 18″ in declination and 0·00014 in the value of H between observations made in the open field near the observatory (Munich) and upon an "aus Backsteinen und hydraulischen Kalk, ausserdem Starke Messingtheile enthaltenden Pfeiler" in the building itself. This discrepancy he does not appear to have investigated further.

It is possible that the Cambridge brick, of which the Jefferson Laboratory is built, contains an unusual amount of magnetic oxide, but it is a fact not to be slighted by those engaged in magnetic work that bricks, without special examination, cannot be assumed to have an insignificant magnetic effect.

In fact, I incline to the belief that in general it is safer to make exclusive use of wood for buildings and piers intended for refined magnetic measurements.

Jefferson Physical Laboratory.

* F. Kohlrausch, Wied. Ann., vol. xix, p. 142, 1883.

† Abhandl. d. k. bayr. Akad. d. Wiss.; Math.-Phys. Kl., v, p. 24, 1847.

ART. LV.—*The Electrical Resistance of the Alloys of Ferro-Manganese and Copper;* (From determinations made by Mr. B. H. Blood); by EDWARD L. NICHOLS.

[Contributions from the Physical Laboratory of Cornell University, No. 6.]

IN the selection of a material for standards of electrical resistance, the influence of temperature upon the conductivity of the wire to be used in their construction is a factor of prime importance. Since the report of the British Association Committee (1867) on electrical standards, no great progress has been made in this matter. The manufacturers of German silver and of similar alloys have, it is true, succeeded in reducing considerably the temperature-coefficients of their metals; so that it is now possible to obtain wires the resistance of which changes less than two hundredths of one per cent per degree Centigrade. Such a variation is, however, by no means negligible in operations of precision; and the coefficient of different wires, even when made from the same metal, vary greatly. In a single resistance box, as has been shown by Professor Anthony, one may have coils which are well adjusted at some one temperature but to which, no single temperature-correction will apply.* On this and on many other accounts, the discovery of an alloy, the resistance of which is unaffected by temperature is a matter of some importance.

In 1888 patents were granted by the United States government, for two new alloys to be used in the construction of resistance coils.† The properties claimed for these alloys were so remarkable—complete freedom from change of resistance upon heating in the one case and a decrease of resistance with rise of temperature, in the other—that in the absence of more complete data concerning them than are contained in the patent office specifications, it seemed to me a matter of some importance to subject them to a detailed experimental investigation.

The necessary experiments were undertaken at my suggestion by Mr. B. H. Blood, and it is upon his results that the following statements are based.‡

* W. A. Anthony: On the Differing Temperature Coefficients of the Different Coils of a fine Rheostat. Transactions of the American Institute of Electrical Engineers, vol. iv, p. 137.

† See Edward Weston, U. S. patents, Nos. 381,304 and 381,305; Specifications and Drawings of Patents, April 17, 1888, p. 1507. Also Official Gazette of the U. S. Patent Office, vol. xliv, p. 339.

‡ B. H. Blood: Temperature Coefficients of Ferro-manganese-Copper Alloys, Thesis (in MS.); Library of Cornell University, 1889.

The materials used in Mr. Blood's investigation were the pure copper of commerce and "ferro-manganese" containing seventy-nine per cent of manganese. These were fused together in a small carbon crucible, the sides of which were lined with porcelain. The mixture was placed in the bottom of the crucible in contact with the carbon, which was connected with the positive pole of a storage battery. A carbon pencil, connected with the other pole of the battery, was then brought into electrical contact with the charge from above, and quickly withdrawn to a distance of a few millimeters. Under the action of the arc thus formed, a charge weighing three or four grams was completely fused in about thirty seconds, without any considerable oxidation of the metals. The irregular ingot thus formed was afterward rendered more nearly homogeneous by being re-melted in the voltaic arc, for which purpose it was removed from the crucible and placed upon a metal plate. The globule of metal thus obtained was rolled into a thin strip, from which was cut a piece fifteen centimeters long and of such width as to give a resistance of about eight-tenths of an ohm.

The method of measurement employed was as follows: The strip of alloy to be tested was connected in series with a comparison standard, the resistance of the two being approximately equal. These, together with a third resistance of about one hundred and fifty ohms, formed the outer closed circuit of a single gravity cell. "Potential wires" from the terminals of the strip of alloy and of the standard, were joined to a switch of such construction that a mirror galvanometer could be connected in shunt with either. The galvanometer had a resistance of two thousand ohms. A comparison of deflections when the galvanometer was shunted around the resistance standard, and around the test piece, afforded data for the calculation of the resistance of the latter.

This method is exceedingly sensitive, and when properly conducted, it is capable of a high degree of accuracy. In the experiments under consideration, a check upon errors arising from fluctuations in the amount of current traversing the test piece and from changes in the constant of the galvanometer, was obtained by ever repeated reference to the indications of the latter when connected with the terminals of the standard.

In order to relieve the observer of the necessity of maintaining the reference standard at a constant temperature, or of applying temperature-corrections to the results obtained, a compensated carbon standard, of the type recently described by the writer, was constructed.* The resistance of this stand-

* On Compensated Resistance Standards; Transactions of the American Institute of Electrical Engineers, vol. v, No. 10, 1888.

ard was 0·770 ohms; and its temperature-coefficient was about ·000010 per degree Centigrade.

The test piece, enclosed in a U-shaped tube of glass, was placed in an oil bath and alternately heated to 100° C. and cooled to 20°. The reference standard was kept at the room temperature. Its changes of resistance were regarded as negligible.

The application of the method just described, to a number of ferro-manganese-copper alloys, brought to light a remarkable and very troublesome property of this class of metals. It was found that they decreased in resistance each time that they were subjected to a change of temperature, even through the small range made use of in the attempt to determine their temperature-coefficients. The character of these changes can best be illustrated by quoting a series of measurements to which one of the alloys was subjected. An alloy containing 80·82 per cent of copper and 19·12 per cent of ferro-manganese, had been hard drawn in the process of obtaining a strip suitable for measurement. Its specific resistance at 20°, referred to pure copper as unity, was 30·38. It was repeatedly heated to 100° and cooled to 20° with the following result:

TABLE I.

Effect of repeated heating and cooling upon the resistance af Alloy No. 6, (hard drawn).

Observation.	Temperature.	Specific resistance.		Relative resistance.	
1	20°	30·380		1·0000	
2	100		30·186		·99331
3	20	30 163		·99287	
4	100		30·151		·99255
5	20	30·138		·99202	
6	100		30·121		·99180
7	20	30·118		·99134	
8	100		30·118		·99134
9	20	30·105		·99093	
10	100		30.099		·99072
11	20	30·092		·99051	
12	100		30·104		·99092
13	20	30·079		·99007	
14	100		30·104		·99092
15	20	30·072		·98985	

We have, in the case of this alloy, a substance which increases in conductivity each time it is heated and cooled through the small range of 80°, the change in resistance diminishing in amount with each operation, but still perceptible at the end of the seventh cycle. At the same time a positive temperature-coefficient is being developed, which continues to increase as the heating and cooling process is repeated.

After being heated to 100° seven times, with the result shown in Table I, the alloy was raised to a red heat. Its temperature-coefficient was then redetermined with the result shown in the following table:

TABLE II.

Resistance and temperature coefficient of Alloy No. 8, (*after annealing at a red heat*).

Temperature.	Specific resistance. (At 20°)	Specific resistance. (At 100°)	Coefficient.
20°	28·478	------	--------
100	------	28·610	+·000052
20	28·446	------	--------
100	------	28·597	--------
20	28·440	------	+·000052

The effect of repeated annealing upon the resistance and coefficient of these alloys, is still more strikingly exhibited in the behavior of a specimen containing a larger proportion of ferro-manganese. The alloy in question consisted of 70·65 parts of copper and 29·35 parts of ferro-maganese. After being brought into a condition of stability, such that further heating and cooling through a range of eighty degrees had but little permanent effect upon its conductivity, it still showed, when hard drawn, an appreciable negative coefficient. It was then annealed three times at a red heat; specific resistance and coefficient being determined for the range 20° to 100°, after each annealing. The results are given in Table III.

TABLE III.

Effect of repeated annealing upon Alloy No. 11.

Condition.	Specific resistance. 20°	100°	20°	Coefficient.
Rather hard	46·10	45·99	46·09	—·000024
Once annealed	45·10	45·18	45·09	+·000021
Twice annealed	44·07	44·33	44·06	+·000068
Thrice annealed	42·76	43·58	42·74	+·000192

This metal possessed very nearly indeed the composition for which, in the patent specifications already referred to, the remarkable property of decreasing resistance with rise of temperature was claimed; which claim is substantiated, so far as the hard-drawn alloy is concerned. It will be seen that the coefficient depends upon the temper of the metal, and that it would probably be an easy matter to bring the latter into such a state that the change of resistance, which is, in all conditions of the alloy, very much smaller than in any other of which we have definite data, would be too small to be detected.

It appears, moreover, that the conductivity of this alloy was increased about 2 per cent by each successive annealing at a red heat, and that even after being thus annealed three times, it was subject to a further slight but measurable increase of conductivity, amounting to at least ·02 per cent, when subsequently heated to 100° and cooled to 20°.

The influence of temper upon the temperature-coefficient of a number of similar alloys was investigated by the method just described. The alloys showed, when hard rolled, a coefficient very near to zero, sometimes positive, sometimes negative. After annealing at 300° to 400° a well defined negative coefficient, after annealing at a red heat, a still larger positive coefficient, was developed. It was found that the positive coefficient produced by annealing, could be reduced again by rolling the alloy. Table IV shows the character of the results obtained. They were verified in every essential detail by frequent repetitions.

TABLE IV.

Influence of alternate annealing and hardening upon the temperature-coefficient.

Alloy No. 7. (Copper, 80·40%, Ferro-manganese, 19·60%).

Condition of the alloy.	Coefficient (20°—100°).
Hard	+·000022
Partially annealed	—·000032
Thoroughly annealed	+·000066
Re-rolled (hard)	+·000021
Again annealed	+·000045

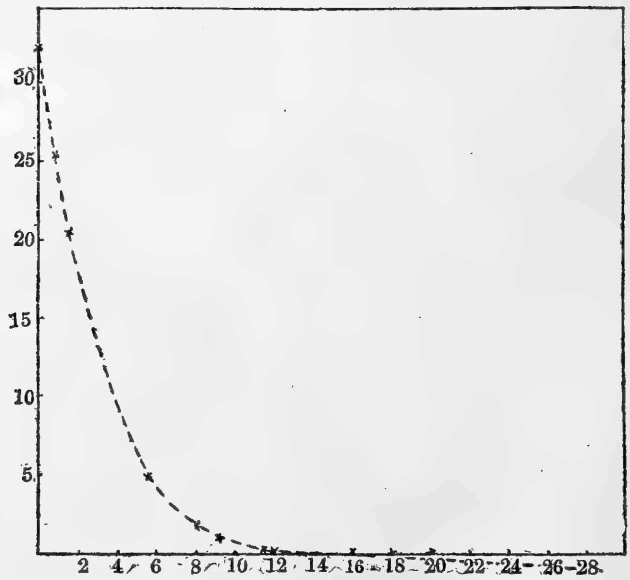
To determine the relation of the composition of these alloys to their temperature-coefficients, Mr. Blood tested twelve specimens, in which the amount of copper ranged from 70 per cent to 99·5 per cent, and also the copper itself from which the alloys were made. The percentage of copper present in each test-piece was determined to within one hundredth of one per cent, by the method of electro-deposition. The results of these determinations are incorporated in Table V.

TABLE V.

Percentage of copper.	Percentage of Ferro-manganese.	Sp. resistance (copper=1·00)	Temperature-coefficient, (20°–100°).		
			Alloy hard.	Alloy semi-annealed.	Alloy annealed.
100·00	0·00	1·00	·003202	------	------
99·58	0·42	1·07	·002579	------	------
99·26	0·74	1·19	·002167	------	------
91·88	8·12	11·28	·000138	------	·000184
91·03	8·97	11·74	·000120	------	------
88·97	11·03	14·07	·000065	------	------
86·98	13·02	20·40	·000016	—·000021	·000080
83·72	16·28	----	·000010	------	·000023
80·88	19·12	30·38	·000012	------	·000046
80·40	19·60	27·50	·000022	—·000032	·000066
77·80	22·20	----	------	------	·000053
77·20	22·80	35·90	—·000012	------	·000010
70·65	29·35	45·10	—·000024	------	·000021

It was found that specimens containing less than eighty per cent of copper could not be worked without frequent partial annealing. Two such specimens were tested, after rolling and again after subsequent annealing. They showed a negative coefficient after rolling, which may have been due to the previous heating, undergone in the process of working them into the necessary form; but since they were as nearly in the condition of the hard-rolled alloys as it was possible to make them, they have been classified in the table among the hard metals.

The coefficients of the hard-rolled alloys, including those above mentioned, have been used in the construction of the accompanying curve, (figure 1). Abscissæ are percentages of ferro-manganese present in the respective specimens; ordinates are the changes of resistance for 100° C. It will be seen that the coefficient of the unalloyed copper falls considerably below Matthiesen's standard, and that the addition of small quantities of ferro-manganese produces a further very rapid



decrease. With ten per cent of ferro-manganese, the change of resistance is less than one per cent for one hundred degrees. Alloys containing from fifteen to twenty per cent of ferro-manganese possess exceedingly small coefficients, the curve crossing the base line at the point corresponding to eighteen per cent. The curve is intended to represent the variations of alloys which are of the same temper, but it is not possible to determine in how far it does so. Indeed for the entire range from fifteen per cent to thirty per cent the coefficient may be given any value between +·00002 and −·00002, by varying the temper of the metal. A positive coefficient could be obtained, however, in alloys containing more than twenty per cent of ferro-manganese, only by thoroughly annealing the specimen; whereas in metals containing a larger proportion of copper, either hardening or complete annealing developed a positive coefficient.

The marked influence of temper upon the conductivity of these alloys, renders it difficult to determine the precise law of the change in specific resistance with the composition. It appears, however, from the results presented in Table V, that the resistance increases nearly in direct proportion to the percentage of ferro-manganese.

Mr. Blood's investigation also included two alloys which contained nickel as well as ferro-manganese. The methods of preparation and measurement were identical with those which have already been described. The results, which are given in Table VI, show exceedingly small negative coefficients in the case of the hardened alloy. Annealing rendered the coefficient of the alloy containing the smaller percentage of nickel positive, and reduced the size of the coefficient of the other specimen.

TABLE VI.

Composition of the alloy.			Temperature coefficients.	
Copper.	Ferro-manganese.	Nickel.	Alloy (hard).	Alloy (annealed).
78·28%	14·07%	7·65%	—·000011	+·000007
52·51%	31·27%	16·22%	—·000039	—·000032

The experiments described in this paper, show that the alloys of ferro-manganese and copper, so far as their electrical behavior is concerned, must be considered as a distinct class. Up to the time of Mr. Weston's discovery of their properties, increase of conductivity with rise of temperature was supposed to be confined to electrolytes, and to the single solid conductor, carbon. Recent investigations have added sulphur to the list, and it is evident that this set of alloys, at least, belongs there also. It is not improbable that the further study of alloys containing metals of the iron group, will lead to the discovery of other combinations, possessing the same interesting and important characteristic.

Art. LVI.—*Fluid Volume and its Relation to Pressure and Temperature;*[1] by C. Barus.

Introductory.

1. The present paper contains the introductory part of a series of experiments on the compressibility of liquids, now in progress at this laboratory. The incentive to the work was given by Mr. Clarence King. In its development I am benefited by his counsel.

The geological purposes in view make it necessary to obtain a preliminary survey of the whole field of inquiry. Experimental details will be filled in later.

2. The literature of the subject has recently been critically digested by Professor Tait.[2] Excellent excerpts are to be found in the Fortschritte der Physik. The work of Canton (1762–64), Perkin (1820–26), Œersted (1822), Colladon and Sturm (1827), Regnault (1847), Grassi (1851), Amaury and Descamps (1869), is discussed in most text-books. Since that date the contributions have been manifold, and are fast increasing. I shall therefore principally confine myself to such papers in which volume changes produced by the simultaneous influence of both pressure and temperature are considered.

Setting aside the literature[3] of critical points, which is too voluminous for admission here, the work of Cailletet[4] is first to be noted, as introducing a long range of pressures (700 atm.). Amagat's[5] early work contains a large temperature interval (0° to 100°), but applies for pressures below 9 atm., only. The results are discussed with reference to Dupré's[6] equation. Passing Buchanan's[7] and Van der Waals[8] results on the compressibility of water and solutions, I come to the important step in the subject made by Lévy[9], though he had been considerably anticipated by Dupré[10]. Lévy endeavors to prove that the internal pressure of a body kept at constant volume is proportional to its temperature. I have already stated[11] that Levy's position is antagonized by H. F. Weber,[12] Boltzmann,[13] Clausius[14]

[1] Communicated with the permission of the Director of the Geological Survey.
[2] Tait: Properties of matter.
[3] See Landolt and Bœrnstein's Physikalisch-chemische Tabellen, Berlin, J. Springer. 1883, p. 62.
[4] Cailletet: C. R., lxxv, p. 77, 1872.
[5] Amagat: C. R., lxxxv, pp. 27, 139, 1877; Ann. ch. et phys., xi, p. 520, 1877.
[6] Dupré: C. R., lix. p. 490, 1864; ibid., lxvii, p. 392, 1868.
[7] Buchanan: Nature, xvii, p. 439, 1878.
[8] Van der Waals: Beiblätter, i, p. 511, 1877.
[9] Lévy: C. R.. lxxxvii, 1878, pp. 449, 488, 676, 554, 649, 826
[10] Dupré: Theorie mecan. de la chaleur, Paris, Gauthier-Villars, 1869, p. 51.
[11] Cf. this Journal. xxxviii, p. 407, 1889.
[12] H. F. Weber: C. R.. lxxxvii, p. 517, 1878.
[13] Boltzmann: C. R., lxxxvii, pp. 593, 773, 1878.
[14] Clausius: C. R., lxxxvii, pp. 718, 1878.

and Massieu,[1] but that important experimental evidence is given in favor of the probable truth of the principle by Ramsay and Young. See below. Amagat's[2] work on the compression of gases must be mentioned because of its important bearing on pressure measurement. In two critical researches Mees[3] perfects Regnault's piezometer and re-determines the compressibility of water. Tait[4] and his pupils, Buchanan[5], Marshal, Smith and Omond,[6] and others carry the inquiry into compressibility and maximum density of water into much detail, and the data are theoretically discussed by Tait. Pressures as high as 600 atm. are applied. Solutions and alcohol are also tested for compressibility. Pagliani,[7] Palazzo and Vicentini,[8] using Regnault's piezometer, publish results for water and a number of other substances, mostly organic. They also examined mixtures. Temperature is varied between 0° and 100°. The results are discussed at length and show the insufficiency of Dupré's formula. DeHeen[9] who has spent much time in studying the volume changes of liquid, deduces a formula of his own chiefly in reference to the thermal changes of compressibility. Theory is tested by experiments. The researches which Amagat,[10] published at about this time are remarkable for the enormous interval of hydrostatic pressure (3000 atm.) applied. Ether and water are operated on. In later work these[11] researches are extended to include other liquid substances with the ulterior object of locating the lower critical temperature. The behavior of water is fully considered. Grimaldi[12] critically discusses the earlier work on the maximum density of water. He also examines the volume changes produced in a number of organic substances[13] by temperature (0° to 100°) and pressure (0 to 25 atm.), and finds Dupré's, DeHeen's and Konowalow's[14] formulæ insufficient.

[1] Massieu: C. R., lxxxvii, p. 731, 1878.

[2] Amagat: C. R., lxxxix, p. 437, 1879; ibid, xc, pp. 863, 995, 1880; ibid., xci, p. 428, 1880, and elsewhere.

[3] Mees: Beiblätter, iv, p. 512, 1880; viii, p. 435, 1884.

[4] Tait: Nature, xxiii, p. 595, 1881; Challenger Reports, ii, 1882, app., pp. 1 to 40; Proc. Roy. Soc. Ed., xi, p. 813, 1882–83; ibid., xii, 1883–84, pp. 45, 223, 226, 757; ibid., xiii, p. 2, 1884–85.

[5] Buchanan: Proc. Roy. Soc. Ed., x, 1880, p. 697.

[6] Marshal, Smith and Omond: Proc. Roy. Soc. Ed., xi, pp. 626, 809, 1882–83.

[7] Pagliani and Palazzo: Beibl., viii, p. 795, 1884; ix, pp. 149, 626, 809, 1885.

[8] Pagliani and Vicentini: Beibl, viii, p. 794, 1884; Journ. de phys., (2) xxx, p. 461, 1883.

[9] DeHeen: Bull. Soc. Roy. Belg., (3), ix, 1885, p. 550; Journal de phys., (2), viii, p. 197, 1889.

[10] Amagat: C. R., ciii, p. 429, 1886.

[11] Amagat: C. R., civ, p. 1159, 1887; ibid., cv, pp. 165, 1120, 1887.

[12] Grimaldi: Beiblätter, x, p. 338, 1886.

[13] Grimaldi: Beiblätter, xi, pp. 136, 137, 138, 1887; Ztschr. für phys. chem., ii, p. 374, 1888.

[14] Konowalow: Ztschr. für phys. chem., ii, p. 1, 1888.

At this stage of progress, the point of view gained in the extensive researches of Ramsay and Young[1] throws new light on the subject. They prove experimentally that if pressure p and temperature θ vary linearly ($p=b\theta-a$), the substance operated on does not change in volume. Ether, methyl and ethyl alcohol, acetic and carbonic dioxide are tested. Exceptional values for the case of acetic acid and nitrogen tetroxide are referred to dissociation. Utilizing James Thomson's[2] diagram, they point out that the locus of the isothermal minima and maxima intersect the locus of maximum vapor tensions at the critical point. Data are given for ether. Fitzgerald[3] reasoning from Ramsay and Young's results arrived at the theoretic results virtually given by Lévy (see above). Tait[4] who is still actively at work on high pressures has recently made further publication on the effect of dissolved substances on internal pressure. An endeavor to formulate Andrew's classical results is due to Dickson.[5] Fitzgerald[6] recently applied Clausius's[7] equation to a discussion of Ramsay and Young's data, and Sarrau[8] has similarly discussed Amagat's data.

3. A few references to thermal expansion of liquids, which enters incidentally into the present paper, must be added. Many formulæ have recently been devised and tested by Avenarius,[9] DeHeen,[10] Mendeleeff,[11] Thorpe and Rücker,[12] Jouk[13] and others,[14] not to mention older observers. None of these forms are satisfactory when long ranges of temperature are introduced, as was shown by Bartoli and Stracciati,[15] testing Mendeleeff's, and Thorpe and Rücker's formulæ, and by the discussion between Mendeleeff and Avenarius.

Special mention must be made of the celebrated papers of J. Willard Gibbs,[16] by whom the scope of graphic methods for exhibiting the thermo-dynamics of fluids was surprisingly

[1] Ramsay and Young: Phil. Mag., (5) xxiii, p. 435, 1887; ibid., xxiv, p. 196, 1887; Proc. Roy. Soc. Lond., xlii, p. 3, 1887.

[2] James Thomson: Phil. Mag., (5), xliii, p. 227, 1872; Nature, ix, p. 392, 1873.

[3] Fitzgerald: Proc. Roy. Soc., xlii, p. 50, 1887.

[4] Tait: Challenger Reports, Phys. and Chem., ii, (4), 1888; Proc. Roy. Soc. Ed., xv, p. 426, 1888.

[5] Dickson: Phil. Mag., x, p. 40, 1880.

[6] Fitzgerald: Proc. Roy. Soc. Lond., xlii, p. 216, 1887.

[7] Clausius: Wied. Ann., p. 337, 18 .

[8] Sarrau: C. R., xciv, pp. 639, 718, 845, 1882; ibid., ci, p. 941, 1885.

[9] Avenarius: Beibl., ii, p. 211, 1878; ibid., viii, p. 806, 1884.

