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JAMES D. AND EDWARD S. DANA.

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Pages 323, 324, for Sumpter, read Sumter.
Page 329, line 20, for NO_2 read UO_2.

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Page 371, line 8 from top, after *railroad* add *cut;* p. 372, line 9 from bottom, for *welded* read *joined;* p. 374, line 19 from bottom, after 450 add *feet;* p. 375, line 11 from top, for *E* 2 read *E* 1.

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ERRATUM.

The notes at the bottom of p. 476 should be transposed.

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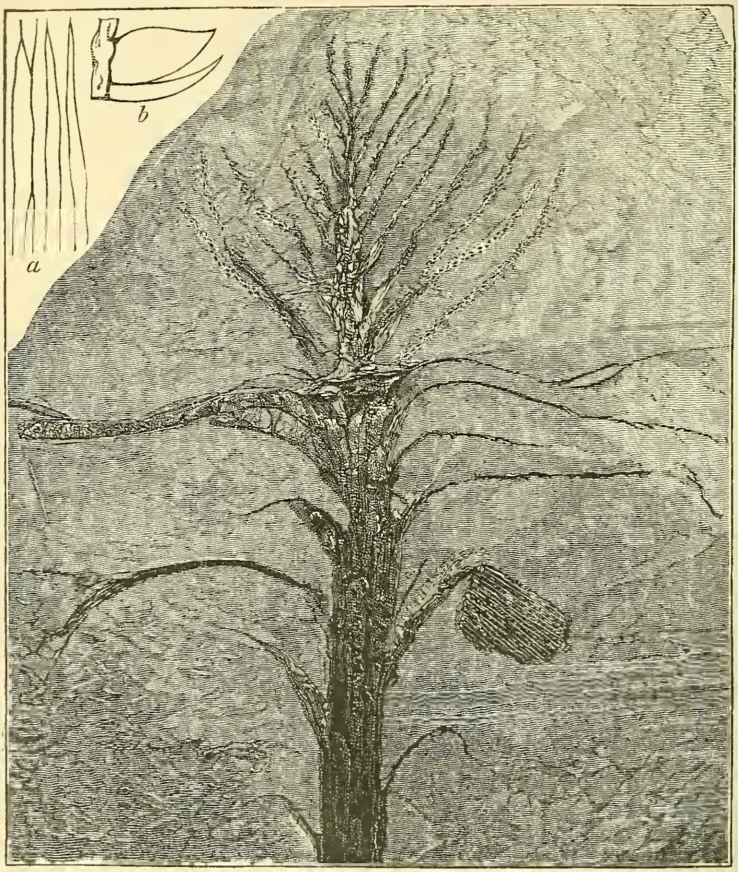
[THIRD SERIES.]

Art. I.—*A new Erian (Devonian) Plant allied to Cordaites;* by Sir Wm. Dawson.

I have recently, through the kindness of R. D. Lacoe, Esq., of Pittston, Pa., had an opportunity to study a remarkably fine specimen collected by him in the lower Catskill (Upper Devonian) at Meshoppen, Wyoming Co., Pennsylvania, and which promises to throw much light on some difficult questions of fossil botany, as well as to add a new and very interesting form to the Devonian flora. The present note is intended as merely a preliminary notice. The full discussion of this unique plant will require a reference to much of the work that has been done in *Cordaites*, *Nœggerathia*, etc., from the time of Sternberg to the recent reports of Lesquereux and Fontaine, and I hope will illustrate a number of fragmentary and enigmatical specimens which have long been in my own collections, and which need further study in connection with it.

The specimen is a branch or small stem $2\frac{1}{2}^{cm}$ in diameter and 46^{cm} in total length. It is flattened and pyritised, and shows, under the microscope, merely the indications of a pith surrounded by a fibrous envelope, the minute structure of which is not very well preserved, but it is hoped by proper treatment may give some further information. The stem shows portions of about 15 leaves which have been at least 16^{cm} long and 3 to 4^{cm} broad. They are decurrent, apparently by a broad base, on the stem. Their distal extremities are seen in a few cases, but in all seem injured by mechanical abrasion or decay. It seems most probable that they were truncate and uneven at their extremities. The stem is terminated by a cluster or compound corymb of spikes of which 20 are seen. They are slender, but seem to have been stiff and woody, and the largest are about 15^{cm} in length. They have short pointed bracts, and some of them bear oval fruits, but only a few of these remain, the greater part of them having apparently fallen off before the plant was fossilized. So far the characters do not differ



from those of the genus *Cordaites*, except that in those plants the spikes of fructification are more usually lateral than terminal. A remarkable peculiarity, however, appears in the leaves, which instead of having the veins parallel, have them forking at a very acute angle, and slightly netted, by the spreading branches of the veins uniting with the others near them. This allies the leaves with those of the provisional genus *Nœggerathia*, some of which have this peculiarity, as also certain modern Cycads of the genus *Zamia*, which Professor Penhallow has kindly pointed out to me. The present plant would seem to be a form of *Cordaiteæ*, tending to *Næggerathia*, which many paleobotanists believe to have been a gymnospermous genus allied to *Cordaites*. The affinities, however, so far as can be judged, are nearer to the latter; and following the example of Grand Eury in his nomenclature of the genera, I would propose the name *Dictyo-cordaites* for the present genus, and the specific name *Lacoi*, in honor of its discoverer.

It is apparent that this specimen combines the fructification of the *Cordaiteæ* with leaves akin to those of *Næggerathia*, thus connecting two groups of paleozoic plants, both of which are now considered as allied to *Cycadeæ* and *Taxineæ*, and I entertain the hope that when it is fully studied and brought into comparison with other specimens in my collections, or which have been figured and described by other paleobotanists, it will throw additional light on a great number of Paleozoic Canadian leaves, fruits and stems, now designated as *Cordaites*, *Næggerathia*, *Psygmophyllum*, *Gingkophyllum*, *Sternbergia*, *Lepidoxylon*, *Saportea*, etc.; and which have been waiting for some specimen thus complete to bring them into harmony with each other.

I hope to be able to bring the whole of this material, which will necessitate some change in the nomenclature of some of my own species, under the notice of geologists at the approaching meeting of the American Association.

I may add that the oldest true *Cordaites* known to me is *C. Robbii* of the Middle Devonian, which is said to have also been found in the Silurian. *C. angustifolia* of the Lower Devonian is a somewhat uncertain species. Plants of the genus *Næggerathia* are known in the Upper Devonian.

Art. II.—*The Law of Thermal Radiation;* by William Ferrel.

1. It is well known that as the temperature of a body is increased, the intensity of its thermal radiation is likewise increased, but with regard to the law of increase, or relation between the intensity of the radiation and the temperature of the body, there is still considerable uncertainty even within the temperature range of experiment and observation. The two principal formulæ expressing this relation are that of Dulong and Petit, given more than seventy years ago,* and that of Ste-

* Journal de l'École Polytechnique, xi, 234–294.

fan of somewhat recent date.* The object of the present research is to compare these formulæ with the principal data on hand derived from experiment and observation, and to ascertain how nearly they represent the true law, and what modifications of these formulæ, if any, are still required in order to this. The want of space will forbid my giving any detailed accounts of the experimental data used, and so for these the reader will have to consult the references. Stefan has done some important work in this line of research, and some of his data will be used here and some of his results will be briefly given.

2. Let H = the rate with which heat is radiated by a body from each unit of surface,
τ = the temperature of the radiating body,
m = the value of H at the temperature of $\tau = 0$.

If we now put

(1) $$H = ma^{\tau},$$

this, in the special case in which $a = 1\cdot0077$ becomes the expression of Dulong and Petit's law.

But if the body is not in empty space, but is contained within a perfect enclosure of temperature τ_0, then by Prevost's law of interchanges the body receives upon each unit of surface an amount of heat $H_0 = ma^{\tau_0}$, and hence we have for the rate with which each unit of surface of the body loses heat,

(2) $H - H_0 = ma^{\tau} - ma^{\tau_0} = ma^{\tau_0}(a^{\delta} - 1)$, in which (3) $\delta = \tau - \tau_0$.

If we now let

R = the rate of cooling of the body,
C = its thermal capacity, supposed to be the same for all temperatures,
c = its specific thermal capacity,
σ = its specific gravity,
s = the area of radiating surface,

we then have

(4) $R = A(a^{\delta} - 1)$, in which (5) $A = \frac{msa^{\tau_0}}{C}$.

In the special case of a spherical body of radius r this becomes

(5′) $$A = \frac{3m}{rc\sigma} a^{\tau_0}.$$

For inclosures of different temperatures it is seen that these expressions of A vary, with a change of temperature of the inclosure, as a^{τ_0}. Where the inclosure is not perfect, as where

* Sitzungsb. Akad. Wien, II, lxxix, 391, 1879.

the body radiates on the one side through the atmosphere into space, the imperfect inclosure is equivalent to a perfect one of the temperature at which the body would stand in the shade.

3. Again, using the same notation as above except the absolute temperatures T and T_0 instead of τ and τ_0, if we put

$$(6) \qquad H=\frac{m}{273^e}T^e,$$

this, in the special case of $e=4$, becomes the expression of Stefan's law. From this we get

$$(7) \qquad H-H_0=\frac{m}{273^e}(T^e-T_0^{\ e})=mq_0^{\ e}(q^e-1),$$

in which the quotient

$$q=\frac{T}{T_0}, \text{ and } q_0=\frac{T_0}{273}.$$

From this form we get

$$(8) \quad R=A(q^e-1, \text{ in which} \qquad (9) \quad A=\frac{ms}{C}q_0^{\ e}.$$

Hence, for different temperatures of the inclosures, A varies as $q_0^{\ e}$, or as the e power of T_0. In the special case of a spherical body we have

$$(9') \qquad A=\frac{3m}{rc\sigma}q_0^{\ e}.$$

4. The law of Dulong and Petit is based upon the results of their noted experiments upon the rate of cooling of a large glass bulb filled with mercury within an inclosure of the temperature of melting ice and several other temperatures, and the expression (4) in the special case of $a=1{\cdot}0077$ perhaps represents the observed rates at different temperatures within the limit of the probable, at least the possible, errors of observation. At the time of these experiments, however, it was not understood that the thermal conduction of gases is independent of pressure except at very low tensions, and it was supposed that the conduction at the tensions of 2 or 3^{mm}, at which the experiments were made, was very small. Dulong and Petit's formula for expressing the rate of cooling V in calories per minute due to both convection and conduction, was based upon experiments made at pressures of 720, 360, 180 and 45^{mm}. From these the following formula was deduced:

$$(10) \qquad V=0{\cdot}00919\,p^{0{\cdot}45}\,\delta^{1{\cdot}233},$$

in which p is the pressure of the air in meters Their observed rates of cooling at the low air tension of their experiments were corrected by deducting the rates given by this formula, in order to obtain those due to radiation alone. But Stefan has shown that this formula, based upon observations at high pressures, gives the effect of convection only, which entirely vanishes before the low tension of 2 or 3^{mm} is reached. He therefore restores this correction, which is very small, and then the corrected rates of cooling R, in degrees per minute, are those given in the second column of the following table, corresponding to the values of δ in the first, which in this are the temperatures of the cooling body since that of the inclosure was $\tau_0=0$.

δ	R	$2{\cdot}02(1{\cdot}0077^{\delta}-1)$	$0{\cdot}925(q^4-1)$	R	$1{\cdot}592(1{\cdot}0082^{\delta}-1)$	$0{\cdot}730(q^{4\cdot2}-1)$
80°	1·74°	+·03	+·08	1·48°	·00	+·06
100	2·30	−·03	00	1·96	−·05	−·02
120	3·02	−·03	−·03	2·60	−·06	−·02
140	3·88	−·02	−·04	3·38	−·04	−·06
160	4·89	+·01	−·04	4·31	·00	−·05
180	6·10	+·08	+·01	5·43	+·08	+·02
200	7·40	+·04	−·01	6·64	+·05	·00
220	8·81	−·10	−·10	7·95	−·08	−·09
240	10·69	−·04	+·08	9·74	−·01	+·11

These rates are satisfied by the expressions at the head of columns 3 and 4, the former being that of Dulong and Petit's, and the latter that of Stefan's law, with the residuals, observation minus computation, given beneath in each column.

5. Stefan has given a formula for computing the rate with which a spherical body within a spherical inclosure is cooled by heat conduction, which is equivalent to

$$v=\frac{3r_2}{r_1^2(r_2-r_1)c\sigma}k_0\delta(1+\tfrac{1}{2}\alpha(\tau+\tau_0)), \tag{11}$$

in which, besides the notation already adopted,

v = the rate of cooling in degrees per minute,
r_1 = the radius of the cooling body,
r_2 = that of the spherical inclosure,
k_0 = the conductivity of air at temperature $\tau=0$,
α = the temperature coefficient.

He puts $k_0=0{\cdot}00324$, which corresponds to his coefficient 0·000054 where the second is the unit of time. He also puts $\alpha=0{\cdot}0027$, $c=0{\cdot}0332$ and $\sigma=13{\cdot}6$. Hence we have $c\sigma=0{\cdot}4515$. The values of r_1 and r_2 in Dulong and Petit's apparatus were respectively 3^{cm} and 15^{cm}. If with these constants and data the values of v in (11) are computed for the several values of δ in the first column of the preceding table and deducted from the second column, we get the values of R in the fifth column, which arise entirely from radiation. But these rates now are not accurately represented by either Dulong and Petit's or Stefan's law, with any given numerical coefficient, but they are represented by the expressions at the heads of the last two columns of the preceding table with the residuals beneath. These expressions are deduced from (4) and (8) by putting $a=1{\cdot}0082$ in the former, and $e=4{\cdot}2$ in the latter, and hence they are modifications of Dulong and Petit's and Stefan's laws respectively. The residuals are as satisfactory as in the other case.

6. The value of A in (4) or (8), if it were a true expression, is the rate with which a body would cool in empty space at the temperature τ_0 or T_0, according to the respective laws, and yet it is seen how different are the values in the preceding case, as seen from the numerical coefficients in the two cases, the one, 1·592, being more than twice as large as the other, 0·730, and yet the two expressions with these very different numerical values of A satisfy the rates of cooling equally well through a range from 80° to 240° C. But the rate of cooling at any given temperature, it is seen, depends upon the difference between the two values of a function of the temperature, and not upon the absolute values of these functions, and it so happens that these differences in the two forms of function, with very different values of A, however, satisfy observation equally well through a considerable range of temperature, although the absolute values of the functions are so different. Little reliance, therefore, can be placed in values of A which best satisfy the observed rates of cooling, as being the actual rate with which the body would cool in empty space. And this is especially the case where the observed rates are through a short range of temperature and not far above the temperature of the inclosure; for then the values of A and of a in the one case, and of A and of e in the other, are somewhat complementary, so that in increasing the one and decreasing the other, and *vice versa*, the differences, or values of R, may remain very nearly the same through a considerable range of temperature.

Not only are very different values of A obtained from the two different forms of expression (4) and (8) but likewise from the same general form of expression by giving different values to a in the one case, or to e in the other; for these values, especially where the range of temperature is small, may differ considerably, and yet the expressions with proper, though very different, values of A satisfy the observed rates of cooling equally well. For instance, in the preceding case of the rates of cooling observed by Dulong and Petit, although the range is 160°, if the value of a is taken a little greater or less than 1·0082 in the one case, or e a little greater or less than 4·2 in the other, the residuals are very nearly as satisfactory. There is, therefore, a great uncertainty in the value of A which satisfies the observations through a considerable range of temperature, and for short ranges it becomes almost entirely indeterminate. The value of m, therefore, as determined from (5) or (9) with values of A thus determined, cannot be relied upon as being any more than a very rough approximation to the heat radiation into empty space from a unit of surface at the temperature of 0° C.

7. With the value of A=1·592, as given in the preceding table, and the values of r, c and σ in § 5, we get from (5′) with the temperature $\tau_0=0$, $m=0\cdot7188$ of a calorie as the rate per minute with which heat is radiated from each square centimeter of the surface of glass at the temperature of 0°. Now with this value of m we get from (2), putting $\tau_0=0$,

$$(12) \qquad H_{100}-H_0=0\cdot7188(1\cdot0082^{100}-1)=0\cdot9092$$

for the difference between the values of H in (1) at 100° and at 0°.

Again, in the other form of expression of the law of radiation, with the value of A=0·730 from the last column of the preceding table, and the values of r, c, σ above, we get from (9′) for the temperature $T_0=273$, in which case $q_0=1$, $m=0\cdot3296$. And with this value of m we get from (7), putting $q_0=1$,

$$(13) \qquad H_{100}-H_0=0\cdot3296\left(\left(\frac{373}{273}\right)^{4\cdot2}-1\right)=0\cdot8926.$$

The value of $H_{100}-H_0$ for glass has been obtained experimentally by Lehnebach by the method of ice calorimetry with apparently great accuracy.* His value is 0·0152 where the second is the unit of time, or in our notation, the same as that used by Dulong and Petit and Stefan, it is 0·912. This value does not differ much from either of the values above, which are also for glass. In obtaining the values above it is seen that the value of $r=3^{cm}$ enters into the computation in the expressions of (5′) and (9′), and it is doubtful whether Dulong and Petit's glass bulb was exactly a sphere with a radius of 3^{cm}, and so there is some uncertainty with regard to these values.

Lehnebach obtained the same value of $H_{100}-H_0$ for both a bare and blackened glass bulb, and so it would seem that the radiativity of glass at 100° is equal to that of lampblack. This does not accord with some other experiments, and so this is a matter which perhaps needs still further research. If the radiativities are the same, then this value of $H_{100}-H_0$ applies to both a lampblack and bare glass surface, at least at high temperatures. Stefan reduced these values obtained from bare glass to a lampblack surface by dividing by 0·88 the assumed relative radiativity of glass with reference to lampblack.

* Pogg. Ann., cxlvi, 497, 1875.

The great differences in the values of m above as obtained from the two different forms of expression of the law of radiation arises from the uncertainty in the values of A upon which they depend. This uncertainty has been explained in § 6. The value of m thus obtained would be the true value if the assumed law were strictly correct and the value of A satisfying the observations could be accurately obtained. But for reasons already given different forms of expression, and different values of the constants in the same expressions, giving rise to very different absolute values of the functions, and of the value of m, can be obtained which all satisfy observation almost equally well. The value of m, therefore, thus obtained, can at best be regarded merely as a rough approximation to the true value.

8. By (4) we have for each value of δ and corresponding observed value of R,

$$A = \frac{R}{a^{\delta} - 1} \qquad (14)$$

and from (8)

$$A = \frac{R}{q^{e} - 1} \qquad (15)$$

These quotients or values of A, for each value of δ and R, except so far as they are affected by errors of observation, should be a constant if the assumed law is correct. We can therefore test the assumed laws in this way as well as by means of the residuals as is done in § 4. Thus Stefan gives the following observed differences in the rates of cooling between a naked and silvered cylindrical thermometer corresponding to the values of δ given in the first line below, the temperature of the inclosure being 20°.

δ	100°	120°	140°	160°	180°	200°
Differences	2·19°	2·96	3·73	4·66	5·74	7·11
Quotients	1·911	1·977	1·950	1·947	1·944	1·972
	1·329	1·363	1·343	1·341	1·345	1·375
	1·731	1·766	1·742	1·729	1·718	1·722
	·900	·917	·897	·891	·887	·907

The quotients of the first and second lines are those given by Stefan for the laws of Dulong and Petit and his own respectively, the first being obtained from (14) by putting $a = 1{\cdot}0077$, and the second from (15), or its equivalent, by putting $e=4$. The near equality of these quotients was considered as a confirmation of the approximate correctness of both laws, as deduced from these data, within the range of temperature used. But the quotients of the last two lines are obtained from the same expressions by putting $a=1{\cdot}0082$ in the former and $e=4{\cdot}2$ in the latter, and these last quotients satisfy the condition of equality about as well as the former. This method of testing the laws is, therefore, even more uncertain than that by means of the residuals as in § 4, and it leaves considerable uncertainty with regard to the best form of expression of the law or the values of the constants to be used in the expression.

9. From the differences in the rates of cooling of a bare and a silvered cylindrical thermometer from $\tau=75°$ to $\tau=137°$ Stefan obtained from his law the following quotients:

4648	4588	4621	4624	4641

These indicate that Stefan's law must hold pretty well for this range of temperature, the mean temperature being 106°; but the range of temperature being short, the law might be varied considerably, that is the value of e in (15) might be considerably greater or less than 4, without affecting much the equality of the quotients.

Dividing the differences in the rates of cooling by $(1{\cdot}0077^{\delta}-1)$ he obtained the following ratios:

6212	6236	6327	6373	6432

These numbers do not satisfy so well the condition of equality, but show, allowing for small errors of observation, a regular increase of values with increase of temperature, indicating that Dulong and Petit's law in some measure fails, and is not as correct as Stefan's law for this range of temperature, and that a value of a in (14) considerably greater than 1·0077 is required here.

Again, Stefan obtained the quotients below corresponding to the values of δ in the first line, the temperature of the inclosure being 14·7.°

δ	48·18°	55·58	80·98	
Quotients	5407	5418	5417	by Stefan's law.
	7044	7105	7277	by Dulong and Petit's law.

These indicate, so far as can be inferred from so short a range of temperature, that Stefan's law, at these temperatures, is more nearly correct than that of Dulong and Petit, the latter quotients again indicating that Dulong and Petit's law fails here and that a value of a in (14) greater than 1·0077 is required to make the quotients equal.

It should be considered here that where the law of the radiation of glass is deduced from the differences in the rate of cooling of bare and silvered bulbs, it is assumed that the laws of both are the same. This is, most probably, not the case, but the radiation of the silver is so small that it cannot affect the results much.

10. We come now to the examination of a series of experimental observations of a different kind, in which the relative radiativities of the face of a Leslie's cube coated with lamp-

black and filled with mercury at different temperatures through a range of 240°, was determined from the deflections of the galvanometer needle of a thermopile. The third column of the following table contains the deviations y of the needle, as obtained by Rosetti,* corresponding to the absolute temperature T in the first column and the differences δ between these and that of the inclosure, 23·8°, in the second column.

T	δ	y	O−C	$40{\cdot}4(1{\cdot}0077^{\delta}-1)$	$22{\cdot}3(q^4-1)$	$19{\cdot}6(q^{4\cdot2}-1$
329·6	32·8	10·0	+0·1	−1·5	−1·6	−0·8
369·6	72·8	29·5	+0·8	−0·8	−1·8	−0·1
389·6	92·8	42·8	+1·5	+0·9	−1·2	+1·1
409·6	112·8	55·0	−1·2	−0·7	−3·6	−1·2
429·6	132·8	72·5	−1·2	+1·0	−3·1	−0·5
449·6	152·8	91·5	−2·3	+1·4	−3·5	−0·9
469·6	172·8	116·7	0·0	+4·9	−0·7	+1·8
489·6	192·8	141·9	−0·7	+4·8	−0·8	+1·2
509·6	212·8	169·5	−2·1	+3·1	−2·0	−0·5
529·6	232·8	204·0	−0·1	+3·2	0·0	+0·5
549·6	252·8	239·5	−0·4	−1·3	−0·7	−1·6
569·6	172·8	283·5	+4·3	−3·9	+3·3	+0·1

The usual care necessary in such experiments seems to have been taken. He says that the experiments were all made at least twice, and whenever, between the first and second experiment, a difference of one, or at most two divisions were found, and of five-tenths of a division in the lower temperatures, a third and fourth experiment were made to obtain a correct average.

Rosetti devised an empirical formula to express the relations between the deviations of the needle, y, and the temperatures, which, expressed in our temperature notation, is

(16) $$y=a\mathrm{T}^2\delta-b\delta$$

in which

$$a=0{\cdot}00000335131$$
$$b=0{\cdot}0636833$$

This expression represents the observed values of y in the table above with the residuals, O−C, in the fourth column. But this expression, it is seen, ignores Prevost's principle of exchanges, since it is not composed of two similar functions for different temperatures, the one representing the heat radiation of the heated body and the other that of the inclosure or surroundings, as in the expressions of (2) and (7) of which Dulong and Petit's and Stefan's laws are special cases.

11. Applying Dulong and Petit's law to these observations, the values of y are represented by the expression at the head

* Memorie della Classe di Scienze Fisiche, Mathematichi, e Naturale della R. Academia dei Lincei. Serie 3a, vol. ii, 1877–1878.

of the fifth column in the preceding table with the residuals, O − C, in the same column beneath. These are not satisfactory, and no modified expression of Dulong and Petit's law obtained by giving a different value to a in the general expression of (4) gives residuals which are more satisfactory. It is evident, therefore, that neither Dulong and Petit's law, nor any law of the general form of (4), represents satisfactorily the law of radiation, at least according to these experiments, through a temperature range of 240°, though this is done through a range of 160°, as we have seen, § 4, in the case of Dulong and Petit's experiments.

Applying Stefan's law, the values of y are represented with the expression at the head of the sixth column with the residuals beneath, which are also unsatisfactory. But if we use a modification of Stefan's law, making the exponent e in (8) equal to 4·2 instead of 4, we get with the expression at the head of the last column the residuals beneath. These are very satisfactory, being small in comparison with the observed values of y in the third column and having a pretty regular alternation of plus and minus signs throughout the whole range. This comparatively simple formula, therefore, represents the results of Rosetti's experiments much better than his own, (16), given above, as is seen by comparing the residuals in the last column with those of the fourth column.

From these comparisons it seems that some function of the general form of (6), of which Stefan's law is a special case, represents the law of radiation, and (8) deduced from it, the law of cooling, much better than those of (1) and (4), since the results of experiment are well represented by a special case of the former through a range of temperature of at least 200°, for the one isolated experiment at a distance of 40° below the lowest of the others should not have much weight, since the value of y is very small.

12. Although neither Dulong and Petit's law, nor any expression deduced from the general form of (4) by giving different values to A and a, represents well Rosetti's experiments through the whole range of temperature, yet by dividing these into two parts we find that the part from T=329·6 to T=489·6 is represented by the expression $y=37·0\ (1·0082^{\delta}-1)$ with the residuals (O − C) below corresponding to the values of δ in the first line :

δ	32·8	72·8	92·8	112·8	132·8	152·8	172·8	192·8
O − C	−1·4	−0·6	+0·8	−1·0	−0·1	−0·5	−1·8	0·0

These residuals are satisfactory through a range of 120°, from $\delta=72·8$ to $\delta=192·8$ the middle of which corresponds to a temperature of about 157°, and they indicate that with a value of

$a=1{\cdot}0082$ instead of $1{\cdot}0077$ as required by Dulong and Petit's law, the experiments are well represented through this range. This comports exactly with what has been found in the case of Dulong and Petit's experiments, in which the value $a=1{\cdot}0082$ was required for the temperature range of 160° from 80° to 240°, the mean of which corresponds to the temperature of 160°, which is nearly the same as the 157° above. The first residual, corresponding to $\delta=32{\cdot}8$, being negative, indicates that for lower temperatures the value of a must be still greater.

13. If we now take the range of observed values of y from $\delta=192{\cdot}8°$ to $\delta=272{\cdot}8°$, the mean temperature of this range being about 257°, we find that they are represented by the expression $y=51{\cdot}87\ (1{\cdot}00692^{\delta}-1)$ with the residuals, O−C:

δ	192·8°	212·8	232·8	252·8	272·8
O−C	0·0	−1·0	+1·0	−0·9	+0·3

These residuals are satisfactory for the short range of 80°, and indicate that for this range of higher temperatures the value of a required is approximately 1·0069, though as has been explained this value, determined from so short a range, is somewhat uncertain. It is evident, however, that a value of a much less than that of Dulong and Petit's law, is required for these higher temperatures, and especially smaller than 1·0082 required for the first division of the experiments comprising the lower temperatures.

We have now seen that the general expression of (4) apparently holds in the special case of $a=1{\cdot}0082$ through a temperature range of about 160° with a mean temperature of 160°, and that there are no values of A and a in the general expression of (4) that will satisfy experiment and observation through any long range of temperature, but that for temperatures considerably above 160° the values of a required are less than 1·0082, while for lower temperatures values which are greater are required. The value of $a=1{\cdot}0077$ most probably holds through a considerable range with a mean of about 200°.

14. It is well known that for high temperatures Dulong and Petit's law gives an increase in the intensity of radiation with increase of temperature very much too great, and that here a value of a less than 1·0077 is required, and one which decreases with increase of temperature. And that the value of a must be much greater than 1·0077, and even than 1·0082 at ordinary temperatures was shown by Provostaye and Desains by means of the thermopile.* For temperatures below 160° they found that the deviations of the galvanometer needle could be represented by the general expression of (4) by putting $a=1{\cdot}009$.

* Daguin. Traité de Physique, vol. ii, p. 90.

The value, also, obtained by Winkelmann for temperatures between 0° and 100° is $a=1{\cdot}0089$.*

Heat radiation should vanish down at the temperature of absolute zero, and hence Dulong and Petit's law cannot hold down at very low temperatures, since it does not make the radiation vanish there, though it reduces it to about one-eighth of what it is at 0° C. For the same reason no special case of the general expression (1) can hold at any low temperature. A value of a gradually increasing and approximating to infinity as the zero point is reached would be required. This being the case it is reasonable to suppose that the increase in the value of a may commence at very high temperatures and continue on down, though this is a consideration of no great weight.

From what has been shown, therefore, it is evident that Dulong and Petit's law holds through only a comparatively short range of temperature, and the same is true of any function of the same general form, but by giving different values to a in the expression of (4), smaller at high temperatures and much greater for low temperatures, an expression may be had which represents the difference of radiation between the body and the inclosure, and so the rate of cooling, approximately through a considerable range of temperature.

15. We have seen, § 9, that the observed rates of cooling seem to confirm Stefan's law for a range of temperature from about 50° to 137°, while for higher temperatures, according to Rosetti's experiments, an exponent of 4·2 instead of 4 is required in the general expression of (8). And according to Schleiermacher's experiments† still higher values of the exponent e are required for very high temperatures to represent approximately the experiments through any given not very great range of temperature. These experiments, however, indicate that different values of the exponent are required for the different kinds of radiating wire, as is to be expected, since the radiations of different qualities with regard to wave-length are not in the same proportion in the different wires, or the same as that of a glass or lampblack surface. For the bright platinum wires of apparatus I and II, Stefan's law is satisfied at temperatures from 150° to 300°, while in apparatus III with a dark, though not coated with lampblack, wire, his law is not satisfied until a temperature of about 400° is reached. This probably arises from the want of a perfect vacuum in the tube through which the heated wire passed, for it is well known that it is almost impossible to have such a vacuum as to render the conduction insensible, and the effect of any conduction, which increases nearly in proportion to the temperature, while

* Pogg. Ann., clix, 177, 1876.

† Wied. Ann., xxvi, 287.

that of radiation increases in a much higher ratio, is to apparently diminish the latter, and render a smaller value of the exponent e necessary. But in all cases these experiments indicate that there must be a gradual, though small, increase of the exponent, with increase of temperature, and that at very high temperatures this exponent must be greater than that of Stefan's law. It is therefore reasonable to suppose that at ordinary temperatures, and especially at very low temperatures, the value of e is less than that of Stefan's law, which, we have seen, seems to hold for temperatures from about 50° to 137°.

It appears, therefore, that neither Stefan's law nor any other of the general form of (6) with a different value of e represents the true law of nature through the whole range of experiments, but that different values of e in (8) are required for different ranges of temperature, and values which increase with increase of temperature, to represent the observed rates of cooling approximately through a given, not very great, range of temperature. But the general expression of the radiation (6), and that of the rate of cooling (8) derived from it, seem to be much better than those of (1) and (4), since only small changes in the value of e with change of temperature are required, and the formulæ, with any given value of e, hold through a much greater range of temperature, as is seen in the case of Rosetti's experiments, which are well represented through a range of 240° with the value $e=4{\cdot}2$, (§ 10).

16. For determining the law of radiation it is necessary to have either experiments on the rate of continuous cooling of a body through a long range of temperature, or to have the observed rates through shorter ranges but for different temperatures of the inclosure. Very interesting and important experiments of the latter kind have been made by Graetz on the rates of cooling of a glass bulb with mercury both in a perfect vacuum, as supposed, and in an inclosure containing air of low tension.* The three temperatures of the enclosures were those of melting ice, boiling water, and boiling aniline, 182·7°. The ranges of the observed rates of cooling were from 33° to 42°, and these rates were observed down to about 20° above the inclosures. The results were discussed with reference to both Dulong and Petit's law and Stefan's. He determined the value of m in an expression similar to that of the special case of (4) in which $a=1{\cdot}0077$, for each group of the observed rates of cooling. It is seen how this may be done by means of (4) and (5′) from the observed rates or values of R. He obtained the following three values of m, expressed here in calories per minute instead of per second.

* Wied. Ann., xi, 973, and xiv, 232, 1881.

$m=0{\cdot}7518$ for temperature of inclosure			0°
$m=0{\cdot}8286$	"	"	100
$m=0{\cdot}8118$	"	"	182·7

If Dulong and Petit's law were correct throughout the whole range of the experiments these values, of course, would be equal, since m in (4) is a constant where the law holds. But these values of m must be referred, not to the temperatures of the enclosures, but to the mean or middle temperatures of the range of each group, since they are determined from the observed rates of cooling within these ranges and are such values as best satisfy the observations. The middle temperatures of the groups are respectively 42°, 142° and 216°. With these values of m for the several temperatures, we get from (1) with $a=1{\cdot}0077$,

$$H_{42}=1{\cdot}038 \qquad H_{142}=2{\cdot}464 \qquad H_{216}=4{\cdot}261$$

If we now wish to determine the value of a in the general expression of (1) which will satisfy any two of these consecutive values of H, and so give a law which will hold approximately through the whole intervening range and accurately for the middle point, or nearly, of this range, we must have values which satisfy the following conditions:

$$\log H_{142} - \log H_{42} = 100 \log a$$
$$\log H_{216} - \log H_{142} = 74 \log a$$

From these conditions we determine the values

$a=1{\cdot}0087$ at a temperature of 92°
$a=1{\cdot}0073$ at a temperature of 179

From these results it is seen again that the value of a decreases with increase of temperature, very much in accordance with what has been shown from other experiments and by different methods, except that the last value of a above is rather too small. We have seen, § 4, that a value of $a=1{\cdot}0082$ satisfies very well Dulong and Petit's experiments for a considerable range on each side of the mean temperature of 160°, and that the same value, § 12, satisfies it fairly well through a range of at least 120°, of which the mean temperature, 157°, is nearly the same; but that Rosetti's experiments through a range of 80° of which the mean temperature is 257°, requires a value of $a=1{\cdot}00692$.

17. Graetz also discussed his results by Stefan's law, and with the following form of the expression of this law, $H=\sigma T^4$, he obtained, where the second is the unit of time:

$\sigma=1{\cdot}086 \,.\, 10^{-12}$ for the group with inclosure of				0°
$\sigma=1{\cdot}057 \,.\, 10^{-12}$	"	"	"	100
$\sigma=1{\cdot}085 \,.\, 10^{-12}$	"	"	"	182·7

But, in accordance with what has been stated in the preceding case with regard to the values of m, these belong properly to the middle temperatures of the groups, and we get from the preceding expression of H for the several temperatures of the middle of each group, making the minute the unit of time:

$$H_{42}=0·6415 \qquad H_{142}=1·8810 \qquad H_{216}=3·7224$$

In order now to determine the value of e in the general expression of (6) which will satisfy any two successive values of H, and so be true for a point very nearly the mean of the two, we have to satisfy the following conditions:

$$\log H_{142}-\log H_{42} =e(\log T_{142}-\log T_{42})$$
$$\log H_{216}-\log H_{142}=e(\log T_{216}-\log T_{142})$$

From these conditions with the preceding values of H for the several temperatures we get

$e=3·90$ at the temperature of 92°
$e=4·16$ " " 179

These results accord very well with those previously obtained by other methods and from other experiments, and indicate that the value of e increases with increase of temperature and that Stefan's law, in which $e=4$, holds through a considerable range of temperature of which the mean is about 125°. We have seen in § 9 that this same value of e satisfies other experiments from 75° to 137°, the mean of which is 106°, while for the higher temperature of about 160° the value of $e=4·2$ is required. While it cannot be claimed that these results are very accurate, and so a very nice agreement in the comparisons can not be expected, yet taken altogether they indicate very clearly that the value of e must be considerably less for low than for high temperatures.

18. So far, in the general expressions (6) and (8) we have regarded the exponent e as constant, and have found that a constant value of e may be found which will make (8) represent observation through a considerable range of temperature, though the value required is a little greater for high than for low temperatures. It is evident, therefore, that the value of this exponent must gradually increase with increase of temperature. We will therefore assume that within the range of experiment

$$(17) \qquad e=e_0+c\tau$$

in which e_0 is the value of e where $\tau=0$. With a varying value of e we must change the last form of the expression of (7) to

$$(18) \qquad H-H_0=A\left(\frac{T^e}{T_0^{\ e}}-1\right) \quad \text{in which} \quad A=m\,\frac{T_0^{\ e}}{273^e}$$

since the value of e is now different in the numerators and denominators in the expression. For the same reason (8) becomes

$$(19) \quad R=A\left(\frac{T^e}{T_0^e}-1\right) \quad \text{in which} \quad (20) \quad A=\frac{ms}{C}\frac{T_0^e}{273^e}$$

or in the case of a spherical cooling body

$$(20') \qquad A=\frac{3m}{rc\sigma}\frac{T_0^e}{273^e}$$

With the expression of e in (17) substituted in (19) such values of the constants A, e_0 and c should be found, if the assumption of (17) is correct, as will make (19) represent, at least within the limits of possible errors of observation, the observed values of R. In the expression of e above, however, the two terms are somewhat complementary, so that by increasing e_0 and decreasing c correspondingly, and *vice versa*, through a considerable range the expression of (18) represents the observed values of R nearly as well through a considerable range of temperature. But with different assumed values of e_0 and corresponding changes of c different values of A are required, and so there is the same uncertainty here with regard to the value of this constant, and consequently by (20) or (20′), in the value of m, which we have found elsewhere. The value of e_0 which is found in general to satisfy observations best is about 3·0, though if it be changed to 2·9 or 3·1 or even made to vary considerably more, if the value of c is changed accordingly, the residuals are nearly as satisfactory.

19. Slightly different values of c in (17) seem to be required for different radiating surfaces, which is to be expected from theoretical considerations, and seem to be indicated by Schleirmacher's experiments as pointed out in § 15. If we put

$$(21) \qquad e=3{\cdot}0+0{\cdot}00038\tau$$

we get from (18) with A=0·905 and $T_0=273°$, the values of R in the second column of the following table corresponding to the values of T in the first column:

T	R	O−C	T	R	O−C	T	R	O−C
353	1·43	+·05	329·6	11·4	−1·4	393	2·21	−·02
373	1·98	−·02	369·6	30·5	−1·0	413	3·91	+·05
393	2·64	−·04	389·6	42·6	+0·2	433	3·74	−·01
413	3·41	−·03	409·6	56·8	−1·8	453	4·69	−·03
433	4·31	·00	429·6	73·4	−0·9	473	5·90	−·06
453	5·37	+·06	449·6	92·5	−1·0	493	7·04	+·07
473	6·60	+·04	469·6	114·7	+2·0			
493	8·02	−·07	489·6	140·0	+1·9			
513	9·67	+·07	509·6	169·1	+0·4			
			529·6	202·6	+1·4			
			549·6	240·5	−1·0			
			569·6	284·0	−0·5			

These values of R compared with the corrected observed values of R in the fifth column of the table in § 4 leaves the residuals, O – C, in the third column of the preceding table. Hence the expression of (19) with the assumed constants, represents the experiments of Dulong and Petit, with the preceding residuals, which are very satisfactory.

With the values of A, e and T_0 above, and the known values of r, c and σ given in § 5, (20′) gives $m=0{\cdot}4086$, which is considerably larger than the value 0·3296 in § 7. With this value and the value of e given by (21) we get from (18)

$$(22) \qquad H_{100}-H_0=0{\cdot}8958$$

This differs but little from the value of (13), § 7, obtained from (7) with the constant value of $e=4{\cdot}2$.

If instead of (21) we put

$$(23) \qquad e=3{\cdot}0+0{\cdot}00032\ \tau$$

we get from (19) with the value of $A=25{\cdot}0$ and $T_0=23{\cdot}8'$, the values of R in the fifth column of the preceding table corresponding to the values of T in the fourth column. These compared with the values of y in the table of § 10, give the residuals, O – C, in the sixth column. These are quite satisfactory considering the large temperature range of 240°.

If in (19) we put $A=1{\cdot}122$, $T_0=20°$, and

$$(24) \qquad e=3{\cdot}0+0{\cdot}00034\ \tau$$

we get the values of R in the last column but one of the preceding table, which compared with the differences of the rates of cooling between a bare and silvered thermometer given in § 8, give the residuals in the last column. The preceding values of H, § 17, obtained from Graetz's experiments should be represented by (6) with proper values of m and e, or with the values of H and e for given temperatures it should give m a constant for each of these temperatures. With the preceding values of H for the temperatures of 42°, 142°, and 216° and with the value of

$$(25) \qquad e=3{\cdot}0+0{\cdot}0004\ \tau$$

we get respectively the following three values of

$$m=0{\cdot}3792, \qquad m=0{\cdot}3804, \qquad m=0{\cdot}3795$$

The numerical coefficient of τ was assumed so as to make the first and last very nearly the same, but the very near agreement of the other with these depends upon the accuracy of (6) with the assumed value of e above.

The difference between the numerical coefficients of τ in the expressions of (21) and (23) indicate that the exponent e for glass increases a little more with increase of temperature than in the case of a lampblack surface, which was used in Rosetti's experiments. The value of the numerical coefficient in (24) is a little less than that in (21) though both are for bare glass, but here the law may be slightly affected by the law for the radiation from the silvered thermometer being a little different from that of glass, although the amount of this radiation is very small. The numerical coefficient in (25), although also for glass, is a little greater than in (21), but this small difference may arise from small errors of observation, or perhaps from a lack of a perfect vacuum which has, as explained in § 15, the effect of making the law of radiation apparently increase more rapidly with increase of temperature than it otherwise would.

20. If in (18) we put $H_{100}-H_0=0\cdot912$, as found by Lehnebach, § 7, we get with the expression of e in (23), which seems to be that required for a lampblack surface, $A=0\cdot438$ and which in this case is also the value of m since $T_0=273°$. With this value and the value of e in (23) we get the values of $H-H_0$ in the second column of the following table corresponding to the different values of δ in the first column, which are the same as τ since $\tau_0=0$ here.

δ	$H-H_0$	$H-H_0$	$H-H_0$	$H-H_0$
100	0·9120	0·9120	0·9120	0·9120
90	·7820	·7828	·7810	·7806
80	·6624	·6634	·6609	·6593
70	·5520	·5532	·5507	·5476
60	·4503	·4513	·4497	·4452
50	·3572	·3576	·3575	·3518
40	·2724	·2719	·2731	·2669
30	·1949	·1940	·1955	·1896
20	·1239	·1232	·1245	·1196
10	·0586	·0585	·0597	·0566

But very nearly the same results may be obtained from (7) with a constant value of e for all temperatures, and with a smaller value of m. Putting

$$(26) \qquad H-H_0=0\cdot3951\,(q^{3\cdot833}-1)$$

the value of q_0 being unity in this case, we get the values of $H-H_0$ in the third column of the preceding table, which differ but little from those of the second column, so that instead of using the expression of (18) with a varying value of e, that of (7) can be used throughout this range without sensible error. The constant $0\cdot3951$ is so determined as to make $H_{100}-H_0=0\cdot912$ as determined by Lehnebach. The value of $e=3\cdot833$, so determined as to give the best agreement in the two expressions, comports very well with the value $3\cdot9$ at the temperature of $92°$ as given in § 17.

We get from (18) by differentiation and substituting for e and $d\mathrm{T}(=d\tau)$ their values from (17),

$$(27)\qquad \frac{d\mathrm{H}}{d\mathrm{T}}=m\frac{\mathrm{T}^{e-1}}{273^e}\left(e_0+c\tau+c\frac{\mathrm{T}\log\mathrm{T}}{\mathrm{M}}\right)$$

in which M is the modulus of common logarithms. The last two terms within the parenthesis depend upon the variation of e and the whole parenthesis is equivalent to an increased value of e. By taking the differential of (18) regarding e as a constant we get

$$\frac{d\mathrm{H}}{d\mathrm{T}}=m\frac{\mathrm{T}^{e-1}}{273^e}e$$

These two expressions become equal by putting

$$(28)\qquad e=e_0+c\tau+c\frac{\mathrm{T}\log\mathrm{T}}{\mathrm{M}}$$

But by satisfying this condition we simply make the two functions of T increase at the same rate at some given temperature T at the middle point or elsewhere of some given temperature range. If the condition is satisfied for the middle point of the range the two functions may agree approximately through the whole range, but the satisfying of this condition does not generally give the best agreement.

For the middle of the range in the preceding table in which T=323°, we get from (28) in the case of a lampblack surface in which we have found $c=0{\cdot}00032$,

$$e=3{\cdot}0+0{\cdot}00032\times50+0{\cdot}597=3{\cdot}613$$

But we have found by a tentative process that the value $e=3{\cdot}833$ gives the best agreement of the two functions throughout the whole range of 100°. The preceding value of e would simply make the rate of increase of the two functions the same at the temperature of 50°. But by comparing the difference of successive values in the second and third columns of the preceding table it is seen that the increased value of e makes them a little greater in the latter column in the middle of the range. This furnishes an explanation of the increased value of e required when regarded as a constant. Up at the temperature of 160°, or T=433°, which is the middle temperature of the range in Dulong and Petit's experiments and also very nearly that in Rosetti's experiments, putting $c=0{\cdot}00038$ in this case, we get from (28) $e=4{\cdot}06$. The value of $e=4{\cdot}2$ was found to satisfy best the observations through the whole range. With $e=0{\cdot}00032$ (28) would give a still smaller value in the case of Rosetti's experiments, but the value 4·2 was found in this case also to be the best; but as has been remarked before, a considerable change in the value of e does not greatly affect the residuals in comparing with observation.

21. Although the general expression of (2) has not been found to represent observation well through as great a range of temperature as that of (7), yet if we put

(29) $$H-H_0=0{\cdot}652(1{\cdot}0088^{\delta}-1),$$

the value of a^{τ_0} being 0 in the case of the examples of the preceding table, we get the values of $H-H_0$ in the last column of this table. It is seen that the values differ but little from those of the other columns throughout the whole range. It is seen, therefore, how nearly three very different functions, with differing values of the constants, give the same results, and consequently would represent observations equally well. In each of these the value of the constant m enters as a numerical coefficient, and these are respectively, taking the expressions in the preceding order, 0·438, 0·3951, and 0·652. And differences of the same order have been found where these expressions have been applied to results of experiment and observation. We have, therefore, only a vague idea of the real value of this constant. It probably falls within the range of the numbers above, and is undoubtedly much smaller than the value given by Pouillet, 1·146, for a lampblack surface, as deduced from Dulong and Petit's experiments in accordance with their law, and putting the relative radiativity of glass at 0·80. These values have all been determined from the experiments of Dulong and Petit with a bare glass surface at temperatures from 80° to 240°. But at the temperature of 100° Lehnebach found the radiativity of bare glass and that covered with lampblack the same. At lower temperatures at least there must be a considerable difference, but not as much as Pouillet supposed.

The three forms of expression from which the results of the preceding table have been computed, are equally as well applicable to any observed rates of cooling, the law in both cases being the same, but the constant coefficient different, as may be seen by comparing the expressions of $H-H_0$ with those of R in (4) and (8). So either of these can be used for all ordinary temperatures by using the values of the constants e and a used in (26) and (29), but the numerical coefficients will of course be different, depending upon the thermal capacity of the cooling body, as is seen from (5) and (9).

By Stefan's law, (7) with $e=4$, we get, by determining the value of m so as to give $H_{100}-H_0=0{\cdot}912$,

(30) $$H-H_0=0{\cdot}3673(q^4-1).$$

This gives the values of $H-H_0$ in the last column of the preceding table. The differences between these numbers and those of the other columns are considerable, but if m were so determined as to give the best general agreement, instead of making $H_{100}-H_0=0·912$, the agreement would be much better. Stefan's law, therefore, can be used without material error down at ordinary temperatures, for a range even of 100°, by using a value of m a little greater than that above.

22. If in (2) we put E equal to the value of $H-H_0$ where $\delta=1$, that is, for the rate with which each unit of surface loses heat by radiation in excess of what it receives when the difference between the temperature of the body and that of the inclosure is 1° C., we get

(31) $$E=ma^{\tau^0}(a-1).$$

This value of E is called by English physicists the emissivity of the body at the temperature of the inclosure τ_0, though this term is often used in the sense of radiativity, or absolute radiating power, without regard to heat received from an inclosure. It is seen that, if (2) expresses the true law the emissivity increases as a^{τ_0}, whatever the value of a may be. With the value of m and a in (29) we get, where the temperature of the inclosure $\tau=50°$,

$$E=0·652\times1·0088^{50}\times0·0088=0·00889.$$

At the temperature of $\tau_0=0$, we get $E=0·00574$.

In like manner we get from (7) by putting $T-T_0=1$ and developing

(32) $$E=\frac{m}{273}eq_0^{e-1}.$$

Hence, if the form of (7) expresses the true law, the emissivity is as the $e-1$ power of $q_0=T_0/273$, or as the $e-1$ power of the absolute temperature, which, by Stefan's law, is the third power. With the values of m and e used in (26) this gives for the temperature $T_0=50°$,

$$E=\frac{0·3951}{273}\times3·833\times\left(\frac{323}{273}\right)^{2·833}=0·893.$$

At the temperature $\tau_0=0$, we get $E=0·00555$.

With the values of m and e in (30) we get for $\tau_0=50°$,

$$E=\frac{0·3673}{273}\times4\times\left(\frac{323}{273}\right)^{3}=0·892.$$

At the temperature of $\tau_0=0$, this gives $E=0·00538$.

Again, for the more general expression of (18), in which e varies with T, the value of E may be deduced from (27) without any sensible error, by using in the first member small finite variations δH and δT instead of dH and dT. If $\delta T=1°$ C., then δH becomes E, and we get

(33) $$E=m\frac{T^{e-1}}{273^e}\left(e_0+c\tau+c\frac{T\log T}{M}\right).$$

This with the values of m in § 20 used in computing the first column of values of $H-H_0$ in the table and the values of e and c in (23), we get for $\tau=50°$ or $T=323°$,

$$E=0{\cdot}438\,.\,\frac{323^{2\cdot016}}{273^3}\left(3{\cdot}0+{\cdot}00032\,\tau+{\cdot}00032\frac{323\ \log\ 323}{0{\cdot}4343}\right)=0{\cdot}00890.$$

At the temperature $\tau=0$, we get $E=0{\cdot}00560$. There is a very nice agreement in these results from these several different forms of expression at the temperature of 50°, but it is not quite so satisfactory at 0°, which was to be expected, since this is one of the limits of the range to which the several forms are applicable. The values of E above at 0° do not differ much from those of Winkelmann* and Kundt and Warburg,† which, reduced to our unit of time, are respectively 0·00528 and 0·00558.

In § 7 we have found from Dulong and Petit's experiments by their law $m=0{\cdot}7188$. With this value and Dulong and Petit's value of $a=1{\cdot}0077$ we get from (31), applied as in a preceding example, $E=0{\cdot}00589$ at the temperature of 0°, but $E=0{\cdot}02202$ at the temperature of 160°. Also with the value of $m=0{\cdot}3296$, as obtained from Dulong and Petit's experiments by Stefan's law, with the exponent $e=4{\cdot}2$, we get from (32), $E=0{\cdot}00507$ at the temperature of 0°, but $E=0{\cdot}02218$ at the temperature of 160°. These values of E from these two different formulæ agree very closely at the temperature of 160°, but not at the temperature of 0°. This is because these formulæ are derived from expressions which represent experiment and observation through a temperature range of which the mean is 160°, but it is not claimed that these expressions hold down to the temperature of 0°; in fact it has been shown that they do not. The values of E, therefore, from (31) and (32) which have been deduced from these expressions, can be correct only within the limits of the range for which they hold, and not down at 0°.

From (33), with the value of e in (21) and the value of $m=0{\cdot}4086$, which are the values deduced from Dulong and Petit's experiments, we get, in the manner of the preceding example, $E=0{\cdot}00574$ at the temperature of 0°, but $E=0{\cdot}02211$ at the temperature of 160°. As these values are deduced from a formula which is supposed to be applicable to all temperatures within the range of experiment they should be more accurate, at least at the temperature of 0°, than the preceding results. The preceding value of E at 160° is very nearly the same as the other two values from expressions less general, but adapted to this range of temperature, and is a mean of the two. The preceding value of E at 0° falls between the two

* Pogg. Ann., clvii, 497. † Pogg. Ann., clvi, 208.

former values from formulæ which are not supposed to hold accurately down to so low a temperature.

It is seen from the computed values of E from the several expressions of E, as well as from the expressions themselves, that these values increase very rapidly with increase of temperature. Also, that while the values of m, as we have seen, as determined from observation for the several laws and expressions, are very scattering and uncertain, the values of E, as determined from the several very different expressions, differ but little.

23. The several preceding laws of radiation here investigated pertain to the radiations of a lampblack or a bare glass surface, between which there seems to be but little, but of course some, difference in the rate with which radiation increases with increase of temperature. According to Violle* this rate is much greater for the short than the long wave-lengths, and the same is to be inferred from Langley's results,† in which it is seen that the maximum intensity with reference to the wave-lengths is thrown toward the end of the shorter wave-lengths in the spectrum as the temperature of the radiating body is increased. The law of radiation, therefore, for the resultant radiation of all wave-lengths must differ very much in different bodies in which the radiativities differ considerably from that of a surface of maximum radiativity, according as the predominating wave-lengths in its radiations are toward the one or the other end of the spectrum. The radiativity of bare glass at ordinary temperatures is supposed to be one-tenth or more less than that of a lampblack surface, but if the deficiency in its radiation at these temperatures is mostly toward the end of the longer wave-lengths, then it is readily seen that for higher temperatures its relative radiativity, that is, radiativity relative to lampblack, must increase and gradually approximate that of the latter, but it could never quite become the same, as it is according to Lehnebach's experiment at the temperature of 100°. For this reason, also, the absolute radiativity in glass must increase with increase of temperature a little faster than that of lampblack, as seems to be indicated by the larger numerical coefficient of τ in the expression of e in (21) than in (23).

24. The condition from which the temperature of the sun is determined where the law of radiation is known is

$$H=\frac{1}{4}\frac{S}{\omega}A \qquad (34)$$

in which S : ω is the ratio between the whole surface of a sphere and the part which subtends the same solid angle as

* Comptes Rend., vol. xcii, p. 1204, 1881.
† This Journal, vol. xxxi, January, 1886.

the sun at its mean distance, and A is the solar constant. For the several laws of radiation H must be expressed in a function of the temperature as in (1), (6), etc., and we then have the relation between the temperature and the solar constant. Putting according to Violle* S : ω=183960, the preceding equation becomes by (1), in the case of Dulong and Petit's law, in which a=1·0077.

$$m(1{\cdot}0077)^{\tau} = 45990\ \text{A} \tag{35}$$

But here as we have seen, §21, there is great uncertainty with regard to the true value of m, and there is also considerable with regard to that of A, to say nothing of the application of a law based upon experiments through a range of only 160° being extended up to the temperature of the sun. This, with Pouillet's large value of m=1·146 and small value of A=1·75 gives a value of τ=1454°. But putting a=1·0082, which has been shown to satisfy the results of Dulong and Petit's experiments as corrected by Stefan, and using the value of m=0·7188, as obtained in §7, and also a greater value of A, say 2·2, we get τ=1456, very nearly the same, though with the same solar constant it would have been considerably less. The true solar constant is probably still considerably greater than this.

By means of (6) we get from (34)

$$m\left(\frac{\text{T}}{273}\right)^{e} = 45990\ \text{A} \tag{36}$$

This, with e=4, as required by Stefan's law, and m=0·4, as determined by him for lampblack and A=2·2, we get T=6122° or τ=5849° as the sun's temperature if it had the radiativity of lampblack. The temperature of the sun obtained upon this hypothesis is often called the "effective temperature of the sun," but this must be very much less than the real temperature, since the radiativity of the sun is undoubtedly much less than that of lampblack. Pouillet supposed it might not be more than one-tenth as much.

With the value of e=4·2 which is required to satisfy the results of Dulong and Petit's experiments as corrected by Stefan, and using the values of m=0·3296 corresponding, §7, which, according to Lehnebach should be the same for a lampblack surface, we get from (36) with A=2·2, T=5528 or τ=5255°.