[10] DeHeen: Bull. Ac. Roy. Belg., (3), iv, p. 526, 1882; Journ. Chem. Soc., xlv, p. 408, 1884.

[11] Mendeleeff: Chem. Ber., xvii, p. 139, 1884; Beibl, viii, p. 806, 1884.

[12] Thorpe and Rücker: Journ. Chem. Soc., xlv, p. 135, 1884.

[13] Jouk: Beibl., viii, p. 808, 1884.

[14] Rosenberg: Journ. d'Almeida, vii, p. 350, 1878.

[15] Bartoli and Stracciati: Beibl., ix, p. 510, 1885.

[16] J. Willard Gibbs: Trans. Conn. Acad., ii, (2), pp. 309, 382, 1873.

enlarged. The terms *isometric*, *isopiestic*, *isothermal*, *isentropics*, etc., are used in the present paper in the sense defined by Gibbs (l. c., p. 311).

4. Surveying the above researches as a whole, it appears at the outset that more work has been spent on the compressibility of water than the exceptional behavior of this substance justifies at the present stage of the inquiry. In other words the volume-pressure-temperature changes of the great majority of liquids probably conform closely with a general thermodynamic law, due respectively to Dupré and Lévy, and to Ramsay, Young and Fitzgerald. It is therefore first desirable to find the full importance of this law experimentally, and then to interpret the exceptional cases with reference to it. Again it appears that researches in which long pressure ranges are applied simultaneously with long temperature ranges, are urgently called for. It is from such work that further elucidation of this important subject is to be obtained.

Among pressure experiments the late researches of Amagat stand out by their originality and importance. One can not but admire the experimental prowess which has enabled him to penetrate legitimately into a region of pressures incomparably high, without lowering his standard of accuracy.

Apparatus.

5. *Force pump and appurtenances.*—In making the experiments detailed in the following pages I used a large Cailletet force pump, of the form constructed both by Ducretet of Paris, and by the Société Génevoise. Its efficiency is 1000 atm. It is made to be fed with water, but I found by using thin sperm oil, it was possible to facilitate the operations, because there is less danger of rusting the fine polished steel parts of the machine. The pump consists of two parts: the pump proper and the strong cylindrical trough into which the compression tubes are to be screwed. The trough is cannon-shaped, its axis vertical, and the open end uppermost. Pump and trough are connected by strong phosphor-bronze tubing, and similar tubes lead to the large Bourdon gauge by which the pressures are measured.

6. *Compression tubes and appurtenances.*—The substance to be tested is enclosed in capillary tubes of glass of very fine bore (·03^{cm} and less) and about ·6^{cm} thick, such as are used for thermometers. The length of these tubes *a b c*, figure 1, was about 50^{cm} or 60^{cm}. To insert them into the trough, the solid glass of the tube was swelled or bulged at *b* about 5^{cm} from one end, and then pushed through an axially perforated steel flange AA BB, in which they fitted snugly. The bulged end and the flange faced the inside of the trough, so as to be acted against by the pressure. To seal the tube *a b c*, in the steel flange AA BB fusible metal was poured around it at *f f*, and the joint was then further tightened by a thick coating of marine glue, *g g*. A strong hollow nut of iron surrounding both the lower end of the tube and the stem of the flange, fastened it to the trough by forcing it against a leather washer. When completely adjusted, the capillary tube projected about 40^{cm} or 50^{cm} clear above the trough. Pressure was transmitted through the oil of the pump to the mercury in the trough, which communicated directly with the open lower end of the capillary tube.

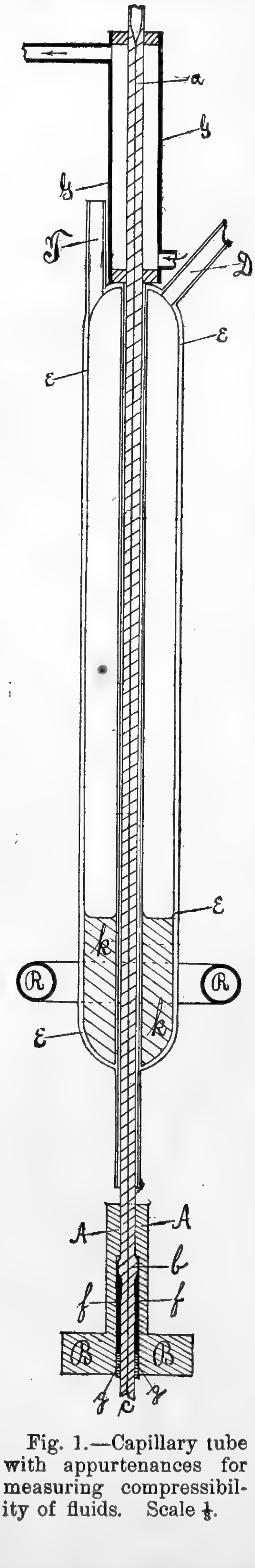


Fig. 1.—Capillary tube with appurtenances for measuring compressibility of fluids. Scale ⅛.

7. A thread of the (solid) substance to be acted on was introduced into the cleansed capillary, between two threads of mercury. This is a delicate operation, requiring much care; but the details of manipulation can not be given here. I will say merely that it is not advisable to seal the upper end, *a*, of the tube *a b c* by fusing the glass, because the strains introduced during cooling greatly diminish the strength of the tube. The end may be sealed by a thread of paraffine 5^{cm} long, properly inserted and kept solid by a cold water jacket, G G. Under these conditions the viscosity of paraffine is too great to admit of its being forced out of the glass by any pressure compatible with the strength of the tube. Faultless adhesion of the paraffine to the glass is however essential.

Passing from top to bottom of the charged capillary, *a b c*, one therefore encounters the following succession of threads: paraffine (5^{cm}), mercury (5^{cm}), substance (20^{cm}), mercury (25^{cm}) in communication with the mercury of the trough. Measurements are made by observing the distance apart of the lower meniscus of the upper mercury thread, and the upper meniscus of the lower thread, with Grunow's cathetometer. When the adjustment is perfect the motion of the upper mercury thread is nearly zero.

8. To heat the sample to any required temperature, I surrounded the capillary tube *abc*, with one of my closed boiling tubes* of clear glass, *ee ee*. By connecting the latter with a condenser, the ebullition may be prolonged indefinitely. The whole length of thread of substance is thus virtually exposed in a vapor bath. Methyl alcohol (65°), water (100°), aniline (185°), and diphenylamine (310°) are available for boiling points. The liquid shown at *kk*, is heated by Wolcott Gibbs's ring burner *RR*. At high temperatures it is of course necessary to jacket the boiling tube appropriately with asbestos wicking (not shown), leaving only two small windows exposed, through which the ends of the thread may be seen with the telescope. When the tube has become fully heated, it is clear, and condensation takes place only in the condenser, connecting at *D*. By adjusting suitable white and black screens with reference to the line of sight, the image of the meniscus may be sharpened. Intermediate temperatures may be reached by boiling the substances under low pressures. For this purpose it is merely necessary to attach the open end of the condenser to Prof. R. H. Richards'† pneumatic exhausting pumps. Provision has been made at *T* for the introduction of a suitable thermometer, by which the temperature of the boiling tube may be checked.

To save space the description here given is a mere sketch. It is scarcely necessary to state that the manipulations are difficult throughout, and that with the best of care breakage of tubes and other failures of experiment are a frequently recurring annoyance. Special pains must be taken to select well annealed glass; otherwise the internal stress adds itself to the applied stress, and the tube is easily broken. Hot vapor baths must not be removed until the tube *a b c* is thoroughly cold. The capillary does not outlast many series of experiments: for sheared glass undergoes a gradual molecular change very analogous to permanent set. Eventually the tube may be ruptured at less than ½ the original test pressure.

9. *Pressure measurement.*—It is easily seen that the method of experiment is necessarily such that temperature is kept constant, while pressure is varied at pleasure.

* Bulletin U. S. G. S., No. 54, pp. 86 to 90, 1889.
† Richards: Trans. Am. Inst. Mining Eng., vi, p. 1, 1879.

To measure pressure, I used a Bourdon gauge,* graduated in steps of 10 atm. each as far as 1000 atm. So graduated the gauge registered smaller differences of pressure than could be measured in terms of the volume changes of the liquid in the capillary tubes.

To test the gauge I compared it with a similar gauge graduated as far as 300 atm., and found the difference no larger than the error of reading. Again I compared the guage indications with the changes of the electrical resistance of mercury under identical conditions of pressure, and found the results equally satisfactory, as will be explained elsewhere.

Curious results were obtained on comparing the gauge with a closed air manometer. The results calculated with reference to Boyle's law, i. e. for isothermal expansion, were found wholly discrepant. The difficulty was interpreted by computing with reference to Poisson's law. Some data are given in table 1, where p, v, k, denote pressure, volume and the specific heat ratio, respectively. The error at $p = 100$ is due to time lost in making the measurement, since it is here that the volume changes are large and require specially adjusted telescopes for close reading.

TABLE 1.—Compressibility of air. Test of Gauge.

p	v	lg $v^k p$		p	v	lg $v^k p$
atm.				atm.		
100	1030	6·25		100	1040	6·25
200	550	6·16		200	552	6·17
300	400	6·15		300	393	6·14
400	329	6·15		400	324	6·16
500	----	----		500	285	6·16

Quick manipulation presupposed, this method is probably available for the measurement of k, particularly with reference to its pressure variation. It follows also that when work is done in capillary tubes, much time must be allowed before the observed volume changes can be considered isothermal.

Since the gauge is based on Hooke's law, errors of the zero point are eliminated by working between indicated pressure and taking differences of reading. So far as the relative pressures are concerned, it is then merely necessary that the attached dial and mechanism be virtually a scale of equal parts.

* I think Mr. Tait who has constructed other gauges based on Hooke's law, under-estimates the ingenuity of Bourdon's gauge. By increasing the number of coils, or by suitably adjusting a mirror index, the gauge can be made serviceable without a multiplying gear. Read off directly the only limit to the scientific efficiency of such a gauge is the viscosity of the Bourdon tube. My own experiments on improving this gauge have thus far been failures, chiefly however because of insufficient facilities for working with steel tube.

Finally I compared the Bourdon gauge with a form of Tait gauge of my own, in which the volume expansion of a suitable steel tube due to pressure, is measured externally. Leaving further description to be given elsewhere, I will here insert an example of the results obtained, selected at random.

TABLE 2.

Comparison of gauges.

	Bourdon.	N. G.		Bourdon.	N. G.		Bourdon.	N. G.
	atm.	cm.		atm.	cm.		atm.	cm.
$p=$	0	0	$p=$	500	870	$p=$	1000	1700
	100	160		600	1045			
	200	335		700	1210			
	300	520		800	1370			
	400	690		900	1530			

Here the reading of the new gauge is given under N. G. Constructing the data graphically, and remembering, that the deviations are to be apportioned between the gauges, it appears that the error must everywhere be less than 10 atm., under most unfavorable conditions.

No stress was placed on the absolute correctness of the standard atmosphere employed. The results sought follow equally well for an approximate standard, correctly multiplied.

11. *Volume changes of glass tubes.*—Professor Tait* has given the following expression for the volume increment of a cylinder subjected to internal pressure:

$$\frac{\Pi a_0^2}{a_1^2-a_0^2}\left(\frac{1}{k}+\frac{a_1^2}{a_0^2}\frac{1}{n}\right),$$

where Π is the pressure, $1/k$ and n the compressibility and the rigidity of the glass, and where a_0 and a_1 denote the inner and the outer radius of the tube, respectively. In my case $a_0=\cdot015^{\text{cm}}$ or less, $a_1=\cdot3^{\text{cm}}$. It is therefore permissible to neglect the factor in the above expression which involve compressibility, with an error no greater than a few tenths per cent. Hence if the proper value† of n be introduced, and P be measured in atmospheres, the above expression reduces approximately‡ to $4\Pi 10^{-6}$. Unfortunately this correction is by no means negligible, and may in unfavorable cases amount to as much as 5 per cent of the corresponding volume decrement of the liquid to be tested. The case is worse: most of the experiments are to be made between 60° and 300°, for which large interval the rigidity of glass can not be said to be known.

* Tait: Challenger Reports, 1882, appendix, p. 29.

† Everett: Units and phys. constants, Macmillan, 1879, p. 53.

‡ The correction is less than the above result, since only the right sectional expansion affects the measurement.

Hence, instead of introducing arbitrary considerations I resolved to neglect the correction altogether, in favor of direct test experiments made with mercury and water. The compressibility of mercury is two small to be measurable by the present method. Hence, since its compressibility is known, it is well adapted for testing the errors of the apparatus.

In table 3 I have given the temperature, θ, and the length, L, of the mercury thread observed; also the volume decrement v/V per unit of volume, for each pressure p, as well as the corresponding mean compressibility β. Many methods were tried, but the best results were obtained with a thread of mercury enclosed between end threads of paraffine. At the low temperature, 30°, the lower thread was alcohol. At high temperatures the greatest care must be taken to free the thread from adhering air bubbles, or of globules of volatile liquid, for in expanding they utterly vitiate the results, as I found in more than one instance.

TABLE 3.
Compression of mercury to test tubes.

θ, L	p	$\frac{v}{V}\times 10^3$	$\beta\times 10^6$	θ, L	p	$\frac{v}{V}\times 10^3$	$\beta\times 10^6$
30°	20	·0	--	185°	20	·0	--
16·7^{cm}	100	·2	2	17·1^{cm}	100	1·1	14
	200	·3	2		200	2·2	13
	300	·7	3		300	2·6	9
	400	1·5	4		400	4·2	11
	mean	---	3		mean	---	12
65°	20	·0	--		Another	thread	
16·8^{cm}	100	·6	8	185°	20	·0	--
	200	2·0	14	19·3^{cm}	100	·8	10
	300	2·0	8		200	3·0	17
	400	3·0	8		300	3·8	14
	mean	---	9		400	4·7	13
100°	20	·0	--		mean	---	13
16·9^{cm}	100	·7	10	310°	20	·0	--
	200	1·5	9	19·7^{cm}	100	1·2	15
	300	2·5	8		200	2·6	14
	400	2·1	8		300	4·0	15
	mean	---	9		400	5·3	14
					mean	---	15

This table is reassuring. From the known low temperature compressibility of mercury,* it appears that the error of β made by neglecting Tait's correction is of the order of 10^{-6}, and that it is not greater than the unavoidable errors of measurement. Again since the compressibility of the organic substances examined as in all cases much greater than 60×10^{-6},

* Everett: l. c, pp. 52, 53. Cf. Amagat: C. R. cviii, p. 228, 1889; Journ. de phys., (2), viii, p. 197, 1889; Tait: l. c.

the said error of β is never larger than 2 per cent. By comparing table 3 with tables 4 to 18, (ϑ), it will be seen that the results at high temperatures are much more favorable. Similar inferences were obtained with water, which may therefore be omitted here.

13. *Isothermals and isentropics.*—To obtain the isothermals of the compressed liquids rigorously, it is necessary to wait a long time after each compression. By so doing the tube is seriously weakened, and at high temperatures, in virtue of the diminished viscosity (cf. § 8), it is probably even distorted. It appears, however, that for liquids like the present, the distinction between isothermal and adiabatic compression is beyond the scope or sensitiveness of the present method of volume measurement. Hence, I made my observations by varying pressure from 20 atm. to the maximum, and then from the maximum back to 20 atm., with only such allowance of time as was necessary to take the observations at the successive stages of pressure. Near the critical temperature this mode of procedure is no longer warranted.

Throughout the work the chief reliance was placed on the constancy of the fiducial zero. The volume decrements corresponding to a given pressure must be identical, no matter whether they are observed in the pressure increasing or pressure decreasing march of the measurements.

14. *Thermal expansion.*—Measurements of heat expansion are necessary for the coördination of the results. Without a thermometer tube, such measurements are not very accurate; and the inaccuracy is much increased by an unavoidable breaking off of the ends of the mercury thread, whenever the substance operated on solidifies. In passing from one constant temperature to another, an exchange of boiling tubes is necessary. It is difficult to keep the substance fused during the whole time of readjustment. On solidification the charge contracts as much as 10 per cent. The mercury thread is therefore forced into the vacuities in the axis of the solid thread. After fusing again it will often be found that the mercury thread is broken into distinct pieces, sometimes in great number, alternating with small threads of substance. All of these must be measured, an operation which is not only excessively tedious, but makes the expansion measurement, inaccurate. For this reason I added no correction for the expansion of glass. The errors thus introduced may amount to 2 or 3 per cent in unfavorable cases. See tables 5 to 19. At high temperature such corrections would be arbitrary for the reasons given in § 11. Here however, it is probably quite negligible, because of the large volume expansions.

Experimental Results.

15. The bulk of the present experiments were made as detailed in § 6, earlier data being rejected. Throughout the tables L is the length of the thread of substance, at the temperature θ; v/V is the corresponding volume-decrement due to the burden of p atmospheres. Finally, β is the mean compressibility between the initial pressure p_0 and the pressure given. Values marked, observed and calculated will be discussed below § 30.

16. *Ether.*—The results for ether are given in table 4. Manipulations were made very difficult, because of traces of sulphur retained by the liquid. This destroys the cohesion of the mercury thread, probably by reducing its surface tension. Above 100° the thermal expansion increases enormously, so that I found it necessary to operate with two threads, a long one for low temperatures, and a short one for 310°. Since the initial pressure could not be kept at 20 atm., the tubes not being long enough, I reduced all data to the uniform pressure $p_0=100$ atm. Table 5 shows the corresponding expansion data. It may be noted that supposing the given conditions to hold linearly, ether would cease to expand at 1100 atm. Cf. § 38.

Table 4.

Compressibility of Ether, referred to 100 Atm.

θ, L	p	Observed $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Comput'd $\frac{v}{V}\times 10^3$	Diff. $\times 10^3$	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
29°	100	0·0	----	0·0	----		
	200	15·6	156	15·4	+·2	165	194
14·37cm	300	28·9	145	28·9	·0		
	400	40·8	136	40·9	—·1		
65°	100	0·0	----	0·0	----		
	200	20·7	207	20·5	+·2	226	282
15·18cm	300	37·7	189	37·8	—·1		
	400	52·8	176	52·8	±·0		
100°	100	0·0	----	0·0	----		
	200	30·5	305	29·9	+·6	343	497
16·25cm	300	53·6	268	53·4	+·2		
	400	72·2	241	72·8	—·6		
185°	100	0·0	----	0·0	----		
20·08cm	200	74·1	741	71·5	+2·6	1005	10060
	300	115·5	577	114·7	+ ·8		
	400	143·5	478	145·6	—2·1		
310°	100	0	----	0·0	----		
*14·59cm	200	382	3820	383	—1	34250	
	300	462	2310	460	+2		
	400	502	2510	503	—1		

* Second sample.

TABLE 5.

Thermal expansion of Ether, $\frac{v}{V} \times 10^3$, referred to 29°.

Atm. =		100	200	300	400
θ=	29°	0	0	0	0
	65	57	51	48	43
	100	131	114	103	93
	185	397	315	274	246
	310	1770	733	528	435

17. *Alcohol.*—The alcohol used was the commercial absolute spirit. Table 6 contains the observations for compressibility. All observations are referred to 150 atm., for the tube was not long enough for observations corresponding to lower initial pressures. Thermal expansions are given in table 7.

TABLE 6.

Compressibility of Alcohol, referred to 150 Atm.

θ, L	p	Observed $v/V \times 10^3$	$\beta \times 10^6$	Comput'd $v/V \times 10^3$	Diff. $\times 10^3$	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$
28°	150	0·0	----	0·0	·0		
	200	4·3	86	4·3	·0	89	101
9·45^{cm}	300	12·7	85	12·6	+·1		
	400	20·2	81	20·2	·0		
65°	150	0·0	----	0·0	·0		
	200	5·5	110	5·6	−·1	115	136
9·78^{cm}	300	16·4	109	16·0	+·4		
	400	25·1	100	25·5	−·4		
100°	150	0·0	----	0·0	·0		
	200	8·4	168	7·6	+·8	158	201
10·27^{cm}	300	21·6	144	21·5	+·1		
	400	33·1	132	34·0	−·9		
185°	150	0·0	----	0·0	·0		
	200	16·0	320	15·4	+·6	331	598
11·62^{cm}	300	41·1	274	40·9	+·2		
	400	61·2	245	61·8	−·6		
310°	150	0	----				
	200	211	4200	219	−8	13830	
21·75^{cm}	300	335	2220	330	+5		
	400	384	1530	385	−1		

TABLE 7.

Thermal expansion of Alcohol, $\frac{v}{V} \times 10^3$, referred to 28°.

Atm. =		150	200	300	400
θ=	28°	0	0	0	0
	65	35	35	31	30
	100	87	82	78	73
	185	229	217	195	178
	310	1290	826	555	447

18. *Palmitic acid.*—Data for palmitic acid are given in tables 8 and 9 on a plan uniform with the above. Owing to accidents two threads were observed; the first between 65° and 185°, and the second between 65° and 310°. At 65°, solidification set in at about 400 atm. The result is a distortion of the curvature of the isothermal. Difficulties were encountered from breaks of the mercury thread. In this and the following tables, two values of v/V are usually inserted. They were obtained during the pressure increasing and the pressure decreasing march of the measurements.

TABLE 8.

Compressibility of Palmitic acid, $C_{16}H_{32}O_2$, referred to 20 atm. Melting point 62°; Boiling point 350°.

L, θ	p	Observed. $\frac{v}{V}\times 10^3$	Observed. $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Comput'd $\frac{v}{V}\times 10^3$	Diff. × 10^3	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
65°	20	0·0	0·0	---	†0·0	·0	91	93
16·72cm	100	7·2	7·2	90	7·1	—·1		
	200	15·0	15·3	85	15·3	—·1		
	300	22·8	23·1	82	23·0	—·1		
	*400	31·1	31·1	82	30·1	+·2		
100°	20	0·0	0·0	---	0·0	·0	102	104
17·16cm	100	8·1	8·1	101	7·8	+·3		
	200	16·9	16·3	93	16·9	—·3		
	300	25·5	25·5	91	25·4	+·1		
	400	33·3	33·3	88	33·2	+·1		
185°	20	0·0	0·0	---	0·0	·0	160	165
18·50cm	100	12·1	12·1	151	12·1	·0		
	200	26·3	26·3	146	25·5	—·2		
	300	37·2	37·8	134	37·5	·0		
	400	48·2	47·7	127	48·5	—·4		
Second sample.								
65°	20	0·0	0·0	---				
14·63cm	100	6·5	6·9	84				
	200	15·1	15·1	84				
	300	22·9	22·3	81				
	400	29·5	29·5	78				
310°	20	0·0	0·0	---	0·0	·0	330	351
17·54cm	100	23·4	24·6	300	23·7	+·3		
	200	47·4	48·3	265	47·5	+·4		
	300	66·3	67·9	240	67·2	—·1		
	400	82·6	84·3	220	83·8	—·1		

TABLE 9.

Thermal expansion of Palmitic acid, $\frac{v}{V}\times 10^3$, referred to 65°.

Atm.=		20	100	200	300	400
θ=	65°	0	0	0	0	0
	100	26	25	24	23	24
	185	107	101	93	91	87
	310	199	179	159	145	133

* Solidifying. † Including the lower series.

19. *Toluidine para.*—Tables 10 and 11 contain data for para toluidine. A feature of these results is the circumflexure of the isopiestics in the undercooled part of their course. This is probably not an error, since it recurs under similar conditions in case of thymol, § 23. If contraction due to cooling were to continue at the rate shown in table 12, there would be no volume change at 1400 atm. To solidify the undercooled liquid, as much as 500 atm. were necessary.

TABLE 10.

Compressibility of Para-Toluidine, $C_7H_7NH_2$, referred to 20 atm.

Boiling point, 198°; melting point, 43°.