If in (36) we regard e as a function of τ of the form of (23), and use the value of m=0·438 as determined in §20, the value of T=2337° or τ=2064° is required to satisfy this equation with A=2·2. This latter is therefore the effective tempera-

* Annales de Chimie et de Physique, vol. x, 1877.

ture of the sun as deduced from (36) with the value of e in (23). And this expression, with the constants used, represents observation fairly well throughout the whole range of experiment with lampblack and bare glass radiating surfaces, while the others do not, especially that of Dulong and Petit's law. But this temperature, as well as that of Pouillet's from Dulong and Petit's law, is doubtless much too low. And this is not surprising, for it has not been claimed or supposed that this new law, although it represents observation better throughout the short range of experiment of only about 240°, can be extended with safety up to the high temperature of the sun. The scattering results obtained indicate that no reliability can be placed in such methods, to show which has been the principal object in touching upon this part of the subject here.

25. According to Langley's deductions from his experiments at the Edgar Thompson steel works near Pittsburg,* solar heat radiation is about 100 times greater than that of melted iron at a temperature of at least 1800°, angular area for area. Supposing both to have the same relative radiativities we could arrive at the sun's temperature if we knew the law of the increase of radiation with increase of temperature from this up to the sun's temperature. We have seen that none of the preceding laws can be relied upon for this purpose, though they of course would give better results by starting at the high temperature of 1800° than in commencing down at ordinary temperatures and extending them through a range 1800° greater. Using Dulong and Petit's law we would have

$$1{\cdot}0077^{\tau}=100\times1{\cdot}0077^{\tau'}$$

as the condition for determining the solar temperature τ, τ' being equal to 1800°. The solution of this gives $\tau=2400°$. As this law gives results demonstrably too small, this is, no doubt, too small, but much more nearly correct than that of Pouillet's obtained by extending the law through a much greater range of temperature. By Stefan's law we should have

$$T^4=100\,T'^4$$

The solution of this, putting $T'=1800+273=2073$, gives $T=6555°$ or $\tau=6282°$ for the sun's temperature. This does not differ greatly from the preceding value of τ as obtained by Stefan's law from (36). With the exponent equal to 4·2, which, we have found, satisfies observation better, we get $\tau=5933°$. These last results are undoubtedly much better, as obtained from these data, than that obtained with Dulong and Petit's law, which, we have reason to think, is very erroneous for high temperatures. If the "100 times" in the comparison

* Proc. of the Am. Academy of Arts and Sciences, 1878.

above refers to the sun's heat-radiation as it reaches the earth's surface, as seems to be the case, then the numerical coefficient in the conditions above should be increased at least one-third for the loss in passing through the atmosphere, the effect of which would be to increase considerably the preceding computed temperatures.

26. The condition which determines the temperature at which a body in space at the distance of the earth from the sun would stand from the effect of the sun's thermal radiation, is

$$H=\tfrac{1}{4}\frac{\delta}{\alpha}A \tag{37}$$

in which H, as in the case of (34), is a function of the temperature of the form of (1), (6), etc., according to the assumed law, and in which δ and α are the relative radiativities and absorptivities of the body with reference to lampblack, supposed to be a perfect absorber. In a lampblack surface, as that of a black-bulb thermometer, or any one in which there is no selective absorption and radiation, but all the wave-lengths are radiated in the same proportions as those of a lampblack surface, we have $\delta/\alpha=1$ in the resultant of the radiations and absorptions of all wave-lengths.

By means of (1) we get from (37)

$$m\alpha^{\tau}=\tfrac{1}{4}\frac{\delta}{\alpha}A \tag{38}$$

as the condition for determining the temperature τ of the body. But here, as in the preceding case with regard to the sun's temperature, the uncertainty in the true value of m comes in, but not so much that of the other part of the law, since we have here to deal with temperatures differing but little from those of the experiments upon which the law is based, and so have to extend the law through a small range only of temperature. Dulong and Petit's value of a has been shown to be too small and Pouillet's value of m too large for ordinary temperatures of the earth's surface. Taking, therefore, the value of $a=1{\cdot}0082$ as given at the head of the last column but one of the table of § 4, which has been found best to satisfy the results of experiment as corrected by Stefan, and the value of $m=0{\cdot}7188$ in § 7, and putting $A=2{\cdot}2$, as heretofore, the preceding equation, (38), gives in any case in which $\delta/\alpha=1$, $\tau=-33°$ as the temperature at which the body would stand, as determined from the preceding condition with the assumed value of the constants, and as the mean temperature of the earth and moon if their surfaces satisfied the conditions above with regard to radiation and absorption.

If we adopt the value of $m=0{\cdot}652$ and value of $a=1{\cdot}0088$ in (29), which have been shown to be probably more nearly correct values for low temperatures, we get $\tau=-19°$. With a larger value of the solar constant these temperatures denoted by τ would be higher.

By means of (6) we get from (37)

$$m\frac{T^e}{273^e}=\frac{1}{4}\frac{\delta}{\alpha}A \qquad (39)$$

The most probable values of m and e for low temperatures are that of § 20, $m=0{\cdot}438$, for the former, and that of equation (23) for the latter, though the value of m here deduced from the radiation of glass at high temperatures should be increased a little for a lampblack surface. With these values (39) gives $T=291°$ or $\tau=18°$, which is a little above the mean temperature of the earth's surface. The values of m deduced from experiments at high temperatures, by Dulong and Petit's law and the values by Stefan's law are found to differ very much, the former being the greater, and the same is true with regard to any modification of these laws, by giving different values to the constants a and e in the general expressions of (1) and (6), but in deducing the values of a and e from experiments at lower temperatures we find that the corresponding values of m decrease in the former case and increase in the latter, so that the tendency is to bring them nearer together. The true value, no doubt, lies somewhere between, but to determine it with greater accuracy it is important to have experiments upon radiation at much lower temperatures than those of any experiments yet made.

Art. III.—*Stratigraphic Position of the Olenellus Fauna in North America and Europe;* by Charles D. Walcott, of the U. S. Geological Survey.

(Continued from page 392, vol. xxxvii.)

Since the first part of this article was written the review of all the species known to me from the Lower Cambrian or Olenellus zone in North America has been completed. To the list published (*ante*, pp. 388, 389) there are to be added the genera Nothozoe, Modioloides and Straparollina, and the species *Lingulella*, sp. undet., *Camerella minor*, n. sp., *Lamellibranch*, gen. and sp. ? (Shaler and Foerste), *Scenella*, sp. undet., *Straparollina remota* Billings, *Nothozoe? Vermontana* and *Olenoides quadriceps* H. & W. *Paradoxides? Walcotti* is referred to Olenellus and *Modiolopsis* (*??*) *prisca* to Modioloides, n. gen. The entire fauna from America now includes 57 genera, 134 species and 10 varieties.

Relations of the Lower Cambrian to the Middle Cambrian Fauna.—In the Atlantic Province the two faunas are respectively called Olenellus and Paradoxides, from the most typical genera of trilobites occurring in them. In the Cambrian sections of the Rocky Mountain or Pacific Province and the Appalachian Province there is a Middle Cambrian fauna, more or less distinctly defined, but it is not the typical Paradoxides fauna of the Atlantic Province. On this account the Middle Cambrian fauna of the Atlantic Province will be spoken of as such, or as the Paradoxides fauna; and the term Middle Cambrian will be used when other portions, or the entire fauna of the Middle Cambrian are referred to.

Physical or Stratigraphic Relations.—The Cambrian section, on Manuel's Brook, shows a continuous deposition of sediments, from the basal conglomerate through Lower Cambrian (Olenellus zone) time to and through Middle Cambrian (Paradoxides zone) time; a thickness of about 250 feet of shale having been deposited between the typical Olenellus zone and the Paradoxides zone. The same conditions of continuous and conformable sedimentation appear to have prevailed on the eastern side of the Atlantic Province in Sweden and Norway.

The great conformable sections of Cambrian strata in the Rocky Mountain Province do not show any break in the sedimentation between the Lower, Middle, and Upper Cambrian strata, except near the eastern shore line, as in the Wasatch section of Utah, where strata of Upper Cambrian age were not deposited.

In Russia, Britain, Spain, Sardinia, and on the western side of the Atlantic, in New Brunswick and Massachusetts, the stratigraphic relations of the faunas are not exhibited; and in the St. Lawrence and Appalachian regions of America the data are wanting by which to place the faunas stratigraphically in any one, unbroken section.

As far as known the physical relations of the faunas do not furnish sufficient reason to account for the change from the Olenellus to the Middle Cambrian fauna; and there is no recognized unconformity indicative of a physical break and a consequent time interruption in the deposition of the sediments forming the strata between the two faunas.

Zoological Relations.—Under this head will be mentioned (1) the species that range from the Lower Cambrian into the Middle Cambrian, in each typical province of the Olenellus fauna; (2) the relation of the genera and species, irrespective of geographic distribution and vertical range; (3) the comparison of the faunas as a whole.

I. *New York and Vermont.*—The Olenellus fauna appears to have a great vertical range in New York, as shown by the Cambrian strata of Washington and Rensselaer counties. I have called it 14,000 feet,* but this may be modified by a more detailed study of the sections. About 2,000 feet from the summit of the strata assigned to the Cambrian, the fauna contains *Olenellus asaphoides* but with it occurs the species *Lingulella Granvillensis*, *Linnarssonia sagittalis var. Taconica*, *Agnostus desiderata*, Agnostus of the type of *A. pisiformis*, *Microdiscus connexus* and *Zacanthoides Eatoni*, all of which are representative species of the Paradoxides fauna. Professor W. B. Dwight has recently permitted me to examine the type specimens of *Olenoides Stissingensis* Dwight, *Leperditia ebinina* Dwight, and *Kutorgina Stissingensis* Dwight, from the Middle Cambrian strata of Dutchess County, New York. None of these species occur in the Olenellus fauna, and the Olenoides belongs to the type of the genus occurring in the Middle Cambrian rocks of Utah. *Kutorgina Stissingensis* is the representative of *Kutorgina Labradorica* of the Lower Cambrian, and *Leperditia ebinina* belongs to a division of the genus that includes a similar type, from a bed referred to the Middle Cambrian, in the Grand Cañon section in Arizona. These species indicate that the Middle Cambrian fauna of eastern New York has the general facies of that of the Southern Appalachian and Rocky Mountain provinces.

In the Georgia section of Northern Vermont the Olenellus zone has a thickness of about 500 feet.† With the possible exception of *Ptychoparia Adamsi* none of the species are known to range upward in the section.

Rocky Mountain Area.—In the Rocky Mountain area the Eureka District and Highland Range sections show the relations of the Lower, Middle and Upper Cambrian faunas.‡ In each section the Olenellus fauna is confined to a comparatively narrow zone, just above the non-fossiliferous quartzite.

In the Eureka District the fauna consists of but six species: *Kutorgina Prospectensis*, *Scenella conula*, *Olenoides quadriceps*, *Olenellus Gilberti*, *O. Iddingsi* and *Anomocare parvum*. Of these, two species, *Olenoides quadriceps* and *Scenella conula*, are found 500 feet higher in the section.§

The Olenellus fauna, in the Highland Range section, includes only *Olenellus Gilberti* and *O. Iddingsi*.‖ One hundred feet higher in the section *Hyolithes Billingsi* is found, just as in the Eureka section, *Stenotheca elongata* occurs 2,000

* This Journal, III, vol. xxxv, 1888, p. 242.
† Bull. U. S. Geol. Survey, No. 30, 1886, pp. 15–20.
‡ Bull. U. S. Geol. Survey, No. 30, 1886, Introduction.
§ Op. cit., p. 32.
‖ Op. cit., pp. 33, 34.

feet above the Olenellus zone, although a Lower Cambrian species in the Atlantic Province.

In the Pioche section * the fauna of the Olenellus zone is larger. It includes *Eocystites ?? longidactylus ? Lingulella Ella*, *Kutorgina pannula*, *Acrothele subsidua*, *Acrotreta gemma*, *Orthis Highlandensis*, *Hyolithes Billingsi*, *Olenellus Gilberti*, *Olenoides levis*, *Crepicephalus Augusta* and *C. Liliana*. Of these *Eocystites ?? longidactylus* is very doubtfully identified by single plates; *Kutorgina panula*, *Acrothele subsidua*, *Acrotreta gemma* and *Hyolithes Billingsi* pass to the zone above or that carrying Olenellus.

In the Wasatch section of Utah *Olenellus Gilberti* occurs in a narrow band of arenaceous shale that is subjacent to silico-argillaceous shales, containing a number of species that I formerly referred to the Olenellus fauna. Restricting the fauna to only those species occurring in association with Olenellus or a grouping of species characteristic of the Olenellus zone, where Olenellus is present, all the species, with the exception of *Olenellus Gilberti* and *Cruziana sp. ?*, are referred to the Middle Cambrian fauna.

In the section of Mount Stephen and Castle Mountain, in British Columbia, Mr. McConnell† found the Olenellus fauna at the base of the Castle Mountain limestone; beneath it there are dark-colored argillites and sandstones, estimated at over 10,000 feet in thickness, which correspond in position and character to the pre-Olenellus strata of the Wasatch section, which are referred to the Algonkian Period. In the collection made by Mr. McConnell from the Olenellus zone there are *Olenellus* sp. ?, *Ptychoparia Adamsi* and *Protypus senectus*. The fauna of the Middle Cambrian zone is 2,000 feet higher in the section and includes in the collection made by Dr. Rominger:

Sponge ?
Lingulella McConnelli (sp.)
Crania ? Columbiana Walcott.
Linnarssonia, like *L. sagittalis*.
Acrotreta gemma var. *depressa* Walcott.
Kutorgina pannula White.
Orthis sp.?
Orthisina Alberta Walcott.
Scenella conula Walcott.
Platyceras Romingera Walcott.
Hyolithellus.
Agnostus interstrictus White.
Karlia Stephenensis White.
Olenoides Nevadensis Meek.
Zacanthoides spinosus Walcott.
Bathyuriscus Howelli Walcott.
Bathyuriscus (*Kootenia*) *Dawsoni* Walcott.
Ogygopsis Klotzi Rominger.
Ptychoparia Cordilleræ Rominger.

* Op. cit., p. 35.

† Geol. and Nat. Hist. Survey Canada, Ann. Rept. new ser., vol. ii, 1887; Rept. Geol. Structure of a portion of the Rocky Mountains, p. 29 D.

The slender Hyolithellus is much like *H. micans* of the Olenellus fauna, but, in the absence of the characteristic operculum, it does not seem best to identify it as the same species.

As known at present six species only pass from the Olenellus zone to the superjacent strata, in the Rocky Mountain province. They are : *Kutorgina pannula*, *Acrothele subsidua*, *Acrotreta gemma*, *Scenella connula*, *Hyolithes Billingsi* and *Olenoides quadriceps*. Of these *Acrotreta gemma* extends up to the Upper Cambrian zone, in Montana.

Newfoundland.—The fauna of the Olenellus zone contains but one species that ranges up into the Paradoxides zone—*Hyolithes princeps*. *Agraulos strenuus* is closely allied to *Agraulos socialis* of the Paradoxides fauna, and *Platyceras primævum* is very like *P. minutissima* of the Upper Cambrian.

The review of the sections shows but little specific relationship between the two faunas, as only nine species are now known to range from zone to zone. A review of the genera shows a large percentage common to the two zones. Of the 68 genera of the Olenellus zone 47 pass up into the Middle Cambrian.

The genera confined to the Lower Cambrian, in America, are :

Leptomitus.	Coleoloides.
Protopharetra.	Hyolithellus ?
Spirocyathus.	Protocaris.
Coscinocyathus.	Olenellus.
Ethmophyllum.	Bathynotus.
Modioloides.	Avalonia.
Fordilla.	Oryctocephalus.
Helenia.	Protypus.

Of the European genera, the following five :

Mickwitzia.	Medusites ?
Volborthella.	Fræna.
Platysonites.	

are referred only to the Lower Cambrian.

II. *Relations of the Genera and Species of the Lower and Middle Cambrian.*—The comparison between the two subfaunas will be made by considering the genera and species of each class of the Lower Cambrian and comparing it with the same class of the Middle Cambrian fauna.

Algæ.—As far as known to me, there are no true Algæ in the rocks of the Lower Cambrian. That such forms existed, there can scarcely be any doubt, but after a study of all of the reported species, I think that they can be referred to trails of worms or mollusks with much more propriety than to the Algæ. Specimens of Cruziana, collected in Newfoundland, lead me to think that it is a trail or burrow and not an Alga.

No traces of land vegetation have been discovered in the rocks of the Cambrian Period.

Spongiæ.—The sponges of the Lower Cambrian are limited to two genera, of which one, Protospongia, is found in the upper beds of the Olenellus zone of the Atlantic Province, and also in the Middle Cambrian in Nevada, New Brunswick, Newfoundland, Wales and Sweden. Leptomitus is confined to the Lower Cambrian.

Hydrozoa.—It is to the researches of Dr. A. G. Nathorst that we owe a knowledge of the occurrence of Medusæ in the Lower Cambrian rocks of Sweden. By a series of comparisons between the casts found in the rocks at Lugnas and the casts made by the impressions of recent Medusæ, more especially of *Aurelia aurita* and *Cyrena capillata*, he has shown that it is extremely probable, if not certain, that the delicately constructed Medusæ lived during the Lower Cambrian epoch and left traces of their existence in the clays and sands of the seashore. Dr. Nathorst figures and describes* *Medusites Lindstromi* Linnrs., *M. favosus* Nathorst and *M. radiata* Linnrs., and states that he thinks the so-called species of Eophyton are the casts of trails made by the Medusæ in moving along the sea bed.

There are, in the collections of the United States Geological Survey, a group of forms from the middle part of the Cambrian in Alabama, that appear to be generically related to *Medusites Lindstromi.* They will be described with the description of the Middle and Upper Cambrian fauna. In ascending the geological series, it is not until the lithographic slate of the Upper Jura, at Solenhofen, etc., is reached, that traces of the Medusæ are again met with.

The Graptolitidæ are represented by two species that are provisionally referred to the genera Phyllograptus and Climacograptus. These generic types are not met with again until the base of the Ordovician is reached, where they are largely developed. Mr. Matthew has described two species of graptolites from the Middle Cambrian of New Brunswick, which he refers to Dendrograptus and Protograptus.

Actinozoa.—It has been an open question for some years whether the forms referred to the genus Archæocyathus were corals or sponges. Dr. G. J. Hinde has recently reviewed the genera and species, and concluded that they form a special family of the *Zoantharia sclerodermata*, in some features allied to the

* Kongl. Svenska Vetenskaps-Akademiens Handlingar, Bandet 19, N. 1, 1881. Om Aftryck af Medusor i Sveriges Kambriska Lager.

group of perforated corals. A re-study of all the species and a personal examination of Dr. Hinde's specimens leads me to agree with him that they should be referred to the Actinozoa.

With the exception of the single doubtful species of Archæocyathus, described by Mr. Matthew, from the Paradoxides zone of St. John, N. B., *A.? pavonoides*, there are no representatives of this family (Archæocyathinæ) in the later Cambrian. The first true corals met with in the ascending series occur near the base of the Ordovician.

Echinodermata.—The Echinodermata are represented by a few scattered plates of a species of Cystid, which is referred provisionally to the genus Eocystites. It is impossible to make any comparison between it and the Cystids of the Middle Cambrian.

Annelida, etc.—The trails, burrows and tracks of animals, that occur in the Lower Cambrian, are nearly all duplicated in the Upper Cambrian. This is true of the genera Planolites, Helminthoidichnites, Scolithus and Cruziana, of the American rocks. As far as determined by traces left by their passage the same type of animals existed throughout the Cambrian.

Brachiopoda.—The Brachiopoda, with 10 genera and 29 species, afford a much broader opportunity for comparison, but even here the specific connection is very slight between the two zones. Of the genera, Lingulella is represented in the Paradoxides zone by a group of forms that have received the names *L. Linguloides* and *L. Dawsoni*, in New Brunswick; *Lingulella* sp., in Linnarsson's Brachiopoda of the Paradoxides beds of Sweden (Plate III, figs. 24–28), and *L. Granvillensis*, in the Olenellus zone of New York. The species of the genus Acrotreta, of the Paradoxides zone of Sweden and New Brunswick and the Middle Cambrian zone of the Rocky Mountain Province, are so closely allied to the species from the Olenellus zone in Nevada that we consider that one species, *A. gemma*, ranges from the base of the Cambrian through to the Upper Cambrian. *Acrothele subsidua* also ranges from the Lower Cambrian to the Middle Cambrian, in the Rocky Mountains; and *A. Matthewi*, of the Paradoxides zone of New Brunswick, is a closely allied if not indentical species.

The genus Iphidea has a vertical range from the Olenellus zone in Labrador, to the Middle Cambrian in Sweden, where it is found in the Paradoxides beds. A very closely allied species also occurs in the lower portion of the Cambrian section, in the Grand Canon of Arizona, an horizon that will probably be referred to the Middle Cambrian.

The genus Kutorgina has one species, *K. Labradorica*, that has a wide geographic range, and a closely allied representative species, *K. Stissingensis*, occurs in the Middle Cambrian zone of New York. *K. pannula* ranges from the Olenellus zone to the Middle Cambrian, in Nevada, and is found in the upper portion of the Olenellus zone in New York.

Linnarssonia sagittalis var. *Taconica* is scarcely to be considered a typical Olenellus zone species, as it occurs so high in the Lower Cambrian section. Still, as it is associated with Olenellus we may consider it as forming a part of the fauna, and compare it directly with the same species as found in the Paradoxides zone of New Brunswick and Sweden. Of the six species of the genus Obolella none are known to occur in the Middle Cambrian, and it is not until we reach the Upper Cambrian that we find representatives of the genus. The genus Orthis, as represented by *O. Salemensis* and *O. Highlandensis* (the broad and narrow hinge types), is not known to occur in the Middle Cambrian zone, although both forms of the genus are represented in the Ordovician. Among the species referred to Orthisina, we find that *O. orientalis* is very closely related to *O. pepina* of the Upper Cambrian, also that *O. festinata* is of the type of *O. exporecta* of the Paradoxides zone of Sweden and *Orthis Billingsi* of the New Brunswick Middle Cambrian. *Camerella antiquata* and *C. minor* have no representatives in the Middle or Upper Cambrian.

As a whole, the Brachiopoda are strongly represented in the Lower Cambrian and do not exhibit any special evidence of embryonic character when compared with the fauna of the Middle and Upper Cambrian.

Lamellibranchiata.—The genus Fordilla and the form described as *Modioloides prisca* appear to be the representatives of the Lamellibranchiata in the Olenellus zone. The presence of these two shells is of unusual interest, as none of the same class are met with in the geologic succession before the abrupt appearance of the group of species in the Arenig (Lower Ordovician) strata of South Wales.

Gasteropoda.—Among the Gasteropoda, the genus Scenella is represented in the Upper Cambrian by simple patelloid shells. It has not been found in the Paradoxides fauna of the Atlantic basin, but in the Middle Cambrian strata of the Mt. Stephen section in the Rocky Mountains a representative species was found by Dr. Rominger. The forms referred to the genus Stenotheca are very closely allied if not identical in the Lower and Middle Cambrian zones. *S. rugosa*, of the Lower Cambrian, and *S. Acadica* of the Paradoxides zone are examples of this intimate specific relationship. The little Platyceras of the Lower Cambrian has a representative in the form described by Dr. C. Rominger from the Mt. Stephen Middle Cambrian of British Columbia. A single species in the Upper Cambrian connects this genus with the Ordovician fauna. *Pleu-*

rotomaria Attleborensis does not appear to have a representative before reaching the species of the Lower Ordovician fauna, and *Straparollina remota* has no connection through the known Middle Cambrian fauna with the fauna of the Ordovician.

Pteropoda.—The four genera and fifteen species of this close are very strongly related to those of the Middle Cambrian fauna. *Hyolithes princeps* is a large form that is very abundant in the Olenellus zone, and it has a great geographical range. It is found in Western Nevada, Eastern Massachusetts and Eastern Newfoundland. A closely allied if not identical species occurs in the Paradoxides zone in Newfoundland. *H. maximus* of the Paradoxides zone of Bohemia is of this same specific type, although differing considerably in detail of form. *H. Americanus* is very closely allied in form to *H. Acadica* of the Paradoxides zone in New Brunswick, and the same type is abundant in the Upper Cambrian of the Mississippi Valley, under the name of *H. primordialis*. *H. Billingsi* is known to range from the Lower to the Middle Cambrian, and has been found in Labrador, New York and Nevada. *H. communis*, *H. impar*, *H. quadricostatus* and *H. Terranovicus* are species which do not appear to have representatives in the Middle Cambrian fauna. *H. similis* is very much like *H. primus* of the Paradoxides zone of Bohemia. The genera Hyolithellus and Coleoloides do not appear to be represented by well authenticated species in the Middle Cambrian. Salterella is not met with again until the Ordovician fauna is reached and there very doubtfully.

Crustacea.—Of the true Crustaceans, *Leperditia dermatoides* has a close specific relationship with an undescribed species from the Middle Cambrian of the Grand Canon section of Arizona; and a representative species, *L. Stissingensis*, occurs in the New York Middle Cambrian.

The genus Aristozoa, although abundantly represented in the Silurian fauna of Europe, is not known from the Middle Cambrian fauna. *Protocaris Marshi* still remains the oldest known Phyllopod crustacean. The Upper Cambrian Phyllopod, *Hymenocaris vermicauda*, is the next met with, unless some of the forms referred to Stenotheca, in the Paradoxides zone, are portions of the carapace of some species whose generic relations are undetermined.

Trilobita.—The sixteen genera and fifty-three species of trilobites constitute less than one-third of the entire fauna. The range of variation among the genera and species includes forms with and without eyes, and with and without facial sutures. One of the surprising facts is that the genus Agnostus, which has been theoretically considered the ancestral form of the trilobite, does not appear to exist in the lower portion of the

Olenellus fauna, but, as shown by Brögger, in Sweden it is more typical of the Middle Cambrian than of the Olenellus zone. The undoubted species of the genus, known from the Olenellus zone, are found in the upper portion, in association with types of the Middle Cambrian fauna. The reference of *Agnostus nobilis* Ford, from the lower part, to Agnostus is very doubtful, as the form is probably a Microdiscus. The type which, by *a priori* reasoning, should succeed Agnostus is Microdiscus, with its three and four segments and eyeless cephalic shield. As known, however, it occurs at the base of the Olenellus zone, and its specific variations indicate prolonged existence in a period of which the record has not yet been discovered. Reaching its known maximum development, in species and size, in the Olenellus zone, the genus diminishes in the Paradoxides zone in about the same ratio that Agnostus increases in importance. In the Upper Cambrian Microdiscus is represented only by *Pemphigaspis bullata* Hall. Agnostus continues on into the Middle Ordovician. *Microdiscus connexus*, of the upper portion of the Olenellus zone, in New York, is the Paradoxides zone type of the genus, *M. punctatus*, while *M. sculptus*, of the lower Paradoxides zone of South Wales, is the Olenellus zone type, *M. speciosus*.

The genus Olenellus has been found wherever the Lower Cambrian fauna is known. It presents great variation in specific characters, and I have included several of the species in the sub-genus Mesonacis. The marked difference between this genus and Paradoxides is the absence of true facial sutures and in the general configuration of the central portion of the head, more notably in the form of the eye. Among the species of Paradoxides the eyes of *P. rugulosus* Corda and the group of species from the St. John terrane, of New Brunswick, approach most nearly to those of Olenellus. In the type *O. Thompsoni*, the distinction between it and Paradoxides is very striking. The absence of facial sutures and the long spine-like telson finds no counterpart in the latter.

O. (*Mesonacis*) *Vermontana* has the typical Paradoxides form of pygidium, also a peculiar posterior series of thoracic segments that are related to those of Paradoxides. This species appears as a link between the type *O. Thompsoni* and the remaining species referred to the genus, all of which have a pygidium like that of Paradoxides, and none of the pleuræ of the thoracic segments are prolonged, as in the type of the genus and in the young of some species of Paradoxides.

I would here call attention to the fact that while no true facial sutures may exist in Olenellus there is, on the underside of the test of the head, a line-like depression that corresponds in position to the suture in Paradoxides. It may be well to note that Olenellus resembles the living Limulus in having well developed eyes, without the presence of facial sutures. The external resemblance to Limulus is further enhanced by the telson-like pygidium of *O. Thompsoni*. The structure of the cephalic appendages of the trilobite also relate it to Limulus.*

If we consider the head of Limulus to belong to a more highly organized form than the head of Paradoxides, the fact that the head of Olenellus is without facial sutures does not make it rank below Paradoxides. In fact, *Olenellus Bröggeri*, of Newfoundland, impresses me as being as highly organized as any of the species of Paradoxides, if not more highly. *Olenellus Thompsoni* and *O. Gilberti* might be considered the progenitors of Paradoxides, inasmuch as they have a strong development of the pleura of one of the thoracic segments, a feature that is present in the young of *P. Bohemicus*, but does not continue in the adult.

American paleontologists have considered the genus Olenellus as the descendant of Paradoxides, but the fact of occurrence proves such a theory to be incorrect. The argument advanced by Mr. Ford,† that the young of *Olenellus asaphoides* passed through the Paradoxides stage, in its embryonic development, may be explained in another way, by assuming that the species of Olenellus, having the pleuræ of the third segment prolonged (macropleural), originated earlier than those with the pleuræ of uniform length (brachypleural), and hence the prolonged pleuræ are shown only in the embryonic phases of growth in the brachypleural species. As pointed out by Mr. Ford, the genus Paradoxides, like Olenellus, has brachypleural and macropleural species, but it is significant that it is in the young of Paradoxides that the macropleural feature of *O. Thompsoni* is developed, while in the adult it is reduced to a very insignificant character. That an intimate if not a genetic relationship exists between Olenellus and Paradoxides there is little doubt. Olenellus exhibits greater specific variation and is more diversified by spines on the head and thorax, but in the essential elements of structure it is very closely related to Paradoxides. With the exception of *O.* (*Mesonacis*) *Vermontana* there are no known connecting species between the typical forms of the two genera.

The genus Olenoides is largely developed in the Middle Cambrian of the interior of the continent. One species only, *O. Marcoui*, is found in the lower portion of the Olenellus zone. Two other species, *O. Fordi* and *O. quadriceps*, are in the upper portion, near the passage between the Lower and

* Bull. Mus. Comp Zool. Harvard College, vol. viii, No. 10, 1881, pp. 208–211.
† This Journal, III, vol. xxii, 1881, pp. 250–259.

Middle Cambrian. As far as the specimens of *O. Marcoui* of the Lower Cambrian will permit of comparison, it and *O. Nevadensis* of the Upper Cambrian are closely related.

The two species of Zacanthoides, *Z. Eatoni* and *Z. levis*, are representative species of the genus, and serve to unite the fauna with that of the Middle Cambrian, as *Z. typicalis* and several species occur in the Middle Cambrian of the interior of the continent. The genera Bathynotus, Avalonia, Oryctocephalus and Protypus are peculiar to the fauna and do not appear to be represented in the Middle or Upper Cambrian.

Conocoryphe trilineata is one of the best marked forms in the New York Lower Cambrian, and is closely related to *C. elegans* and *C. coronata*, of the Paradoxides zone, in having the same general form and in the absence of eyes. The genus Ptychoparia is represented by nine species, all of which are more or less closely related to forms in the Middle and Upper Cambrian.

Agraulos strenuus is represented in the Upper Cambrian by *A. socialis*. *Ellipsocephalus Nordenskiöldi*, of Sweden, is represented by *E. Hoffi* of the Paradoxides zone of Bohemia. *Crepicephalus Augusta* and *C. Liliana* are types that are more or less abundant in the Upper Cambrian fauna of the interior of the continent. They are not represented, to my knowledge, in the Middle Cambrian fauna. The small head that I have referred to *Anomocare parvum* may be compared to *A. sulcatum* of the Paradoxides beds of Sweden. The genus Solenopleura, with its five species, is also well developed in the Middle Cambrian fauna. *S. Howleyi*, from the base of the Olenellus zone of Newfoundland, is very closely related to the type of the genus, *S. holometopa*, of the Paradoxides zone of Sweden.

Comparison of the Faunas as a whole.—The first thing that strikes one in comparing the fauna of the Olenellus zone with that of the Middle Cambrian is that the latter is not wholly known, or in other words, there existed somewhere a Middle Cambrian fauna which has not yet been found. We are now obtaining evidence of a considerable fauna that lived during Middle Cambrian time, on the west or Pacific coast of what then existed as the North American continent, and of which there is scarcely any representation in the Middle Cambrian or Paradoxides fauna of the Atlantic Province. This will add to the fauna, but there is still a notable absence of certain forms in the Middle Cambrian fauna which are present in the Lower Cambrian. The first noticeable exception is the absence of representatives of the peculiar group of corals that occur in the Olenellus zone. With a single possible exception the Archæocyathinæ are not represented in the Middle Cambrian.

Among the Brachiopoda the genus Obolella has a large development in the Lower Cambrian and is present in the Upper Cambrian, but is scarcely represented in the Middle Cambrian; and the Brachiopoda, as a whole, are more largely developed in species and number of individuals than in the Middle Cambrian. Lamellibranchs are represented in the Lower Cambrian, but not in the Middle Cambrian.

Among the Gasteropods, Pleurotomaria and Straparollina are yet to be discovered in the Middle Cambrian. The same is true of the Phyllopod crustacean *Protocaris Marshi.*

Viewing the Olenellus fauna as a whole and comparing it with the known Middle Cambrian fauna of the Atlantic Basin, or the Paradoxides fauna, the impression made is that the former is more highly differentiated, and, zoologically considered, the successor of the Paradoxides fauna. If, in our comparison, we include the Middle Cambrian fauna of the interior of the continent, this conclusion will be changed, owing to the presence of a group of trilobites, from the Middle Cambrian of Nevada, Utah and British Columbia, that includes the genera Olenoides, Asaphiscus, Bathyuriscus, Karlia and Ogygopsis. These genera suggest the trilobites of the second or Ordovician fauna, and serve to connect the Middle Cambrian fauna so closely with the second fauna that the idea of its preceding the Olenellus fauna cannot be entertained.

It was owing to the comparison made between the two faunas in the Atlantic Basin that led me to so long retain the view that the Olenellus fauna succeeded the Paradoxides fauna in time, and to think that the Paradoxides fauna would be found, if at all, beneath the Olenellus zone, in the interior of the continent. Now that we know that the Olenellus fauna occurs beneath the Paradoxides zone in America, and that there is a representative Middle Cambrian fauna, in the valley of the Hudson, that serves in a measure to connect the Paradoxides fauna of the Atlantic Basin and the Middle Cambrian fauna of the interior of the continent, there is no hesitation in referring the group of species, forming the fauna between the Olenellus and the Upper Cambrian zone, in the Rocky Mountain province, to the Middle Cambrian, and in correlating its stratigraphic position with that of the Paradoxides fauna of the Atlantic Province.

Comparison and Correlation.—If a comparison is made between the fauna of the Olenellus Zone and that of the Ordovician, the superiority of the latter in number of species, genera and families is at once apparent. If the comparison is extended to class characters the disparity between the two is very much reduced and it is made evident that the evolution of life between the epoch of the Olenellus fauna and the epoch of the Ordovician fauna has been in the direction of differentiating the class types that existed in the earlier fauna with one or two exceptions, the most notable of which is the Cephalopoda. The classes represented by non-testaceous species may or may not have existed.

The study of the Olenellus fauna adds a little more to our knowledge of the rate of convergence backward in geologic time of the lines representing the evolution of animal life and at the same time proves that an immense time interval elapsed between the beginnings of life and the epoch represented by the Olenellus fauna.

The study of the Olenellus and Middle Cambrian faunas illustrates very forcibly the strength and weakness of paleontological correlation. To the student reading this paper it may appear that the correlation is based on a correspondence in age, whereas, it is the homotaxis or similarity of order that is used in correlating the widely separated portions of the Olenellus fauna. It is the expression of the similarity of serial relation in the faunas contained in the strata of different provinces or areas. We cannot state that the Olenellus fauna of Sweden, New York and Nevada was contemporaneous in time, but we can state that the relations of this fauna to the succeeding Middle and Upper Cambrian and Ordovician faunas is essentially the same in the widely separated localities. Also that the Olenellus fauna is the basal fauna wherever it has been found.

As an element of weakness in paleontologic correlation, we may cite the character of the Middle Cambrian or Paradoxides fauna of the Atlantic Province as compared with the essentially different Middle Cambrian fauna of the Rocky Mountain Province. The position of the latter in the geologic series would not be inferred from its zoologic characters. It is only its occurrence at an horizon between the Lower and Upper Cambrian faunas that gives any strong reason for correlating it with the Paradoxides fauna. The latter retains all the essential characters of the Primordial fauna whereas the former partakes in its trilobites largely of the characters that are more typical of the Ordovician fauna. It appears from what we now know of the two, that the Middle Cambrian fauna of the Rocky Mountain Province had advanced further in development toward the Ordovician fauna than had the Paradoxides fauna of the Atlantic Province. It is an interesting fact in this connection that the Upper Cambrian fauna of the Rocky Mountain Province and the Atlantic Province appears to be essentially of the same grade or phase of development. What became of the descendants of the Middle Cambrian fauna of the Rocky Mountain Province during Upper Cambrian time is one of the unsolved problems.

ART. IV.—*Notes on the occurrence of a Leucite Rock in the Absaroka Range, Wyoming Territory;* by ARNOLD HAGUE.

BEYOND the confines of Europe occurrences of leucite as a constituent of rock masses are exceedingly rare and up to fifteen years ago they were unknown. With the introduction of the searching methods employed in modern petrographical investigation many microscopic minerals have been detected in crystalline rocks, whose presence had not previously been suspected. In most instances, as soon as the observations were published, other investigators have been able to confirm the results of their fellow workers and these exceptional minerals were soon reported in allied rocks in widely separated parts of the world. With leucite, however, the case is somewhat different, and although it is a mineral which has excited much interest and considerable discussion among chemists, mineralogists and geologists over its composition, crystallographic form and mode of occurrence, the microscope, in spite of diligent search, has added but one or two new localities of European basalts carrying leucite and still fewer from other parts of the world.

In 1874 Vogelsang detected small crystals of leucite in the basaltic rock from Gunong Bantal Soesoem, a small island of the Bawean group not far from the Island of Java. In the following year Prof. Zirkel* discovered an exceedingly large amount of leucite in a remarkable rock from Wyoming Territory in the collections of the Geological Survey of the Fortieth Parallel. The mode of occurrence of this rock accompanied by a chemical analysis, was published by Mr. S. F. Emmons† in his geological description of the region, he designating the group of hills where the mineral occurs as the "Leucite Hills." Not until ten years later was leucite again found in a new locality, when Von Chrustschoff‡ determined the mineral in a rock from Cerro de las Virginas, in Lower California, and in this case he only received a single hand-specimen upon which to carry out his investigation. In a paper presented to the Royal Geological Society of London, by Orville A. Derby, a short description is given of an occurrence of leucite in a black basalt found near Pinhalzinho, Brazil.§ This announcement was followed soon after by the discovery by Prof. John W. Judd of an occurrence of leucite in Australia in a rock which, according

* U. S. Geol. Expl. of 40th Par., vol. iv, p. 259.

† U. S. Geol. Expl. of 40th Par., vol. ii, p. 236.

‡ Tschermak's Mittheilungen, vol. vi, 1885.

§ Quart. Journ. Geol. Soc., vol. xliii, Pt. 3, p. 463.

to him, had many points of resemblance to the rock of the Leucite Hills. This leucite rock is found near Bourke, in the colony of New South Wales, about 450 miles northwest from Sydney. Last year Mr. J. S. Hyland* described a small collection of rocks from Mt. Kilimanjaro in Africa, among which were specimens of basanite carrying small crystals of leucite along with nepheline. Within the last few years we have the announcement of the detection of leucite in Asia, Africa, South America and Australia, but as yet from only one locality in each of these great land divisions of the globe. Up to the present time the two North American occurrences already mentioned, are the only instances reported from this country; new localities, therefore, are not without interest.

In the early autumn of 1888, the writer, while engaged in geological explorations in the southern end of the Absaroka Range in northwestern Wyoming, collected a specimen of basic lava which subsequently proved to carry a considerable amount of microscopic leucites. Unfortunately, only a single hand-specimen was obtained, slight importance being attached to the rock at the time, as it was not found in place, but taken from a bowlder whose precise mode of occurrence was unknown. The bowlder was found in the gorge of the Ishawooa River, the main north branch of the South Fork of the Stinking Water, the river rising in the summits of the mountains not far from the sources of the Yellowstone. The Absaroka range presents one of the boldest and wildest regions of the Rocky Mountains; it stretches in a north and south line for over one hundred miles, with an average width of more than twenty miles, extending from about the 45th parallel, the boundary between Montana and Wyoming, southward until it joins the Wind River range. Geologically, the Absaroka range throughout its entire length and breadth, is formed of enormous masses of volcanic lavas, no other rocks being known in the more elevated portions. For the most part these lavas are made up of coarse and fine breccias and agglomerates of basic andesites and transition rocks to true basaltic breccias. Deep and profound cañons afford admirable sections through this volcanic material, two, three and four thousand feet in thickness. It was while engaged in examining these lavas and their relations to the wonderful system of dikes which penetrate them, that the bowlder was noticed. Along the gorge no rocks are known other than the great sheets of lava and the intrusive dikes. The configuration of the country precludes the possibility of the leucite bowlder having been transported there from any distant region.

* Tschermak's Mittheilungen, vol. ix, 1888.

At first glance the most striking feature of the rock is the number and size of the grains of fresh olivine scattered through it. Indeed, it was this feature which first attracted attention, the amount of olivine present being exceptional for the rocks of this region. Associated with the olivine and the only other mineral easily recognized by the eye, are large and well developed porphyritic augites. The two porphyritic minerals, olivine and augite, lie in a groundmass made up for the most part of leucite and orthoclase, very little plagioclase being present. The other minerals present are magnetite, apatite, and sparingly, minute flakes of brown mica The groundmass may contain a small amount of glass base, but the rock comes very near being holocrystalline in structure. Thin sections show no indication of either nepheline or nosean.

I am indebted to Mr. Joseph P Iddings for the following observations on the leucite:

"The leucite is partly idiomorphic and exhibits the characteristic outlines derived from the icositetrahedron; much of it, however, is allotriomorphic. Many of the leucites exhibit twin lamination and optical anomalies characteristic of this mineral, but others appear to be wholly isotropic in thin section. A number of the individuals, including those with allotriomorphic forms, carry minute augite grains arranged centrally or in a spherical zone about the centre of the crystal. They are also penetrated by needles of apatite. In parts of the rock the leucites show signs of alteration to a cloudy isotropic substance which is probably analcite. The rock contains remnants of glass base which resemble those found in many basalts. They are filled with brown mica and apatite and appear to have been devitrified as they are no longer isotropic."

No rock with which I am acquainted quite agrees with this one in mineral composition, apparently failing to fall into place under any generally accepted classification. It corresponds more closely to a leucite-phonolite than anything else; that is to say, a rock composed of orthoclase, leucite and augite. According to Rosenbusch, leucite-phonolite only carries olivine as an accessory mineral, whereas the Ishawooa rock is strongly characterized by olivine. The presence of a considerable amount of orthoclase and the small amount of plagioclase seems to exclude the rock from the basalts. Provisionally the rock may be called an olivine-leucite-phonolite. Mr. J. E. Whitfield of the chemical laboratory of the U. S. Geological Survey, made an analysis of the rock, which is found in column 1 of the following table:

	No. 1.	No. 2.	No 3.	No. 4.
Silica	47·28	54·42	52·11	44·35
Titanic acid	·88	----------	·16	--------
Alumina	11·56	13·37	23·01	10·20
Ferric oxide	3·52	·61	8·41	13·50
Ferrous oxide	5·71	3·52	1·75	--------
Manganous oxide	·13	----------	trace	--------
Lime	9·20	4.38	3·40	11·47
Magnesia	13·17	6·37	2·18	12·31
Soda	2·73	1·60	3·10	3·37
Potash	2·17	10·73	5·37	4·42
Chlorine	·18	----------	----------	--------
Phosphoric acid	·59	----------	·19	--------
Carbonic acid	----------	1·82	----------	--------
Water	2·96	2·76	1·10	--------
	100·08			
Less 0 for Cl	·04			
Total	100·04	99·58	100·78	99·62

No. 1, Ishawooa Cañon, Wyoming Territory; No. 2, Cerro de las Virginas, Lower California; No. 3, Leucite hills, Wyoming Territory; No. 4, Bongsberg, near Pelm in the Eifel.

The analysis of the bowlder from Ishawooa Cañon shows a somewhat exceptional magma and affords a striking example of a rock whose chemical composition gives but slight indication of its mineral composition. No one would be led to suspect the presence of leucite in a rock carrying so low a percentage of alkalies. In most rocks characterized by the presence of leucite, the mineral has crystallized out of a strongly alkaline magma, and one in which potash is usually considerably in excess of the soda as shown in the Vesuvian lavas and those from the Leucite Hills. In the case of the Ishawooa rock the soda and potash taken together only sum up about five per cent of alkali with soda in excess of the potash The amount of magnesia present is exceptionally high with a correspondingly low amount of alumina, in this respect quite unlike the Vesuvian leucite-basalts. It is evident from a study of this olivine-leucite-phonolite that the olivine, augite, magnetite and apatite were the product of the first generation of crystals and were developed out of the magma before the crystallization of the orthoclase and leucite. Now by removing from the original magma the material required for the earlier crystallization there would remain a magma carrying in a more concentrated form the greater part of the alkalies, which as shown by the second generation of crystals, was more favorable for the development of orthoclase and leucite. It is a marked instance of the potassium and sodium silicates being the last to solidify. Under different conditions of crystallization a mineral development quite at variance with that found in this rock may possibly have been produced from the same original magma.

At some future time the locality will be revisited with the expectation of finding the rock in place and exposed in a way to permit of the study of any modifications of structure the rock mass may undergo. It will, I think, be found to occur as one of the intrusive dikes cutting the earlier andesitic lava sheets and broad fields of breccias. Ishawooa Canon lies north of the Leucite hills about 150 miles, the geological conditions being quite different from those surrounding the earlier known locality.

In columns 2 and 3 of the table will be found analyses from the two other American localities of leucite-bearing rocks. In column 4 of the table the analysis of a leucite-basalt from the Eifel, described by Hussak, is given for the purposes of comparison, it corresponding more closely in chemical composition to the Ishawooa rock than any other published analysis. It is, however, like most leucite rocks, richer in alkalies with potash in excess of the soda.

Art. V.—*On Allotropic Forms of Silver*; by M. Carey Lea.

[Continued from page 491, vol. xxxvii.]

In the first part of this paper were described certain forms of silver; among them a lilac-blue substance, very soluble in water with a deep red color. After undergoing purification it was shown to be nearly pure silver. During the purification by washing it seemed to change somewhat, and consequently some uncertainty existed as to whether or not the purified substance was essentially the same as the first product: it seemed possible that the extreme solubility of the product in its first condition might be due to a combination in some way with citric acid, the acid separating during the washing. Many attempts were made to get a decisive indication and two series of analyses, one a long one, to determine the ratio between the silver and the citric acid present, without obtaining a wholly satisfactory result, inasmuch as even these determinations of mere ratio involved a certain degree of previous purification which might have caused a separation.

This question has since been settled in an extremely simple way, and the fact established that the soluble blue substance contains not a trace of combined citric acid.

The precipitated lilac-blue substance (obtained by reducing silver citrate by ferrous citrate) was thrown on a filter and cleared of mother water as far as possible with a filter pump.

Pure water was then poured on in successive portions until more than half the substance was dissolved. The residue, evidently quite unchanged, was of course tolerably free from mother water. It was found that by evaporating it to dryness over a water bath, most of the silver separated out as bright white normal silver; by adding water and evaporating a second time, the separation was complete and water added dissolved no silver. *The solution thus obtained was neutral.* It must have been acid had any citric acid been combined originally with the silver. This experiment, repeated with every precaution, seems conclusive. The ferrous solution, used for reducing the silver citrate had been brought to exact neutrality with sodium hydroxide. After the reduction had been effected the mother water over the lilac-blue precipitate was neutral or faintly acid.

A corroborating indication is the following. The portions of the lilac-blue substance which were dissolved on the filter (see above) were received into a dilute solution of magnesium sulphate, which throws down insoluble allotropic silver of the form I have called B, (see previous paper.) This form has already been shown to be nearly pure silver. The magnesia solution, neutral before use was also neutral after it had effected the precipitation, indicating that no citric acid had been set free in the precipitation of the silver.

It seems therefore clear that the lilac-blue substance contains no combined citric acid. Had the solubility of the silver been due to combination with either acid or alkali, the liquid from which it was separated by digestion at or below 100° C. must have been acid or alkaline; it could not have been neutral.

We have therefore this alternative. In the lilac-blue substance we have, either pure silver in a soluble form, or else a compound of silver with a perfectly neutral substance generated from citric acid in the reaction which leads to the formation of the lilac-blue substance. If this last should prove the true explanation, then we have to do with a combination of silver of a quite different nature from any silver compounds hitherto known. A neutral substance generated from citric acid must have one or more atoms of hydrogen replaced by silver. This possibility recalls the recent observations of Ballo, who by acting with a ferrous salt on tartaric acid, obtained a neutral colloid substance having the constitution of arabin, $C_6H_{10}O_5$.

To appreciate the difficulty of arriving at a correct conclusion, it must be remembered that the silver precipitate is obtained saturated with strong solutions of ferric and ferrous citrate, sodium citrate, sulphate, etc. These cannot be removed by washing with pure water, in which the substance itself is very soluble, but must be got rid of by washing with saline solutions, under the influence of which the substance itself slowly but continually changes. Next, the saline solution used for washing must be removed by alcohol. During this treatment, the substance, at first very soluble, gradually loses its solubility and when ready for analysis, has become wholly insoluble. It is impossible at present to say whether it may not have undergone other change: this is a matter as to which I hope to speak more positively later. It is to be remarked, however, that these allotropic forms of silver acquire and lose solubility from very slight causes, as an instance of which may be mentioned, the ease with which the insoluble form B recovers its solubility under the influence of sodium sulphate and borate and other salts as described in the previous part of this paper.

The two insoluble forms of allotropic silver which I have described as B and C; B, bluish green, C rich golden color, show the following curious reaction. A film of B, spread on glass and heated in a water stove to 100° C. for a few minutes becomes superficially bright yellow. A similar film of the gold-colored substance C treated in the same way, acquires a blue bloom. In both cases it is the surface only that changes.

Sensitiveness to Light.—All these forms of silver are acted upon by light. A and B acquire a brownish tinge by some hours' exposure to sunlight. With C the case is quite different, the color changes from that of red gold to that of pure yellow gold. The experiment is an interesting one, the exposed portion retains its full metallic brilliancy, giving an additional proof that the color depends upon molecular arrangement, and this with the allotropic forms of silver is subject to change from almost any influence.

Stability.—These substances vary greatly in stability under influences difficult to appreciate. I have two specimens of the gold yellow substance C, both made in Dec. 1886, with the same proportions, under the same conditions. One has passed to dazzling white, normal silver, without falling to powder, or undergoing disaggregation of any sort; the fragments have retained their shape, simply changing to a pure frosted white, remaining apparently as solid as before, the other is unchanged and still shows its deep yellow color, and golden luster. Another specimen made within a few months and supposed to be permanent has changed to brown. Complete exclusion of air and light is certainly favorable to permanence.

Physical condition.—The brittleness of the substances B and C, the facility with which they can be reduced to the finest powder, makes a striking point of difference between allotropic and normal silver. It is probable that normal silver, precipitated in fine powder and set aside moist to dry gradually, may cohere into brittle lumps, but these would be mere aggregations of discontinuous material. With allotropic silver the case is very different, the particles dry in optical contact with each other, the surfaces are brilliant and the material evidently continuous. That this should be brittle indicates a totally different state of molecular constitution from that of normal silver.

Specific Gravities.—The allotropic forms of silver show a lower specific gravity than that of normal silver.

In determining the specific gravities it was found essential to keep the sp. gr. bottle after placing the material in it for some hours under the bell of an air pump. Films of air attach themselves obstinately to the surfaces and escape but slowly even in vacuo.

Taken with this precaution, the blue substance B gave specific gravity 9·58 and the yellow substance C, sp. gr. 8·51. The specific gravity of normal silver, after melting was found by G. Rose to be 10·5. That of finely divided silver obtained by precipitation is stated to be 10·62.*

I believe these determinations to be exact for the specimens employed. But the condition of aggregation may not improbably vary somewhat in different specimens. It seems however clear that these forms of silver have a lower specific gravity than the normal, and this is what would be expected.

Chestnut Hill, Philadelphia, May, 1889.

ART. IV.—*The Peridotite of Pike County, Arkansas;* by JOHN C. BRANNER, State Geologist of Arkansas, and RICHARD N. BRACKETT, Chemist of the Geological Survey of Arkansas. With Plate I.

PART I, *by John C. Branner.*

TWO and a half miles southeast of Murfreesboro in Pike county, Arkansas, is a small exposure of peridotite whose position and topographic features are shown in detail upon the accompanying map (Plate I.) The entire exposure is about 2400 feet long by 1600 feet wide, and lies upon the middle of the line between sections 21 and 28 of township 8 south, range 25 west.

From a geological standpoint this exposure is an important one, for, small as it is, it offers a suggestion regarding the time and character of the disturbing influences, which, about the

* Watts' Dict., orig. ed., v, 277.

close of the Cretaceous, sank the greater part of Arkansas as well as the large Tertiary-covered portions of the neighboring states beneath the ocean. It is important, also, from a petrographic standpoint as being the third reported occurrence of picrite-porphyry in the United States.

With the accompanying map and section before the reader, it will not be necessary to give a detailed description of the locality. It was first reported by Dr. Owen in his "Second Geological Report," p. 32, but was not studied by him in detail, and the rock is simply spoken of by him as a "porphyritic greenstone" and a "trachytic rock." Since Dr. Owen's time no one seems to have made any observations upon it. Some of the geological maps that have, from time to time, been published of the United States, have represented in this place a large Archæan area. The rock presents no great variety in lithologic characters, and the specimens examined microscopically by Dr. Brackett, and described by him in the second part of this paper, fairly represent them, except that in many places through the general mass it contains a good many angular and sub-angular inclusions of crystalline rock, which are especially noticeable wherever the rock is deeply decomposed, and that one small dyke coming up through the Mesozoic beds contains a vast quantity of fragments of Paleozoic sandstone and shale and of soft sandstone and quartz pebbles from the Mesozoic. Only in the three hills shown upon the map, and in the one very small dyke is the rock found solid, disintegration having gone so far in the lower grounds that it there occurs only in the form of a soft earthy wacke, which washes very readily into deep gullies. This earth, where freshest and unmixed with organic matter, presents many beautiful shades of green, brown, red, and gray colors. At one point a dyke is uncovered in one of these gullies. This dyke is about six feet wide, runs east-west, and in place of the olive-green color so characteristic of the general mass, it is of a beautiful bright blue color. It is so deeply decomposed that no solid specimens could be had from it. On the summit and sides of the central hill the rock mass is broken into large blocks, which, by concentric disintegration and exfoliation, are left in the form of bowlders of various sizes.

If the overlying Post-tertiary and Quaternary debris could be removed in the immediate vicinity of this exposure, it is probable that the area of igneous rocks, as shown upon the accompanying map, would be somewhat enlarged, at least by disclosing dykes radiating from the central mass. There is no reason for supposing, however, that the Post-tertiary obscures any great area of peridotite. There are no exposures of it in Prairie creek, except a single small dyke not more than ten inches wide and about fifty feet long, while a deep gully on the north side of the outburst (Poor House branch on the map), shows no exposures. East of the exposure, at the house of Mr. McBrayer (shown upon the accompanying map), a well recently dug to a depth of 162 feet penetrated only the clay, cobble stones and soft calcareous beds, such as characterize the Post-tertiary and lower Cretaceous in this region.

The following is the section of Mr. McBrayer's well:

10′	Clays	Quaternary and recent.
10′	Cobbles and pebbles	Post-tertiary.
142′	Soft arenaceous clays and calcareous beds variously colored.	Lower Cretaceous ("Trinity" of Hill).

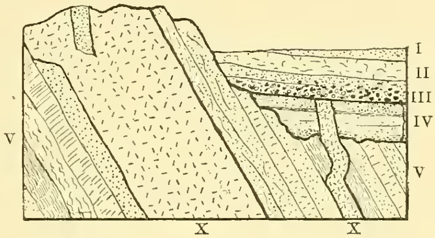
These facts appear to indicate that the outburst was confined to this very circumscribed area, there being no eastward extension of it at the depth reached in McBrayer's well—162 feet below the level of his house—and but one westward exposure uncovered at the mouth of Prarie creek.