θ, L	p	Observed. $\frac{v}{V}\times 10^3$	Observed. $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Computed $\frac{v}{V}\times 10^3$	Diff. $\times 10^3$	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
*28°	20	0·0	0·0	---	0·0	±·0	--	
14·14cm	100	4·3	4·6	56	4·6	—·1	59	60
	200	10·0	10·0	56	10·2	—·2		
	300	15·8	15·6	56	15·5	+·2		
	400	20·6	20·9	55	20·5	+·2		
65°	20	0·0	0·0	---	0·0	±·0	--	
14·73cm	100	5·5	5·5	69	5·3	+·2	68	69
	200	11·6	11·9	65	11·7	±·0		
	300	17·4	17·4	62	17·7	—·3		
	400	23·5	23·5	62	23·4	+·1		
100°	20	0·0	0·0	---	0·0	·0	87	88
15·02cm	100	6·3	6·3	79	6·8	—·5		
	200	14·5	14·5	81	14·7	—·2		
	300	22·2	22·3	79	21·1	+·1		
	400	29·0	29·3	77	28·8	+·4		
185°	20	0·0	0·0	---	0·0	·0		
16·36cm	100	11·0	10·9	137	10·6	+·4	138	142
	200	22·8	22·8	127	22·5	+·3		
	300	33·4	33·4	119	33·1	+·3		
	400	42·4	42·2	112	43·1	—·8		
310°	20	0·0	0·0	---	---	0·	392	422
19·05cm	100	29·0	29·4	365	276	+2·		
	200	56·1	? 52·0	300	545	+2·		
	300	76·2	75·7	271	763	—0·		
	400	92·7	92·5	243	945	—2·		

TABLE 11.

Thermal expansion of Para-Toluidine, $\frac{v}{V}\times 10^3$, referred to 28°.

Atm.=		20	100	200	300	400
θ=	28°	0	0	0	0	0
	65	42	41	40	39	38
	100	63	60	57	56	53
	185	158	149	142	136	131
	310	348	313	287	265	247

* Liquid under-cooled. Solidifies at 500 atm.

20. *Diphenylamine.*—Values for diphenylamine are given in tables 12 and 13. The initial pressure is unfortunately zero. This introduces a possible discrepancy, since the zero of the gauge is not vouched for.

TABLE 12.

Compressibility of Diphenylamine, $NH(C_6H_5)_2$, referred to zero atm.

Melting point, 54°; boiling point, 310°.

L, θ	p	Observed. $\frac{v}{V}\times 10^3$	Observed. $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Computed $v/V\times 10^3$	Diff. $\times 10^3$	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
16·2cm	0	0·0	0·0	---	0·0	− ·0		
65°	100	6·5	6·0	63	6·3	− ·0	65	65
	200	11·9	11·9	60	12·2	− ·2		
	300	17·9	17·3	59	17·9	− ·3		
	400	23·2	22·5	57	23·5	− ·7		
	500	29·2	28·4	57	28·4	+ ·9		
16·4cm	0	0·0	0·0	---	0·0	·0		
100°	100	6·1	6·3	62	6·7	− ·5	69	69
	200	12·8	13·1	64	13·1	− ·2		
	300	19·3	19·3	64	19·0	+ ·3		
	400	24·6	25·1	62	24·7	+ ·1		
	500	29·9	30·5	60	30·1	+ ·1		
17·7cm	0	0·0	0·0	---	0·0	+ ·0	110	110
185°	100	11·2	10·7	110	10·4	+ ·6		
	200	20·6	20·3	102	20·0	+ ·5		
	300	29·2	28·9	97	28·9	− ·1		
	400	37·1	36·1	91	37·0	− ·4		
	500	44·1	44·3	89	44·7	− ·5		
19·7cm	0	0·0	0·0	---	·0	·0		
(20·3cm)	100	18·5	17·8	202	19·0	−1·2	213	213
310°	200	36·1	36·1	190	36·0	+ ·1		
	300	51·5	50·7	176	50·3	+ ·7		
	400	62·4	63·5	161	63·1	− ·1		
	500	74·1	71·1	152	74·6	·0		

TABLE 13.

Thermal expansion of Diphenylamine, $\frac{v}{V}\times 10^3$, referred to 65°.

Atm.=		0	100	200	300	400	500
θ=	65°	0·0	0·0	0·0	0 0	0·0	0·0
	100	12·4	12·4	11·3	10·1	10·1	11·0
	185	93·0	88·0	83·1	80·0	78·0	76·0
	310	235·	221·	205·	193·	186·	178·

21. *Caprinic acid.*—Tables 14 and 15 finally give the results for caprinic acid. Thermal expansion is irregular, possibly due to motion of the thread in the tube, so that virtually two threads were observed. The substance has a low melting point, 30°, and is easily under-cooled to 25°. It then solidifies under 300 atm.

TABLE 14.

Compressibility of Caprinic acid, $C_{10}H_{20}O_2$, referred to 20 atm.

Melting point, 30°; boiling point, 269°.

θ, L	p	Observed. $v/V\times10^3$	Observed. $v/V\times10^3$	$\beta\times10^6$	Computed $v/V\times10^3$	Diff. $\times10^3$	$\vartheta\times10^6$	$\vartheta_0\times10^6$
30°	20	0·0	0·0	---	0·0	·0		
	100	4·9	5·7	66	5·9	−·6	76	76
under-cooled	200	13·4	12·9	73	12·9	+·3		
15·91^{cm}	300	19·5	19·8	71	19·5	+·2		
	400	25·5	25·8	68	25·7	·0		
65°	20	0·0	0·0	---	0·0	·0		
14·39^{cm}	100	7·3	7·0	90	7·3	−·1	95	97
	200	16·1	15·9	89	16·0	·0		
	300	23·6	23·9	84	23·8	·0		
	400	31·4	31·1	82	31·3	·0		
100°	20	0·0	0·0	---	0·0	·0	119	121
16·85^{cm}	100	8·5	9·1	110	9·0	−·2		
	200	19·1	20·1	109	19·5	+·1		
	300	29·1	28·7	104	29·1	−·1		
	400	36·8	36·8	97	37·8	+·2		
185°	20	0·0	0·0	---	0·0	·0	200	207
18·30^{cm}	100	15·3	15·1	190	14·9	+·3		
	200	31·2	31·1	173	31·2	·0		
	300	45·4	45·5	163	45·2	+·3		
	400	57·4	57·1	151	57·7	−·4		

TABLE 15.

Thermal expansion of Caprinic acid, $\frac{v}{V}\times10^3$, referred to 30°.

Atm.=		20	100	200	300	400
θ=	30°	0	0	0	0	0
	65	30	28	28	26	25
	100	59	55	52	49	47
	185	151	139	129	120	113

22. *Paraffine.*—Results for paraffine are in hand in large number. The best of these are given in tables 16 and 17. At 64°, solidification set in at 400 atm., changing the curvature of the isothermal. Supposing the present conditions to hold indefinitely, there would be no contraction on cooling under 1200 atm.

23. *Thymol.*—Finally tables 18 and 19 contain data for thymol. Like toluidine, § 19, thymol admits of considerable undercooling; and the isopiestics show circumflexure in that region. Supposing all conditions to hold, no volume changes would ensue on cooling under 1200 atm.

TABLE 16.

Compressibility of Paraffine referred to 20 atm. Melting point 55°.

L, θ	p	Observed. $\frac{v}{V}\times 10^3$	Observed. $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Comput'd $\frac{v}{V}\times 10^3$	Diff. $\times 10^3$	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
64°	20	0·0	0·0	----	0·0	—·0	88	89
15·86cm	100	6·8	6·5	83	6·8	—·1		
	200	14·9	14·9	83	14·8	+·1		
	300	23·6	23·8	84	----	----		
	400	solidify'g	(56·6)	(149)	----	----		
100°	20	0·0	0·0	----	0·0	—·0		
16·28cm	100	8·5	8·5	106	8·5	·0	111	114
	200	18·5	18·7	103	18·5	+·1		
	300	27.6	27·7	99	27·4	+·2		
	400	35.6	35·8	94	35·8	—·1		
185°	20	0·0	0·0	----	0·0	·0		
17·57cm	100	13·8	13·8	172	13·3	+·5	178	184
	200	27·9	28·2	156	28·1	·0		
	300	41·2	41·4	147	41·1	+·2		
	400	52·3	52·0	137	52·7	—·5		
310°	20	0·0	0·0	----	0·0	·0		
19·70cm	100	26·8	26·2	331	26·0	+·5	366	392
	200	51·9	52·1	289	51·7	+·3		
	300	72·4	71·8	257	72·7	—·6		
	400	89·9	89·6	236	90·3	—·6		

TABLE 17.

Thermal expansion of paraffine, $\frac{v}{V}\times 10^3$ referred to 64°.

Atm.=		20	100	200	300	400
θ=	64°	0·0	0·0	0·0	0·0	0·0
	100	26·4	24·1	23·1	22·6	22·1
	185	108·0	100·0	92·9	87·8	83·8
	310	241·0	210·0	196·5	181·0	167·0

24. Similar data are in hand for benzoic acid, monobrom camphor, α-naphtol, azo-benzol, vanilline, naphthaline, and monochloracetic acid. But as the data are less complete and add no new features to the discussion, I omit them here.

To illustrate the general character of the results I have constructed the data for para-toluidine graphically in figures 2 and 3. The former shows the relative isothermal volume decrements the latter the relative isopiestic volume increments. The undercooled region is marked by *a*.

TABLE 18.

Compressibility of Thymol, $C_{10}H_{14}O$, referred to 20 atm. Melting point 53°, boiling point 233°.

L, θ	p	Observed. $\frac{v}{V}\times 10^3$	Observed. $\frac{v}{V}\times 10^3$	$\beta\times 10^6$	Comput'd $\frac{v}{V}\times 10^3$	Diff. $\times 10^3$	$\vartheta\times 10^6$	$\vartheta_0\times 10^6$
*28°	20	0·0	0·0	----	0·0	----	--	
14·67cm	100	5·5	5·3	67	5·1	+·3	65	66
	200	10·9	11·0	61	11·1	—·1		
	300	17·0	17·0	61	16·7	+·3		
	400	21·8	21.7	57	22·1	—·4		
64°	20	0·0	0·0	----	0·0	----	--	
15·29cm	100	5·6	5·4	69	5·7	—·2	74	75
	200	12·4	12·3	69	12·6	—·2		
	300	19·6	19·9	70	19·0	+·7		
	400	25·5	24·5	66	25·1	—·1		
100°	20	0·0	0·0	----	0·0	----	--	
15·78cm	100	7·6	7·5	94	7·4	+·1	96	97
	200	16·2	16·2	90	16·0	+·2		
	300	24·4	24·2	86	23·9	+·4		
	400	30·7	30·9	80	31·4	—·6		
185°	20	0·0	0·0	----	0·0	----	--	
17·05cm	100	12·3	12·2	153	12·2	·0	161	166
	200	26·1	25·9	144	25·8	+·2		
	300	38·0	37·8	135	37·8	+·1		
	400	48·3	48·5	127	48·8	—·4		
310°	20	0	0	----	†0	----		
19·5cm	100	3·3	3·2	407	3·1	+·2	448	487
	200	61·1	60·5	338	6·1	+·1		
	300	83·6	83·6	299	8·4	—·1		
	400	102·0	101·0	267	10·3	—·2		
310°								
16·47cm	20	0		----				
	100	3·4		425				
	200	62·4		347				
	300	82·5		295				
	400	102·0		269				

TABLE 19.

Thermal expansion of Thymol, $\frac{v}{V}\times 10^3$, referred to 28°.

Atm.=		20	100	200	300	400
$\theta=$	28°	0	0	0	0	0
	65	42	43	41	39	39
	100	76	73	71	68	65
	185	162	154	145	138	130
	310	329	293	263	239	220

* Liquid undercooled. † From both the 310° series.

Method of Discussion.

25. *Isothermal band.*—Having given certain corresponding values of pressure and volume obtained at any given temperature, let a close-fitting function be investigated, such that for the same pressures, the calculated values of volume decrement must eventually be greater than the observed decrements will be. Let another function be investigated, such that for the same pressures, the calculated values of volume decrement must eventually be less than the observed values will be. From the nature of the variation, the observed or actual relation between volume and pressure will probably lie within the band or pathway included between the two limiting functions in question.

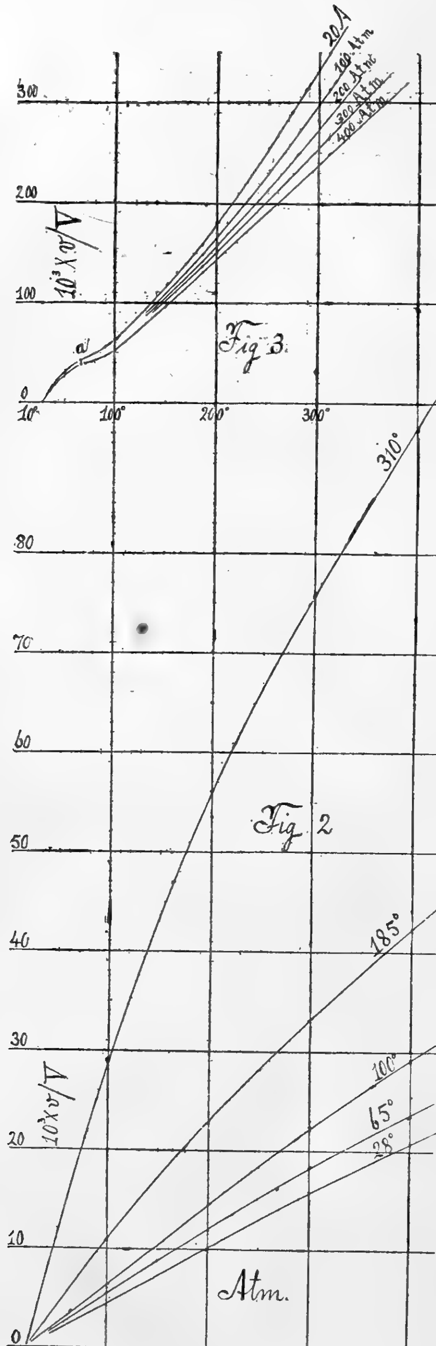


Fig. 2.—Isothermal decrements of para-toluidine, referred to unit of volume at 20 atm. and the respective isothermal temperatures.

Fig. 3.—Isopiestic increments of para-toluidine, under the same conditions. *a*, region of undercooling.

Suppose it is possible (the proof must be given by trial) to so adjust the two functions, that throughout the interval of observation they both fall within the limits of error. Then any property which is simultaneously predicted by both functions, may confidently be assumed as the property of the unknown isothermal. So long as the functions do not diverge seriously, there is here given a judicious mode of extrapolation, by which relations beyond the limits of experiment may be apprehended.

26. *Quadratic constants.*—In order to arrive at the probable nature of such functions, I passed parabolas through the observations. The ordinary vertical parabola is clearly inapplicable. It predicts a maximum and is therefore not compatible with the locus to be found. Nevertheless the zero-compressibility may thus be deduced, and from the relation of the two constants

inferences as to curvature may be obtained. In table 20 I have entered the two constants in question, supposing that $y_\theta = 10^3 \times v/V = mp - np^2$, where y_θ is a thousand times the volume decrement at pressure p. under conditions of constant temperature θ.

TABLE 20.

Quadratic constants.

Substance.	θ	$10^3 \times m$	$10^6 \times n$	Substance.	θ	$10^3 \times m$	$10^6 \times n$
Ether	310°	---	---	Diphenylamine	310°	197	92
	185	776	990		185	113	54
	100	340	346		100	64	3
	65	224	170		65	62	12
	29	167	107	Caprinic Acid	185	196	125
Alcohol	310	---	---		100	116	46
	185	---	---		65	92	27
	100	178	209		30	71	5
	65	111	28	Paraffine	310	349	320
	28	87	20		185	177	110
Palmitic Acid	310	315	267		100	110	43
	185	161	93		65	83	9
	100	100	36	Thymol	310	435	484
	65	88	25		185	159	85
Para-Toluidine	310	387	404		100	97	40
	185	141	81		65	69	2
	100	81	6		28	67	26
	65	69	25				
	28	56	3				

COMPRESSIBILITY INCREASING INVERSELY AS THE FIRST POWER OF THE PRESSURE BINOMIAL.

27. *Transition to exponential constants.*—These data show that compressibility increases at a rapidly accelerated rate with temperature, and that compressibility m and the datum for curvature n, are intimately related. This suggests the probability of a fundamental relation between y_θ and p, independent of the material operated on. § 38. In case of alcohol and ether at 310°, quadratic constants are manifestly impossible; for the maximum would lie within the field of observation. This is to some extent true for ether at 185°. Rejecting these exceptional cases, and considering the relation of m and n separately for each substance and collectively for all, it appears that a relation $2n = b(m-a)$ is available for trial. Since $y = mp - np^2$, or $dy/dp = m(1 - 2np/m)$, replace m by ϑ and $2n/m$ by α, for the sake of distinction. Then inasmuch as the quadratic equation applies more accurately in proportion as p is small, it may be nearly replaced by $dy/dp = \vartheta/(1+\alpha p)$, whence

$$y = ln(1+\alpha p)^{\vartheta/\alpha} \quad . \quad . \quad . \quad . \quad (2)$$

This equation has an advantage over the other, since it does not predict a maximum. It is therefore more in keeping with the isothermals of the above pages. In view of its simplicity, and of the additional fact that for $p=\infty$, $y=\infty$ generally, it may be taken as one limit of the isothermal band described in § 25.

$(A+p)$, where A is constant, is conveniently termed the *pressure binomial.* Approximate values of the constants in (2) might be derived from table 20, since $\alpha=b(m-a)/m$, and $\vartheta/\alpha=m^2/b(m-a)$, nearly. I was inclined to infer that at the melting point, for the above class of substances, compressibility is constant and independent of pressure. In such a case $\vartheta=\alpha$ would be the criterion of fusion. Subsequent results did not substantiate this surmise. Another similar inference that the resistance to compression is equal to the incipient resistance to extension even in liquids, and that therefore $1/\vartheta$ must have a constant value at the boiling point independent of substance is not warranted by the experiments made.

28. *Properties of the exponential.*—Certain salient properties of equation (2) may be grouped together here. The occurrence of $y=10^3v/V=\infty$ for $p=\infty$ is not a fatal objection against the equation. For its application necessarily ceases at a finite value of p, i. e. at the point of solidification of the substance, by pressure. As far as this point equation (2) may faithfully represent the volume decrements observed. Suppose for a given substance $y'=ln(1+\alpha_0(p+p_0))^{\vartheta_0/\alpha_0}$ and simultaneously $y_0=ln(1+\alpha_0 p_0)^{\vartheta_0/\alpha_0}$, where p and p_0 are any two consecutive intervals of pressure. Then

$$y=y'-y_0=ln\left(1+\frac{\alpha_0}{1+\alpha_0 p_0}p\right)^{\vartheta_0/\alpha_0} \quad . \quad . \quad . \quad . \quad (3)$$

Hence, if $\alpha=\alpha_0/(1+\alpha_0 p_0)$ and $\vartheta=\vartheta_0/(1+\alpha_0 p_0)$, equation (3) at once reverts to the form (2). Thus from the observations y made along any arc of the whole curve, between $p=0$ and $p=p$, it is at once possible to obtain the constants for the whole curve referred to an origin at zero atmospheres, by the equations

$$\alpha_0=\alpha/(1-\alpha p_0) \text{ and } \vartheta_0=\vartheta/(1-\alpha p_0) \quad . \quad . \quad . \quad . \quad (4)$$

so that the reductions are simple. Equations (4) suggest an important consequence: when $\alpha p_0>1$, both α_0 and ϑ_0 become imaginary. It is a matter for curious remark, that this takes place in case of ether and of alcohol, near or above the critical temperature. I inferred that the compressibility of liquids $d\frac{v}{V}/dp=-\vartheta/(1+\alpha p)$ changes form and passes into the compressibility of gasses $\frac{dv}{v}/dp=-1/p$, through an imaginary form.

When p is small, $y=\vartheta p(1-ap/2)$, which will be further simplified in the next paragraph.

The expression for compressibility has a counterpart* which is applicable for thermal expansion, viz:

$$d\frac{v}{V}/d\theta=\tau/(1-\beta\theta).$$

This application must be omitted here.

Finally the change of p when regarded as a function of the radius ρ of any unit sphere within the compressed liquid is of interest. It appears that $p=(e^{a(1-\rho^3)/\vartheta}-1)/a$. This equation points out the nature of the inadequacy of (2); for if ρ decreases indefinitely, p eventually becomes $(e^{a/\vartheta}-1)/a$. In the next paragraph a/ϑ is found to be nearly 9. Hence the limit in question is $8290/a$. In the cases where (2) applies this value lies somewhere between 10^6 and 10^7 atmospheres. Hence the interval within which (2) may apply satisfactorily is reasonably large; for the pressures stated are such as would be met with at the center of the earth for instance.

29. *Direct computation.*—After the suggestions contained in § 27, approximate values for the constants in the equation $v/V=ln(1+ap)^{\vartheta/a}$ are easily derived.† Constants thus obtained are crude. Hence starting with these, I computed more accurate data by a method of gradual approximation, finally selecting such values of ϑ and a as reduced the errors to a reasonably small amount. This computation is exceedingly tedious and unsatisfactory at best, because pairs of values of ϑ and a differing very widely from each other, are often found to satisfy the equation about equally well. Nevertheless it was necessary to avoid any scheme of selection other than the criterion of errors specified, the object being to obtain a set of exponential constants independent of ulterior purposes or considerations. The results are given in table 21, in which the first column contains the initial pressure p_0 for which ϑ and a apply at the temperature θ. The table also contains the ratio $2{\cdot}3\ \vartheta/a$, the factor reducing it to common logarithms. At the end of the table I have added the mean datum $2{\cdot}3\ \vartheta_0/a_0$, derived from all the values of the table.

30. *Investigation of mean constants.*—The tabulated constants for ether and alcohol above 185°, substantiate the remarks made in § 28, relative to the limited high temperature application of $v/V=ln\ (1+ap)^{\vartheta/a}$. The critical temperatures

* Applying this equation to the isopiestics of ether between 30° and 310°, I found the observations well reproduced, in a way to include the remarkable volume changes at and above the critical temperature.

† Reference to y is conveniently dropped here.

of these substances are 195° and 234°, respectively. Hence ether shows an imaginary ϑ_0 even at 185°, and both liquids do so at 310°.

TABLE 21.

Exponential constants. Direct computation.

Substance.	θ	$\vartheta \times 10^6$	$a \times 10^3$	$10^3 \times 2{\cdot}3\vartheta/a$
Ether	310	31800	280	261
p_0=100	185	1130	12·0	217
	100	361	3·8	218
	65	225	2·0	259
	30	167	1·6	240
Alcohol	310	15000	140	247
p_0=150	185	351	3·9	207
	100	164	2·0	189
	65	116	1·2	223
	30	88	·6	336
Palmitic Acid	310	332	3·0	250
p_0=20	185	160	1·5	245
	100	104	1·0	238
	65	89	.8	257
Para-	310	421	4 5	215
Toluidine	185	145	1·7	196
p_0=20	100	82	·4	470
	65	68	·5	315
	28	57	·3	440
Diphenyl-amine	310	216	2·0	248
	185	113	1·2	217
p_0=0	100	68	·5	311
	65	62	·3	470
Caprinic Acid	---	----	---	---
p_0=20	185	201	1·9	243
	100	114	1·0	263
	65	92	·7	303
	30	77	·7	252

Substance.	θ	$\vartheta \times 10^6$	$a \times 10^3$	$10^3 \times 2{\cdot}3\vartheta/a$
Benzoic Acid p_0=20	185	140	1·4	230
Paraffine	310	362	3·2	260
p_0=20	185	180	1·8	231
	100	113	1·1	232
	65	89	·8	256
Thymol	310	466	4·7	230
p_0=20	185	163	1·6	234
	100	100	1·2	191
	65	74	·7	243
	28	65	·6	248
Monobrom Camphor p_0=20	185	121	1·0	280
	100	82	·5	376
a-Naphtol p_0=20	185	86	·8	246
	100	63	·7	207
Vanilline p_0=20	185	96	·9	235
	100	59	·5	271
Azo-Benzol p_0=20	185	130	1.2	250
	100	80	·8	229

Mean $2{\cdot}3\vartheta/a = {\cdot}257 \pm {\cdot}008$

$\vartheta/a = {\cdot}1119 = 1/9$ nearly.