Relations of the igneous to the sedimentary rock.—Besides this peridotite, the rocks exposed in this part of Arkansas are of Paleozoic, Lower Cretaceous ("Trinity" of Hill), Post-tertiary and Quaternary ages. The Paleozoic rocks form the high lands of the hilly and mountainous region of the state lying north of the Neozoic exposures. They are made up of alternations of sandstones and shales, and are highly flexed, the axes of the folds varying but little from due east and west. Just north of Murfreesboro, and four miles from the exposure of peridotite, these sandstones and shales have a high south dip, at many places standing almost or quite vertical. These south dips continue for many miles to the north, a section measured across the beds farther east showing an aggregate vertical thickness of strata of at least four miles. Against and upon the eroded, upturned edges of these Carboniferous rocks the lower Cretaceous beds have been deposited. The rocks of the Cretaceous are soft sandstones, shales, lignites, clays, etc., all beautifully variegated, the predominating colors being straw, lead, pink, and terra cotta, and the beds exhibit a low and almost imperceptible dip to the east and southeast.*

The Little Missouri River and its predecessor, flowing along the original inland margin of the Cretaceous, have here cut out a valley five miles wide, its right and southern wall being a

* Through the kindness of the Director of the U. S. Geological Survey, Prof. R. T. Hill spent the past year in studying the Mesozoic geology of Arkansas. His report is already completed and forms Vol. II of the annual report of the Geological Survey of Arkansas for 1888. In this report, Prof. Hill shows that the Mesozoic rocks in the vicinity of this exposure belong to what he calls the Trinity, which he thinks is equivalent of the Wealden of Europe.

line of nearly vertical Cretaceous cliffs, which are the attacked northern edges of these beds; the left or northern border is formed by the Paleozoic highlands, while the bottom of the valley is in lower Cretaceous beds covered by Post-tertiary debris and by Quaternary and recent sediments. It is in this plain that the exposure of peridotite occurs. The accompanying section shows the relations of the intruded rocks to those of sedimentary origin.



Section through the Pike County Peridotite and the adjacent Formations.

I. River silt.
II. Yellow loam.
III. Post-tertiary.
IV. Lower Cretaceous ("Trinity" of Hill).
V. Paleozoic (lower Carboniferous?)
X. Peridotite.

(The relations shown in this section, with the exception of the exact contact of the Paleozoic with the igneous rocks, may all be seen, though not at any one exposure.)

The contact between the Paleozoic and the Cretaceous is exposed in Prairie creek about two miles northeast of Murfreesborough where the Cretaceous rock is a conglomerate with calcareous cement. These parti-colored Cretaceous beds are cut into and exposed in many places, and at low water almost continuously, along Prairie creek from this point to the mouth of the stream, while on the right bank of the Little Missouri they rise in beautifully exposed cliffs to a height of nearly one hundred feet above the river.

Where Prairie creek enters the Little Missouri, a dyke of peridotite not more than ten inches wide stands out for fifty feet across the mouth of the former stream, and on the left bank of the river this dyke is seen to penetrate the soft sandstones of the lower Cretaceous. Where the Cretaceous has been cut away by Post-tertiary erosion and covered with the water-worn debris, the dyke is also cut off even with the eroded Cretaceous surface and covered with debris. At the line of contact between the dyke and the Cretaceous sandstone, the most careful microscopic examination does not reveal the slightest trace of metamorphism. The original material injected into this crevice is so thoroughly filled with the debris of the beds through which it has passed—shales, sandstones and quartz pebbles—that their included fragments form about two-thirds of the dyke as it now stands. Even the soft inclusions from the Cretaceous are unaffected. The great number of these inclusions suggest that the injected mass was cooled by them to such an extent that it was rendered incapable of producing contact metamorphism even on a very small scale.

The horizontally bedded Cretaceous strata do not appear to be disturbed in any way whatever by the presence of this dyke or even by that of the main body of peridotite. This little dyke affords the principal evidence in regard to the age of these igneous rocks.

The Paleozoic exposure at this locality is the most southerly one known in the state. The rocks are all sandstones or quartzites, frequently false-bedded, and contain many so-called "fucoid impressions." They are much fractured and jointed and occur, for the most part, as irregular and angular blocks, and only at the extreme southwest part of the exposure is it possible to determine their dip satisfactorily. The dip moreover is not uniform either in amount or direction, the one measured being 26° southwest, and somewhat below the average. The exact contact between the Paleozoic and the igneous rock is not visible.

The rocks of this group vary considerably from flinty greenish quartzites to light-colored and porous sandstones, but this variation is no greater than one might expect to find in the variable sandstones of the Lower Carboniferous to which these are supposed to belong. Some of the quartzites are extremely hard, but the appearance of freshly broken specimens shows that this hardness is to be attributed to the indurating effects of weathering, rather than to contact metamorphism. In some instances the sandstones are of a light brown color and contain traces of vegetable matter, though no recognizable forms have thus far been discovered. In other cases they are tinged with green coloring matter, probably due to the presence of chlorite.

Inasmuch as it has been suggested that the South African diamonds may have been generated by the metamorphism of the carbon in the carbonaceous shales penetrated by peridotite, I should add that no such phenomenon is suggested by observations at this locality or upon these rocks.

The Post-tertiary wash so widespread in southwestern Arkansas is thinly scattered about the foot of the ridge of peridotite. Its cobbles and pebbles are of sandstone, quartz, novaculite, and jasper, cemented here and there into a ferruginous conglomerate. The fragments are usually much water-worn, but some of them are subangular, while in size they range from that of one's head downward. Careful search was made among this material for fragments of peridotite or serpentine, but none was found. From the readiness with which this rock decomposes, however, it could hardly be expected that such fragments would be preserved for any great length of time.

The sum of our evidence favors the hypothesis that this peridotite is a simple injection which took place about the close of the Cretaceous through and between the Paleozoic strata, and penetrating the lower Cretaceous beds, and that whatever its relations to orographic movements may have been, it caused no great direct disturbance either chemical or physical in the beds with which it appears in contact.

It naturally occurs to one that the Tertiary subsidence and the intrusion of these igneous rocks are associated in some way; but which is the cause and which the effect, the facts to be gathered at this locality do not indicate.

The course of geologic events at this place as indicated by the geology of the region was as follows:

Time.	Event.
1. Close of the Carboniferous.	At the close of the Carboniferous, the rocks of that age were flexed, lifted, and subjected to very extensive subaerial erosion.
2. Early Cretaceous.	The southeast margin of the eroded land sank beneath the ocean and the lower and Upper Cretaceous beds were deposited against and upon them.
3. Close of the Cretaceous.	The land was elevated and the Cretaceous beds exposed to a brief period of erosion.
4. Early Tertiary.	The igneous rocks were ejected through the Paleozoic shales and sandstones and the clays and soft sandstones of the lower (and upper?) Cretaceous, and the land sank beneath the seas in which the Tertiary beds were laid down.
5. Post-tertiary.	The Tertiary series was elevated and in the slow process of passing through the beach condition, its soft beds were subjected to extensive erosion and denudation.
6. Quaternary.	Quaternary events, which need not be specified here.

Of about a dozen known occurrences of crystalline rocks in the state of Arkansas, the peridotite of Pike county offers the best evidence of the date of its intrusion. All the other known exposures are north of the Cretaceous area and in a region in which metamorphism has been so general that every trace of the paleontologic evidence of the age of the rocks penetrated that may have existed has been entirely obliterated, and we are therefore unable to determine by any evidence thus far collected, the precise age of those beds, and are consequently unable to determine the age of the eruptives.

The syenites of Little Rock are not Archæan as they have so long been supposed, but are intrusions into Paleozoic rocks, probably of Lower Carboniferous age. They are overlain, however, by Tertiary beds. The Magnet Cove crystallines are also in Paleozoic rocks, and are overlain here and there by Post-tertiary debris.

PART II. *A Microscopic Study of the Peridotite of Pike County, Arkansas, by Richard N. Brackett.*

THE specimens of eruptive rock from the middle hill shown in the map, consists in the main, of a dark colored somewhat green, heavy rock having a porphyritic structure, and specific gravity of 2·728 to 2·651. Examined microscopically it is seen to be made up of black grains, some slightly yellow and having glistening surfaces, imbedded in a dark green to brownish-green groundmass. The material from the base of the northeastern hill, is a brown, much decomposed rock, with a more distinctly porphyritic structure due to the decomposition of the black to yellow grains, and of the groundmass to a decided brown, against which the yellow grains stand out sharply. The specific gravity of this rock is 2·317. Through it extends a vein of white barite about four inches in thickness.

In contact with the barite vein are veins of serpentine formed by the decomposition of the rock. In immediate contact with the barite the serpentine vein is white, but shades through a light green into the brown rock.

A microscopic study of thin sections prepared from specimens from the first exposure mentioned, reveals a rock of true porphyritic structure, consisting of crystals and grains of more or less decomposed, colorless olivine and some irregular patches of a yellow to brownish-yellow mica imbedded in a quite uniform, fine-grained groundmass made up of colorless little lath-shaped crystals, yellow grains, black grains and a yellowish base (Nos. 34, 35 and 36).*

The olivine crystals and grains are decomposed in the usual well-known way, being cracked and changed to serpentine along the cracks. Few or none of the olivines are entirely unchanged, though there are many fresh cores and almost entire grains and crystals remaining. (No. 35). Where no olivine is left the outlines of the former olivine crystals are often well preserved. In such cases the olivines are entirely changed to serpentine, of both yellow and light green color and to carbonates, and hydroxide of iron, to which last the reddish stain of many is due (Nos. 34 and 36). Many of the decomposed olivines contain also "trichites," slender, black, hairlike bodies which occur singly and in bunches. These "trichites" are probably magnetite.

*Numbers in parenthesis refer to numbers of specimens in the collections of the Geological Survey of Arkansas.

The yellow mica is grown through with little colorless lath-shaped crystals like those in the groundmass. It has a weak pleochroism; O=orange or faintly reddish; E=yellow.* In some cases the patches of mica are of a darker color and have a stronger pleochroism: O=brown; E=light brown, almost yellow (Nos. 34 and 36).

The colorless lath-shaped crystals that make up a large portion of the groundmass and penetrate the patches of mica, have an extinction angle as high as 45°, and many of them give lively polarization colors. From their association, appearance, optical behavior and close resemblance to similar crystals found in the groundmass of the Syracuse serpentine (to be referred to later), they are probably augite. They were so considered by Dr. Williams who has kindly examined a section of this rock.

The yellow grains are scattered all through the groundmass, and are next in importance to the augites, and like them are an original constituent of the rock. They are highly refracting, and stand out well in the slide. In color they range from colorless through yellow to yellowish-brown. In form, some appear as irregular grains, others are diamond-shaped or square. They occur singly or grown together in groups. Very many have crystalline planes and few or none of them are quite isotropic. They resemble very closely the yellow grain described by Dr. Williams † as occurring in the serpentine (peridotite) from Syracuse, New York, which he found by actual separation and analysis to be perofskite. Mr. J. S. Diller ‡ described yellow grains in the peridotite from Elliott County, Kentucky, which they resemble, perhaps, more closely than they do those described by Dr. Williams. Mr. Diller at first took these to be anatase, but a subsequent separation and analysis showed them to be perofskite also. An unsuccessful attempt was made by the writer to separate the yellow grains by the method of Stelzner § as recommended by Dr. Williams in his paper on the Syracuse serpentine. But the identity in appearance of the yellow grains in the Pike County rock with those in the Kentucky peridotite which Mr. Diller found to be perofskite after this attempted separation was made, coupled with the fact that by Gooch's method ‖ 0.89 per cent of TiO_2 was found in the rock, made it so probable that the mineral was perofskite, that no further attempt at separation was made.

*(Slide No. 35). Determined by Dr. G. H. Williams, Johns Hopkins University. To Dr. Williams thanks are also due for kindness in examining a section of this rock, and for a specimen of the Syracuse serpentine.

† This Journal, xxxiv, August, 1887, pp. 140–142.

‡ Bulletin of U. S. Geological Survey, No. 38, p. 18.

§ Neues Jahrbuch für Mineralogie, etc., Beiträge Bd. ii, p. 392.

‖ American Chemical Journal, vol. vii, p. 283.

The presence of perofskite here is interesting as being the third instance of its occurrence as a constituent of any American rock, the first instance being that reported by Dr. Williams in the Syracuse serpentine, the second that by Mr. J. S. Diller, in the peridotite from Elliott County, Kentucky. It is also interesting as occurring in the same type of rock as will be mentioned later.

The black grains scattered in not inconsiderable quantity through the groundmass, are believed to be magnetite. The yellow base "looks as though it had been a glass once and some of it is still isotropic, though most of it polarizes."* A considerable amount of it is still isotropic as was found in other sections (No. 36 and 42.) From its mineral composition and structure, then, this rock belongs to the family of peridotites, and to the new type of picrite porphyry or "Kimberlite" of H. Carvill Lewis.†

The rock differs somewhat from either of the other occurrences. Unlike the Kentucky peridotite it contains no enstatite, its pyroxenic constituent being augite. It contains no ilmenite, and in only one section was any garnet found, a single, small, pink piece, quite isotropic. The perofskite, especially, occurs in great abundance in the Pike County rock and here is undoubtedly original, while in the Kentucky rock it is believed to be secondary, arising from the decomposition of the ilmenite, and the quantity is comparatively small. Finally the Kentucky peridotite contains much more fresh olivine than that from Pike County, and pyrope which is abundant in the former is rare in the latter. The Syracuse serpentine or peridotite, on the other hand, is much less fresh than the Pike County rock, and while it contains augite in the groundmass, the augites are much less abundant, as are also the perofskites. This rock is in some respects a new type. There is total absence of a rhombic pyroxene, which occurs as such in Mr. Diller's rock, and is probably represented by decomposition products in the Syracuse serpentine.

The brown rock, of which there is an exposure not far from the picrite porphyry just described, shows in thin sections a similar porphyritic structure. But here all the olivines are changed to serpentine, carbonates and hydroxide of iron. The outlines of the olivine and the structure of the rock are generally well preserved, although no fresh olivine remains. A great many patches of mica, partially grown through with colorless little augite crystals are present, and perofskite is abundant. The most striking characteristic of the rock is the almost total absence of augite in the groundmass. This

* Dr. Williams on No. 35.

† Rosenbusch, Mik.-Phys., vol. ii, p. 519.

absence of augite is rendered still more striking by the fact that in the Syracuse peridotite, which is no more decomposed than this rock, the augites in the groundmass are apparently as fresh as when they were first formed. The explanation of this probably lies in the fact that the patches of yellow base, some of which is quite isotropic, are much more abundant here than in the other rock described, and, perhaps, the augites did not have a chance to crystallize out, being deposited as a glass. There seems to be no doubt from its general appearance that this is a portion of the same original rock mass as that before described, and probably so situated with reference to it at the time of formation, that the now brown rock crystallized more rapidly than the other portion of the eruptive mass, represented by the rock at the first exposure described.

The dyke of blue earthy material, spoken of in Part I., has yellow grains scattered through it. The nature of the original rock, which this blue decomposed dyke represents, cannot be definitely determined. A thin slice shows a few fragments of brown mica, and sections composed entirely of serpentine, occurring for the most part in irregular grains, but occasionally showing the form of olivine, imbedded in a green to bluish-green groundmass, which appears to be partly serpentine and partly chlorite. The porphyritic grains are composed of white, yellow and greenish yellow serpentine. The arrangement of the serpentine, the olivine forms still preserved, indicate that all the porphyritic serpentinized sections originally were olivine. It is quite probable that the rock consisted once of olivine with a small quantity of biotite imbedded in a groundmass made up largely of glassy base consisting chiefly of olivine substance which has weathered to serpentine and chlorite.

ART. VI.—*On Urao;* by THOMAS M. CHATARD.*

IN this Journal for August, 1888, p. 146, I gave the analyses of the waters of some American alkali lakes, among them, Owens Lake, Cal. The salts now to be described were obtained by the spontaneous evaporation of the water of the lake, and in connection with the results obtained from other localities, throw much light on the true character of the composition of the native sodium carbonates.

* Condensed from "Natural Soda, its occurrence and Utilization," a forthcoming bulletin of the U. S. Geological Survey. Published by permission of the Director.

The occurrence, in Venezuela, of the mineral urao has been described by Faxar* and by Boussingault.† The latter gives the following analysis:

		Hypoth. Comp.	
Na_2O	41·22	Na_2CO_3	46·98
C_2O	39·00	$NaHCO_3$	37·24
H_2O	18·80	H_3O	14·80
Impurities	0·98	Impurities	0·98
	100·00		100·00

By deducting the impurities from this analysis, Laurent‡ obtained as the formula of the pure salt,

$$Na_2CO_3, NaHCO_3+2H_2O.$$

The impurities in such salts are insoluble matter, with chloride and sulphate of sodium, all of which can be deducted when we wish to calculate the formula since they are, under the circumstances, anhydrous and merely diminish the percentage of urao in the material. If we deduct the impurities from this analysis and recalculate the residue to 100 per cent, and likewise calculate the theoretical percentages for the above formula, we shall have:

	Found.	Theoret.	Hypoth. Comp.		Theoret.
Na_2O	41·63	41·15	Na_2CO_3	47·44	46·90
CO_2	39·38	38·94	$NaHCO_3$	37·61	37·17
H_2O	18·99	19·91	H_2O	14·95	15·93
	100·00	100·00		100·00	100·00

If we take the theoretical proportion between the Na_2CO_3 and the $NaHCO_3$ we have $Na_2CO_3 : Na_2HCO_3 :: 106 : 84 :: 47·44 : 37·51$ while the amount of $NaHCO_3$ found in 37·61, a difference of only 0·11 per cent. Hence Boussingault's urao is an almost theoretically pure salt, showing only a small loss of water and a trifling increase of $NaHCO_3$.

The existence of a native sesquicarbonate of sodium, Na_2CO_3, $2NaHCO_3+3H_2O$, to which the mineral name trona has been given, rests on an analysis by Klaproth,§ and under this head the numerous analyses of natural sodas to be found scattered through the literature of the subject have been referred. A careful revision and recalculation of these analyses, in the manner described above, show that none of them, excepting those of Popp,‖ agree, even reasonably closely, with this formula,

* Faxar, Ann. de Chimie, II, ii, 432.

† Boussingault, ibid., II, xxix, 110.

‡ Laurent, Ann. de Chimie, III, xxxvi, 348.

§ Klaproth, Beiträge, iii, p. 83, 1802.

‖ Popp, Ann. der Chem. u Pharm., 155, p. 348.

but that on the contrary, the salts were uraos with a widely varying excess of one or the other of the two carbonates. A repetition of Winkler's* method for the artificial production of sodium sesquicarbonate gave additional proof, for the salt obtained was physically and chemically a urao having an excess of $NaHCO_3$ as would be expected from the conditions of this formation. Hence the conclusion that *there is no such salt, either natural or artificial, as sodium sesquicarbonate*, but that the true salt is a union of one molecule of Na_2CO_3 with one of $NaHCO_3$, although the presence of an excess of $NaHCO_3$ may occasionally give results approaching the composition of a sesquicarbonate. Many analyses, notably those of Wallace,† who suspected the non-existence of sesquicarbonate, show uraos containing an excess of Na_2CO_3 while de Mondesir‡ was the first to publish a method for the artificial production of the pure salt to which, on account of the relation of $3NO_2O$ to $4CO_2$, he gives the name "carbonate quatre-tiers" or "four thirds carbonate." It might be called the "tetra-trita" or "tetritacarbonate."

The five salts now to be described, were obtained by spontaneous solar evaporation of natural water and hence are "minerals." Nos. 1 and 2 are from the same specimen and were formed in an artificial ground vat. When the water of Owens Lake is allowed to evaporate, the first crop obtained is granular crystalline and retains much mother liquor. The mother liquor is therefore drawn off and this first crop, as far as practicable, redissolved in lake water, thus forming a new solution which deposits a sheet of crystals much larger and purer than the first product. The specimen of this sheet taken for analysis was about two inches thick; the upper portion was well crystallized and translucent (No. 1); the intermediate part showed an interlamination of thin, translucent, crystallized sheets and of fine-grained crystalline, white material (No. 2), the undissolved portion of the first product; the bottom part of the specimen was a layer similar to the upper portion but thinner, the crystals being much smaller. No. 1 presented a radiated columnar structure, the crystals being so grown together that the terminations alone were visible and these so combined that each combination had a curved ridge-like termination or cock's-comb form. The specific gravity of this material was 2·1473 taken in benzol at 21·7° C.

No. 3 or "Twig" was formed on a branching grass-root which chanced to be suspended in the water of a small lagune on the east side of the lake. It has the form of a stout twig or of a

* Winkler, Buchner's Repert. f. Pharm., xlviii, p. 215.

† Wallace, Chem. News, xxvii, p. 203.

‡ De Mondesir, Comptes Rendus, civ, p. 1505, May 31, 1887.

branching coral, each of the branches forming a cylinder, a section of which shows the radiated structure, while the surface of the cylinder is rough, the curved edges of the crystal aggregates giving a lenticular appearance. The color is brownish and one side of the specimen shows crystals of NaCl and much sand as the evaporation of the water finally left it lying on the mud of the bottom.

No. 4 or "Lagune" is from another small lagune near by, and consists of a thin sheet, the surfaces of which are rough like the preceding specimen. Color pink, due to organic matter.

No. 5 or "Beach vat" was formed in a vat dug in the beach and allowed to fill by seepage from the surrounding soil. This seepage water differs somewhat in composition from the water of the lake.

	No. 1.	No. 2.	No. 3. Twig.	No. 4. Lagune.	No. 5. Beach vat.
Insol. inorg.	·02	·22	2·92	·40	4·10
" organic	----	----	·14	·12	·27
SiO_2	.. ..	·10	·05	·09	·04
CaO	----	----	----	·06	----
MgO	----	----	----	·02	----
K_2O	----	----	----	tr.	----
Na_2O	$\frac{2}{2}$ 40·995	41·26	40·22	40·08	39·36
Cl	$\frac{2}{2}$ ·193	1·57	2·73	·21	1·83
SO_3	$\frac{2}{2}$ ·702	·79	·76	·63	·84
CO_2	$\frac{3}{3}$ 38·13	37·00	35·24	37·50	35·10
H_2O	$\frac{3}{3}$ 20·07	19·62	18·31	19·94	18·58
	100·11	100·56	100·37	99·05	100·12
O=Cl	·04	·35	·61	·05	·41
	100·07	100·21	99·76	99·00	99·71

Calculating the hypothetical composition, deducting the impurities and recalculating to 100 per cent we have:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Na_2CO_3	46·57	47·20	46·76	50·35	46·65
$NaHCO_3$	37·03	36·22	37·04	32·53	36·83
H_2O	16·40	16·58	16·20	17·12	16·52
	100·00	100·00	100·00	100·00	100·00

If we compare these new percentages with the theoretical figures for urao, previously given, we shall find the following differences.

	Theoret.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Na_2Co_3	46·90	−·33	+·30	−·14	+3·45	−·25
$NaHCO_3$	37·17	−·14	−·95	−·13	−4·64	−·34
H_2O	15·93	+·47	+·65	+·27	+1·19	+·59

These small differences show that each of the samples is urao. In each case there is a varying amount of other salts and impurities to be deducted, but when this is done the residue, in four out of the five samples, shows a very close agreement with the formula of the mineral. In the case of No. 4 or the "Lagune" the differences are quite large, but as the local conditions attending the production of each specimen are well known, the explanation is simple. Unlike the others which are products of undisturbed crystallization, this one is apparently the result of an interchanging concentration and dilution of the mother liquor in which it was formed. As the water in such a shallow basin evaporates the tendency is to leave a crust of very pure urao, at the edge of the basin, the deposit towards the center becoming more and more impure as the concentrating liquid deposits its chloride and sulphate and becomes, as experiments show, a comparatively pure solution of sodium mono-carbonate. If then the basin be refilled by seepage, as would be the case when the lake rises in the spring, the solution would contain a larger proportion of the neutral carbonate and, on reconcentration, would leave on its edges a urao containing an excess of hydrated monocarbonate. If we calculate the excess of monocarbonate and water present, we shall find that the two combine to form $Na_2CO_3+2H_2O$ and that the sample represents 84·71% urao, 12·06% Na_2CO_3, $2H_2O$, ·02% H_3O and 2·21% impurities.

Artificial Urao.

A series of experiments was undertaken, in order to determine the conditions under which urao is formed and also to find out if, by spontaneous evaporation, under known conditions the sesquicarbonate or any other combination of mono- and bicarbonate, other than urao, might be formed. For this investigation a number of solutions was prepared, each of which contained Na_2CO_3, $NaHCO_3$ and NaCl, the amount of each salt employed having a certain definite relation to its molecular weight. NaCl was added because its presence appears to exercise a favorable influence on the crystallization of the mixed carbonates. A full account of these experiments and results will be found in the Bulletin from which this paper is condensed; for the present it is sufficient to say that in no case, no matter what the relative proportions of the salts might be, was any other mixed carbonate but urao obtained. If the $NaHCO_3$ was present in excess a portion crystallized out first, as such, but this was invariably followed by crystallizations of urao. On the other hand if the Na_2CO_3 was in sufficient excess, the urao first obtained was contaminated with the former salt. The following examples will show this. The solutions were made up as follows:

	No. 1.	No. 2.	No. 5.	No. 6.	No. 7.	No. 9.
$NaHCO_3$ grms...	10·5	21·0	10·5	10·5	42·0	5·25
Na_2CO_3 " ..	53·0	53·0	53·0	53·0	53·0	3·50
NaCl " ..	29·25	29·25	14·62	58·5	58·5	29·25

The first products obtained from the solutions by spontaneous evaporation had the following compositions:

	No. 1, 1st. Acicular.	No. 2, 1st. Scales.	No. 5, 1st. Acicular.	No. 6, 1st. Acicular.	No. 7, 1st. Scales.	No. 9, 2d. Acicular matted.
H_2O....	19·58	11·78	19·54	19·42	11·63	18·91
CO_2....	38·73	51·69	37·88	37·76	51·52	36·46
Na_2O...	40·07	36·54	41·02	39·85	36·49	39·22
NaCl...	1·46	·51	1·72	2·88	undet.	5·58
	99·84	100·52	100·16	99·91	99·64	100·27

Hypothetical Composition.

H_2O....	15·37	1·25	15·96	15·55	·92	15·41
Na_2CO_3.	43·69	·42	49·00	45·29	·64	46·60
$NaHCO_3$	39·32	98·34	33·48	36·19	98·08	32·68
NaCl...	1·46	·51	1·72	2·88	undet.	5·58
	99·84	100·52	100·16	99·91	99·64	100·27

	Urao.	$NaHCO_3$	Na_2CO_3,H_2O	H_2O	NaCl
No. 1 corresponds to	93·15+	4·70+	....	·53+	1·46
No. 2 " "	·89+	98·01+	....	1·11+	·51
No. 5 " "	90·08+	....+	7·89	·47+	1·72
No. 6 " "	96·56+	·30+	....	·17+	2·88
No. 7 " "	1·37+	97·57+	....	·70+	undet.
No. 9 " "	87·92+	....+	6·27	·50+	5·58

A solution made up in the proportions of No. 6 would seem to be best for the production of this salt as the crystallizations were much finer than in any of the others. If the proportion of $NaHCO_3$ is increased, the excess separates before the urao is formed, while if it is reduced the urao contains monohydrated carbonate. The presence of NaCl is not absolutely necessary, for experiment has shown that a very good crystallization of urao can be obtained without its aid, and even a solution of chemically pure Na_2CO_3, if exposed to the air for some time so that it can absorb CO_2, will yield crystals of the double salt. It is therefore somewhat remarkable that this salt which seems to be the natural form of sodium carbonate, should receive no notice in the most extensive treatises on the sodium salts or, if mentioned, be confounded with another which, so far as my own observations extend, does not exist at all.

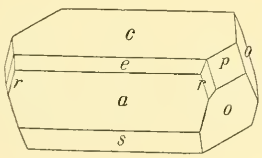
ART. VII.—*Notes on the Crystallization of Trona* (*Urao*); by EDWARD F. AYRES.

AN examination has been made by the writer of a series of crystals of trona, in part natural crystals from Borax Lake, San Bernardino Co., California, and in part artificial crystals, furnished through the kindness of Dr. Thomas M. Chatard.