The last column 2·3 ϑ/a is of special interest. Looking at these results as a whole and taking the enormous range of variation fully into account, it appears that ϑ and a are not only closely related, but that this relation is linear. The values 2·3 ϑ/a, though frequently irregular show no consistent grouping. It is also to be remembered that the computation of table 21 was an entirely independent procedure. Values more nearly in keeping with the mean ratio ϑ/a could easily have been obtained had I entered into the work with any bias. Hence it is justifiable to regard the equation

$$v/V = ln\ (1 + 9\vartheta p)^{1/9}$$

as applicable to the whole series of organic substances examined. With this point of departure I made a recalculation of ϑ, and have inserted the results in tables 4 to 14 above. Table 22 contains additional substances.

TABLE 22.

Mean exponential constants. $v/V = ln\,(1+9\vartheta p)^{1/9}$.

Substance.	θ	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$	$1/\vartheta_0$
Ether	29	165	194	6060
p_0=100	65	226	282	4420
B. P.=34°	100	343	497	2910
	185	1005	10060	990
	310	34250	*	290
Alcohol	28	89	101	11240
p_0=150	65	115	136	8700
B. P.=78°	100	158	201	6330
	185	331	598	3020
	310	13830	*	720
Palmitic	65	91	93	10750
Acid	100	102	104	9610
p_0=20	185	160	165	6060
B. P.=350° M. P.=62°	310	330	351	285
Para	28	59	60	16670
toluidine	65	68	69	14490
p_0=20	100	87	88	11360
B. P.=198° M. P.=43°	185	138	142	7040
	310	392	422	2370
Diphenyl-	65	65	65	15380
amine	100	69	69	14490
p_0=0	185	110	110	9090
M. P.=54° B. P.=310°	310	213	213	4690
Caprinic	30	76	76	13160
acid	65	95	97	10310
p_0=20 M. P.=30°	100	119	121	8260
B. P.=270°	185	200	207	4830
Benzoic acid				
p_0=20 M. P.=121°	185	138	141	7090
B. P.=249°				
Paraffine	64	88	†89	11240
p_0=20	100	111	114	8770
M. P.=55°	185	178	184	5430

Substance.	θ	$\vartheta \times 10^6$	$\vartheta_0 \times 10^6$	$1/\vartheta_0$
	310	366	392	2550
Paraffine	65	-----	†100	10000
p_0=10	100	-----	118	8470
	185	-----	186	5380
α Naphtol.				
p_0=20	100	62	62	16130
M. P.=94°	185	85	87	11490
B. P.=280°				
Thymol.	28	65	66	15150
p_0=20	64	74	75	13330
M. P.=53° B. P.=233°	100	96	97	10310
	185	161	166	6020
	310	448	487	2050
Monobrom				
camphor	100	83	85	11760
p_0=20	185	123	126	7940
M. P.=76°				
B. P.=274°				
Azo-				
Benzol				
p_0=20	100	79	80	12500
M. P.=68°	185	131	134	7460
B. P.=293				
Vanilline				
p_0=20	100	58	58	17240
M. P.=80°	185	92	93	10750
B. P.=285°				
‡Naphtha'ne	100	93	97	10310
p_0=50	153	115	121	8260
M. P.=80°	185	133	141	7090
B. P.=215°				
‡Monochlor-				
acetic acid	65	-----	72	13900
p_0=0	185	-----	142	7040
M. P.=62°				
B. P.=188°				

31. *Subsidiary inferences.*—If $1/\vartheta_0$, the resistance to compression, be constructed as a function of temperature, θ, it will be seen that except in the extreme cases of ether and alcohol, $1/\vartheta_0$ decreases nearly proportional to θ, at a rate nearly the same for all the substances examined. Again if the values of ϑ at melting points and boiling points be found, no perspicuous relation is discernable. This substantiates the remarks of § 27. Turning to tables 4 to 14 it appears by consulting the difference columns, that the errors of v/V are

* Imaginary. Reciprocals of ϑ are taken. † Solidification.
‡ Results of an older method.

within the range of accuracy specified in the critical paragraphs 9 to 15.

TABLE 23.

Isothermals of Ether, referred to unit of volume at 28° and 100 atm.

$\theta=$	*310°	185°	100°	65°	28°	Isometrics. θ	Δp	Volume.
$p=0$	----	----	----	----	----	28°	0	1·00
100	2·77	1·397	1·131	1·057	1·000	65	310	
200	1·70	1·298	1·097	1·035	·984	100	600	
300	1·50	1·236	1·071	1·017	·971	185	1300	
400	1·38	1·193	1·049	1·001	·959	Rate ·12° per atmosphere.		
500	1·29	1·159	1·030	·987	·948			
600	1·22	1·132	1·014	·974	·938			
700	1·16	1·109	1·000	·963	·929			
800	1·12	1·088	·986	·953	·921			
900	1·08	1·069	·975	·944	·913			
1000	1·04	1·053	·964	·935	·906			
1100	1·01	1·039	·955	·927	·899			
1400	·93	1·001	·929	·904	·881			
1600	·88	·983	·914	·893	·870			

TABLE 24.

Isothermals of alcohol, referred to unit of volume at 28° and 150 atm.

$\theta=$	310°	185°	100°	65°	28°	Isometrics. θ	Δp	Volume.
$p=0$	----	----	----	----	----	28°	0	1·0
150	2·29	1·229	1·087	1·035	1·000	65	367	
250	1·63	1·193	1·071	1·024	·991	100	740	
350	1·47	1·165	1·057	1·014	·983	185	1470	
450	1·37	1·142	1·044	1·004	·976	Rate ·10° per atmosphere.		
550	1·29	1·122	1·033	·996	·969			
650	1·24	1·105	1·022	·988	·963			
750	1·19	1·089	1·013	·980	·956			
850	1·16	1·075	1·004	·973	·951			
950	1·12	1·063	·995	·966	·945			
1050	1·09	1·051	·988	·960	·940			
1150	1·06	1·041	·980	·954	·935			
1450	1·00	1·013	·961	·938	·921			
1650	·96	0·997	·949	·928	·912			

32. *Isothermals computed.*—From these results the actual isothermals of the above substances can be constructed. To recapitulate: the volume decrement $v/V = ln(1+9\vartheta p)^{1/9}$, refers in all cases to unit of volume at the temperature of the isothermal and under the initial pressure p_0. The compressed volume is therefore $1 - ln\ (1+9\vartheta p)^{1/9}$; and if in consequence of the *observed* thermal expansion at p_0, the volume at θ be v_θ, the actual isothermal is

* Special measurement, made later.

$$v_{\theta p} = v_\theta (1 - ln(1 + 9\vartheta p)^{1/9}) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

referred to the initial temperature θ_0. v_θ is directly measured. Hence the only hypothesis occurring in equation (5) is equation (2). In tables 23 to 28 I have given the value of $v_{\theta p}$ computed conformably with equation (5), for the temperatures of observation. If these results be constructed graphically, the conditions subject to which pressure and temperature must vary, in order that $v_{\theta p}$ may remain constant are given by drawing horizontals. In the supplementary tables certain isometric data are inscribed.

TABLE 25.

Isothermals of Diphenylamine, referred to unit volume at 65° and 0 atm.

θ=	310°	185°	100°		Isometrics.		
					θ	Δp	
p= 0	1·235	1·093	1·012	1·000	65	0	1.00
100	1·211	1·082	1·006	·994	100	190	
200	1·191	1·071	·999	·988	185	1200	
300	1·173	1·061	·993	·982			
400	1·157	1·053	·988	·977	Rate ·09° per atmosphere.		
500	1·143	1·044	·982	·971			
600	1·130	1·036	·976	·967			
700	1·119	1·029	·972	·962			
800	1·108	1·022	·967	·957			
900	1 098	1·016	·962	·953			
1000	1·089	1·010	·958	·949			
1300	1·064	·993	·945	·937			
1500	1·050	·983	·938	·930			

TABLE 26.

Isothermals of Thymol, referred to unit volume at 20° and 20 atm.

θ=	310°	185°	100°	65°	28°	Isometrics.		
						θ	Δp	Volume.
p= 20	1·329	1·162	1·076	1·042	1·000	65	40	1·04
120	1·279	1·145	1·066	1·035	·994	100	410	
220	1·242	1·129	1·057	1·028	·988	185	1090	
320	1·212	1·116	1·049	1·021	·982	310	1500	
420	1·188	1·103	1·041	1·015	·977	Rate ·11° per atmosphere.		
520	1·167	1·092	1·033	1·009	·972			
620	1·148	1·081	1·026	1·003	·967			
720	1·131	1·072	1·020	·998	·962			
820	1·116	1·064	1·013	·993	·957			
920	1·103	1·055	1·007	·988	·953			
1020	1·091	1·047	1·002	·983	·949			
1320	1·059	1·026	·986	·970	·937			
1620	1·040	1·014	·977	·961	·930			

33. *Isometrics.*—Some remarks on these tables are essential. In case of alcohol the curves for 28° to 185° are a family of

like properties. The curve for 310° intersects these at high pressure. This, however, was suggested in § 28, since above the critical temperature the *mean* equation (2), is not applicable. The chief result of the table is given in the supplement, for $v_{\theta p}=v_{28,150}=1$. It appears that θ and p as far as 185°

TABLE 27.

Isothermals of Paraffine, referred to unit volume at 65° and 20 atm.

$\theta=$	310°	185°	100°	65°	Isometrics. θ	Δp	Volume.
$p=$ 20	1·241	1·108	1·026	1·000	65	0	1·00
120	1·202	1·090	1·015	·991	100	250	
220	1·171	1·074	1·005	·983	185	880	
320	1·146	1·060	·996	·975	310	1430	
420	1·125	1·047	·988	·968	Rate 1·3° per atmosphere.		
520	1·107	1·036	·980	·962			
620	1·091	1·025	·973	·956			
720	1·076	1·016	·966	·950			
820	1·063	1·007	·959	·945			
920	1·051	·999	·953	·939			
1020	1·040	·991	·947	·935			
1320	1·012	·970	·931	·921			
1520	·995	·958	·922	·912			

TABLE 28.

Isothermals of Para-Toluidine, referred to unit volume at 28° and 20 atm.

$\theta=$	310°	185°	100°	65°	28°	Isometrics. θ	p	Volume.
	----	----	----	----	----	65	25	1·04
$p=$ 20	1·348	1·158	1·063	1·042	1·000	100	270	
120	1·303	1·143	1·054	1·035	·994	185	1200	
220	1·268	1·130	1·046	1·028	·989	Rate ·10° per atmosphere.		
320	1·240	1·117	1·038	1·022	·983			
420	1·216	1·106	1·030	1·017	·978			
520	1·196	1·096	1·023	1·011	·973			
620	1·178	1·087	1·017	1·006	·969			
720	1·162	1·078	1·011	1·001	·965			
820	1·147	1·069	1·005	·996	·960			
920	1·134	1·062	1·000	·992	·956			
1020	1·122	1·055	·994	·987	·952			
1320	1·090	1·035	·979	·974	·941			
1520	1·072	1·023	·970	·967	·934			

are linear functions of each other. The rate of change is ·10° C. per atmosphere.

Similar remarks apply for ether, where conformably with the lower critical point, the high temperature discrepancy is more pronounced. The rate of variation of θ and p for $v_{\theta p}=v_{28,100}=1$ is here ·12° per atmosphere.

In case of paraffine, which is the first substance solid at ordinary temperature, $v_{\theta p}=1$ shows a somewhat larger variation of θ relative to p, the rate being ·13° C. per atmosphere. The rate for thymol is ·11° per atmosphere, for toluidine ·10° per atmosphere, for diphenylamine ·09 per atmosphere. In most of these cases the expansion difficulties, § 14, make the present results irregular, particularly in the case where two or more threads are observed. At 310° the behavior is usually exceptional, the discrepancy which shows itself is similar to the case of ether and alcohol, but much less pronounced.

4.

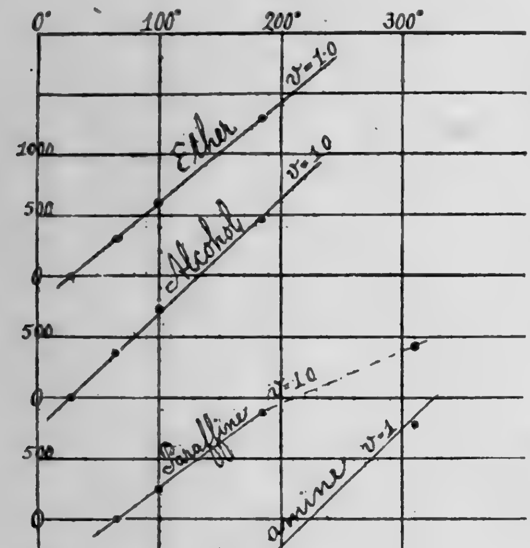


Fig. 4. Isometrics of Ether, Alcohol, Paraffine, Diphenylamine, Toluidine and Thymol. *a*, region of undercooling.

In figure 4 I have represented these relations graphically. It is seen at once that the errors left show no march. For diphenylamine the distribution is zigzag; for toluidine and thymol in an opposite sense for the two cases.

Taking these results (0° to 185°) as a whole it follows with remarkable uniformity that if temperature and pressure vary linearly with each other, at a rate of about ·1° C. per atmosphere, there will be no change of volume. More rigorously: *if with the observed thermal expansion compressibility be supposed to increase inversely as the first power of the pressure binomial* (§ 27), *then temperature and pressure must vary linearly to maintain constancy of volume.* Change of the state of aggregation is excluded. The thermodynamic signification of this result has been suggested in § 2. So far as the present results go, 0° to 185°, the surface $v_{\theta p}$ will be generated by moving the initial section, when θ is constant, parallel to itself, in such a way that each point describes an oblique horizontal. It is not to be inferred that these horizontals are parallel, though within the limits of the above investigation such a result is nearly given.

Compressibility increasing inversely as the square of the pressure binomial.

34. *Properties of the equations.*—Equation (2) as used in § 27, furnished a family of curves which in their ultimate contour necessarily fall below the corresponding isothermals of the substance under discussion. It is the object of this section to investigate a similar family, the ultimate contours of which are above the actual isothermals. This may be done by assuming $d\frac{v}{V}/dp=\mu/(1+\nu p)^2$, whence

$$v/V=\mu p/(1+\nu p) \quad . \quad . \quad . \quad (6)$$

In this case, when $p=\infty$, $v/V=\mu/\nu=2/9$, as will be seen in the following tables. In the actual case,* v/V, though it can not be greater than 1, will in all probability eventually exceed 2/9.

The method of discussion to be adopted is similar to that in the foregoing section. Let

$$y_0=\mu_0 p_0/(1+\nu p_0) \text{ and } y'=\mu_0(p_0+p)/(1+\nu(p_0+p)).$$

Then $y=y'-y_0=\mu_0 p/((1+\nu_0 p_0)^2(1+\nu_0 p)/(1+\nu_0 p_0))$; or if

$$\mu=\mu_0/(1+\nu_0 p_0)^2 \text{ and } \nu=\nu_0/(1+\nu_0 p_0) \quad . \quad (7)$$

equation (6) again results. Hence if p_0 and p are consecutive pressure intervals between 0 and $p+p_0$, then the constants obtained from observations within the interval p, may be reduced to those applying to the whole interval p_0+p, by equations (7), or their equivalents

$$\mu_0=\mu/(1-\nu p_0)^2,\ \nu_0=\nu/(1-\nu p_0) \quad . \quad . \quad (8)$$

According to Mendeleef, Thorpe and Rücker, (l. c.), the volume of liquids in case of thermal expansion may be represented by $V_\theta=1/(1-k\theta)$, where pressure is constant, V_θ the actual volume at temperature θ, and k a constant. Introducing equation (6) and denoting by V, the volume for pressure p and temperature θ, $V=(1+(\nu-\mu)p)/(1-k\theta)(1+\nu p)$, which for pressures and temperatures not too great may be put $V=1+(\nu-\mu)p/(1-k\theta+\nu p)$. If, therefore, $V=V_c$ is constant,

* Cf. Rücker (Nature, xli, p. 362, 1890). Converging lines of evidence obtained from optical, electrical and thermal researches show that liquids can not be compressed more than ·2 to ·3 of their normal bulk.

$\theta = -(1-V_c)/kV_c + p(\nu(1-V_c)-\mu)/kV_c$; so that in case of constant volume, temperature varies linearly with pressure, small intervals of variation presupposed. The rigorous deduction from (6) and Mendeleef's equation is $kV_c\theta = -(1-V_c) + \mu p/(1+\nu p)$, which is linear in proportion as νp is small compared with 1. In § 33 it was shown that the relation of θ and p is probably linear throughout great intervals. It follows that (6) is insufficient for large ranges of pressure. Finally regarding Mendeleef's equation, it follows, if θ_0 and θ be two consecutive intervals of temperature, the former measured from zero, that $V_0 = 1/(1-k_0\theta_0)$, $V_\theta' = 1/(1-k_0(\theta_0+\theta))$, and $V_\theta = 1 + V_\theta' - V_0 = (1+k^2\theta\theta_0)/(1-k\theta)$, if $k = k_0/(1-k_0\theta_0)$. Thus observations may be referred to any convenient temperature as a point of departure.

35. *Computation of hyperbolic constants.*—Applying equation (3) to the observations in § 15 to 24, I obtained the constants given in table 29. Clearly ν must be some function of μ; but the observations are now too crude to indicate its nature. If the ratios of ν to μ be found either graphically or by computation, the consecutive values show no discernable march or grouping. Hence I assume this ratio to be constant, and add its mean value in the table. As before the ether and alcohol points at 310° are to be excluded, and the discrepancy is apparent in the ether point for 185°.

TABLE 29.

Hyperbolic constants. Direct computation.

θ	$\mu\times10^6$	$\nu\times10^6$	θ	$\mu\times10^6$	$\nu\times10^6$	θ	$\mu\times10^6$	$\nu\times10^6$
Ether			Toluidine			Paraffine		
29	169	830	28	56	58	65	85	191
65	228	1030	65	70	413	100	111	475
100	353	1570	100	81	110	185	181	845
185	1028	3870	185	146	801	310	368	1510
Alcohol			310	401	1730	Thymol		
28	87	243	Diphenylamine			28	68	465
65	111	276	65	61	162	65	69	157
100	182	1630	100	69	285	100	99	553
185	348	1755	185	114	613	185	162	715
			310	215	889	310	465	2000

Mean $\nu/\mu = 4{\cdot}5$.

36. *Mean constants.*—Utilizing the ratio $\nu/\mu = 4{\cdot}5$, I constructed the next table. The agreement as a whole is not as good as were the data for ϑ and α in § 30.

37. *The isothermal band.*—With the constants of table 30, I computed the actual isothermals, in the way suggested in § 32. Expansion being directly observed, the only hypothesis introduced is equation (6). The results so obtained are to be tabulated in the manner shown in tables 23 to 28, with which they

are to be compared. The two sets of results then exhibited the upper and the lower limit of the isothermal band, § 25. I will omit the new results here and confine myself to a statement of the degree of accordance.

TABLE 30.

Hyperbolic constants. Mean values. $v/V = \mu p/(1 + 4{\cdot}5\ \mu p)$.

Substance.	θ	$\mu \times 10^6$	Substance.	θ	$\mu \times 10^6$
Ether	29	167	Diphenylamine	65	64
	65	229		100	69
	100	354		185	112
	*185	1220		310	216
Alcohol	28	89	Paraffine	65	88
	65	115		100	112
	100	163		185	181
	185	340		310	382
Para-Toluidine	28	59	Thymol	28	66
	65	69		65	73
	100	86		100	97
	185	141		185	162
	310	412		310	481

* Equation begins to fail.

In case of ether the divergence, or the width of the band at 1000 atm. is ·4 per cent at 28°, 1 per cent at 65° and at 100°. At 185° the hyperbole begins to fail. Constructing the isometrics for p and θ, when $V_c = 1$, it is seen that whereas for the exponential formula (2) the straight line is predicted as far as 185° and 1300 atm., this is not the case with the hyperbolic equation, for which the isometrics are straight only below 100° and 700 atm.

The conformity of results for alcohol is better throughout. At 1000 atm., the divergence at 28° is nil; at 65° it is 2 per cent; at 100°, ·3 per cent; at 185°, 2 per cent. When $V_c = 1$, the exponential relation is satisfied by linear isometrics as far as 185° and 1500 atm. The hyperbola admits of this only below 100° and 700 atm.

Divergences in case of paraffine at 1000 atm. is ·1 per cent at 65°, ·2 per cent at 100°, ·7 per cent at 185°, 6 per cent at 310°. As far as 185° and 900 atm. both isometrics are linear. At 310° both show curvature, toward opposite sides of the common line. The exponential is in better agreement. The divergence at 1000 atm. in case of diphenylamine is ·1 per cent at 65° and at 100°, ·2 per cent at 185°, 1 per cent at 310°. The linear isometrics hold almost to 310°. Thymol at 1000 atm. shows a divergence of ·1 per cent at 28°, ·2 per cent at 65°, ·1 per cent at 100°, ·6 per cent at 185°, 3 per cent at 310°. Finally, para-toluidine at 1000 atm. shows a divergence of nil at 28° and 65°, ·3 per cent at 100° and at 185°, 3 per cent at 310°.

38. *Conclusion.*—Summarizing these results it appears that the exponential $v/V=ln(1+ap)^{a/\vartheta}$ is more in keeping with the general character of the isothermals discussed than is the hyperbolic form $v/V=\mu p/(1+\nu p)$. Both equations *apparently* fail at 310°. It is difficult to assign a reason for this. It is not probably due to occluded air, since the substances were boiled and introduced into a hot capillary tube. Moreover in case of mercury (table 3) an air bubble discrepancy would necessarily have shown itself at 310°. Errors due to the fact that my curves must be in some small measure isentropic, would induce too slow a volume variation and hence only emphasize the break. There may be dissociation in some of the above organic substances at this high temperature. Azobenzol actually decomposes and turns black at 310°. What the effect of dissociation may be in modifying the computed isothermal is not easily conjectured; for the greater compressibility of the dissociated substances is in some degree compensated by larger initial volumes. Equation (2), however, must certainly begin to fail. Cf. § 28.

The high temperature break in question would result in case of inconstancy of temperature in the boiling tube. I did not test the thermal distribution; the behavior was such throughout that I see no reason to suspect inconsistency. Final reference might be made to the pressure expansion of the capillary tube.

To throw light on these particulars, I made the following direct measurements with ether, a case in which the high temperature break is most pronounced. Table 31 contains an example of the results. The isothermal are referred to unit of volume at 22° and 100 atm. To reduce them to 29° and 100 atm., conformably with table 23, the volumes at 310° are to be decreased 1·5 per cent. The length of thread at 22° is only $1{\cdot}85^{cm}$, thus enabling me to observe the whole thread at 310°. In other respects the work was done in the manner indicated above to make the different data comparable.

TABLE 31.

Isothermals of Ether. Direct measurement.

$\theta=300°$; $L_{100}=6{\cdot}00^{cm}$

p	Volume.	Volume.	p	Volume.	Volume.	p	Volume.	Volume.
atm.			*atm.*			*atm.*		
100	3·30	3·12	400	1·43	1·41	700	1·24	1·23
200	1 83	1·76	500	1·34	1·32	800	1·19	1·19
300	1·56	1·52	600	1·28	1·26	900	1·16	1·16
$\theta=22°$; $L_{100}=1{\cdot}84^{cm}$								
100	1·00	1·00	300	·97	·97			
200	·99	·99	400	·96	·96			

Constructing the isometric for $V_{\theta,p}=V_{29,100}=1$, it will be seen that the 310° point may be looked for in the region above 2000 atm. Hence, these observed results substantiate the computed isometric in figure 4, which predicts the corresponding point at 2300 atm. Nevertheless it cannot be too carefully noted, that if the isometrics for $V_{\theta,p}=1{\cdot}2, 1{\cdot}3, 1{\cdot}4, \ldots$ be constructed the break between 185° and 310° remains in full force, quite in conformity with the other data (alcohol, paraffine, etc.).

The full interpretation of these discrepancies is of great importance and will therefore be made the subject of my subsequent work. The isometric, curved as above, introduces certain interesting conditions of maximum volume.

The chief observational discrepancy remaining in the results is the expansion error encountered in case of substances which solidify between observations at different temperatures. Hence the effect of different volumes on the slope of the isometrics cannot be satisfactorily discussed. Since the compression measurements retain their value independent of the thermal expansion, and since the method pursued is such that all necessary measurements for thermal expansion can be made under atmospheric pressure, the difficulties may easily be rectified. For by using a bulb and stem arrangement, the purely thermal data can be supplied with any desired accuracy. This I conceive to be the advantage of the mode of investigation set forth in the present paper.

Among the important results of the above tables is the fact that compressibility moves in the even tenor of its way quite independent of normal boiling points and melting points, provided of course the conditions are not such that boiling or melting can actually occur. For this reason compressibility is particularly adapted for exploring the nature of the environment of the molecule in its relations to temperature, i. e. for exhibiting the character of the thermal changes of the molecular fields of force.

The above work though confined to relatively low ranges of pressure was believed to have a more general value for reasons such as these: instead of tracing the isothermals of a single substance throughout enormous ranges of pressure, similarly comparable results may possibly be obtained by examining different substances, conceived to exist in as widely different thermal states as possible. For in such a case, since the actual or total pressure is the sum of the pressures externally applied and the internal pressure, the total pressure in question virtually varies enormously. This calls to mind the remarks made in §§ 28, 34, relative to observations confined to a limited part of the isothermal.

Finally the work of the present paper may be looked at from quite a different point of view. Suppose for instance, I regard the linear isometric proposed by Ramsay and Young (l. c.) as an established fact. Then the chief result of the present work, viz: that the exponential equation (2) if applied to the observed changes of volume predicts a linear isometric throughout an enormous range of pressure, affords favorable evidence of the truth of the exponential equation in question. In other words, it is probable that along any isothermal compressibility increases inversely as pressure increased by a constant. The interpretation of this constant cannot now be given.

Since the above work was done, I have succeeded in constructing a screw compressor,* by aid of which 2000 atm. may be hydrostatically applied with facility. I have also constructed gauges suitable for the accurate measurement of such pressure. The general adjustment is of a kind that all necessary electric insulation of different parts of the apparatus is guaranteed, so that most of the measurements may be made electrically. With these advantages I hope to subject the data which the above pages have tentatively outlined, to a direct and more searching test.

Phys. Lab. U. S. G. S., Washington, D. C.

ART. LVII.—*On Hamlinite, a new rhombohedral Mineral from the Herderite locality at Stoneham, Me.*; by W. E. HIDDEN and S. L. PENFIELD.

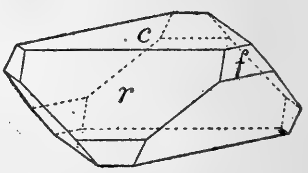
SHORTLY following the announcement of herderite† from Stoneham, the mineral, which we are about to describe, was detected by one of us occurring as minute rhombohedral crystals attached to the herderite and margarodite and associated with a mineral which was subsequently identified as the rare beryllium silicate, bertrandite. As the crystals were observed on only a single specimen and would not have weighed much more than 0·01 gram, if they could have been successfully detached from the matrix, it seemed imperative that more material should be obtained before commencing any investigation. During the past five years, therefore, we have kept up a diligent search for the crystals, examining carefully every available herderite specimen; we have also informed various

* A description of this apparatus will be found in the Transactions of the American Academy of the present year. I have now done much work with ether, tracing the isometrics directly as far as 1850 atm. and something over 215°, without however being able to reach a decision, May, 1890.

† This Journal, III, xxvii, pp. 73 and 135, 1884.

mineralogists of the occurrence of a probably new rhombohedral mineral, requesting them to examine the specimens in their own collections, but as up to the present time no success has attended our efforts we feel warranted in giving as complete a description as possible of the material in hand. We hope that in the future sufficient material may be obtained for a complete chemical investigation. We shall, moreover, consider it a great favor if the readers of this article will carefully examine the specimens of herderite which may be in their possession and aid us in securing the necessary material.

The system of crystallization is hexagonal-rhombohedral. The crystals vary from one to two millimeters in diameter and are quite flat from the predominance of the basal pinacoid. They exhibit the forms *c*, 0001, O; *r*, 10$\bar{1}$0, 1 and *f* 02$\bar{2}$1,−2, which are developed as shown in the accompanying figure. All of the planes are more or less uneven, especially *r*, which always yielded a number of reflections of the signal, so that it was quite impossible to obtain accurate measurements from them. The angle which was selected as fundamental was $f \wedge f$, 2$\bar{2}$01 $\wedge$ 02$\bar{2}$1 = 108° 2′ from which the length of the vertical axis $\dot{c}$ = 1·135 was calculated.



Other measurements resulted as follows:

		Measured.	Calculated.
$r \wedge r$,	10$\bar{1}$1 $\wedge$ 01$\bar{1}$1 =		87° 2′
$c \wedge r$,	0001 $\wedge$ 10$\bar{1}$1 =	about 55°	52° 40′
$c \wedge f$,	0001 $\wedge$ 02$\bar{2}$1 =	69° 15′ – 70° 30′	69° 7½′
$f \wedge r$,	02$\bar{2}$1 $\wedge$ 10$\bar{1}$1 –	53° 35′ – 54° 27′	54° 1′

The cleavage is perfect parallel to the base. The luster on the basal plane is pearly and on the rhombohedral faces is greasy vitreous, very similar to that of herderite. Some of the crystals are transparent and colorless, others show a faint yellow tint, owing probably to some impurity. Crystals lying on a basal plane, when examined under the microscope in convergent polarized light, show a perfectly normal, uniaxial interference figure, with positive and not very strong double refraction.

The hardness is 4·5. Specific gravity taken with the barium-mercuric iodide solution was 3·228.

Before the blowpipe the mineral fuses at about 4 to a white porcelain-like mass, coloring the flame pale green (P_2O_5). In the closed tube it gives abundant water which is strongly acid and etches the glass (F). It is slowly soluble in acids and gives with ammonium molybdate a strong P_2O_5 reaction. With H_2SO_4 it gives no micro-chemical reaction for Ca. The presence of P_2O_5 interfered with making the ordinary micro-chemical reactions, but a few tests, made on two small crystals by the usual analytical methods, indicate that alumina is probably present, while, from its association with herderite and bertrandite, beryllium may be expected. We have, therefore, undoubtedly a new species, a phosphate (probably of beryllium and aluminum) containing fluorine, and one which promises to be of unusual interest. As it seems best to designate the mineral by a distinctive name we propose for it the name *Hamlinite*, in honor of Dr. A. C. Hamlin of Bangor, Me., whose life-long interest in the development of the mineral resources of his state, and particularly of Oxford County (where this new mineral occurs), has tended to make that region famous as affording some of the most beautiful and highly interesting minerals known to science.

It is to be hoped that the mineral developments now going on in Oxford County will bring to light an abundant supply of this mineral, or enough, at least, to enable us to determine its chemical composition.

April 23d, 1890.

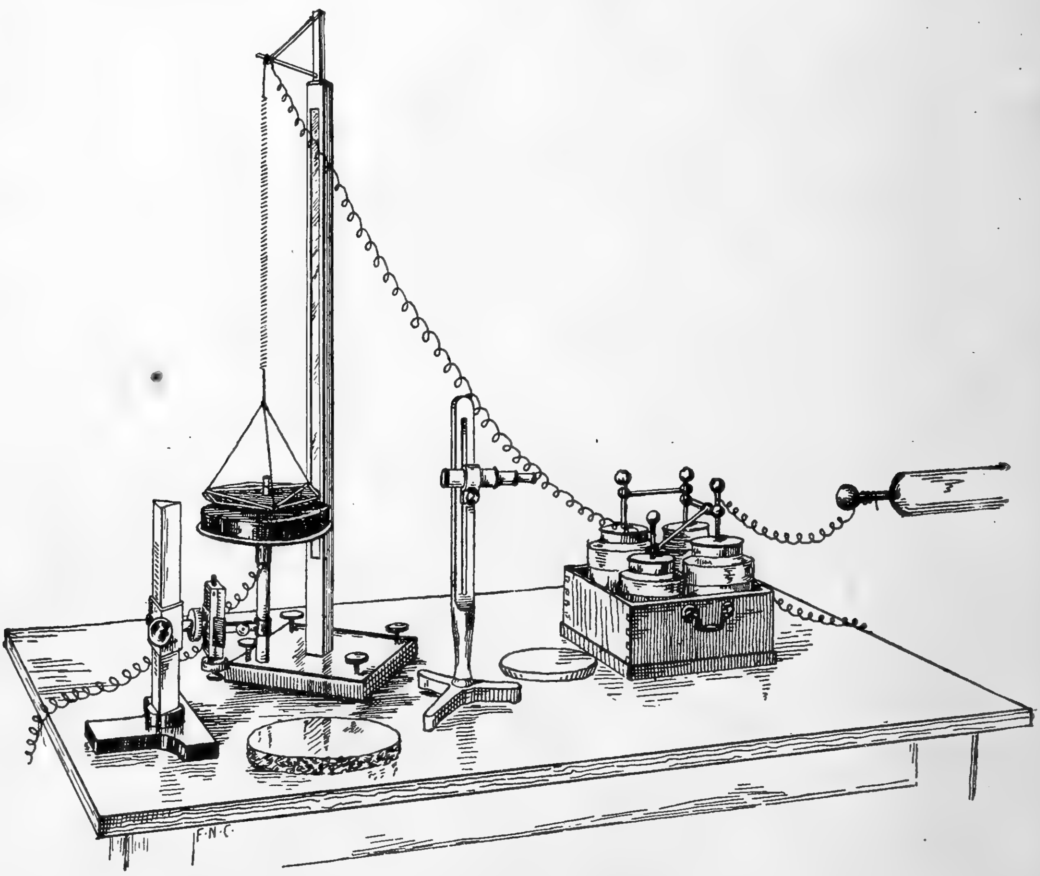
ART. LVIII.—*On a large spring-balance Electrometer for measuring (before an audience) specific inductive capacities and potentials;* by ALFRED M. MAYER.

THIS apparatus was devised by me for showing to my classes the general phenomena of induction through various dielectrics, and for making approximate measures of their specific inductive capacities. These phenomena and measurements are rarely shown to students, and when their exhibition is attempted the actions on the apparatus used are generally too minute to be seen by a class, and hence the measures deduced from these actions are unsatisfactory.

The apparatus here described has done excellent service during five courses of lectures. Its chief characteristic is that it shows *directly*, and not inferentially, that different dielectrics transmit the force of electricity in different degrees.

The engraving gives a general view of the apparatus. A helical spring, made of brass wire of ·012 in. diameter and with 800 turns, is supported by a bracket formed of rods of glass. These rods were dried by heating in a gas-flame and while hot were coated with parafin. To the lower end of the spring is suspended a disc of thin mica 16½ c.ms. in diameter, silvered on its upper and lower surfaces in a silvering solution. This disc, which was nearly flat, was made rigid and as nearly flat as possible, by cementing (under pressure) to its upper surface nine light and straight rye straws. Six of these formed chords of 60°, the other three formed an equilateral triangle included by the hexagon. This prevents flexure of the plate when it is suspended at three points by the fine wires shown in the figure. This silvered disc is surrounded by a guard-ring supported on three paraffined glass rods. The ring and rods are not shown in the figure.

Under the silvered disc and parallel to it is a brass plate connected with the earth, and moveable up and down by means of a rack and pinion and a micrometer-screw. In ordinary work



before a class the micrometer-screw is not required. The *difference* between the distances of the earth-plate from the mica-disc is only required in the measurement of specific inductive capacity, and this difference can be measured accurately enough by means of a millimeter scale cut on the column of the support of the earth-plate.

A tube of thin glass is cemented at the center of the top of the mica disc. On this tube is pasted a piece of paper with a fine line drawn on it parallel to the disc. Through the telescope on the right we sight on a horizontal thread this line, and when the apparatus is charged we can then always depress the mica-plate to the same level, and with the same force, by gradually raising the earth-plate.

The helical spring is connected with the Leyden battery, which latter is charged with + electricity from an electrical machine. To insure a constant charge during the two measures required to determine a specific inductive capacity, a simple torsion-balance carrying a gilded pith-ball is repelled by a similar ball at the end of a rod connected with the battery. A pointer on the torsion-rod moves over a graduated arc.

To show the general phenomena of the action of a dielectric compared with air, we charge the apparatus and bring up the earth-plate till the mica-disc is sensibly depressed by the attraction existing between it and the plate connected with earth. The disc of the dielectric is now slid on the earth-plate, when every one sees a considerable depression of the mica-disc by the increased force between the two plates through the intervention of the dielectric. Or, we may reverse the operation, and first place dielectric on earth-plate, then slowly raise this plate, with dielectric, till the attraction between earth-plate and disc has caused the latter to be depressed so far that it is just above the point from which it would descend to *contact* with the dielectric. Now suddenly slide dielectric from the earth-plate. The disc at once rises through a considerable distance, which is distinctly visible throughout the lecture-room. In the case of a glass disc of 2 c.ms. thick this upward motion may amount to 3 c.ms. and after a few oscillations the mica-disc comes to rest at a distance of about $1\frac{1}{2}$ c.ms. above its previous level.

To show the "electric absorption," "residual charge," "permeability," or "dielectric afterworking" (Boltzmann) of a dielectric we use a disc of paraffin. With this on the apparatus we raise the earth-plate till the mica-disc is sensibly attracted, and is stationary. This condition, however, only lasts for a short time. Soon the disc begins to descend, and after a minute or two has come near the paraffin, to whose surface it now rushes. It cannot now be detached till the battery has been discharged, or the earth-plate has been lowered so much as to unduly stretch the spring.

This experiment presents clearly a fact long known, that, with the exception of sulphur, all dielectrics, and especially paraffin are "permeated," or "polarized," in the condenser by time-action of induction, and so the attraction existing between the plates is increased. Boltzmann* shows from his experiments that with times of inductive action lasting $\frac{1}{360}$ to $\frac{1}{64}$

* Wiener, Sitzungsber., lxviii, 1873.

sec.; $\frac{9}{10}$ sec.; $1\frac{8}{10}$ sec.; and 45 secs., the specific inductive capacity of paraffin is respectively 2·32; 2·51; 2·56; and 8·12. Schiller's* experiments show that for times of charging plate-glass in the condenser of $\frac{1}{20000}$ and $\frac{1}{25}$ sec., the specific inductive capacity is respectively 5·83 and 6·34, or an increase of 9 per cent in ·03995 of a second. Wüllner† gives these conclusions from his experiments on the subject: "The instantaneous capacity (that is, the capacity when the charging lasts for a very small fraction of a second) is of quite a different nature to that capacity which increases slowly as the electrification continues. The 'instantaneous capacity' is independent of the conductivity—the 'slow capacity' is not."

To measure the specific inductive capacity of a substance, we place the guard-ring around the mica-disc. This ring has projecting from the edge of its circular opening three short fine wires, so adjusted that when the mica-disc rests on these wires the lower surfaces of disc and guard-ring are in the same plane. The apparatus having been charged, the dielectric is introduced and the earth-plate is raised till the mica-disc is attracted so that it rests on the three wires of guard-ring. The plate is now very slowly lowered till the tension of the spring just exceeds the attraction of plates, when the disc suddenly rises. The scale reading on support of earth-plate or of micrometer-screw is read. The dielectric is now removed and the disc brought down on the wires by raising earth-plate and then by lowering this plate the disc again leaves the wires, and the corresponding scale reading is taken. From the *difference* of the scale readings the specific inductive capacity is determined, as follows:

Let the scale reading when only air is between the plates be s; when the dielectric is introduced, $s_{,}$; then $s_{,}-s$ is the distance the earth-plate has been moved so as to give in the two experiments the same force of attraction on the mica-disc. A dielectric of thickness t and specific inductive capacity K equals in capacity a condenser with a thickness of air between plates equal to $\frac{t}{\mathrm{K}}$. Now when we introduce the dielectric plate it replaces a thickness of air, t. So the effect of introducing the dielectric is to increase the electric capacity of the apparatus as if we had brought the earth-plate and the mica-disc nearer by this distance t and then farther apart by the distance $\frac{t}{\mathrm{K}}$, which is the same as if we had diminished the distance between

* Pogg. Ann., clii, 1874.
† Sitzungsb. köngl. bayer. Acad., 1877.

the earth-plate and disc by $t-\frac{t}{K}$. But as in the two experiments the force on the mica-disc is equal, we must have caused an equal *decrease* in *capacity* by increasing the distance between earth-plate and disc by the quantity $s_{,}-s$, when the dielectric intervened, and this *measured* increase of distance equals the imaginary decrease of distance produced by the dielectric, and we have $t=\frac{t}{K}(s_{,}-s)$ and $K=\frac{t}{t-(s_{,}-s)}$.*

We use a disc of sulphur about $2\frac{1}{2}$ c.ms. thick as the body to experiment on in this measure before a class, as sulphur is very slightly, if at all, affected by time-induction during the interval occupied by the measure.

If the guard-plate be removed the phenomena become more apparent to the audience, but the measure is not so exact. In making measures without the guard-plate we use the telescope and the line on the glass tube, or, for ordinary qualitative illustration a pointer may replace these.

It need hardly be stated that measurements with this apparatus are of little value when compared with the measures made with the excellent apparatus of Gordon where entire control of the time of charging and means of measuring, very minute differences of capacity are used. Nevertheless the measures obtained with this apparatus are really more reliable than those obtained by some of the older experiments. The exhibition of the actions of this apparatus, however, are well worthy of being shown to students. The clear ideas and lasting impressions they give, from their directness and easy comprehension, will reward the teacher for the time he may give to the construction and use of the apparatus.

The same instrument will also measure potential, for it is really a huge and rough absolute electrometer. Certain precautions are, however, needed in its use in such measures. In the formulæ used in measurements with the absolute electrometer, $V = D\sqrt{\frac{8\pi W.g}{A}}$, or $V-V'=(D-D')\sqrt{\frac{8\pi W.g}{A}}$, one might suppose that W could be determined for the spring-balance electrometer by merely adding the weight in grams required to depress the silvered disc down to the level of the guard-plate; but, on electrifying the helical spring, its coils separate by mutual repulsion and a certain lengthening of the spring results. This action may be determined and allowed for by first ascertaining the weight of mica-disc and its wires and additional weight required to depress the disc to contact with the wires of guard-plate. The disc is now detached from

* See Gordon's Electricity and Mag., vol. i, p. 111.

the spring and placed on the guard-plate wires. On the top of the disc is a tube, in electrical connection with the disc, and containing mercury. The earth-plate is at the position it has when we are measuring potential. The spring is so stretched by a weight that the straight end of its wire dips into the mercury in the tube on the mica-disc, and the apparatus is charged to the same potential it has when we are making a measure of that potential. We now ascertain the weight required to stretch the spring to the same extent it was stretched in the previous experiment. The difference in weight required in the two experiments gives the repulsive action of the electricity on the spring. This correction, however, is not precise, for the wire at the end of spring is slightly pushed upward by the mutual action of the electrified wire and mercury.

Stevens Institute of Technology, Hoboken, N. J.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Emission-spectrum of Ammonia.*—Magnanini has examined the spectrum given by the flame of ammonia when burning in oxygen gas, and has given in a table the wave-lengths, intensities and peculiarities of the lines and bands existing in the region from wave-length 6666 to 4492. The spectrum of ammonia obtained in this way, is much richer and more complex than that obtained by means of the electric spark. On comparing the spectrum of burning ammonia with the spectra of ethylamine and trimethylamine obtained in the same way with suitable access of oxygen, it is easy to recognize in the latter besides Swan's spectrum of the burning gaseous organic compounds, the ammonia spectrum also, though its intensity is feeble. A comparison of the ammonia spectrum with the spectrum of hydrogen of the second order, shows that a large number of lines in both spectra coincide exactly so far as position goes, but do not agree either in intensity or in appearance otherwise. Whether this coincidence is real or only apparent, resulting from insufficient dispersion, must be determined by further observations.—*Zeitschr. Phys. Chem.*, iv, 435; *Ber. Berl. Chem. Ges.*, xxiii, (Ref.) 171, March, 1890. G. F. B.

2. *On the Absorption-spectrum of Nitrosyl Chloride.*—The absorption-spectrum of gaseous nitrosyl chloride, prepared by acting on sodium nitrite with phosphoric chloride in excess, has also been examined by Magnanini. The chloride was contained in a glass tube 49^{cm} long, so blown at the ends as to give nearly plane and parallel surfaces. The spectrum resembles closely that of the liquid chloride, being a band spectrum, not broken up into lines. It consists of three bands in the red, of which the middle

one is the strongest, and three bands in the green-blue, weaker than the others. From wave-length 5268 the general absorption rises to 5203, becoming total for the more refrangible region beyond this. The wave-lengths of the six bands characteristic of nitrosyl chloride are given as 6228–6133, 6063–5970, 5898–5843, 5634–5600, 5432–5581 and 5411–5363.—*Zeitschr. Phys. Chem.*, iv, 427; *Ber. Berl. Chem. Ges.*, xxiii, (Ref.) 171, Mch. 1890. G. F. B.

3. *A Dictionary of Applied Chemistry;* by T. E. THORPE, assisted by eminent contributors. In three volumes. Vol. I, London, 1890 (Longmans, Green & Co.).—In a notice of the new edition of Watts's Dictionary of Chemistry in a recent number (vol. xxxviii, 409) attention was called to the fact that the plan, that had been adopted, contemplated a companion work which should deal with the application of chemistry to the arts. The first volume of this work has now appeared, under the able editorship of Professor Thorpe and well fulfills the promises that were made for it. The subject matter differs in this case from that treated of in the work on theoretical chemistry in that the variety and mass of material is less great and hence the necessity for compression and the great amount of abbreviation does not exist, which it must be confessed is a relief to the reader. The wide range of topics has been handled by a series of workers, eminently qualified for the task they have undertaken, and the combined result of their labors with those of the chief editor is one of the best works of reference ever presented to the English-reading public, one whose completeness and accuracy leave little to be desired.

4. *Method of obtaining the oscillatory discharge used by Hertz.*—H. CLASSEN employs a blast of air which is blown between the terminals of a Ruhmkorf coil. The glow of hot particles of metal is suppressed and a sharp crackling spark suitable for the repetition of Hertz's work takes its place. A blast of steam answers the same purpose.—*Wied. Annalen der Physik*, No. 4, 1890, p. 647. J. T.

5. *Oscillatory discharge of the Ruhmkorf coil.*—M. R. COLLEY discusses the theory of the Ruhmkorf coil with reference to the problem of mutual induction. He introduces coils into the circuit in order to modify these factors and studies the character of the discharges of the Ruhmkorf coil through Geissler tubes by means of a revolving mirror. The changing nature of the stratification of the luminous tubes is an indication of the character of the oscillatory discharge. The experiments confirm the conclusions deduced from the equations of the author.—*Comptes Rendus*, March 31, 1890, p. 700. J. T.

6. *Application of Photography to the study of Superficial Tension.*—Prof. SMITH described the method, (Royal Society Edinburgh, March 17,) as follows: Ripples are set up on the surface of the liquid by means of a tuning fork and the surface is then photographed along with a suitable scale. The lengths of the ripples can thus be obtained by micrometric measurements of

the negative. The results obtained for mercury were very concordant and agreed with the mean value obtained by Quincke. Strong electrification of the surface reduced the value of the surface tension by more than 20 per cent.—*Nature*, April 17, 1890. J. T.