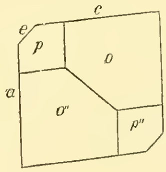
The natural crystals are of considerable size, up to 15^{mm} in length, but they were rough and so covered with saline incrustations that they afforded no good measurements. In habit they were flat and tabular with the basal plane largely developed and some indistinct orthodomes all deeply striated; they were terminated by the usual pyramidal planes (*o*).

The artificial crystals gave much better opportunity for accurate crystallographic work. These are slender acicular crystals very much elongated in the direction of the orthodiagonal axis. They average from 8 to 15^{mm} in length and about 1^{mm} in diameter; they are usually grouped in little radiating clusters. The different samples received from Dr. Chatard vary among themselves chiefly in size; some of them being excessively slender. Those which were subjected to measurement were from one of the samples mentioned by Dr. Chatard. The symmetry of these crystals may be viewed as almost orthorhombic, the angles *ae*, *ec*, and *ao''*, *co* respectively varying but little from each other. This is shown in fig. 2, a projection on the clinopinacoid plane.

1



2



The crystallization of trona was first described by Haidinger* in 1825, and recently Zepharovich† has given a new determination of the form with a number of new planes; he gives as the composition $Na_6C_4O_{11} + 5H_2O$. The position here adopted is that of Zepharovich. The planes observed are:

a(100, *i-i*), *c*(001, *O*), *e*($\bar{1}$01, -1-*ī*), *s*($\bar{3}$02, $\frac{3}{2}$*ī*), *p*(111, -1), *o*($\bar{1}$11, 1), *r*(211, -2-2).

The two planes *p* (111) and *r* (211) are new; *p* (111) is quite brilliant though small, and *r* (211) gives angles close enough for identification. The habit of the more complex crystals is shown in fig. 1. There is very perfect cleavage parallel to the

* Pogg. Ann., v, 367, 1825. † Zeitschrift f. Kryst., xiii, 135, 1887.

orthopinacoid, which affords surfaces suitable for measurement, but the other planes in the orthodome zone are striated parallel to the macrodiagonal axis, and the angles they yield are less satisfactory. The crystals when newly prepared are very bright and transparent, but soon lose their luster on exposure to the air.

For fundamental angles the following were accepted :

oo'', $\bar{1}11 \wedge 11\bar{1} = 47° \; 30'$, co, $001 \wedge \bar{1}11 = 76° \; 0'$, ao'', $100 \wedge 11\bar{1} = 75° \; 7\frac{1}{2}'$.

The axial ratio obtained is as follows, that of Zepharovich being added for sake of comparison :

$$\grave{a} : \bar{b} : \grave{c} = 2{\cdot}8426 : 1 : 2{\cdot}9494, \quad \beta = 76° \; 31'.$$

$$\grave{a} : b : \grave{c} = 2{\cdot}8459 : 1 : 2{\cdot}9696, \quad \beta = 77° \; 23' \text{ Zeph.}$$

The following table gives a comparison between calculated and measured angles :

	Calculated.	Measured.	Limits.
$11\bar{1} \wedge \bar{1}11 =$	47° 30′	*47 30′	47° 19½ 47° 56.
$001 \wedge \bar{1}11 =$	76 0·	*76 0	75 to 78
$100 \wedge 11\bar{1} =$	75 7 30″	*75 7 30″	75 to 75 36·
$100 \wedge 111 =$	67 14 13	67 13	65 53 to 68 23
$100 \wedge 101 =$	37 25 28	38 approx.	
$001 \wedge 101 =$	39 5 33	39 35	40 39 to 40 38′
$\bar{1}11 \wedge 111 =$	37 38 17	37 32	36 35 to 36 39′
$001 \wedge 111 =$	68 8 29		52 26 ⌃ 53 8
$100 \wedge 211 =$	52 41 8	52 47	
$001 \wedge \bar{3}02 =$	68 10 14	67 approx.	
$001 \wedge 100 =$	76 31 1		
$001 \wedge 011 =$	70 46 43		
$100 \wedge 110 =$	70 6 44		
$100 \wedge 101 =$	37 25 28		

ART. VIII.—*On prevailing misconceptions regarding the Evidence which we ought to expect of former Glacial Periods*;* by JAMES CROLL, LL.D., F.R.S.

WITHIN the whole range of geological science there is perhaps not a point on which a greater amount of misapprehension prevails than in regard to the evidence which we ought to expect of former Glacial periods. The imperfection of geological records is far greater than is generally believed: so great, indeed, that the mere absence of direct geological evidence can hardly be regarded as sufficient proof that the conclusions derived from astronomical and physical considerations regarding former ice-periods are improbable. Nor is this

* From the Quarterly Journal of the Geological Society of London for May 1889, by request of the Author.

all. Not only are the geological records of ancient glacial conditions imperfect, but this imperfection *follows as a natural consequence from the principles of geology itself.* There are not merely so many blanks or gaps in the records, but a reason exists in the very nature of geological evidence why such breaks in the record might naturally be expected to occur.

The evidence of Glaciation is to be found chiefly on land-surfaces.—It is on a land-surface that the principal traces of the action of ice during a glacial epoch are left, for it is there that the stones are chiefly striated, the rocks ground down, and the bowlder clay formed. But where are all our ancient land-surfaces? They are not to be found. The total thickness of the stratified rocks of Great Britain is, according to Professor Ramsay, nearly fourteen miles. But from the top to the bottom of this enormous pile of deposits there is hardly a single land-surface to be detected. Patches of real old land-surfaces of a local character may indeed be found, as, for example, the dirt-beds of Portland; but, with the exception of coal-seams, every general formation has been accumulated under water, and none but the under-clays *ever existed as a land-surface.* And it is here, in a general formation, that the geologist has to collect all his information regarding the existence of former glacial epochs. The entire stratified rocks of the globe, with the exception of the coal-beds and under-clays (in neither of which would one expect to find traces of ice-action), consist almost wholly of a *series of old sea-bottoms*, with here and there an occasional fresh-water deposit. Bearing this in mind, what is the sort of evidence which we can now hope to find in these old sea-bottoms of the existence of former ice-periods?

All geologists of course admit that the stratified rocks are not old land-surfaces, but a series of old sea-bottoms formed out of the accumulated material derived from the degradation of primeval land-surfaces. And it is true that all land-surfaces once existed as sea-bottoms; but the stratified rocks consist of a series of old sea-bottoms which never were land-surfaces. Many of them no doubt have been repeatedly above the sea-level, and may once have possessed land-surfaces; but these, with the exception of the under-clays of the various coal measures, the dirt-beds of Portland, and one or two more patches, have all been denuded away. The important bearing which this consideration has on the nature of the evidence which we can now expect to find of the existence of former glacial epochs has certainly been very much overlooked.

If we examine the matter fully we shall be led to conclude that the *transformation of a land-surface into a sea-bottom* will probably completely obliterate every trace of glaciation which that land-surface may once have presented. We cannot, for example, expect to meet with polished and striated stones belonging to a former land glaciation; for such stones are not carried down bodily and unchanged by our rivers and deposited in the sea. They become broken up by subaerial agencies into gravel, sand, and clay, and in this condition are transported seawards. Even if we supposed it possible that the stones and bowlders derived from a mass of till could be carried down to sea by river action, still these stones would certainly be deprived of all their ice-markings, and become water-worn and rounded on the way. Professor James Geikie states that the great accumulations of gravel which occur so abundantly in the low grounds of Switzerland, and which are, undoubtedly, merely the re-arranged materials originally brought down from the Alps as till and as moraines by the glaciers during the Glacial period, rarely or never yield a single scratched or glaciated stone. The action of the rivers escaping from the melting ice has succeeded in obliterating all trace of striæ. It is the same, he says, with the heaps of gravel and sand in the lower grounds of Sweden and Norway, Scotland and Ireland. These deposits are evidently in the first place merely the materials carried down by the swollen rivers that issued from the gradually melting ice-fields and glaciers. The stones of the gravel derived from the demolition of moraines and till, have lost all their striæ and become in most cases well rounded and water-worn. Further, we cannot expect to find bowlder clay among the stratified rocks, for bowlder clay is not carried down as such and deposited in the sea, but under the influence of the denuding agents becomes broken up into soft mud, clay, sand, and gravel, as it is gradually peeled off the land and swept seawards. Patches of bowlder clay may have been now and again forced into the sea by ice and eventually become covered up; but such cases are wholly exceptional, and their absence in any formation cannot fairly be adduced as a proof that that formation does not belong to a glacial period.

It may, however, be replied that there is one kind of evidence of former glacial periods which we ought to expect in the stratified rocks, viz: the presence of large erratic blocks embedded in strata which, from their constitution, have evidently been formed in still water. But even allowing this to be the case we cannot regard the absence of such blocks as proof that no glacial period occurred during the time of the formation of the strata; for their mere absence may be the indication either of a period of extreme glaciation, or a period absolutely free from ice. This absence is a result which would as truly follow from the former condition of things as from the latter. Glaciers carry erratic blocks on their surfaces, but such blocks are seldom, if ever, on the surface of an ice-sheet. The reason is obvious. When a country is completely buried under ice there is no source from which the ice can obtain erratics on its surface. The stones which lie under the ice, before they can reach the sea, are ground down to powder. Large erratic blocks have never been found, for example, on the ice-sheet of Greenland. No one, of course, has as yet had an opportunity of examining the surface of the Antarctic ice, but judging from the character of the icebergs derived from it, we are almost certain that it contains no bowlders. Were the seas surrounding these continents elevated into dry land, a geologist judging from the comparative absence of bowlders in the sedimentary deposits which have been forming for the past thousands of years, would be apt to conclude that these continents had never been covered by ice. In fact, a conclusion of this kind has been arrived at by Professor Nordenskjöld, who maintains, because he has never seen in the strata of Greenland or Spitzbergen a bowlder larger than a child's head, that down to the termination of the Miocene period, no glacial condition of things existed in these regions: a conclusion most certainly utterly erroneous. Now both of these lands are at present in a state of glaciation; and were it not for the enormous quantity of heat which is constantly carried northward from the equatorial regions by the Gulf Stream, not only Greenland and Spitzbergen, but the whole of the Arctic regions would be far more completely under ice than they are. A glacial state of things is the normal condition of polar regions; and if at any time, as during the Tertiary age, the Arctic regions were free from snow and ice, it could only be in consequence of some peculiar distribution of land and water and other exceptional conditions. That this peculiar combination of circumstances should have existed during the whole of that immense lapse of time between the Silurian and the close of the Tertiary period is certainly improbable in the highest degree. In short, that Greenland during the whole of that time should have been free from snow and ice is as improbable, although perhaps not so physically impossible, as that the interior of that continent should at the present day be free from ice and covered with luxuriant vegetation.

In fact, it is the severity of glacial conditions in these regions during glacial periods that has rendered the strata to which Prof. Nordenskjöld refers so comparatively free from erratic blocks. Had these regions been occupied by glaciers reaching to the sea, instead of being covered by a sheet of ice, bowlders in the strata would no doubt have been far more common.

As evidence of former glacial periods we may, however, expect to find in temperate regions erratic blocks, imbedded here and there in the stratified rocks, which may have been transported by icebergs and dropped into the sea. But unless the glaciers of such epochs reached the sea, we could not possibly possess even this evidence. This sort of evidence, when found in low latitudes, ought to be received as evidence of the existence of former glacial epochs; and, no doubt, would have been so received had it not been for the erroneous idea that, if these blocks had been transported by ice, there ought in addition to have been found striated stones, bowlder clay, and other indications of the agency of land-ice.

It is, of course, by no means the case that all erratics are transported by masses of ice broken from the terminal front of glaciers. The "ice foot," formed by the freezing of the sea along the coasts of the higher latitudes, carries seawards quantities of blocks and *débris*. Again, stones and bowlders are frequently frozen into river ice, and when the ice breaks up in spring are swept out to sea, and may be carried some little distance before they are dropped. But both these cases can occur only in regions where the *winters are excessive;* nor is it at all likely that such ice-rafts will succeed in making a long voyage. If, therefore, the erratics occasionally met with in certain old geological formations in low latitudes were really transported from the land by an ice-foot or a raft of river-ice, we should be forced to conclude that very severe climatic conditions must have obtained in such latitudes at the time the erratics were dispersed.

Why we now have, comparatively speaking, so little direct evidence of the existence of former glacial periods will be more forcibly impressed upon the mind if we reflect on how difficult it would be, in a million or so of years hence, to find any trace of what we now call the glacial epoch. The striated stones would by that time be all, or nearly all, disintegrated, and the till washed away and deposited in the bottom of the sea as stratified sands and clays. And when these became consolidated into rock and were raised into dry land, the only evidence that we should probably then have that there ever had been a glacial epoch would be the presence of an occasional large block of the older rocks found imbedded in the upraised formation. We could only infer that there had been ice at work from the fact that by no other known agency could we conceive such a block to have been transported and dropped in a still sea.

Few geologists probably believe that during the Middle Eocene and the Upper Miocene periods our country passed through a condition of glaciation as severe as it has done during the Post-pliocene period; yet when we examine the subject carefully, we find that there is actually no just ground to conclude that it has not. For, in all probability, throughout the strata to be eventually formed out of the destruction of the now existing land-surfaces, evidence of ice-action will be as scarce as in Eocene or Miocene strata.

Did the stratified rocks forming the earth's crust consist of a series of old land-surfaces instead (as they actually do) of a series of old sea-bottoms, then traces of many glacial periods might be probably detected. Nearly all the evidence which we have regarding the Glacial period has been derived from what we find on the now existing land-surfaces of the globe. But probably not a vestige of this will exist in the stratified beds of future ages, formed out of the destruction of the present land-surfaces. Even the very arctic shell-beds themselves, which have afforded to the geologist such clear proofs of a frozen sea during the Glacial period, will not be found in those stratified rocks; for they must suffer destruction along with everything else which now exists above the sea-level. There is probably not a single relic of the Glacial period which has ever been seen by the eye of man that will be treasured up in the stratified rocks of future ages. Nothing that does not lie buried in the deeper recesses of the ocean will escape complete disintegration and appear imbedded in those formations. It is only those objects which lie in our existing sea-bottoms that will remain as monuments of the Glacial period of the Post-tertiary era. And, moreover, it will only be those portions of the sea-bottoms that may happen to be upraised into dry land that will be available to the geologist of future ages. The point is this: *Is it probable that the geologist of the future will find in the rocks formed out of the now existing sea-bottoms more evidence of a glacial epoch during Post-tertiary times than we now do of one during, say, the Miocene, the Eocene or the Permian period?* Unless this can be proved to be the case, we have no ground whatever to conclude that the cold periods of the Miocene, Eocene and Permian periods were not as severe as that of the Glacial period. This is evident, for the only relics which now remain of the glacial epochs of those periods are simply what happened to be protected in the then existing sea-bottoms. Every vestige that lay on the land would in all probability be destroyed by subaërial agency and carried into the sea in a sedimentary form.

The question of the existence of former glacial periods is one on which paleontology can afford but little really reliable information. One of the main characteristics of a glacial period is the scarcity or comparative absence of plant and animal life. He certainly would be a bold geologist who would affirm, in relation to a given epoch, that because he could not find the remains of plant and animal life which he considered could have existed under glacial conditions, no glacial conditions existed during that epoch. And the more so seeing how difficult it is to determine with certainty, more especially in relation to remote periods, how much cold a plant or an animal might be able to endure.

Besides all this, supposing the organic remains of former glacial epochs were found in abundance, these remains would probably mislead most geologists. For if the theory of the glacial epoch, advocated in "Climate and Time" be correct, viz: that those epochs consisted of alternate cold and warm periods, it is evident that the greater part, or nearly all of those remains would belong to the warm or interglacial periods. A geologist who did not believe in interglacial periods, judging from the character of those remains, would naturally come to the conclusion that the epochs in question were warm and equable, not glacial. His disbelief in interglacial periods would thus induce him to give a wrong interpretation of the facts.

Assuming that a glacial epoch occurred at every time that the earth's orbit attained a very high state of eccentricity, it is quite apparent, when we reflect on the imperfection of geological records on the matter, that we have in reality about all the evidence which we could possibly expect of the existence of such epochs.

Art. IX.—*Mineralogical Notes, on Fluorite, Opal, Amber and Diamond*; by George F. Kunz.

Fluorite.—About four years ago, a small vein of fluorite in Archæan limestone was discovered in the town of Macomb, St. Lawrence Co., New York. It was worked from time to time until last summer, when the vein suddenly widened, breaking through into a cavity or cave. This cave is 22 feet north and south, and 18 feet east and west, and is 8 feet below the surface. It dips from the south to the north, and is about 8 feet lower than at the mouth or entrance. It is about 5 feet between the walls. A pool of water in the northeast corner, about two feet in depth, often rises ten or twelve inches during the day. The top, bottom, and sides were lined with a magnificent sheet of crystals, varying from one to six inches in diameter, each in turn forming part of larger composite crystals. Between the floor and the walls was a layer of partly decomposed calcite, which was readily removed, so that groups of crystals, weighing from ten to several hundred pounds each, and one of them measuring 2×3 feet, were easily detached.

The cavity contained at least fifteen tons of fluorite. The habit of the crystals is, in nearly every instance, that of the simple cube, but the faces of the octahedron, slightly developed, are often present. Almost all the crystals have on the surface in small botryoidal elevations, an even coating of brown hydrodolomite, which is readily removed with diluted hydrochloric acid. The crystals are all well colored, but the surfaces are dull. The fluorite is of a uniform light sea-green, except where it is attached to the gangue, or at the junction of the crystals; here there are small spots, from one to two inches in diameter, of a rich emerald-green. Attached to the fluorite are small masses of lithomarge, and imbedded in these, very perfect tetrahedral crystals of chalcopyrite. With the fluorite are found small bunches of pyrite crystals, which are nearly always altered to limonite. Galenite has not been observed, although this locality is only one and a half miles from the well-known Macomb Lead Mines. Several years ago, a large quantity of rhombohedral crystals of calcite were obtained here; one now in the State Cabinet of Albany weighs 120 pounds and a number were of the size of a man's head, in form they were simple rhombohedrons and twinned. This find is strikingly like that of the famous Muscalonge Lake localities of forty years ago, except that the crystals are of a finer color and in larger groups. The occurrence of a second deposit in this country leads to the inference that fluorite may exist in commercial quantity, for the arts.

Amber.—For the last fifteen or twenty years, travelers have occasionally brought specimens of a very remarkable amber from some locality in Southern Mexico. The only information gained concerning it is that it is brought to the coast by natives, who say that it occurs in the interior so plentifully that it is used by them for making fires. The color of this amber is a rich golden yellow, and when viewed in different position it exhibits a remarkable fluorescence, similar to that of *uranine*, which it also resembles in color. A specimen now in the possession of M. T. Lynde measures 4×3×2 inches, is perfectly transparent, and is even more beautiful than the famous so-called opalescent or green amber found in Catania, Sicily. This material would be extremely valuable for use in the arts. It is believed that an expedition has started for the locality where it is found in the interior.

Opal.—A specimen of fire opal $1\frac{1}{2}\times1\times\frac{1}{2}$ inches in size, evidently a water-worn fragment, was found near John Davis River, in Crook County, Oregon. It is transparent, grayish-white in color, with red, green, and yellow flames. The play of colors equals in beauty that of any Mexican material, and it is the first opal found in the United States that exhibits color. Undoubtedly, better material of the kind exists where this was found.

Diamond.—During the summer of 1888 a small diamond was said to have been found by Mr. C. O. Helm, on the farm of Henry Burris, about three hundred yards from Cabin Fork Creek, Russell County, near Adair County, Kentucky. While walking through an old field, on the top of a hill, Mr. Helm observed in the gravel, this small, bright stone, which on investigation proved to be a diamond, an elongated hexoctahedron, with curved faces, lustrous, but slightly off-color, weighing 7/16 carats. The rock in the vicinity is said to be composed of granite dykes, slates, and some floating rocks, such as quartz, feldspar, magnetic iron ore, flint, garnet, etc., mingled in clayey hills.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the action of Hydrogen peroxide on Chromic acid.*—Berthelot has investigated the reaction which takes place when hydrogen peroxide is mixed with chromic acid or a chromate, and finds that if no excess of acid is present a given quantity of chromate can decompose an unlimited quantity of peroxide, and this without suffering itself any apparent change. This result he accounts for upon the supposition that an unstable intermediate product is continually formed and decomposed. When solutions of the peroxide and potassium dichromate are mixed together, and as soon as the mixture has become dark brown in color, ammonia is added, a brown precipitate falls, which contains hydrogen peroxide, chromic acid and chromic oxide. It is very unstable, evolves oxygen even when washed with water, and gives a yellow filtrate containing chromate. The small residue finally left undissolved, contains the same constituents as the original precipitate but in quite different proportions.—*C. R.*, cviii, 24, 157, 477; *Ber. Berl. Chem. Ges.*, xxiii, Ref. 217, May, 1889. G. F. B.

2. *On the Atomic Mass of Chromium.*—The atomic mass of chromium has been determined by Rawson by means of ammonium dichromate, using two methods. The first consisted in igniting this salt, measuring the nitrogen evolved and weighing the chromic oxide remaining. The second depended upon the reduction of the dichromate with alcohol and hydrogen chloride, and the determination of the chromic oxide precipitated by ammonia. The first method, though simple in theory, did not prove

satisfactory in practice. The dichromate burned like tinder, the nitrogen coming off with such rapidity as to carry away some of the oxide and perhaps even some of the dichromate. Moreover, the gas set free does not seem to be pure nitrogen, but has a brownish color with a nitrous smell and an acid reaction. The second method resulted satisfactorily and gave for the ratio of the atomic mass of chromium to that of hydrogen in six experiments 52·130, 52·010, 52·020, 52·129, 52·016, 52·059 : the general mean being 52·061.—*J. Chem. Soc.*, lv, 213, April, 1889.

G. F. B.

3. *On the new Element Gnomium.*—Hugo Müller exhibited at the Conversazione of the Royal Society on May 8th, some compounds of the new element gnomium discovered by Krüss and Schmidt of Munich as associated with the metals nickel and cobalt. Among the preparations shown were gnomium oxide, gnomium chloride (in aqueous solution), nickel from which the gnomium, which had always accompanied it hitherto, had been removed; and nickel oxide also free from gnomium.—*Nature*, xl, 67, May, 1889. G. F. B.

4. *Concentration of Electric Radiation by lenses.*—"Prof. O. J. Lodge and James L. Howard have constructed two large cylindrical lenses of plano-hyperbolic section of mineral pitch cast in zinc moulds, the plane faces being nearly a meter square, the thickness at vertex 21 centimeters, and each lens weighed about 3 cwt. The eccentricity of the hyperbola was made 1·7 to approximate to the index of refraction of the substance. The lenses were mounted about six feet apart with their plane faces parallel and toward each other on a table and an oscillator was placed about the principal focal line of one of them at a distance of 51 centimeters from the vertex. The field was explored by a linear receiver made out of two pieces of copper wire mounted in line on a piece of wood, and the air gap between their inner ends was adjustable by a screw. When the oscillator worked satisfactorily, the receiver would respond to about 120 centimeters, and with the lenses the distance was 450. The receiver responded anywhere between the lenses and within the wedge between the second lense and its focal line, the boundaries being clearly defined, but no special concentration was noticed about the focus. Interference experiments were carried out by placing a sheet of metal against the flat face of the second lens, and determining the position of minimum intensity between the lenses. The distance between these points was 50·5 centimeters, corresponding with a wave-length of 101 centimeters, whereas the calculated wave-length of the oscillator was 100 centimeters. In a discussion upon the results of this experiment Prof. Fitzgerald said that he had made experiments on electrical radiations analogous to Newton's rings, and had successfully observed the central dark spot and the first dark band."—*Physical Soc., London,* May 11, 1889. J. T.

5. *Wave-length of the principal line in the Spectrum of the Aurora.*—Huggins details a careful determination of the position

of this line and finds its wave-length to be 5571 ± 0·5. Vogel gives for the same line 5571·3 ± 0·92. Gyllenskiöld gives a value 5570·0 ± 0·88. Krafft however found 5595 and 5586. Huggins points out that Lockyer's recent statement "that the characteristic line of the aurora is the remnant of the brightest manganese fluting at 558," is clearly inadmissible considering the evidence we have of the position of this line.—*Nature*, May 16, 1889. J. T.

6. *Quartz as an insulator.*—At a Royal Society Conversazione, Mr. C. V. Boys exhibited an "experiment showing the insulation power of quartz. A pair of gold leaves are supported by a short rod of quartz which has been melted and drawn out about three quarters of an inch. The atmosphere is kept moist by a dish of water. Under these circumstances a glass insulating stem allows all the charge to escape in a second or two. With the quartz but little change is observed in four or five hours. The quartz may be dipped in water and put back in its place with the water upon it. It insulates apparently as well as before."—*Nature*, May 16, 1889. J. T.

7. *Light and Magnetism.*—Mr. Shelford Bidwell has made the following experiment. One end of an iron bar which had been magnetized and demagnetized, was placed near a magnetometer needle. On directing a beam of light on the bar an immediate deflection of the needle resulted, and on cutting off the light the needle promptly returned to near its initial position. The direction of magnetization induced by the light is the same as the previous magnetization, and the bar seems to be in an unstable magnetic state. That the effect is due to light and not to heat, the author thinks, is rendered probable by the suddenness of the action.—*Physical Soc., London.*—*Nature*, May 16, 1889. J. T.

8. *Telephonic vibrations.* — Dr. Fröhlich attaches a small mirror to the iron plate of a telephone and from this the light of an electric lamp is reflected to a polygonal rotating mirror, from which it falls on a screen. The vibrations of the plate were thus made visible on the screen, and since each side of the polygonal mirror cast its own image, when the mirror was rotated the curves were seen moving over the screen. The more rapidly the mirror was rotated the slower did the curves move over the screen, and when the rotation was as rapid as the vibration of the plate, the curves became stationary and could thus be exactly observed and drawn. These luminous curves could also be photographed. The speaker had employed this method in a series of researches on certain electrical phenomena which might influence the efficiency of the telephone. Thus the action of alternating currents, of self induction, of the rise and fall of the current on making and breaking, of the introduction of electromagnets, and of other conditions, were studied by means of the altered mode of vibration of the telephone plate. The speaker had further obtained a graphic record of the vibration of the

telephone plate when vowels and consonants were sung and spoken into it.—*Physical Soc., Berlin.—Nature*, May 16, 1889.
J. T.

9. *On an Electrostatic Field produced by varying Magnetic Induction.*—Experiments on the subject have been undertaken by Dr. O. J. Lodge and Mr. A. P. Chaltock. The magnetic circuit employed has a wire Gramme ring of trapezoidal section wound with copper over only a part of its periphery. The indicating apparatus was a suspended needle consisting of the oppositely charged bodies carried on a small shellac arm, to which a mirror or pointer was attached, and was suspended vertically in the plane of the ring. Great difficulty was experienced from Foucault currents when metallic films were used for the needle, and the magnetic properties of other semi-conductors tried complicated the matter. Eventually the charged bodies were made of paper in the form of cylinders $\frac{1}{8}$ inch diameter, and $\frac{5}{8}$ inch long. Considerable trouble was caused by the electrostatic action between the needle and exciting coils, and various means of screening were tried and abandoned, and subsequently the wire was replaced by a single spiral of copper ribbon, the outer turn of which was put to earth. Observation was rendered difficult owing to the wandering of the zero when the needle was charged. Heat also created considerable disturbance and the convection currents were cut off by a series of concentric cylinders of tin plate. The method of observation was to charge the two insulated parts of the needle and then reverse the magnetizing current in synchronism with the period of the needle, noting whether the amplitude of any residual swing could be increased or diminished according as the impulse assisted or opposed the motion. In this way slight indications have been observed, and the effects reverse when the charge of the cylinders are reversed. —*Physical Soc., London*, May 11, 1889. J. T.

II. Geology and Mineralogy.

1. *Fossil Fishes and Fossil Plants of the Triassic Rocks of New Jersey and the Connecticut Valley*, by John S. Newberry. 96 pp. 4to, with xxvi plates. 1888. Making vol. xiv of the Monographs of the U. S. Geological Survey.— This very valuable contribution to American Mesozoic geology gives the first connected account yet published of the fossil fishes of the Triassic beds, and supplements the volume by Prof. Fontaine on the Mesozoic plants. The geological sketch, with which the Report opens, contains a brief history of the views that have been presented respecting the age and origin of the Triassic beds. The author, in his discussion of their age, states that owing to the small number of plants from the Connecticut valley and New Jersey and the small number of fishes from Richmond, Virginia, a satisfactory comparison is not possible. Only one species of fish, *Catopterus gracilis*, is certainly known to be common to New Jersey and Richmond, though *Ischypterus ovatus*, if identical with a fragment referred to *Tetragonolepis* by Egerton, may be a second.