7. *Suppression of Photographic Halos.*—MM. Paul Henry and Prosper Henry state that these halos can be obviated by covering the back of the negative with a film of collodion which contains in solution a small quantity of *chrysoïdine*. This varnish has an index of refraction which differs slightly from that of glass. The halos from even the most brilliant stars are suppressed completely by it. The varnish dries rapidly and is perfectly transparent.—*Comptes Rendus*, April 8, 1890, p. 751. J. T.

II. Geology and Mineralogy.

1. *The Potomac or Younger Mesozoic Flora*; by Wm. M. Fontaine. Monographs of the U. S. Geological Survey, vol. xv, Washington, 1880. Text 377 pp. 4°. Atlas 180 plates, bound separately.—This highly important and long looked-for work, though bearing date 1889, did not appear until late in the spring of the present year. Ever since the announcement of its general nature and contents in the number of this Journal for August 1888 (vol. xxxvi, p. 119), anxious inquiries have been coming in as to when it would be in the hands of scientific men. It is now before the world and is all that its title indicates. As a revelation of the hidden treasures of a little known deposit, placing the appearance of the most prominent type of vegetation a long way farther back in time than it had hitherto been recorded, it cannot fail to awaken a lively interest among geologists and paleontologists, while as a monument of prolonged and patient labor in a most difficult field of research, it reflects the highest credit upon its author. It would be impossible to do justice in a brief notice to a work of this nature. Suffice it to say that it is chiefly a record of the facts, the important deductions that flow from these being modestly left to the reader. Three hundred and sixty-five species of fossil plants are described in the text and profusely illustrated. The drawings, all by the author's own hand, were a little too realistic for the process employed in their reproduction, by which the perfection of the work suffers somewhat through no fault of his. Professor Fontaine may almost be said to have discovered this flora, and nearly every specimen was collected by himself in the soft clays and preserved with the utmost difficulty. Whatever may be the true age of this formation the fossil plants must constitute the chief factor in determining it. L. F. W.

2. *Geological Survey of Missouri, Bulletin No.* 1.—This first Bulletin of the Survey contains after the Administrative Report of the State Geologist, Arthur Winslow, an account of the Coal beds of Lafayette Co., by Mr. Winslow; of the Building Stones and Clays, and Iron sands of St. François and Madison Cos., by G. E. Ladd; the Mineral waters of Saline Co., by A. E. Wood-

ward; and a preliminary account of the fossils occurring in Missouri, with a table giving their localities and geological periods, by G. Hambach.—Mr. Winslow states that the investigation of the Zinc and Lead Regions is under the charge of Mr. Walter P. Jenney, of the U. S. Geological Survey. Missouri is a rich State in economical mineral materials and in the scientific interest of its geology, and much is to be expected from this new survey.

3. *A preliminary Check list of the Cretaceous Invertebrate fossils of Texas*, accompanied by a short description of the lithology and stratigraphy of the system, by R. T. HILL. Bulletin No. 4 of the Geological Survey of Texas, E. T. DUMBLE, State Geologist.—A valuable Catalogue of Texas Cretaceous fossils, in which the species of the Lower Cretaceous thus far described are referred to their right places in the series. It was prepared for the use of the Survey and not as the final result of its work.

4. *Geological Map of Scandinavia.* — A small geological map, handsomely colored, prepared by the excellent geologist of Christiania, Dr. Hans Reusch, has recently been published by H. Aschehoug & Co. of Christiania. Upon it are geological maps also of Iceland, Spitzbergen, and the Færö Islands. It is accompanied by an explanatory pamphlet of 32 pages.

5. *Gems and Precious Stones of North America.*—A popular description of their occurrence, value, history, archæology, and of the collections in which they exist; also a chapter on pearls and on remarkable foreign gems in the United States. 336 pp. large 8vo, with 8 colored plates; by GEORGE FREDERICK KUNZ. New York, 1890 (The Scientific Publishing Company).—The American reader, who is attracted to the subject of gems, will find much to interest and instruct him in the handsome volume by Mr. Kunz. Starting off in each chapter with a brief mineralogical description of the species under discussion, the author goes on to give a detailed account of its occurrence in this country, the value of the stones found, the present owners of the finest ones and other allied points, embracing much information which has not been brought together before, and which the author's position has given him peculiar facilities for collecting. The fact that the book has been written in popular form for the general public should give it a wide range of readers. At the same time this removes it from the kind of criticism to which a work striving for minute scientific accuracy would be liable. The publishers have shown much enterprise in the handsome form in which the book has been put as regards paper and press work, and the numerous colored plates which ornament it are of very unusual excellence; it is rare indeed that the delicate coloring of the various gem stones, and of the natural mineral specimens, has been reproduced so faithfully.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. ***Fall of Meteorites in Iowa***; by JOSEPH TORREY, JR., and ERWIN H. BARBOUR. (Communicated.)—The large and brilliant meteor which fell in northern Iowa on the afternoon of May 2d,

at 5.30 was widely observed throughout the adjoining country. It appears that the phenomenon was rather in the nature of a meteoric shower, judging by appearances and the fact that several complete meteorites of considerable size—10, 70, 100 pounds—have been found, at long distances from each other, with a large number of smaller ones. The splendor of this great luminous ball—bright even in full sunlight—its fiery comet-like tail, three to four degrees in length, and the long train of smoke lingering behind it fully ten minutes plainly marking its course in the sky, inspired all who saw it with awe. It is described as sputtering throughout its course like fireworks. To the students who saw it enter the atmosphere, it appeared to start a few degrees below the zenith, and to pass below the horizon to the N.N.W. of this place, descending at an angle of fifty degrees. The meteoric shower covered an area, some two to three miles wide, near Forest City, Winnebago Co., Iowa, while one meteorite, weighing one hundred pounds, passed into Kossuth Co. We were so fortunate as to secure several fragments broken from the seventy pound mass, together with a rather small, but complete and characteristic meteorite, weighing one fifth of a pound. These meteorites belong to the "Stone" class. Their most noticeable feature is the large amount of metal contained in the fragments examined, it amounting to 45 per cent by weight. The metal is in exceedingly small globules and thin flakes, making its separation from the matrix a matter of considerable difficulty. The matrix has been analyzed by us with the following results:

SiO_2 47·03, Fe_2O_3 29·43, Al_2O_3 2·94, CaO 17·58, MgO 2·96=99·94.

Specific gravity of matrix 2·63, of the metal freed from matrix as well as possible at present 5·75. As early as is consistent with accuracy, these preliminary notes will be followed with a full report on this important meteor.

Iowa College, Grinnell, Iowa, May 9, 1890.

2. *Orbit of the Meteor of May 2d.*—The newspaper accounts of the path of the Iowa meteorite of May 2d are definite enough to give a fair idea of its orbit about the sun before entering the atmosphere. The path that satisfies best the accounts that appear to be reliable was directed from a point a little north of west and somewhat higher than the sun,—the sun being then about 20° high and due west. The velocity of the meteorite may be safely assumed to have been greater than that of Encke's comet at distance unity, and less than that belonging to a parabolic orbit. With this assumption the orbit would be inclined to the ecliptic between 10 and 20 degrees with direct motion. The ascending node is in longitude 42°·5. The body had passed perihelion several weeks, how long depends mainly upon the inclination to the horizon of the path through the air. The perihelion distance was probably between ·50 and ·70, this element also being largely dependent upon the same inclination. Better observations of this inclination than are now in hand are hoped for. H. A. N.

APPENDIX.

Art. LIX.—*Notice of New Tertiary Mammals;* by O. C. Marsh.

Recent researches in the Tertiary deposits of the West have made known several new forms of large mammals, some of which are here briefly described. All the latter are from the Brontotherium beds of Dakota, and show a closer connection of the fauna of these deposits with that below than has hitherto been suspected. They will all be described more fully by the writer in a later communication.

Diploclonus amplus, gen. et sp. nov.

The type-specimen of this genus is a nearly complete skull, in good preservation, but without the lower jaws. One of the most marked features is seen in the horn-cores, which are high, compressed transversely, and have a prominent knob on the inner superior margin, about one-third of the distance to the summit. Seen from the front, the horn-cores thus appear to be branched. It is probable that in life this feature was still more evident, and the covering of the horn-core may have shown an actual division, but this cannot be determined from the present specimen. There is a sharp ridge at the base of the horn-cores on the outside.

The nasals project but very little in front of the horn-cores. The zygomatic arches are especially strong, and widely expanded. The posterior nares have their front margin opposite the back of the last upper molars.

There were apparently but two upper incisors, and no diastema exists behind the canines. The premolars have a strong inner basal ridge, and the last upper molar has two inner cones.

This genus appears to be most nearly related to *Titanops*, but the horn-cores will distinguish it readily from all known forms of the *Brontotheridæ*.

The skull measures twenty-eight inches from the front of the nasals to the back of the occipital condyles, and twenty-four inches in greatest width across the zygomatic arches. The space occupied by the upper dental series is thirteen and one-half inches, and by the true molars, eight inches.

Teleodus avus, gen. et sp. nov.

The present genus is allied to *Brontotherium*, but differs from it in having six lower incisors instead of four. It has the same number of inferior premolars and molars, and these teeth are similar in the two genera. From *Diplacodon* of the Upper Eocene, the present genus may be distinguished by having only three lower premolars on a side instead of four. The type-specimen indicates an old animal, somewhat smaller than *Brontotherium gigas*.

Of the three lower incisors in place on each side, the middle one is the largest. There is a short diastema behind the lower canine, but no first premolar. The dental formula of the lower jaws is as follows:

Incisors, 3; canine, 1; premolars, 3; molars, 3.

The space occupied by the lower dental series is fourteen and one-half inches, and by the last three molars, eight and one-half inches.

Colodon luxatus, gen. et sp. nov.

The present genus appears to be nearly allied to *Lophiodon*, but may be distinguished from it by the upper premolars having two inner cones, and by the absence of canines in the lower jaws. The upper and lower true molars are of the same general structure as those of *Lophiodon*. From *Hyrachyus*, of the Eocene, the upper premolars, the absence of canines below, and the last lower molar with a posterior lobe, will separate it. The present genus is probably a lineal descendant of the Eocene *Helatetes*, and an intermediate form between that genus and *Tapiravus* of the Pliocene. The lower dental series has the following formula:

Incisors, 3; canine, 0; premolars, 3; molars, 3.

This series occupies in the type-specimen a space of five and one-half inches, and the last three lower molars, two inches.

Hyopotamus deflectus, sp. nov.

A second American species of the genus *Hyopotamus* is indicated by the greater portion of a skull with lower jaws, recently found in the Miocene of Dakota. These belonged to an animal about the size of *Hyopotamus Americanus*, Leidy, of which teeth only are known.

The two forms may readily be distinguished by the last upper molar, which, in the latter species, has the middle anterior cusp situated almost directly between the outer and the inner cones. In the present specimen, this cusp is placed in front of the other two, the posterior margin of its base reaching only to the middle of the main cones.

The postorbital processes are long, and more nearly close the orbit behind, than in the other known species of this genus.

The space occupied by the last six teeth of the upper premolar and molar series is four and three-fourth inches, and by the corresponding lower series, five inches. The distance from the last upper molar to the back of the occipital condyles is four and one-half inches.

Limnohyops laticeps, gen. nov.

In 1872, the writer described a large mammal from the Eocene of Wyoming under the name *Palæosyops laticeps.** As the name *Palæosyops* has since been restricted, this species must be regarded as representing a distinct genus, which may be called *Limnohyops.* In this form, the last upper molar has two inner cones, and in *Palæosyops*, as now defined, there is only one.

New Haven, Conn., May 21, 1890.

* This Journal, vol. iv, p. 122, August, 1872.

INDEX TO VOLUME XXXIX.*

* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ROCKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

C. D. WALCOTT.

PUBLICATIONS OF ELIAS LOOMIS.

1. On shooting stars. *Am. Jour.* (1), vol. 28, pp. 95–104. April, 1835.

2. Halley's comet (Olmsted and Loomis). *New Haven Daily Herald*, September 1, September 4, September 28, and December 31, 1835.

3. Halley's comet (Olmsted and Loomis). *Am. Jour.* (1), vol. 29, pp. 155–156. October, 1835.

4. Observations on the comet of Halley, made at Yale College. *Am. Jour.* (1), vol. 30, pp. 209–221. July, 1836.

5. Observations on the variation of the magnetic needle, made at Yale College in 1834 and 1835. *Am. Jour.* (1), vol. 30, pp. 221–233. July, 1836. (*Sturgeon's Ann. Electr.*, vol. 2, pp. 270–282.)

6. Letters from Europe. (Thirty-six letters.) *Ohio Observer* (1837).

7. Meteoric shower of November 13. *Cleveland Observer*, November, 1837.

8. Hourly meteorological observations for the December solstice of 1837, made at Western Reserve College. *Cleveland Observer*, December 23, 1837.

9. Hourly meteorological observations for the vernal equinox of 1858, made at Western Reserve College. *Cleveland Observer*, March, 1838.

10. Observations on a hurricane which passed over Stow, in Ohio, October 20, 1837. *Am. Jour.* (1), vol. 33, pp. 368–376. January, 1838.

11. Splendid meteor (May 18, 1838). *Cleveland Observer*, May 22, 1838.

12. Hourly meteorological observations for the summer solstice of 1838, made at Western Reserve College. *Cleveland Observer*, June, 1838.

13. On the variation and dip of the magnetic needle in different parts of the United States. *Am. Jour.* (1), vol. 34, pp. 290–309. (With a map.) July, 1838.

14. On the latitude and longitude of Yale College Observatory. *Am. Jour.* (1), vol. 34, pp. 309–313. July, 1838.

15. Meteors of August 9. *Cleveland Observer*, August 11, 1838.

16. An inaugural address, delivered August 21, 1838. 8vo, pp. 38. New York, 1838.

17. Hourly meteorological observations for the autumnal equinox of 1838, made at Western Reserve College. *Cleveland Observer*, September, 1838. (Professor Loomis also observed on the term days in December, 1838, and in March and June, 1839.)

18. On the meteor of May 18, 1838, and on shooting stars in general. *Am. Jour.* (1), vol. 3, pp. 223–232. January, 1839.

19. Meteorological table and register. *Am. Jour.* (1), vol. 36, pp. 165–173. April, 1839.

20. Observations to determine the magnetic dip at various places in Ohio and Michigan. In a letter to Sears C. Walker, Esq. Read June, 1839. *Am. Phil. Soc. Trans.*, vol. 7, pp. 1–6. (*Am. Phil. Soc. Proc.*, vol. 1, p. 116; *Am. Jour.* (1), vol. 38, p. 397.)

21. Astronomical observations made at Hudson Observatory, latitude 41° 14′ 37″ north and longitude $5^h\ 25^m\ 42^s$ west, with some account of the building and instruments. (Latitude of observatory; moon culminations; occultations.) *Am. Phil. Soc. Trans.*, vol. 7, pp. 43–51. Read October, 1839. (*Am. Phil. Soc. Proc.*, vol. 1, pp. 129–130.)

22. Additional observations of the magnetic dip in the United States. *Am. Phil. Soc. Trans.*, vol. 7, pp. 101–111. Read October, 1839. (*Am. Phil. Soc. Proc.*, vol. 1, pp. 144–145.)

23. On the storm which was experienced throughout the United States about the 20th of December, 1836. *Am. Phil. Soc. Trans.*, vol. 7, pp. 125–163. (With three plates.) Read March, 1840. (*Am. Phil. Soc. Proc.*, vol. 1, pp. 195–198; *Am. Jour.* (1), vol. 40, pp. 34–37.)

24. Meteorological sketches. (Eight papers.) *Ohio Observer*, 1840.

25. On the variation and dip of the magnetic needle in the United States *Am. Jour.* (1), vol. 39, pp. 41–50. (With a map.) July, 1840.

26. Observations to determine the magnetic intensity at various places in the United States, with some additional observations of the magnetic dip. *Am. Phil. Soc. Trans.*, vol. 8, pp. 61–72. Read November, 1840. (*Am. Phil. Soc. Proc.*, vol. 2, pp. 308–310.)

27. On the magnetic dip in the United States. *Am. Jour.* (1), vol. 40, pp. 85–92. (*Sturgeon's Ann. Electr.*, vol. 7, pp. 156–162.) January, 1841.

28. Meteorological observations made at Hudson, Ohio, latitude 41° 14′ 40″ north, longitude $5^h\ 25^m\ 47.5^s$ west, during the years 1838, 1839, and 1840. (Barometer; thermometer and hygrometer; winds; rain.) *Am. Jour.* (1), vol. 41, pp. 310–330. October, 1841.

29. Astronomical observations made at Hudson Observatory, latitude 41° 14′ 40″ north and longitude $5^h\ 25^m\ 45^s$ west. (Latitude of observatory; moon culminations; occultations; comet 1840, II; orbit of comet.) *Am. Phil. Soc. Trans.*, vol. 8, pp. 141–154. Read April, 1841.

30. On the dip and variation of the magnetic needle in the United States. *Am. Jour.* (1), vol. 43, pp. 93–116. April, 1842.

31. Encke's comet. *Ohio Observer*, April, 1842.

32. On a tornado which passed over Mayfield, Ohio, February 4, 1842, with some notices of other tornadoes. *Am. Jour.* (1), vol. 43, pp. 278–300. (With a map.) April, 1842.

33. Supplementary observations on the storm which was experienced throughout the United States about the 20th of December, 1836. *Am. Phil. Soc. Trans.*, vol. 8, pp. 305–306. Read May, 1842.

34. Observations on the magnetic dip in the United States. *Am. Phil. Soc. Trans.*, vol. 8, pp. 285–304. Read May, 1842. (*Am. Phil. Soc. Proc.*, vol. 2, pp. 176–178.)

35. Icebergs in the Atlantic. *Ohio Observer*, July, 1842.

36. The comet. (Five papers, with orbit.) *Ohio Observer*, March, 1843.

37. On two storms which were experienced throughout the United States in the month of February, 1842. *Am. Phil. Soc. Trans.*, vol. 9, pp. 161–184. (With 13 maps.) Read May, 1843. (*Am. Phil. Soc. Proc.*, vol. 3, pp. 50–56.)

38. On vibrating dams. *Am. Jour.* (1), vol. 45, pp. 363–377. (Cuyahoga Falls; East Windsor; Springfield; Northampton; Gardiner; Hartford.) October, 1843.

39. Meteorological journal kept at Western Reserve College. (Forty-seven papers.) March, 1840, to January, 1844. *Ohio Observer.*

40. Modern astronomy. *New Englander*, vol. 2, pp. 3–18. January, 1844.

41. Comparison of Gauss's theory of terrestrial magnetism with observation. *Am. Jour.* (1), vol. 47, pp. 278–281. October, 1844.

42. Astronomical observations made at Hudson Observatory, latitude 41° 14′ 42.6″ north and longitude $5^h\ 25^m\ 39.5^s$ west. Third series. *Am. Phil. Soc. Trans.*, vol. 10, pp. 1–15. Read November, 1844. (*Astron. Nachr.*, vol. 22, pp. 203–210, No. 517, October, 1844. *Roy. Astr. Soc., Month Notices*, December, 1844.) (Latitude of observatory; moon culminations; occultations; longitude of observatory; Encke's comet; comet of 1843; Mauvais's comet; Faye's comet.)

43. Meteorological observations made at Hudson, Ohio, latitude 41° 14′ 42″ north, longitude $5^h\ 25^m\ 40^s$ west, during the years 1841, 1842, 1843, and 1844, with a summary for seven years. (Barometer; thermometer and hygrometer; winds; clouds; rain.) *Am. Jour.* (1), vol. 49, pp. 266–283. October, 1845. (*Astr. Nachr.*, vol. 22, pp. 203–210.)

44. Physical constitution of the moon. *Sidereal Messenger*, vol. 1, pp. 20–22. September, 1846. (*Am. Jour.* (2), vol. 2, pp. 432–433.)

45. A treatise on algebra. 12mo, pp. 346. New York, 1846.

46. On Biela's comet. *Am. Jour.* (2), vol. 2, pp. 435–438. November, 1846.

47. The planet Neptune. *Am. Review*, vol. 6, pp. 145–155. August, 1847.

48. On the determination of differences of longitude made in the United States by means of the electric telegraph, and on projected observations for investigating the laws of the great North American storms. (Letter to Lieutenant Colonel Sabine.) *Phil. Mag.*, 3d series, vol. 31, pp. 338–340. August, 1847.

49. Notice of some recent additions to our knowledge of the magnetism of the United States and its vicinity. *Am. Jour.* (2), vol. 4, pp. 192–198. September, 1847.

50. Elements of geometry and conic sections. 8vo, pp. 222. New York, 1847.

51. Notice of a water-spout. *Am. Jour.* (2), vol. 4, pp. 362–364. November, 1847.

52. Report on the meteorology of the United States, submitted to the Secretary of the Smithsonian Institution. *Sen. Doc.* No. 23, 30th Congress, first session, pp. 193–207. Ordered printed January, 1848.

53. Historical notice of the discovery of the planet Neptune. *Am. Jour.* (2), vol. 5, pp. 187–205. March, 1848.

54. Note respecting Halley's comet. *Am. Jour.* (2), vol. 5, pp. 370–372. May, 1848.

55. The relations of Neptune to Uranus. *Am. Jour.* (2), vol. 5, pp. 435–437. May, 1848.

56. Elements of plane and spherical trigonometry, with their applications to mensuration, surveying, and navigation. 8vo, pp. vi, 148. New York, 1848.

57. Tables of logarithms of numbers and of lines and tangents for every ten seconds of the quadrant, with other useful tables. 8vo, pp. xvi, 150. New York, 1848.

58. On the determination of the difference of longitude by means of the magnetic telegraph. *Roy. Soc. Proc.*, vol. 5, pp. 787–789. 1849.

59. Experiments on the electricity of a plate of zinc buried in the earth. *Am. Jour.* (2), vol. 9, pp. 1–11. January, 1850. (*Am. Assoc. Proc.*, pp. 196–200, 1849. *Bibl. Univ.*, *Archives*, vol. 13, pp. 265–281.)

60. On the longitude of Hudson (Ohio) Observatory. *Astron. Jour.*, Nos. 8 and 9. May, 1850.

61. On the proper height of lightning rods. *Am. Jour.* (2), vol. 10, pp. 320–321. (Read August, 1850.) (*Am. Assoc. Proc.*, pp. 38–43. 1850.)

62. On the electrical phenomena of certain houses. *Am. Jour.* (2), vol. 10, pp. 321–323. (Read August, 1850.) (*Am. Assoc. Proc.*, pp. 12–15, 1850. *Edin. New Phil. Jour.*, vol. 50, pp. 225–227.)

63. On optical moving figures. *Am. Assoc. Proc.*, pp. 293–295. 1850.

64. The recent progress of astronomy, especially in the United States. 8vo, pp. 257. New York, 1850.

65. Elements of analytical geometry and of the differential and integral calculus. 8vo, pp. 278. New York, 1851.

66. On Kirkwood's law of the rotation of the primary planets. *Am. Jour.* (2), vol. 11, pp. 217–223. March, 1851.

67. Observations on the first comet of 1850, made at Hudson, Ohio. *Gould's Astr. Jour.*, vol. 1, pp. 179–180. March, 1851.

68. On the apparent motion of figures of certain colors. *Am. Assoc. Proc.*, pp. 78–81. 1851.

69. On the distribution of rain for the month of September. *Am. Assoc. Proc.*, pp. 145–149, 1851. (*Annual Sci. Disc.*, pp. 389–391, 1852.)

70. The elements of algebra, designed for beginners. 12mo, pp. 260. New York, 1851.

71. On the satellites of Uranus. *Am. Jour.* (2), vol. 14, pp. 405–410. November, 1852.

72. Notice of the hail-storm which passed over New York city on the 1st of July, 1853. *Am. Assoc. Proc.*, pp. 59–79, 1853. (*Am. Jour.* (2), vol. 17, pp. 35–55. *Annals of Science*, vol. 1, pp. 209–215.)