Among the plants of Richmond and North Carolina the following have been found also in New Jersey or the Connecticut valley: *Schizoneura planicostata*, *Macroptæniopteris magnifolia*, *Clathropteris platyphylla*, *Bambusium Carolinense?*, *Palissya Braunii*. *Pachyphyllum* (*Cheirolepis*) *Münsteri*, *P. brevifolium* Newberry, *Dioönites longifolius* Emmons. The age arrived at, for the beds is that of the Rhætic or Upper Triassic.

Dr. Newberry mentions his discovery, many years since, of Triassic plants in New Mexico, at the old copper mines of Abiquiu, and at the Los Bronces on the Yaki River in Sonora, and the important fact that among the species four of those from Los Bronces are also North Carolina species: *Pecopteris bullatus* Bunbury, *P. falcatus* Emmons, *Tæniopteris magnifolia* Rogers and *Otozamites Macombii*, which last was also found at Abiquiu. The Abiquiu beds are in the upper part of the Triassic formation (there 2000 feet thick) and directly under the Dakota group of the Cretaceous.

The fossil fishes described belong to 28 species and half of them are new. The genus *Diplurus*, a new Cœlacanth genus, contains one species, *D. longicaudatus* Newb.; *Ptycholepis*, one; *P. Marshii* Newb.; *Dictyopyge*, one; *D. macrura* Egt. which is the most common species in the Richmond basin, *Acentrophorus* one; *A. Chicopensis* Newb.; *Catopterus*, six; and *Ischypterus*, eighteen. Of these, as the Report states, *Catopterus gracilis*, *C. anguilliformis*, *C. parvulus*, *C. macrurus* (Egerton's *Dictyopyge macrura*), *Ischypterus macropterus*, *I. ovatus*, *I. Agassizii*, *I. parvus*, *I. Marshii*, were described by Mr. W. C. Redfield, the first early systematic worker on these Triassic fishes, and one, *Ischypterus latus*, by J. H. Redfield. The fishes are finely figured on twenty of the twenty-six plates. The *Diplurus longicaudatus* is grandly exhibited full size on the folded plate, pl. 20, though $2\frac{1}{4}$ feet long. The other plates are occupied with figures of the fossil plants.

2. *Map of the region of Duck and Riding Mountains in Northwestern Manitoba;* by J. B. Tyrrell, Geol. Survey Canada.—Duck and Riding Mountains are elevations rising from 2000 to 2700 feet above tide level just west of the Winnipeg region. The Map has a special interest because of its contour lines and the bearing of the facts on the western boundary of the Quaternary Lake Agassiz. The "ancient beach," a gravel ridge, has, near longitude 100° 20′ W., 51° 15′ N., an elevation of about 1084 feet above the sea level, and 50 miles to the north at 52° N., in longitude 100° 40′ W., 1201 feet. Another similar ridge about a mile west of this is 50 to 75 feet higher in corresponding positions. The author discusses briefly the condition of the ancient lake or lakes, the glaciers of the country, and the question as to changes of level over the region.

3. *Bulletin of the American Museum of Natural History*, Central Park, New York City. Vol. ii, No. 2, March, 1889.—This number of the Museum Bulletin contains two papers by J. A.

Allen on Birds of Ecuador and Bolivia, and four by R. P. Whitfield, illustrated by seven plates, on new Calciferous fossils of the Lake Champlain region, on *Asaphus canalis* Conrad, and on a Balanus from the Marcellus shale, with a comparison of the Cretaceous fauna of New Jersey and the Gulf States. The Balanus, *Protobalanus Hamiltonensis* of Whitfield, is already figured and described in vol. vii of Hall's Paleontology plate 36, p. 209. Mr. Whitfield here gives a new and corrected figure with the description. The paper on Calciferous fossils makes a large addition to the number of known species.

4. *Plattnerite* from Idaho;* by H. A. Wheeler. (Communicated.)—A new occurrence of *Plattnerite*, or plumbic di-oxide, was recently called to my attention by the receipt of a very pure specimen from one of the lead mines of the Cœur d'Alêne district, Idaho, through the kindness of Mr. John M. Desloge, of St. Louis. As this rare mineral is called a doubtful species in Dana's System of Mineralogy, the following description is offered.

The specimen was irregular, massive, about the size of an egg and was superficially coated with limonite; the fracture, which is uneven to sub-conchoidal, shows a compact, dense structure, opaque, metallic luster, with no cleavage visible. The color is iron-black and the streak chestnut-brown; hardness, 5 to 5·5, and the specific gravity of a pure black piece was 9·411. Fusibility 2; readily reducing to metallic lead. Easily soluble in hydrochloric acid and aqua-regia; on warming, passing into the chloride of lead. An analysis gave:—

$$\text{Pb } 83{\cdot}69 \text{ p.c.; } PbO_2\ 96{\cdot}63,\ SiO_2\ 1{\cdot}62,\ Fe_2O_3\ 1{\cdot}12 = 99{\cdot}37.$$

Washington University, St. Louis, May 21, 1889.

III. Miscellaneous Scientific Intelligence.

1. *Luminous night-clouds.*—Appeal is made by Mr. O. Jesse of the Berlin Observatory for observations of the luminous night-clouds which have been annually observed in June and July since 1885. The following description of the phenomenon is translated from the Astronomische Nachrichten by the Astronomical Journal.

The luminous night-clouds are seen only within that portion of the evening or morning heavens which is illuminated by the twilight and separated from the night-sky by a more or less washy semicircle, the twilight-arch. When they are seen in the evening, it is when the sun is about 10° below the horizon, and they usually remain visible as long as the twilight lasts. In the morning this order is reversed. In their form and structure the luminous night-clouds much resemble ordinary cirrus-clouds, but they differ from these in some essential respects, by which they can generally be

* In a letter dated Washington, May 25, Mr. W. S. Yeates announced that he had identified plattnerite from the "You Like" Lode, Mullen, Idaho; the specific gravity is stated to be 8·56. He also mentions some curious pseudomorphs of copper after azurite, occurring in the "Copper glance" and "Potosi" copper mines, in Grant Co., New Mexico. A full description is promised.—Eds.

at once distinguished. For if common cirrus-clouds are within the twilight segment, when the sun is 10° or more below the horizon, they are always darker than the twilight-sky around them; while, on the other hand, the luminous night-clouds are always brighter than this sky. Moreover, the ordinary cirrus-clouds do not usually disappear, when the twilight-arch passes by them so that they are left in the night-sky; they only change their aspect in such wise that, whereas they were previously darker than the sky around them, they appear, after their entrance into the night sky, brighter than this is. But the luminous night-clouds disappear entirely so soon as the twilight-arch has moved past them, and only such portion remains visible as remains within the twilight-segment. With regard to the color of the luminous night-clouds, it should be mentioned that they glow with a white and silvery luster, which changes toward a golden yellow in the vicinity of the horizon. And furthermore, it is worthy of notice, that the phenomenon is not manifested on every otherwise cloudless evening or morning during the season of its visibility, but occurs for the most part with intervals of from 8 to 14 days, and then usually remains visible for several successive nights. For observing it, it is requisite that the horizon in the direction of the twilight be as free as possible. Electric and gas-light generally interfere with its perceptibility.

2. *American Association for the Advancement of Science.*—The next meeting of this Association will open at Toronto, Canada on Tuesday the 27th of August. The prospectus of the meeting states that the Queen's Hotel will be the hotel headquarters of the Association. The first general session will take place on Wednesday, the 28th at ten o'clock in the Convocation Hall, University Buildings. The address of the retiring President, Major J. W. Powell, will be delivered Wednesday evening.

The President of the meeting, is Prof. T. C. Mendenhall of Indiana.

For all matters pertaining to membership papers and business of the Association, the Permanent Secretary, Prof. F. W. Putnam, should be addressed at Salem up to August 22, and after that time to Toronto, A. A. A. S. A circular will soon be issued by the Local Committee, of which C. Carpmael, Esq , is President, and Prof. J. Loudon, Local Secretary.

The meeting of the American Geological Society is to be held at Toronto on the 28th and 29th of August, as mentioned on p. 503 of the last volume of this Journal. The Entomological Club will meet at 9 A. M., on Wednesday, July 28, and the Botanical Club, on Tuesday, Aug. 27.

3. *Sir Wm. Dawson on New Erian plant*, p. 1.—*Explanation of figure.*—*Dictyo-cordaites Lacoi*, much reduced. (*a*) Venation of leaf, natural size. (*b*) Fruit enlarged.

APPENDIX.

Art. XI.—*Discovery of Cretaceous Mammalia;* by Professor O. C. Marsh. (With Plates II, III, IV, and V.)

It has long been a reproach to paleontology that no remains of mammals were known from the Cretaceous formation, which almost everywhere contains abundant evidence of other vertebrate life. In the Jurassic below, many small mammals have been found, both in Europe and America, and in the Tertiary above, this class was dominant, and even at the base of the formation is represented by many and varied forms.

A comparison of the mammals known from the Jurassic and the Tertiary made it almost certain that many intermediate forms must exist in the Cretaceous, and their discovery was one of the prizes held out to explorers. For many years, therefore, special search has been made in various countries for Cretaceous mammals, but thus far, almost invariably without success.

The most promising field for discovery was evidently in the Rocky Mountain region, and the first announcement was made in 1856, when Leidy described as mammalian, under the name *Ischyrotherium antiquum*, certain vertebræ found by Hayden in the Judith basin, Montana.* It is now known that these remains, as Leidy himself suspected, are reptilian, and the generic name has been changed by Cope, to *Ischyrosaurus*.†

* Proceedings Philadelphia Academy, vol. vii, p. 89. See also, Transactions American Philosophical Society, 1859, p. 150.

† Synopsis of Extinct Batrachia, Reptilia, etc., p. 38, 1869.

A second announcement was made by Cope, in 1882, based upon a few fragmentary remains discovered by Dr. J. L. Wortmann, in Dakota. These fossils, although not found in place, were apparently from the Laramie formation. The name *Meniscoëssus conquistus* was given by Cope to two of these specimens.* One of them was considered a premolar, and first described. The second was an imperfect molar tooth. A third specimen, the distal end of a humerus, was thought to represent a second smaller species, indeterminable. These three specimens were figured by Cope, in 1884.†

It is now known that the tooth first described, and regarded as a premolar, is the tooth of a Dinosaurian reptile, as suggested by Cope, and not of a mammal. The name given, therefore, must apply to this alone. On this point, the rules of nomenclature are clear and decisive. The imperfect molar tooth, subsequently described, and the fragment of a humerus, are evidently mammalian, but without a name.

The writer has made a careful search for Cretaceous mammals in various parts of the West, both personally, and through parties under his direction. Last season, a special exploration was made in the Laramie formation of Dakota and Montana, but without the expected success. [This spring, a renewed search, and more systematic investigation, were undertaken in the same formation, in Dakota and Wyoming, and the results already attained have furnished the material for a new chapter in paleontology. Mr. J. B. Hatcher, the writer's valued assistant, had entire charge of the field work, and to him belongs the main credit of the fortunate discoveries made.]

These discoveries consist, in part, of not less than one hundred specimens of mammalian remains, including jaws, teeth, and various portions of the skeleton, most of them in good preservation. They represent many individuals, all of small size, and not a few new genera and species. Some of the more important of these are described below, and others will be noticed in a later communication.

[The remains here described were found in the typical Laramie formation, either in place, or in association with other fossils that determine their geological position beyond reasonable doubt. The vertebrate fossils found with them are mainly the remains of Dinosaurs, which are represented by at least two orders, and several families. The most abundant specimens are teeth of carnivorous forms allied to *Megalosaurus*, others of *Hadrosaurus* and its allies, and two or more species of *Ceratops*. The kind of tooth described as *Meniscoëssus* is not

* American Naturalist, vol. xvi, p. 830, 1882. † *Ibid.*, vol. xviii, p. 693, 1884.

uncommon, and the vertebræ of *Ischyrosaurus* occur with them. The remains obtained place the reptilian nature of both beyond question. Crocodiles of small size, turtles of the genus *Compsemys*, and various fishes, mostly Ganoids, are abundant in the same horizon. The invertebrate fossils indicate that the deposits are of brackish, or fresh water origin.*

The mammalian remains themselves also indicate to some extent their horizon, and this is one of the interesting points connected with the discovery. Many of them belong to the group the writer has called the *Allotheria*, which contains the Triassic *Triglyphus*, *Tritylodon*, and *Microlestes*, the Jurassic *Stereognathus*, *Plagiaulax*, and *Bolodon*, in Europe, and *Allodon* and *Ctenacodon*, in America, as well as some later forms.

Most of the new genera show close affinities with the Triassic and Jurassic forms, and one genus cannot at present be distinguished from *Dryolestes.* Another genus appears more like an insectivore, with teeth of the same general form as *Tupaia.* Besides these, there are several genera of small marsupials, which, although quite distinct, seem to have near affinities with some American Tertiary forms, or others still existing.

Carnivores, Rodents, and Ungulates, appear to be entirely wanting in this unique fauna. A still more surprising fact is the absence of their probable ancestors, unless, indeed, the insectivorous forms are entitled to this important position. Many known facts point in this direction.

As a whole, the mammals already found in these deposits are very nearly what was expected from the Cretaceous, but thus far, the older types seem to predominate. The *Allotheria* from this horizon appear to be distinct from the *Marsupialia*, and some specimens secured point to the Monotremes as possible allies. One genus, at least, of the new forms has a free coracoid, as well as some other characters of Monotremes, and it is possible that these features belong to the whole group. These points will be discussed more fully later.

The specimens briefly described below give some idea of the rich mammalian fauna that lived during Cretaceous time, and indicate what may be expected from future discoveries. These and other remains from the same horizon will be fully described and figured in a memoir on Mesozoic mammals, now in preparation by the writer, under the auspices of the United States Geological Survey.

* Remains of a single bird were found at one locality in association with the mammals. It was about as large as a pigeon, and had strong powers of flight. It appears to be related to *Apatornis*, one of the toothed birds described by the writer. It may be called *Cimolopteryx rarus*.

Cimolomys gracilis, gen. et sp. nov.

The type specimen of the present genus and species is the upper molar tooth represented on Plate II, figures 1–4. It is apparently from the right side, and is in excellent preservation, the entire crown being complete, and only portions of the fangs wanting. The surface of the crown is divided into three rows of cones. These rows are separated by two deep longitudinal grooves. In the outer row, there are seven tubercles; in the middle row, eight; and in the inner row, nine. The middle row has the largest elevations, and the inner row, the smallest, those of the outer row being intermediate in size.

In general structure, the teeth of the present genus are similar to those of *Tritylodon*, Owen, from the Triassic of South Africa. In the latter genus, however, the upper molar teeth have but three tubercles in each row. This is true, also, of the known teeth of *Triglyphus*, Fraas, from the Trias of Germany, which is probably identical with *Tritylodon*. The present genus apparently belongs to the same family, the *Tritylodontidæ*.

The present specimen is from the Laramie formation of Wyoming. It indicates an animal about as large as a weasel.

Cimolomys bellus, sp. nov.

A smaller species of this genus is indicated by an upper molar apparently the last on the right side, which may be considered the type specimen. In this tooth, the inner series of tubercles is not so fully developed as in the corresponding row of the larger species. In the outer row, there are five tubercles; in the middle, six; and in the inner row, three well-developed cones, and three more of minute size. The crown of this tooth is 5^{mm}. in length, and 2^{mm}. in width at its widest part. The type specimen is from the Laramie deposits of Wyoming. It indicates an animal of about the size of a mouse.

Cimolodon nitidus, gen. et sp. nov.

The teeth of the present genus have the same general structure in the molars as those in the last genus, but there are two rows of tubercles instead of three. The upper molar represented in Plate II, figures 5–8, may be regarded as the type specimen, and the figures given, three times natural size, will show its characteristic features. In what may be regarded as the outer row, there are eight tubercles, and four only in the inner series.

This genus represents a new family, which may be called the *Cimolodontidæ*.

The specimens known indicate an animal nearly the size of a rat. They were found in the Laramie of Wyoming.

Nanomys minutus, gen. et sp. nov.

A fourth genus allied to those above described is indicated by some very minute teeth, one of which, selected as the type, is shown on Plate II, figures 9–12, three times natural size. It is apparently the last upper molar of the left side. The composition of the crown is peculiar in having two rows of cones separated from each other by a longitudinal depression which is not a straight groove, but irregular in direction. On what appears to be the outer side, there are eight cones, the the anterior four being large, and the posterior ones, quite small. On the opposite side, there are two large cones in front, and five minute tubercles behind them.

The remains representing this diminutive species were found in Wyoming, in the Laramie formation.

Dipriodon robustus, gen. et sp. nov.

The present genus has a form of dentition not before seen. This is represented in the type specimen shown on Plate II, figures 13–15. This specimen is the last upper molar of the left side, its position being decided by a portion of the maxillary attached to it. The composition of the crown of this tooth consists of two rows of cones, separated by a deep longitudinal groove. The elevations in each series are crescentic in form, the convex portion of the crescent being forward. There are three cones in the outer row, and but two in the inner row. Their points are somewhat worn, apparently most by a lateral motion of the jaws.

A second isolated last upper molar, evidently of the same species, was found at another locality in the same horizon. It agrees in all essential characters with the type specimen figured.

A smaller species of the same genus is indicated by the upper molar tooth represented on the same plate, figures 16–18. This tooth is apparently a first or second molar, also from the left side. It has four cones in the outer row, and three in the inner. This species may be called *Dipriodon lunatus*.

The animal represented by the larger specimen was about as large as a rabbit, and the other, somewhat smaller. The type specimens are from the Laramie of Wyoming. Various parts of a skeleton were found with these remains, some of which are figured on Plate V.

The family represented by the two species may be named the *Dipriodontidæ*.

Tripriodon cœlatus, gen. et sp. nov.

In the present genus, the type specimen of which is figured in Plate II, figures 19–21, the upper molar teeth have three rows of elevations, separated by two longitudinal grooves. The outer cones are tubercular, and the central and inner rows, crescentic. In the type specimen, which is apparently the first upper molar of the left side, there are four cones in the outer row; three, in the middle row; and only two in the inner series. The crown of the tooth is subtriangular in outline, with the narrow end in front.

The teeth of this genus resemble those of *Stereognathus*, from the Jurassic of England. Several lower molars with two rows of cones were found with the type, but the association may be accidental.

The type specimen is from the Laramie of Wyoming. It represents an animal about as large as a rabbit.

Tripriodon caperatus, sp. nov.

A larger species, apparently of this genus, is indicated by a number of teeth, some of them in good preservation, and others in fragments. Among the more perfect are a number of lower incisors, one of which, represented in Plate III, figures 18–20, may be regarded as the type. This tooth is nearly flat on one side, and strongly convex on the other. The enamel of the crown is irregularly wrinkled into ridges. The flat side is more nearly smooth, and was evidently placed closely against the adjoining tooth, as shown in figure 19.

Smaller teeth of the same general form and pattern were also found, and these probably pertain to the species above described. The two species indicate a new family, which may be called the *Tripriodontidæ*.

The remains at present known are from the Laramie of Wyoming.

Selenacodon fragilis, gen. et sp. nov.

The present genus is clearly allied to the one last described, but may be readily distinguished from it by the molar teeth. The upper molars have three rows of cones, arranged in the same manner, but the elevations are smaller, more numerous, and sharply pointed. All of those well developed are distinctly crescentic. The type specimen is an upper molar, and is represented on Plate II, figures 22–24. The longitudinal grooves which separate the series of cones, and the transverse valleys between the crescents, are deeply cut, and this renders the crown of the tooth especially fragile. The present type specimen pertained to an animal somewhat smaller than a rabbit. It is also from the Laramie deposits of Wyoming.

Halodon sculptus, gen. et sp. nov.

The present genus is an interesting form of the *Plagiaulacidæ*, and the type specimen is represented on Plate III, figures 11–13. It is the characteristic fourth premolar of the lower jaw. It indicates an intermediate form between *Ctenacodon* and *Plagiaulax*. The summit of the crown is notched, and there are seven distinct ridges on the sides. The posterior third of the crown is smooth.

An upper incisor, apparently the median one, was found with the type specimen, and is provisionally referred to the same species. It is represented on Plate III, figures 1–3. A second incisor, much smaller, and apparently the exterior one, is represented on the same plate, figures 7–10.

A much smaller species, probably of the same genus, was secured from the same horizon. The type specimen, a lower third or fourth premolar, is represented on the same plate, figures 14–17. The upper incisor shown in figures 4–6 of the same plate is provisionally referred to this species, which may be called *Halodon serratus*.

The larger species was nearly the size of a squirrel, and the smaller one, about as large as a rat. The remains representing both are from the Laramie formation of Wyoming.

Camptomus amplus, gen. et sp. nov.

One of the largest mammals found in the Laramie is represented by the several parts of the skeleton, and fragments of teeth, but the association of the various remains may be accidental. The important character of the genus is seen in the scapula, which has an articular face for a distinct coracoid. This specimen is represented on Plate V, figures 1 and 2, and may be considered the type. With it was found the interclavicle, and also the calcaneum and astragalus, represented on the same plate.

It is probable that this genus should be placed in the order *Allotheria*, but future discoveries must settle this point. The specimens now referred to this species are from the Laramie of Wyoming.

Dryolestes tenax, sp. nov.

The only specimen so far found in the Laramie deposits that resembles the Jurassic *Pantotheria* is a lower jaw. In size and shape, this is very similar to some of the smaller jaws of *Dryolestes*, and the species it represents may be provisionally placed in that genus. A characteristic feature of this specimen is a distinct mylo-hyoid groove, which has essentially the same position as in *Dryolestes*. This jaw measures 5mm. in depth, under the molar series, and about 2mm. in thickness, at the same place. The number and form of the teeth cannot be determined from the present specimen. The animal represented was about as large as a mole. It was found in Wyoming.

Didelphodon vorax, gen. et sp. nov.

In the present collection of mammalian remains, there are quite a number of teeth, and various parts of the skeleton, indicating several species of small animals which appear to be related to the modern opossum. A tooth of one of these is represented in Plate IV, figures 1–3, which may be taken as the type of the genus.

It is apparently the penultimate upper molar, and has the essential structure of the corresponding tooth in the genus *Didelphys*. It has, however, a pair of intermediate small cusps near the middle longitudinal line of the tooth, one in front, and one on the posterior border, as shown in figure 2. A number of other teeth, apparently of the same species, were also secured. They are all from the Laramie of Wyoming. They indicate an animal about the size of a rabbit.

Didelphodon ferox, sp. nov.

A still larger species, equal in size to the Virginia opossum, is represented also by a number of teeth, of which the lower molar, shown in Plate IV, figure 4, may be considered the type. Its crown has the same general composition as that of the lower molars of the modern *Didelphys*, but the anterior portion is more elevated. The fangs are especially large and powerful. The canine tooth of destructive form, figured on Plate IV, figures 26–28, probably pertains to this animal. The remains of this species are apparently the largest of any of this class yet found in the Laramie of Wyoming.

Didelphodon comptus, sp. nov.

A third species, much smaller than either of the other two, is indicated by various teeth. The lower molar, shown in Plate IV, figures 5, 6, and 7, is a characteristic tooth, and may be taken as the type. The structure of the crown is well shown in the cuts mentioned. There is a well-marked basal ridge on the outer surface, but not on the inner. The premolar, represented on the same plate, figures 20–22, apparently pertains to the same species.

These specimens indicate an animal about as large as a rat, and were found in Wyoming, in the Laramie formation.

Cimolestes incisus, gen. et sp. nov.

Another genus of small mammals, apparently marsupials, and more distantly related to *Didelphys*, are well represented in the Laramie by various teeth in good preservation. A characteristic lower molar is shown in Plate IV, figures 12–15, and this is a typical form. The anterior half of the crown is much elevated, and its three cusps are distinct and sharp. The posterior half is much excavated. The premolar represented on the same plate, figures 16–19, probably pertains to the same species. They indicate an animal about as large as a weasel, and are from Wyoming.

Cimolestes curtus, sp. nov.

A much larger species, apparently of this genus, is represented by several teeth, one of which, shown on Plate IV, figures 8–11, is selected as the type. It is a lower molar in good preservation, and its distinctive feature are well shown in the cuts. The crowns of these teeth are unusually short. The remains known indicate an animal about as large as a rabbit, and are from the Laramie deposits of Wyoming.

This species and the one last described represent a distinct family, which may be called the *Cimolestidæ*.

Pediomys elegans, gen. et sp. nov.

Among the more minute mammalian teeth from the Laramie are some that apparently pertain to a very small insectivorous mammal, the exact affinities of which are uncertain. The teeth secured resemble those of *Tupaia*. The type specimen is represented in Plate IV, figures 23–25, four times natural size. It is an upper molar, apparently the last on the right side, and its characteristic features are well shown in the cuts. Several lower teeth were found at the same locality, which may pertain to this species, but their association with the type specimen may be only accidental. The latter indicates an animal about as large as a mouse, and was found in the Laramie of Wyoming.

The bones represented on Plate V are from the same localities as some of the teeth described, but their closer association with them must for the present be regarded as provisional. Future discoveries will doubtless show what relations they all have to each other.

The specimens here briefly described are from several localities, which may belong to distinct horizons of the Laramie formation, but are certainly within the limits of its typical deposits They were all found by Mr. J. B. Hatcher, who has done so much to bring to light the fossil vertebrate treasures of this country.

New Haven, Conn., June 24th, 1889.

EXPLANATION OF PLATES.

PLATE II

FIGURES 1–4.—Upper molar tooth of *Cimolomys gracilis*, Marsh.

FIGURES 5–8 —Upper molar of *Cimolodon nitidus*, Marsh.

FIGURES 9–12.—Upper molar of *Nanomys minutus*, Marsh.

FIGURES 13–15.—Last upper molar of *Dipriodon robustus*, Marsh.

FIGURES 16–18.—Upper molar of *Dipriodon lunatus*, Marsh.

FIGURES 19–21.—Upper molar of *Tripriodon cœlalus*. Marsh.

FIGURES 22–24.—Upper molar of *Selenacodon fragilis*. Marsh.

PLATE III.

FIGURES 1–3.—Upper incisor of *Halodon sculptus*, Marsh.

FIGURES 4–6.—The corresponding tooth of *Halodon serratus*, Marsh.

FIGURES 7–10.—Outer upper incisor, probably of the same species.

FIGURES 11–13.—Fourth lower premolar of *Halodon sculptus*.

FIGURES 14–17.—Third or fourth lower premolar of *Halodon serratus*.

FIGURES 18–20.—Lower incisor of *Tripriodon caperatus*, Marsh.

FIGURES 21–23.—Lower incisor of *Tripriodon cœlalus*.

PLATE IV.

FIGURES 1–3.—Upper molar tooth of *Didelphodon vorax*, Marsh.

FIGURE 4.—Lower molar of *Didelphodon ferox*, Marsh.

FIGURES 5–7 —Lower molar of *Didelphodon comptus*, Marsh.

FIGURES 8–11.—Lower molar of *Cimolestes curtus*, Marsh.

FIGURES 12–15.—Lower molar of *Cimolestes incisus*, Marsh.

FIGURES 16–19.—Upper premolar of same species.

FIGURES 20–22.—Upper premolar of *Didelphodon comptus*.

FIGURES 23–25.—Upper molar of *Pediomys elegans*, Marsh.

FIGURES 26–28.—Canine tooth of *Didelphodon ferox*.

PLATE V.

FIGURES 1–2.—Right scapula of *Camptomus amplus*, Marsh.
c, articular face for separate coracoid.

FIGURES 3–4.—Interclavicle, referred provisionally to the same species.

FIGURES 5–6.—Distal end of humerus, probably of *Didelphodon vorax*.

FIGURES 7–8.—Distal end of humerus, referred to *Dipriodon lunatus*.

FIGURES 9–11.—Proximal end of radius, referred to *Cimolestes incisus*.

FIGURES 12–15.—Left lunar bone, probably of *Dipriodon robustus*.

FIGURES 16–17.—Proximal end of femur, probably of *Halodon sculptus*.

FIGURES 18–20.—Right astragalus of *Camptomus amplus*.

FIGURES 21–23.—Right calcaneum, apparently of same individual.

Note.—The figures enlarged from natural size have the increase given in diameters over each cut.

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[THIRD SERIES.]

Art. XI.—*On the Observation of Sudden Phenomena;* by S. P. Langley.