73. Does the moon exert a sensible influence upon the clouds? *Am. Assoc. Proc.*, pp. 80–83, 1853.

74. On the measurement of heights by the barometer. *Am. Assoc. Proc.*, pp. 169–171. 1853.

75. Comparison of the British Association Catalogue of Stars with the Greenwich Twelve-year Catalogue. *Gould's Astron. Jour.*, vol. 3, pp. 177–182. May, 1854.

76. On the resistance experienced by bodies falling through the atmosphere. *Am. Jour.* (2), vol. 17, pp. 67–70. July, 1854.

77. On the satellites of Uranus. *Am. Assoc. Proc.*, pp. 52–55. 1854.

78. The zone of small planets between Mars and Jupiter. (Lecture.) *Smithsonian Report*, pp. 137–146, 1854. (*Harper's New Month. Mag.*, vol. 10, pp. 343–353. February, 1855.)

79. An introduction to practical astronomy, with a collection of astronomical tables. 8vo, pp. 497. New York, 1855.

80. On the temperature of the planets, and on some of the conclusions resulting from this temperature. *Am. Assoc. Proc.*, pp. 74–80. 1855.

81. On the storm which was experienced throughout the United States about the 20th of December, 1836. *Am. Assoc. Proc.*, pp. 176–183. 1855.

82. Astronomical observations in the United States. *Harper's New Month. Mag.*, vol. 13, pp. 25–52. June, 1856.

83. A treatise on arithmetic, theoretical and practical. 12mo, pp. 352. New York, 1856.

84. The recent progress in astronomy, especially in the United States Third edition; mostly rewritten and much enlarged. 8vo, pp. 396. New York, 1856.

85. On the relative accuracy of the different methods of determining geographical longitude. *Brit. Assoc. Rep.*, 1857 (2), pp. 25, 26. August, 1857.

86. On certain electrical phenomena in the United States. *Brit. Assoc. Rep.*, 1857, pp. 32–35; August, 1857. (*Pogg. Annalen*, vol. 100, pp. 599–606. 1857.)

87. Elements of natural philosophy, designed for academies and high schools, with three hundred and sixty illustrations. 12mo, pp. 344. New York, 1858.

88. On the electrical phenomena observed in certain houses in New York. *Am. Assoc. Proc.*, pp. 33–38, 1858. (*Am. Jour.* (2), vol. 26, pp. 58–62.)

89. On the variation of the magnetic needle at Hudson, Ohio. *Am. Jour* (2), vol. 28, pp. 167–169. March, 1859.

90. Observations of the magnetic dip in the United States. *Am. Phil. Soc. Trans.*, vol. 11, pp. 181–186. Read August, 1859.

91. On certain storms in Europe and America, December, 1836, *Smith. Cont.* (accepted for publication August, 1859), vol. 11, pp. 26, and 13 colored charts.

92. The great auroral exhibition of August 28 to September, 1859. *Am. Jour.* (2), vol. 28, pp. 385–408. November, 1859.

93. On the European storm of December 25, 1836. *Am. Assoc. Proc.*, pp 281–283. 1859.

94. Notices of the meteor of November 15, 1859. *Am. Jour.* (2), vol. 29, pp. 137–138, 298-300, and 447. January, March, and May, 1860.

95. The great auroral exhibition of August 28 to September 4, 1859—2d article. *Am. Jour.* (2), vol. 29, pp. 92–97. January, 1860.

96. The great auroral exhibition of August 28 to September 4, 1859—3d article. *Am. Jour.* (2), vol. 29, pp. 249–266. February, 1860.

97. The great auroral exhibition of August 28 to September 4, 1859—4th article. *Am. Jour.* (2), vol. 29, pp. 386–399. May, 1860.

98. The great auroral exhibition of August 28 to September 4, 1859, and the geographical distribution of auroras and thunder storms—5th article. *Am. Jour.* (2), vol. 30, pp. 79–100. July, 1860.

99. The great auroral exhibition of August 28 to September 4, 1859—6th article. (Selected from the Smithsonian papers.) *Am. Jour.* (2), vol. 30, pp. 339-361. November, 1860.

100. The great auroral exhibition of August 28 to September 4, 1859—7th article. *Am. Jour.* (2), vol. 32, pp. 71–84. May, 1861.

101. The great comet of 1861. *Am. Jour.* (2), vol. 32, pp. 252–256. September, 1861.

102. On the great auroral exhibition of August 28 to September 4, 1859, and auroras generally—8th article. *Am. Jour.* (2), vol. 32, pp. 318–335. September, 1861.

103. On electrical currents circulating near the earth's surface and their connection with the phenomena of the aurora polaris—9th article. *Am.*

Jour. (2), vol. 34. pp. 34–45. July, 1862. (On the action of electrical currents and the motion of auroral beams.)

104. Remarks upon the article of Prof. J. D. Everett. (On reducing observations of temperature.) *Am. Jour.* (2), vol. 35, pp. 31–34. January, 1863.

105. The elements of arithmetic, designed for children. 16mo, pp. 166. New York, 1863.

106. On vibrating water-falls. *Am. Jour.* (2), vol. 36, pp. 352–365. November, 1863. (South Natick; Holyoke; Lawrence.)

107. A treatise on astronomy. 8vo, pp. 338. New York, 1865.

108. The aurora borealis or polar light, its phenomena and laws. *Smithson. Rep.*, pp. 208–248, 1865. (*Archives Sci. Phys. Nat.*, vol. 31, pp. 273–285, 1868.) Rewritten and published with illustrations in *Harper's New Month. Mag.*, vol. 39, pp. 1–21. June, 1869.

109. On the physical condition of the sun's surface and the motion of the solar spots. *Am. Assoc. Proc.*, pp. 1–5. 1866.

110. On the period of Algol. *Am. Assoc. Proc.*, pp. 5–7. 1866.

111. Notices of auroras extracted from the meteorological journal of Rev. Ezra Stiles, S. T. D., formerly president of Yale College, to which are added notices of a few other auroras recorded by other observers at New Haven, Conn. *Trans. Conn. Acad.*, vol. 1, pp. 155–172.

112. On the mean temperature and on the fluctuations of temperature at New Haven, Conn., latitude 41° 18′ north, longitude 72° 55′ west of Greenwich (E. Loomis and H. A. Newton). *Trans. Conn. Acad.*, vol. 1, pp. 194–246. (Three plates.)

113. A treatise on meteorology, with a collection of meteorological tables. 8vo, pp. 305. New York, 1868.

114. Shooting stars, detonating meteors, and aerolites. *Harper's New Month. Mag.*, vol. 37, pp. 34–50. June, 1868.

115. A treatise on algebra, revised edition. 8vo, pp. 384. New York, 1868.

116. Influence of the moon upon the weather. *Am. Assoc. Proc.*, pp. 118–122. 1868.

117. On the period of η Argus. *Roy. Ast. Soc., Month. Not.*, vol. 29, pp. 298-299. April, 1869.

118. Remarkable meteor of May 20, 1869. *Am. Jour.* (2), vol. 48, pp. 145–146. July, 1869.

119. Meteorology and astronomy, for academies and high schools. 12mo. New York, 1869.

120. Elements of astronomy, designed for academies and high schools. 12mo, pp. 254. New York, 1869.

121. The descendants of Joseph Loomis, who came from Braintree, England, in the year 1638 and settled in Windsor, Conn., in 1639. 8vo, pp. 292. New Haven, 1870.

122. Recent auroral displays in the United States. *Am. Jour.* (2), vol. 50, pp. 146, 147. July, 1870.

123. Comparison of the mean daily range of the magnetic declination, with the number of auroras observed each year, and the extent of the black spots on the surface of the sun. *Am. Jour.* (2), vol. 50, pp. 153–171. September, 1870. (*Archives Sci. Phys. Nat.*, vol. 40, pp. 352–358.)

124. Recent auroral displays in the United States. *Am. Jour.* (3), vol. 1, p. 309. April, 1871.

125. Recent auroral displays in the United States. *Am. Jour.* (3), vol. 3, p. 389. May, 1872.

126. The elements of analytical geometry, revised edition. 8vo, pp. 261, New York, 1872.

127. Instances of remarkably low temperature observed at New Haven, Conn. *Am. Jour.* (3), vol. 5, pp. 238–239. April, 1873.

128. Comparison of the mean daily range of the magnetic declination and the number of auroras observed each year, with the extent of the black spots on the surface of the sun. *Am. Jour.* (3), vol. 5, pp. 243–260. April, 1873. (*Palermo, Mem. Spettr. Ital.*, vol. 2, pp. 123–124.)

129. Results derived from an examination of the United States weather maps for 1872 and 1873. (With two plates.) *Am. Jour.* (3), vol. 8, pp. 1–15. Read in N. A. S. April, 1874. (Influence of rainfall upon the course of storms; influence of the wind's velocity upon the progress of storms; relation between the velocity of the wind and the velocity of a storm's progress; to determine whether a storm is increasing or diminishing in intensity; form of the isobaric curves; classification of storms; where do the storms which seem to come from the far West originate?)

130. Elements of the differential and integral calculus, revised edition. 8vo, pp. 309. New York, 1874.

131. Results derived from an examination of the United States weather maps for 1872 and 1873. *Am. Jour.* (3), vol. 9, pp. 1–14. (With plate.) Read in N. A. S. November, 1874. (Direction and velocity of the wind within areas of maximum pressure; consequences of the outward flow of air from an area of high barometer; monthly minima of temperature; long-continued periods of cold weather; storm of January 6–8, 1874; connection between the velocity of the wind and the distance between the isobars in the neighborhood of a storm center.)

132. Results derived from an examination of the United States weather maps for 1872, 1873, and 1874—3d paper. (With plate.) *Am. Jour.* (3), vol. 10, pp. 1–14. Read in N. A. S. April, 1875. (Directions of storm paths; diurnal inequality in the progress of storms; influence of rainfall upon the course of storms; influence of a neighboring area of high barom-

eter upon the progress of a storm; form of the isobaric curves; great and sudden changes of temperature; storm of January 15, 1875, at Denver, Colo.)

133. The descendants of Joseph Loomis, who came from Braintree, England, in the year 1638 and settled in Windsor, Conn., in 1639, second edition, revised and enlarged. 8vo, pp. 611. New Haven, 1875.

134. Key to treatise on algebra. 12mo, pp. 219. New York, 1875.

135. Contributions to meteorology, being results derived from an examination of the United States weather maps and from other sources—4th paper. (With plate.) *Am. Jour.* (3), vol. 11, pp. 1–17. Read in N. A. S. November, 1875. (Movement of areas of high barometer; monthly minima of temperature; influence of winds on the temperature, moisture, and pressure of the atmosphere; diurnal inequality in the rainfall; comparison of storm paths in America and Europe; oscillations of the barometer in different latitudes; storms traced across the Atlantic Ocean; velocity of ocean storms; storms of January 29 to February 8, 1870, on the Atlantic Ocean; application of Ferrel's formula; stationary storms.)

136. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—5th paper. (With two plates.) *Am. Jour.* (3), vol. 12, pp. 1–16. Read in N. A. S. April, 1876. (Low temperature of December, 1872; form of areas of maximum and minimum pressure; relation of rainfall to variations of barometric pressure; stationary storms near the coast of Newfoundland; course and velocity of storms in tropical regions.)

137. Elements of geometry, conic sections, and plane trigonometry. Revised edition, with appendix. 8vo, pp. 443. New York, 1876.

138. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—sixth paper. (With three plates.) *Am. Jour.* (3), vol. 13, pp. 1–19. Read in N. A. S. October, 1876. (Period of unusual heat in June, 1873; rain areas, their form, movements, distribution, &c.; rainfall of two inches at stations south of latitude 36°; rainfall of two inches at stations north of latitude 36°.)

139. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—7th paper. (With three plates.) *Am. Jour.* (3), vol. 14, pp. 1–21. Read in N. A. S. April, 1877. (Rain areas, their form, dimensions, movements, distribution, &c.; areas of low pressure without rain.)

140. Key to elements of algebra. New York, 1877.

141. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—8th paper. (With two plates.) *Am. Jour.* (3), vol. 15, pp. 1–21. Read in N. A. S. October, 1877. (The origin and development of storms; violent winds; barometric gradient.)

142. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from

other sources—9th paper. (With three plates.) *Am. Jour.* (3), vol. 16, pp. 1–21. Read in N. A. S. April, 1878. (Low barometer at Portland, Oregon; low barometer at San Francisco; areas of high barometer; temperature of Iceland and Vienna compared.)

(The above nine papers were translated by M. H. Brocard into French, and were published as No. 50 (2) of *Moigno's Actualitès Scientifique*, Paris, 1880, with the title *Memoires de Mêtéorologie Dynamique.*)

143. A collection of algebraic problems and examples for the use of colleges and high schools in examinations and class instruction. 8vo, pp. 258. New York, 1878.

144. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—10th paper. (With two plates.) *Am. Jour.* (3), vol. 17, pp. 1–25. Read in N. A. S. November, 1878. (Storms of the Atlantic Ocean; fluctuations of the barometer on Mt. Washington and Pike's Peak; high winds on Mt. Washington; high winds on Pike's Peak.)

145. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and other sources—11th paper. (With two plates.) *Am. Jour.* (3), vol. 18, pp. 1–16. Read in N. A. S. April, 1879. (The winds on Mt. Washington compared with the winds near the level of the sea; abnormal storm paths.)

146. Anthony D. Stanley, professor of mathematics. In *Yale College, a sketch of its history, &c.*, vol. 1, pp. 254–256. 1879.

147. Connecticut Academy of Arts and Sciences. *Ibid.*, pp. 329–337.

148. Contributions to meteorology, being the results derived from an examination of the observations of the United States Signal Service and from other sources—12th paper. (With three plates.) *Am. Jour.* (3), vol. 19, pp. 89–109. Read in N. A. S. October, 1879. (Mean pressure of the atmosphere over the United States at different seasons of the year; comparison of barometric minima in Europe and America; barometric minima advancing with unusual velocity.)

149. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—13th paper. (With two plates.) *Am. Jour.* (3), vol. 20, pp. 1–21. Read in N. A. S. April, 1880. (Great and sudden changes of temperature; barometric minima across the Rocky Mountains; mean monthly range of the barometer.)

150. The descendants (by the female branches) of Joseph Loomis, who came from Braintree, England, in the year 1638 and settled in Windsor, Conn., in 1639. 2 vols., 8vo, pp. 1132. New Haven, 1880.

151. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—14th paper. (With three plates.) *Am. Jour.* (3), vol. 21, pp. 1–20. Read in N. A. S. November, 1880. (Course and velocity of

storm centers in tropical regions; American storms advancing in a southeasterly direction; American storms advancing northerly and easterly; course of hurricanes originating near the Bay of Bengal, China Sea, &c.; rainfall in tropical cyclones; storms in the middle latitudes advancing in a westerly direction; storms advancing westerly over Europe and the Atlantic Ocean.)

152. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—15th paper. (With one plate.) *Am. Jour.* (3), vol. 22, pp. 1–18. Read in N. A. S. April, 1881. (Reduction to sea level of barometric observations made at elevated stations; height of the Signal Service stations.)

153. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—16th paper. (With a map.) *Am. Jour.* (3), vol. 23, pp. 1–25. Read in N. A. S. November, 1881. (Mean annual rainfall for different countries of the globe; cases of excessive rainfall; cases of deficient rainfall.)

154. Contributions to meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources—17th paper. (With three plates.) *Am. Jour.* (3), vol. 24, pp. 1–22. Read in N. A. S. April, 1882. (Relation of rain areas to areas of low pressure.)

155. Contributions to meteorology—18th paper. (With a map.) *Am. Jour.* (3), vol. 25, pp. 1–18. Read in N. A. S. November, 1882. (Mean annual rainfall for different countries of the globe; relation of rain areas to areas of low pressure.)

156. Contributions to meteorology—19th paper. (With three plates.) *Am. Jour.* (3), vol. 26, pp. 442–461. Read in N. A. S. April, 1883. (The barometric gradient in great storms.)

157. Contributions to meteorology—20th paper. (With two plates.) *Am. Jour.* (3), vol. 28, pp. 1–17 and 81–93. Read in N. A. S. April, 1884. (Reduction of barometric observations to sea level.)

158. Letter addressed to the Chief of the Bureau of Statistics in regard to the principal sources of the rainfall of different sections of the United States. *Report on the internal commerce of the United States.* Submitted May, 1885. Appendix No. 6, p. 208. Washington, February, 1885.

159. Contributions to meteorology—21st paper. (With a plate.) *Am. Jour.* (3), vol. 30, pp. 1–16. Read in N. A. S. April, 1885. (Direction and velocity of movement of areas of low pressure.)

160. Contributions to meteorology. *Nat. Acad. Sci. Mem.*, vol. 3, part 2, pp. 1–66. (Areas of low pressure, their form, magnitude, direction, and velocity of movement; also published as *Contributions to meteorology, revised edition.* 4to, pp. 1–67, plates 1–66. New Haven, 1885.)

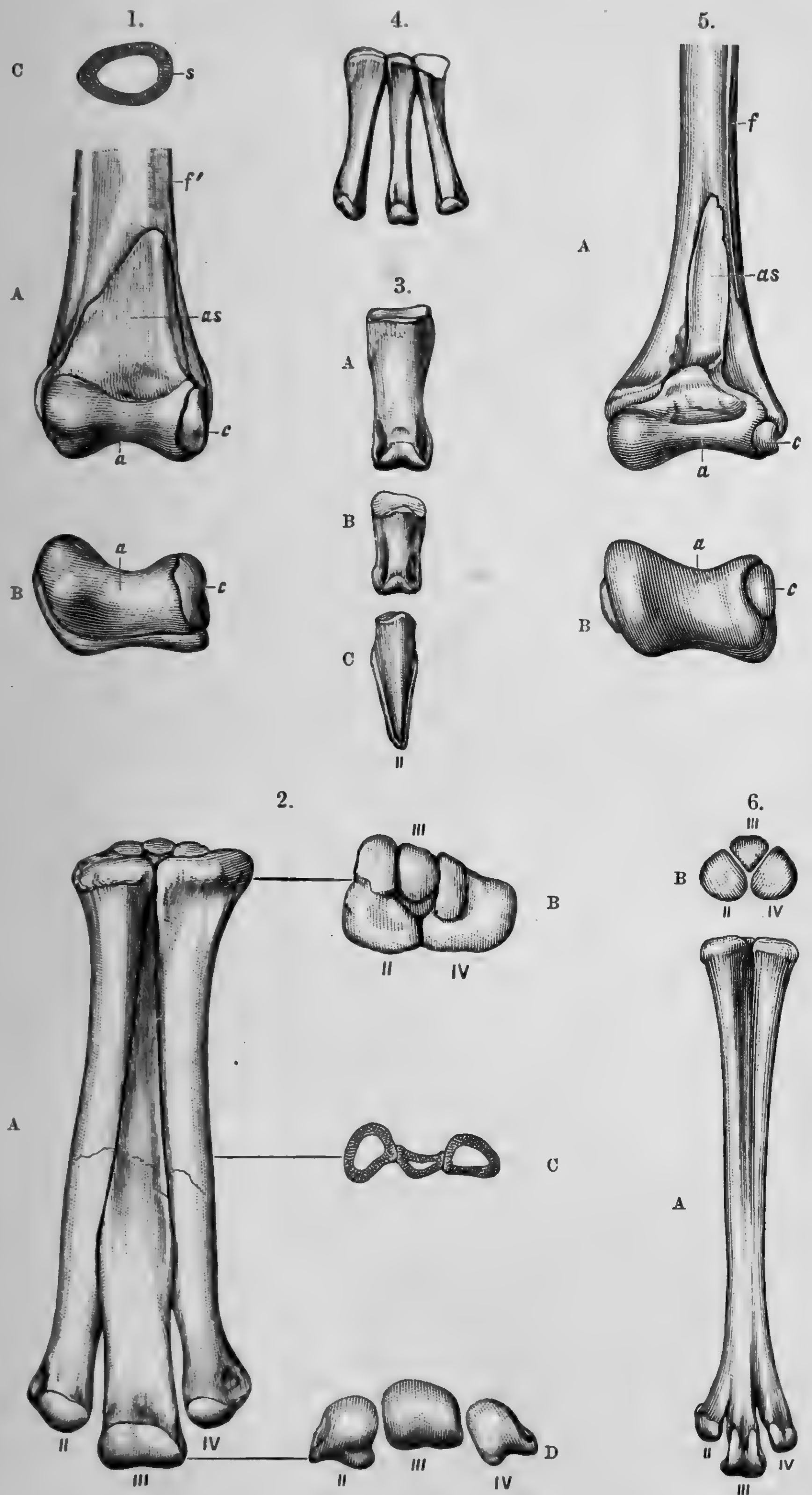
161. Contributions to meteorology—22d paper. (With a plate.) *Am. Jour.* (3), vol. 33, pp. 247–262. April, 1887. (Areas of high pressure,

their magnitude, and direction of movement; relation of areas of high pressure to areas of low pressure.)

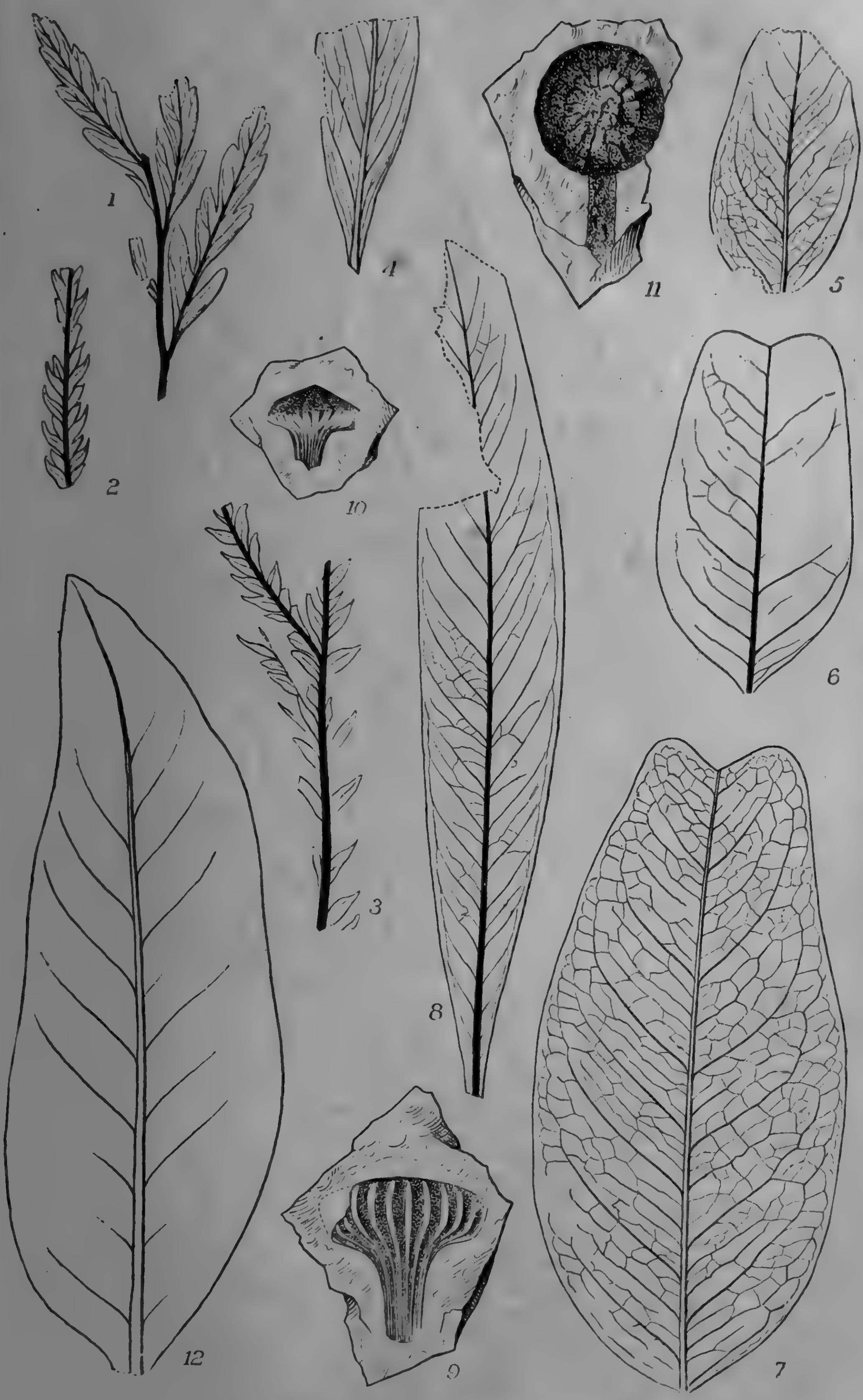
162. Contributions to meteorology. *Nat. Acad. Sci. Mem.*, vol. 4, part 2, pp, 1-77 (with 16 plates). (Areas of high pressure, their form, magnitude, direction, and velocity of movement; relation of areas of high pressure to areas of low pressure;) also published as *Contributions to meteorology, chapter II, revised edition.* 4to, pp. 67–142, plates 17–32. New Haven, 1887.

163. Contributions to meteorology—23d paper. *Am. Jour.* (3), vol. 37, pp. 243–256. Read in N. A. S. November, 1888. (Relation of rain areas to areas of high and low pressure.)

164. Contributions to meteorology. *Nat. Acad. Sci. Mem.*, vol. 5, part 1. (Mean annual rainfall for different countries of the globe; conditions favorable to rainfall; conditions unfavorable to rainfall; examination of individual cases of rainfall in the United States, in Europe, over the Atlantic Ocean; areas of low pressure without rain;) also published as *Contributions to meteorology, chapter III, revised edition.* 4to, pp. 143–232, plates 33–51. New Haven, 1889.



FIGURES 1–4, ORNITHOMIMUS; 5, STRUTHIO; 6, MELEAGRIS.


1
2
3
4
5
6
7
8
9
10
11
12

Group IV

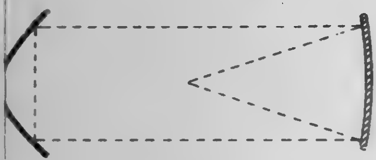


Fig 1

Fig 3

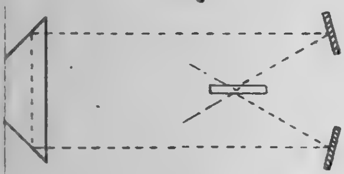


Fig 2

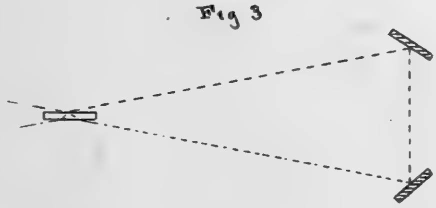
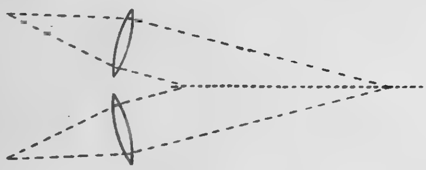


Fig 4

Group V

Fig 1



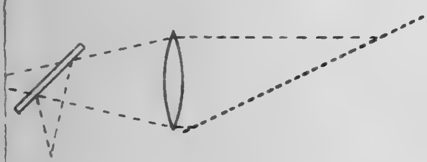


Fig 2

Fig 3

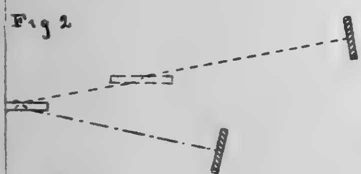


Fig 4

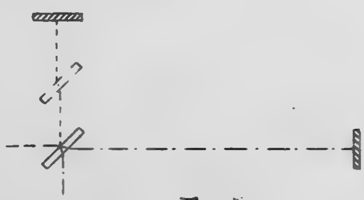


Fig 5

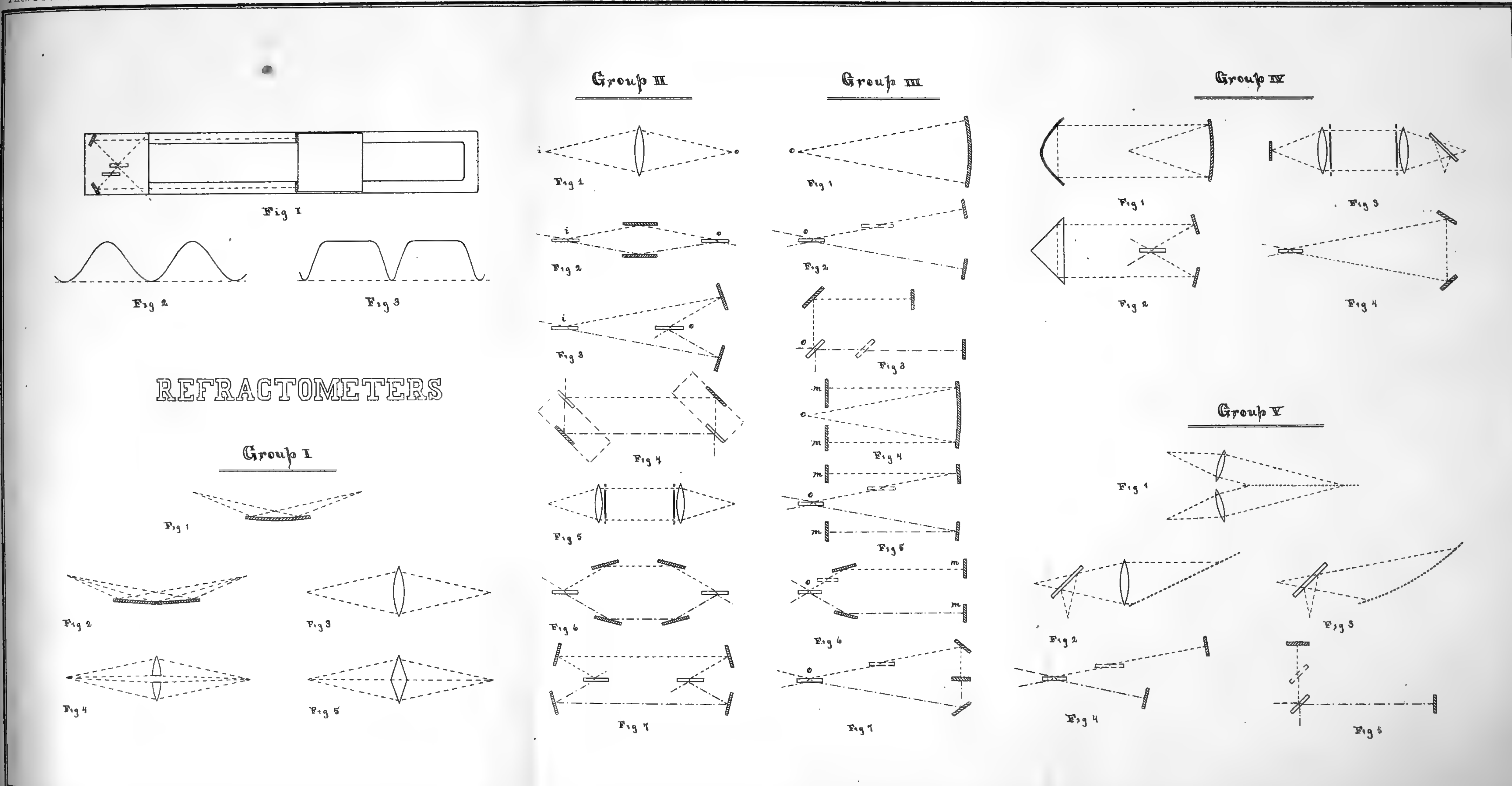
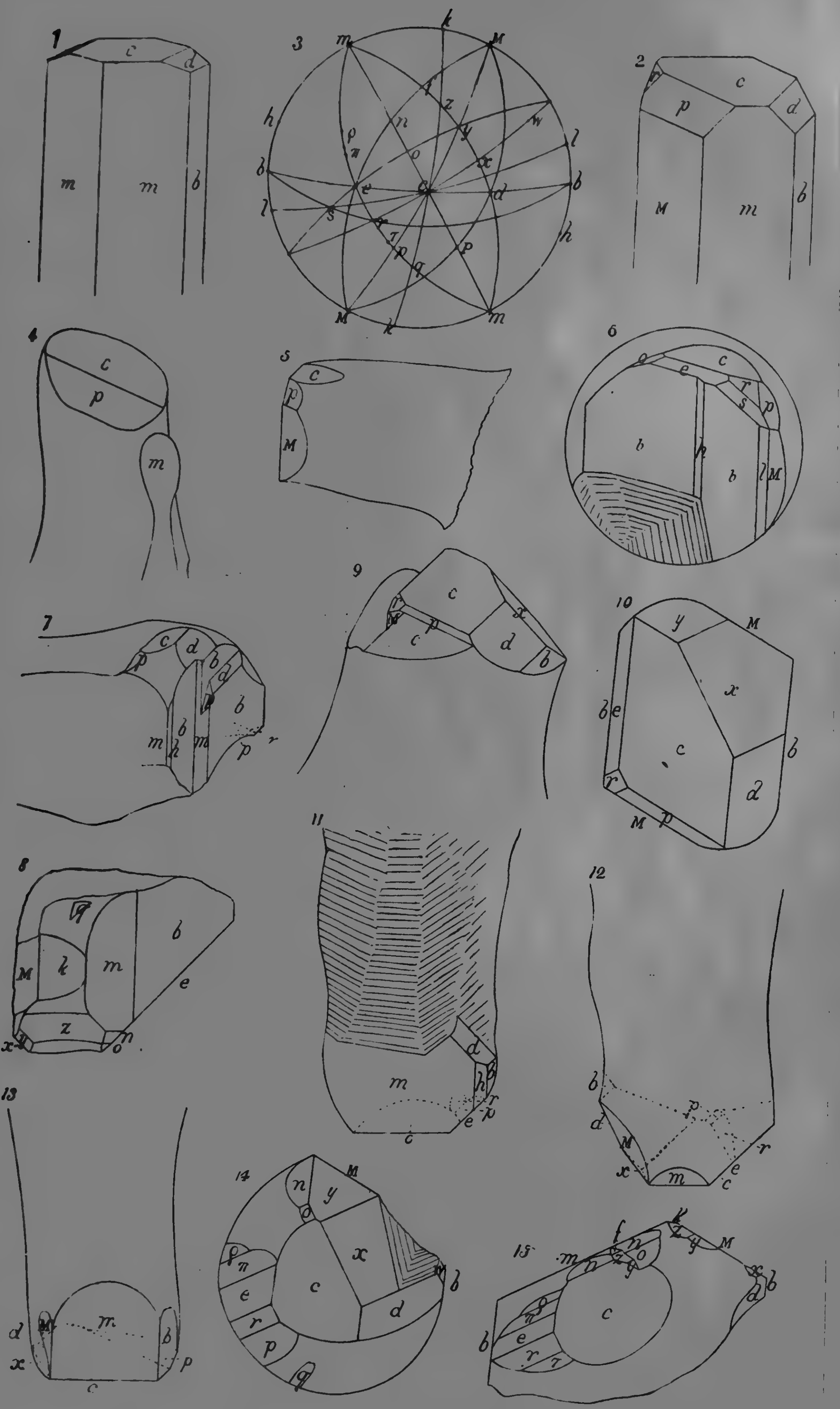
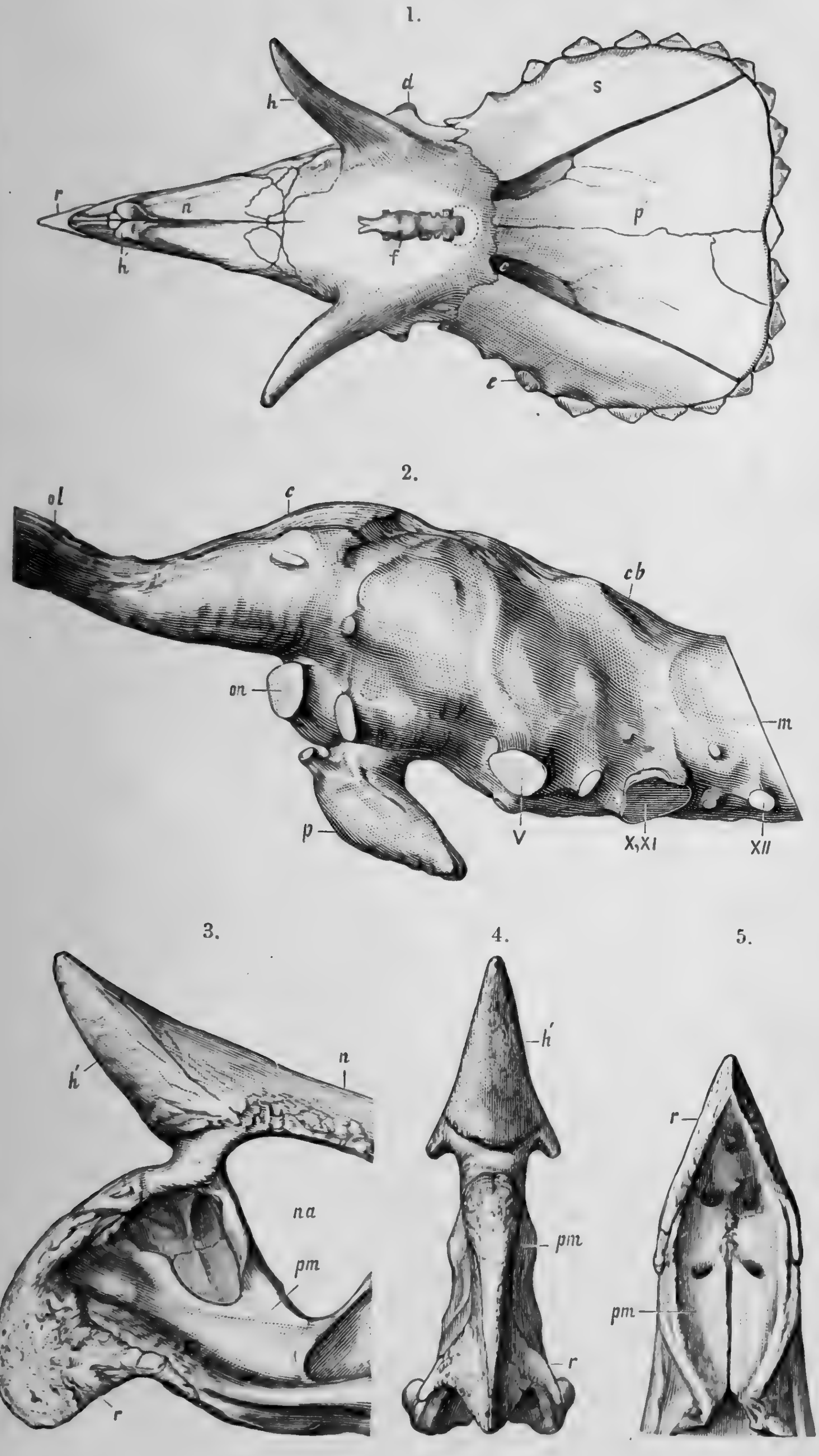


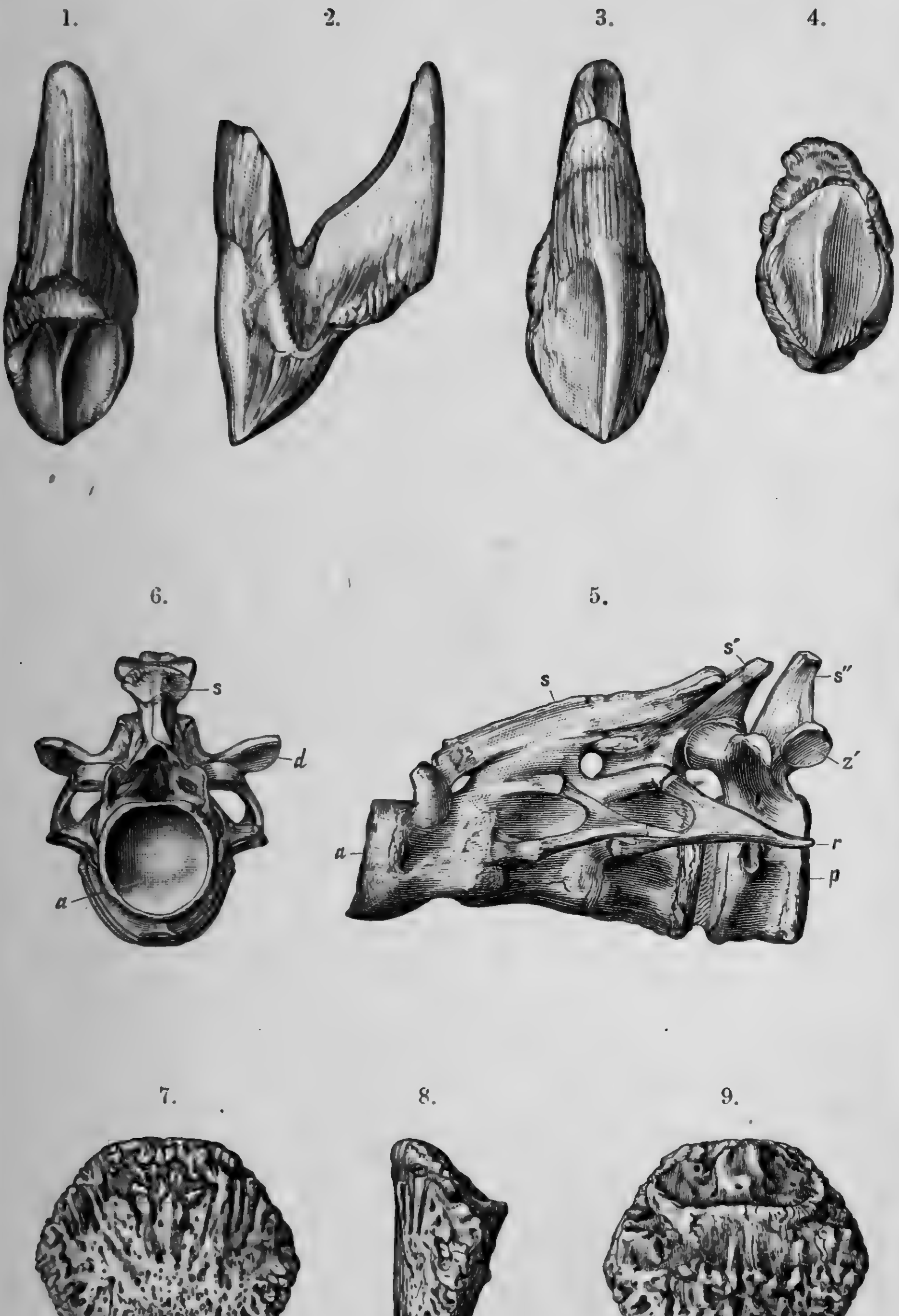
Fig 1
Fig 2
Fig 3
REFRACTOMETERS
Group I
Fig 1
Fig 2
Fig 3
Fig 4
Fig 5
Group II
Fig 1
Fig 2
Fig 3
Fig 4
Fig 5
Fig 6
Fig 7
Group III
Fig 1
Fig 2
Fig 3
Fig 4
Fig 5
Fig 6
Fig 7
Group IV
Fig 1
Fig 2
Fig 3
Fig 4
Group V
Fig 1
Fig 2
Fig 3
Fig 4
Fig 5



LANSFORDITE AND NESQUEHONITE.

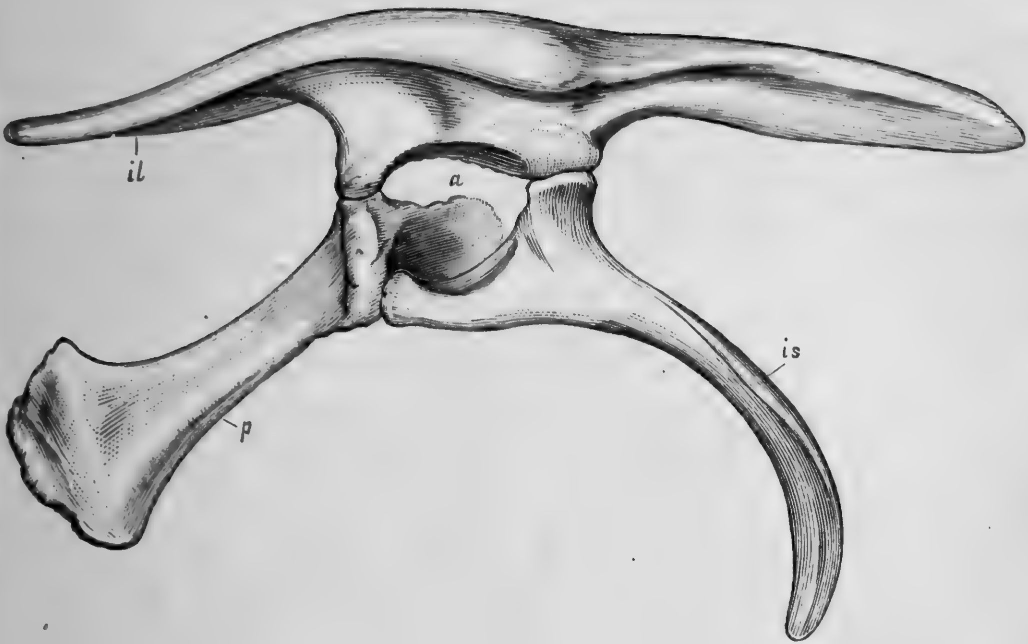


TRICERATOPS.

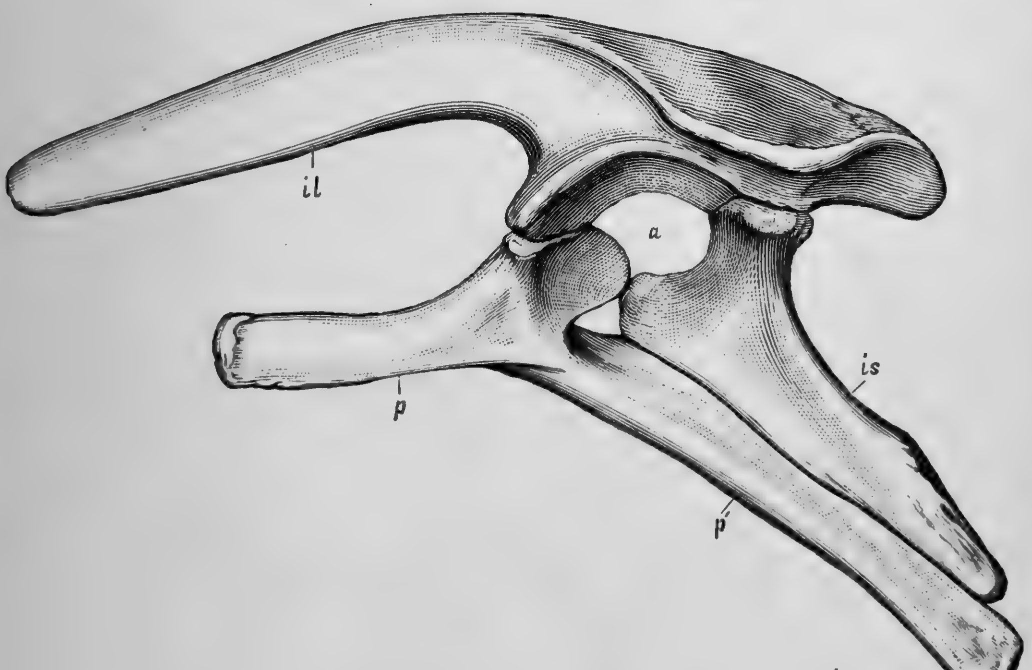


TRICERATOPS.

1.



2.



1. TRICERATOPS. 2. STEGOSAURUS.

Koffmann

CONTENTS.

CORRECTION.—Page 100, top line, after lignite, read, seldom reveal.

Barker