[Read before the Philosophical Society of Washington, March 2, 1889.]

By a sudden phenomenon is here meant one of that large class where the occurrence is awaited without the observer's previous knowledge of its exact instant, and of which familiar examples may be found in the bursting of a rocket, the appearance of a meteor, or the emergence of a star from behind the moon. A great part of all the phenomena of daily life, as well as of scientific observation, are of this kind, though the importance of a special instance of another class, (I refer to the gradual and foreseen approach of a star to a wire), has drawn to this latter such particular attention that we are apt to think of it only when "personal error" is in question.

When in an observatory, we study the means taken to record the precise time of the transit of a star, we find that the precision of modern apparatus has reduced the error which we may expect in almost any part of the mechanism to an extremely minute amount, which may be calculated to the fractional part of the one hundredth of a second. I say "almost" for, as we are all aware, there is one notable exception, at least until photography can be made to intervene. The human brain and nerves, and behind these the inscrutable processes of the will, themselves form an inevitable link in the chain of apparatus of observation, and here an error may and does arise enormously greater than that of all the rest put together.

We all know that this error varies with the individual and the occasion. It is most constant in the experienced observer, but even in his case it varies with the daily accidents of the human organism, and even with him it is presumably constant only for the particular observation to which the experience applies. There is not even a presumption, I think, that the personal equation belonging to an experienced transit observer would apply to the same person's notation of the occultation or emergence of a star, and still less, if possible, to any phenomenon outside his ordinary professional experience; for we must, of course, recognize that we carry this fallibility with us in every act of life, and that it is just as present when we attempt to determine the instant at which a race horse passes the winning post, as when we seek to note the particular hundredth of a second at which a star passes the wire.

The very words "personal equation" imply that the errors due to this fallibility can be ascertained and allowed for, and may lead us to think (if we think carelessly) that there is a personal equation always ascertainable; whereas, as we in fact know, it is only possible to apply the correction where long habit has settled the amount of error to be expected with regard to some one special phenomenon.

The number of devices for obtaining and correcting the personal equation, even in the special case of meridian observation, is, as those who have studied the subject know, surprisingly great. I think I have myself examined more than fifty such, and with hardly an exception they all exhibit variations on one idea—the idea, that is, that the error must have been committed *first;* the committing of the error being assumed to be an inevitable necessity for which subsequent correction is to be made.

I have thought, then, that it might be interesting if I were to ask you to consider with me what may seem at first the somewhat paradoxical suggestion, that means may be found by which any individual, skilled or ignorant, may make, not only meridian observations, but an observation of any sudden visible event, of whatsoever nature, so accurately that we need apply no correction, because the precision may be, if not absolute, at least such that no correction will in ordinary practice be needed. I may deceive myself in thinking that what I have to suggest involves a novel idea, but I am led to suppose so from the fact that I have met no application of it in a somewhat extended reading on this point.

Let me first remark that while such error as that in question doubtless belongs to all the senses in some degree, we are at this moment considering it in connection with the sense of sight only.

When we see anytbing in motion (let us suppose for instance a passing train on the railroad) we have the well-known facts that—

First. An instantaneous photograph is made by the optic lens upon the retina, there being a picture formed there, which is perfectly distinct, but which fades out upon the retinal plate in from one-tenth to one-quarter of a second, while the perception of this image is under ordinary circumstances * sensibly instantaneous; but—

Second. Nerves convey the distinct impression of every part of the picture to the brain, and it is here, if we have to act on this impression, that a certain time is lost, not only in the carrying of the message along one set of nerves and the bringing back the answer on the other, but in the decision that is being made by that unknown and inner self, which appears to us to exert here a more or less conscious act of will.

In the case of a sudden and startling event, the time elapsed may be almost indefinitely great; and in some cases, probably several entire seconds may pass without the consciousness of the observer. A very imperfectly appreciated interval must occur in all cases, for what we have just said applies to every event of our daily lives, and the professional observation is only a particular instance of it.

Now, I ask your attention to the practical instantaneity of the *formation* of this visual picture, which is known to be obtained where the duration of the phenomenon to be observed is much less than the one thousand-millionth of a second, while where we have every reason to believe that the actual formation of the image on the retina under known ordinary conditions requires a time of like order.

We may say, then, that the casting of a picture on the retina is instantaneous. It is its fading out that requires time, and it is while this fading out takes place, and even long after it, that the work of perception, decision, and action is going on behind the retinal curtain in the chambers of the brain. Notice then, that while to determine *when* a phenomenon occurs may require, under some circumstances, several seconds, and under all ordinary circumstances a notable fraction of a second, to determine *where* it occurs requires (sensibly) no time at all, for one single impression remains on the retina

* The writer's observations (this Journal, Nov., 1888) show that appreciable time is required for perception of the retinal impression, with certain excessively faint lights; but these are not here in question.

long enough to obtain full recognition and to be reproduced by processes of memory.

I can make my meaning clearer, perhaps, by using the same specific instance as before. Let us suppose that an accident to a passenger on the passing train is the phenomenon, the time of whose occurrence is to be noted, and that this accident is seen from a room in which there are two windows looking on the track. We must have seen the accident, if it be instantaneous, either through the first window or the second. If we had been led to anticipate that we should be called upon to say through which window we saw it, I think we may all admit that there would be no discrepancy on this point between different observers, for in this case we are considering only the element of position, and the element of time does not directly enter at all, so that observers in the same position who had been bidden to note through which window they saw it would all agree on this point.

Now a connection can here obviously be established between the place and the time, from which to infer the latter, if we are granted the knowledge of two facts: the time at which the carriage could have first come into view from the first window, and the time at which it must have passed out of view behind the second; for if we suppose the speed of the train to have been uniform, we have the means of deciding the fraction of the time when we know the fraction of space. Here then, as in the case of a common clock or chronograph, or any device where time and space are proportional, we can infer the latter from the former; only let it be observed that we here need no recording apparatus. What we use is the memory of where the event occurred; in other words, we recall the impression on the retinal screen and have no need to bring into use what we may call the time-perception apparatus of the brain which lies behind it; *nor do we in fact need that the object of our observation shall be really in motion, but only that it shall be made to appear to be so.*

This last point is all important, and what I ask your attention to is an experiment heretofore, I think, untried, and which is perhaps a novel application of the fundamental horological idea that time and space must be made proportional, for it seems to me it must be theoretically possible, not only in the case of the clock or the chronograph, but always, to so connect the former with the latter that the essential task of the time observer is only to say *where* any visible event apparently occurred, and then let some mechanism outside of himself say when.

That at least is the idea, and if it has, as I hope, been clearly apprehended by you, I will now ask your attention to a working plan for carrying it out. Numerous different devices have been under my consideration. I will take one which is primarily designed for the observation of any celestial phenomenon, though it could very well be adapted to terrestrial ones; and in order to fix our ideas, I will suppose that we have an event which we know the approximate time of, but which may burst upon us at some fraction of a second which we want to determine. I will assume (merely to fix our thoughts) that we wish to note the time at which a star emerges from behind the dark body of the moon, with an accuracy which ensures us that we have not made an error so great as one-twentieth of a second.

You see I hold in my hand a peculiar eye-piece, which has been made to observe this or any other terrestrial or celestial phenomenon of sudden occurrence. It can also be used for meridian observation, but its special field seems to lie in noting an event where no ordinary correction for personal equation is applicable. This event may be anything celestial or terrestrial, from the entrance of Venus on the disc of the sun, to the explosion of a mine; but, for the purpose of illustration merely, let us take it to be the sudden appearance of the star.

On looking into the telescope we see, in the first place, two prominent wires crossing each other at right angles, dividing the field of view into four quadrants. Now, by a simple mechanism, which I shall shortly explain, any object that our telescope is directed on—any fixed star for example—seems to be revolving in the field, passing successively through the first, second, third and fourth quadrants. If the star is hidden the mechanism is working just the same, and when the star appears it must evidently first be seen in some particular one of these four quadrants, and experience shows that we shall have no difficulty in telling in which one. The mechanism itself has recorded for us by an electric contact the limiting instant between which it is possible to see the beginning and the end of the cycle during which revolution may be supposed to be made. It is not necessary that this cycle should last just a second; but supposing it (still for illustration only) to be a second, if it was seen in the first quadrant, it was seen in the first quarter of the second; if it was seen in the second quadrant; some time in the second quarter of the second; in the third, in the third quarter; in the fourth, in the final quarter. All that we have to do in this case is to know in which second it occurred; for the quarter of a second we may say is noted for us by the purely automatic action of the optic lens and retina, since the first image on the retina must be that of the star as seen in some particular one of the four quadrants.

Going a little farther, we will now suppose each of the four quadrants, which in turn correspond to quarter seconds, to be divided into five parts, so that the whole circle is divided into twenty. All the observer has to say is in which quadrant and in which subdivision of the quadrant the star appears, to say in which twentieth of the second (or other brief cycle) it emerged.

The reticule I have just described is fixed in the focus of the eye-piece and does not revolve. What does revolve is a minute double prism of total reflection just before the reticule, the middle of whose reflecting face lies in the optical axis, and by whose means this axis is twice broken at a right angle, so that when the telescope is directed on a star the image of the star is not seen at the center of the field, but on one side of it. If the prism is revolved, the star must appear to revolve in a circle whose radius is nearly that of the side of the prism.

The little prism is turned by a small piece of watch-work, but it is not at all necessary that this should be exact, since all we demand is that the rate shall be constant during a second or so—a condition easily secured with the most ordinary mechanism.

The sketch and the apparatus exhibited sufficiently indicate, I think, the simple means by which this is brought about.

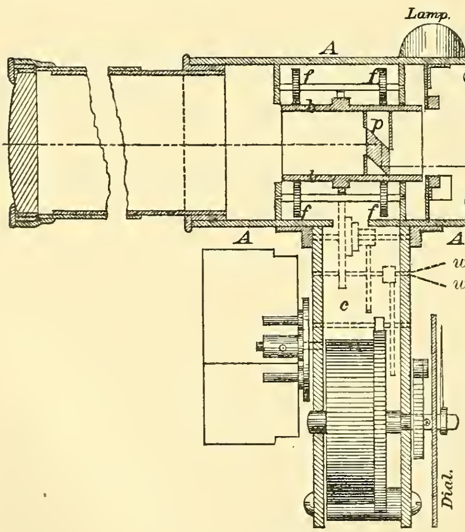


FIG. 1. SECTION.
½ FULL SIZE

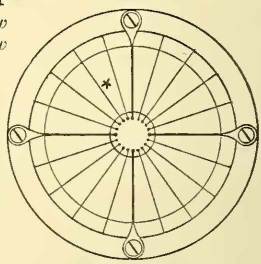


FIG. 2. DIAPHRAGM.
FULL SIZE.

S. P. LANGLEY. INVT

Figure 1 is a section one-half full size. A A is the outer tube, which can be fitted, if desired, into the eye end of a telescope. *b b* is the inner tube, resting on friction wheels *f f*, revolved by the clock-work *c c* about once a second, and recording the time at which a key in the observer's hand may be pressed to indicate the particular second. This record may be made electrically by the wires *w w* on a chronograph, or more simply and directly on a little attached dial like that of a recording stop-watch.

p p is the prism of double total reflection, *r r* is the position of the fixed reticule (shown independently as it appears to the observer and of full size in figure 2).

e e are the lenses of a positive eye-piece. The lamp is for giving wire illumination, if desired, when a telescope is employed.

Field illumination is readily obtained otherwise by making the diaphragm in which the prism *p p* is set of translucent material.

Finally it should be remarked that on removing the eye-piece events may be observed without using any telescope. In this, its simplest form, the chronograph may also be dispensed with, and the record of the second made on an attached stop-watch dial and the instrument may thus carry its own complete recording apparatus and be more portable than an ordinary opera-glass.

I have not found opportunity to use this apparatus on the moon or occultations, but I have, what is possibly more to the purpose now, tried it on an artificial star, the instant of whose appearance and disappearance was independently recorded on a chronograph by an electrical contact. Different observers, entirely unskilled and ignorant in the use of the instrument, were invited to look into it and to determine the quadrant and section in which the star appeared and disappeared.

I have momentarily mislaid my notes containing in full detail the results of four observers but I can summarize them approximately by saying that after being simply told what to note; the average probable error (that is, for any single observation) was rather less than one-twentieth of a second. As far as I can judge from the limited number of instances, the younger the observer the better the observation. The worst of the observers (the oldest), however, had a probable error considerably less than one-tenth of a second; the youngest, a probable error of something like one-fortieth of a second, which implies, as you will observe, that he not only readily noted the quadrant and the subdivisions of the quadrant, but, also as a rule, even the part of the subdivision in which the star was first seen. None of these observers had so much as one hour's practice.

The plan in question is easily adapted to meridian observations, but for these we have numerous plans for correcting personal equation, and the writer may also direct attention to the fact of the existence of a distinct device (this Journal, July, 1877) which practically eliminates the personal error in the very act of a transit observation. It is more elaborate than the present one, which is so simple that it may be useful even in longitude work with the transit, though its proper field seems to be the observation of sudden events; but, to whatever purpose it is applied, I beg leave to present it to your attention less for any interest that attaches to the particular mechanism exhibited than as an illustration of a principle which seems to me to have not been employed before, at least in this way, and which I trust may have useful applications.

Art. XII.—*A Spectro-photometric Comparison of Sources of Artificial Illumination;** by Edward L. Nichols and William S. Franklin.

[Contributions from the Physical Laboratory of Cornell University, No. 5.]

In the comparison of the various sources of light available for the purposes of artificial illumination, the question of color, though scarcely less important than that of intensity, has been very generally disregarded.

The neglect of this factor has doubtless been due in great part to the fact that differences of color are not so easily determined as mere variations in candle power. Progress in this domain involves the study of the distribution of energy in the spectrum, and since it is with the visible wave-lengths that we have to do, often under exceedingly small intensities, the superiority of the eye in sensitiveness over any device for the direct measurement of the energy of the rays in question, dictates in many cases the choice of an optical method.

The experiments to be described in this paper were made in the Physical Laboratory of Cornell University during the summer of 1888. They consisted in the spectro-photometric comparison of various artificial sources of light, and of daylight, with that emitted by a sixteen candle-power incandescent lamp. The sources of light subjected to measurement were:

1. a standard candle;
2. various petroleum flames;

* Paper read at the Cleveland meeting of the American Association for the Advancement of Science, August, 1888.

3. various illuminating-gas flames;
4. a lime-light.
5. electric arc-lights of the two prevailing commercial types (long-arc and short-arc);
6. daylight by clear and by clouded sky;
7. an incandescent lamp of high resistance, at various temperatures;
8. an incandescent lamp of low resistance, at normal candle-power.

The spectro-photometer employed in these measurements was of the type already described in the pages of this Journal.* For the comparison-flame usually employed, we substituted however a sixteen-candle Edison lamp, maintained constantly at its normal voltage.

The rays from this lamp, having been rendered parallel by means of a lens of four inches aperture and short focal length, were passed through two Nicol's prisms, the first of which was free to revolve, before entering the total-reflection prisms at the slit of the spectroscope. This comparison lamp was placed at the observer's right hand, the axis of the condensing lens and of the Nicol's prisms being at right angles with the collimator tube and in the same vertical plane as the slit. The light to be compared was introduced into the collimator tube from the opposite side, by means of a similar pair of total reflection prisms. The arrangement of these four prisms has been described in the article last cited.

One of the chief sources of error in the comparison of various illuminants, lies in the great range of temperature in the glowing material which constitutes the source of light. Each element of the radiating surface adds its quota to the general illumination, and it is impossible to find any single region, the spectrum of which is identical with that of the entire source. We met this difficulty by allowing the light under observation to fall upon the face of a block of magnesium carbonate, taking the spectrum of the rays reflected by the latter. Magnesium carbonate is not a pure white,† but it reflects all the wave-lengths of the visible spectrum in sufficient quantity for the purpose in question.

Ten regions of the visible spectrum were selected for measurement, and the intensity of the spectrum of an Edison incandescent lamp, giving 16 candles at 100 volts, was taken as the unit of comparison for each region. All other spectra were reduced to unit intensity in the region of the D line,

* This Journal, vol. xxxvi, p. 332.

† See E. L. Nichols, "On Black and White," Transactions of the Kansas Academy of Science, vol. x.

their brightness in other regions being expressed in terms of that of the corresponding wave-length of this standard spectrum. This method of presenting the results of spectro-photometric comparisons, seems to us to offer many advantages. It was adopted by Mr. W. H. Pickering in an investigation made some years since, and covering very much the same ground as our own;* and although other wave-lengths have been selected by some writers, for instance that of a certain region in the green ($\lambda=5570$) which Otto Schumann has taken as unit of brightness in his recent study of the spectrum of the incandescent lamp, there seems to be no good reason for abandoning the region of the D line, as a reference point, in favor of any other portion of the spectrum.

Candles, Oil and Gas.

Measurements were first made upon two standard candles burning side by side in a double holder designed for use in the Bunsen photometer. Every one who has had experience with this light in photometry is aware that the candle is very far from being a constant source of illumination. Pickering in the paper already cited has expressed the opinion that, "of all the artificial lights examined . . . none was so uncertain in color as the standard candle." We concluded from the consideration of many widely fluctuating values, taken in various parts of the spectrum, that the color of the candle, under the most favorable conditions of combustion, was very nearly the same as that of the 16-candle lamp used as a standard in our measurements, but that its average color was decidedly redder than that of the incandescent lamp.

Experiments upon various petroleum and gas flames showed that these also were of very nearly the same color as the incandescent lamp. Nearly all of them were subject to slight fluctuations in color and intensity, due to variations in the conditions of combustion which were beyond control. These fluctuations, although much less marked than in the case of the candle, were sufficient to cause changes of color greater than the average difference of color between the flame under investigation and the incandescent lamp. One of the gas flames subjected to measurement, that of a lamp of the type known as the "board of trade" argand, a sixteen-candle standard constructed especially for photometric work, was however of remarkable steadiness both in color and intensity, and measure-

* W. H. Pickering, Photometric Researches; Proceedings of the American Academy of Arts and Sciences, vol. xv, 1880.

ments throughout its spectrum showed the quality of its light to be identical with that of our standard incandescent lamp.

It appears then, that the temperature of the carbon filament in the glow lamp of to-day, when heated to the highest degree of incandescence compatible with permanence, agrees very closely with that reached by the light-giving particles of oil and gas flames when the latter are maintained under the conditions of combustion most favorable to the production of light.

The Lime Light.

The source of illumination to which our attention was next directed, was a lime-light of the type used in the magic lantern. The oxy-hydrogen flame by means of which the lime cylinder was maintained in incandescence, was fed by oxygen and hydrogen gas obtained by electrolysis. The gas was drawn from large storage reservoirs under constant pressure and neither burner nor cylinder was readjusted during the time occupied by a complete set of observations. It was found that the lime reached its highest temperature very soon after ignition and then fell rapidly in brightness to an almost constant condition, in which it could be maintained without further marked change for a considerable length of time.

During this first period of incandescence the lime-light is very much whiter than in the permanent condition into which it soon sinks. Its color indeed approaches very closely to that of burning magnesium. Table I gives the results of a single set of observations upon the freshly ignited lime, comprising the mean of three readings in each of nine regions of the spectrum. The mean of several complete sets of observations upon the lime when it had reached its permanent state of incandescence are also given, and these last results are compared with those obtained by Pickering by measurement of the spectrum of a similar source of light.

In these and the following tables the intensity of each region is given in terms of the brightness of the corresponding region in the spectrum of the 16-candle incandescent lamp selected as a standard; the region of the D line in both spectra being taken as unity. The four regions studied by Pickering do not coincide in wave-length with those selected by us, nor was his standard of comparison an incandescent lamp. The wave-lengths of his positions and the brightness of his standard in those positions, as compared with that of a gas flame, are given in his paper. Now the color of an argand gas flame does not differ materially from that of our standard, and it is therefore a simple matter to bring his observations and our own into direct comparison.

TABLE I (Lime-light.)

Region of the Spectrum.	Lime freshly ignited.	Lime in final state of incandescence.	
	Lime-light / Standard lamp.	Lime-light / Standard lamp.	Lime-light / Gas-light. (Reduced from observations of W. H. Pickering.)
λ=7530	0·65	0·49	----
6685	0·76	0·72	----
6562	----	----	0·76
6080	0·89	0·89	----
5890	1·00	1·00	1·00
5570	1·24	1·18	----
5185	2·10	1·32	----
5180	----	----	1·10
4920	3·84	1·62	----
4685	5·38	1·81	----
4500	10·80	2·08	2·28

It will be seen that the lime-light, in its final condition is relatively twice as bright in the violet (λ=4500), and relatively one-half as bright in the extreme red (λ=7530) as an argand gas flame or the standard incandescent lamp. The comparison of our results with those of Pickering is of interest because of the evidence it affords that the quality of the lime-light remains nearly constant under presumably very different conditions. The two sets of results were obtained by entirely different methods. Pickering used a diffraction grating and brought the spectra under observation to equal brightness by varying the distance of the standard lamp from the slit. His standard consisted of a portion of a gas flame which was decidedly redder than the same flame taken as a whole. We used a glass prism, brought the two spectra to equal brightness by means of a pair of Nicol's prisms and adopted a standard which was relatively about three-fourths as bright in the red and five-fourths as bright in the violet as Pickering's standard.

1.

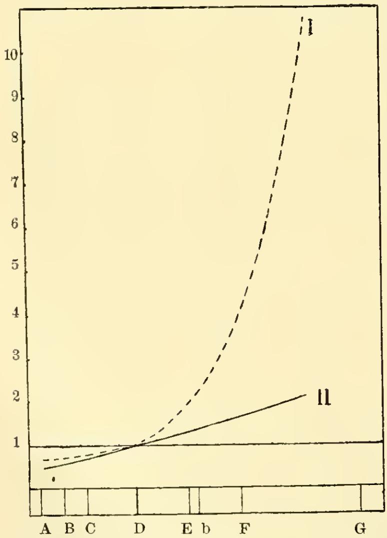


Figure 1. Curves of relative intensities in the spectrum of the lime-light. Curve I, gives results of measurements upon the freshly ignited lime. Curve II, upon lime in permanent state of incandescence.

We shall have further occasion presently to compare these two methods, and to place the results side by side with those obtained by the use of still other forms of photometer.

The Light of the Electric Arc.

Our experiments with the arc-light were made for the most part upon a lamp of the "long-arc" type, with about 10 amperes of current and 50 volts. The lamp was suspended at a distance of 70^{cm} from the block of magnesium-carbonate. It could be raised or lowered at will, so as to expose the latter to the rays emitted in the horizontal plane, or at angles above or below the same. A lens placed near the lamp threw an enlarged image of the carbons upon a screen carrying a vertical scale, so that the length of the arc could be determined at a glance.

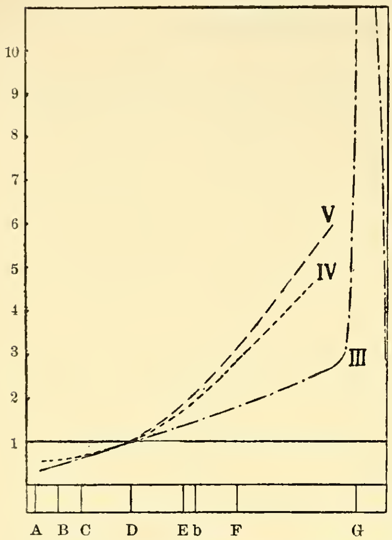
Measurements were made with the magnesium-carbonate in the horizontal plane with the arc, and at positions 16° above, and 14°, 28° and 50°, respectively, below that plane. The carbons used in the lamp were $1{\cdot}2^{cm}$ in diameter. They were of the commercial brand known as the "Faraday carbon," and were copper plated.

The observations made upon rays given off in the horizontal plane and in directions below the horizon, viz: in the three last named positions above mentioned, showed that although the quantity of light increased rapidly from the horizontal plane downward, reaching a maximum in the neighborhood of 50°, as in all arc-lamps of the type in question, the quality of the light was very nearly constant throughout that entire zone. The variations in color with change of angle were indeed very much less than those due to the fluctuations occurring during a single set of readings in a single position. Just above the horizontal plane, however, there occurred a quite abrupt and very marked change in the color of the rays emanating from the arc, and the light became much bluer than that within the zone below the horizon.

This change of color, which was apparent to the unaided eye, was found to be due chiefly to the increased brightness of the wave-lengths lying beyond the E line; the distribution of intensities in the red, and yellow being nearly the same in the spectrum of the rays falling below the horizontal plane and in that of the light 16° above the horizon. The manner in which the relative brightness of the spectrum increases toward the violet is best seen by an inspection of curves III and IV, fig. 2, in which these results are exhibited.

During these measurements the current, potential and length of arc were very nearly constant. We found, however, that they might be varied through the widest limits compatible with the maintenance of the arc, without appreciably changing the character of those portions of the spectrum which were under observation. The length of arc was reduced from $3{\cdot}5^{mm}$ to $1^{\cdot mm}$, the shortest arc which the lamp in question could be made to sustain, without introducing any change in the distribution of intensities; and a "short-arc" lamp using the same carbons, with 21 amperes, $27^{\cdot 5}$ volts and an arc too short to be measured, gave almost precisely the same values throughout the spectrum as those obtained from the long arc lamp. (See Table II.)

2



Curves of relative intensities in the spectrum of the electric arc. Curve III is from measurements below the horizontal plane, curve IV from measurements above the horizontal plane (16°), curve V is from Vogel's measurements of the Foucault regulator.

A study of the spectrum of the arc-light which included only the regions lying between $\lambda=7530$ and $\lambda=4500$, would, however, be incomplete and misleading. Our measurements of that part of the spectrum show, as will be seen by an inspection of Table II and the curves already referred to, that the distribution of energy between the above mentioned limits is very similar to that in the spectrum of the lime-light. The latter is slightly stronger in the red and weaker in the violet than the arc-light, but the difference is not sufficient to account for the much greater brilliancy of color in the electric-light, nor for its higher actinic value. The source of the difference in character, and also of the well known excess of violet light in the "long-arc," as compared with the "short-arc" light, is to be found, however, for the most part among still shorter wave-lengths. The electric arc possesses an extremely brilliant band, really of complex structure, but apparently continuous under the conditions of observation with which we have to deal here, having its maximum in the neighborhood of wave-length 4280 and entirely embraced within the region lying between $\lambda=4320$ and $\lambda=4250$.

Special measurements of the "long-arc" lamp were made to include this violet band. No break in the curve of intensities was found until the edge of the band was reached, the relative brightness at $\lambda=4330$ being scarcely three times that of the standard. From this point it rose at once to more than twenty times that of the standard, a quantity approximating to that of daylight in the same region. Beyond $\lambda=4250$ the values fell again into the continuation of the original curve. The results of these measurements are also given in Table II and curve III, figure 2.

TABLE II (*the Electric Arc*).

Wave-lengths.	Short-arc 21 amperes 27·5 volts $a=30°$. † Electric arc / Standard lamp.	Long-arc * (10·5 amperes, 52 volts). Below the horizon. Electric arc‡ / Standard lamp.	Long-arc * (10·5 amperes, 52 volts). Above the horizon. $a=-16°$.† Electric arc / Standard lamp.
7530	8·50	0·36	0·55
6680	0·71	0·55	0·66
6080	0·88	0·90	----
5890	1·00	1·00	1·00
5570	1·26	1·26	----
5185	----	1·63	1·96
4920	----	1·73	2·85
4685	2·08	2·03	3·88
4500	2·50	2·51	4·64
4340	----	2·80	----
4250	----	20·40	----
4100	----	3·22	----

The results of measurements of the light from the "Foucault regulator" arc-lamp, by A. Crova,§ W. H. Pickering ‖ and H. C. Vogel,¶ reduced to a common scale for purposes of comparison, are incorporated in Table III. Crova's standard of comparison was a moderator lamp burning colza oil, concerning the color of the flame of which we only know that it was slightly redder than that of the stearine candle. The set of values given in Table III, are obtained from his measurements without taking into consideration the quality of his standard lamp. They are between those of Pickering and Vogel.

None of these determinations take cognizance of the violet band at λ 4280. They are introduced here because they afford a comparison of the results of three distinct methods of spectro-

* Length of arc $=3·5^{mm}$.

† a is the angle which the line, joining the block of magnesium carbonate with the arc, makes with the horizontal plane.

‡ Mean of values for $a=0°$, $a=14°$, $a=28°$ and $a=50°$.

§ A. Crova, Comptes Rendus, t. lxxxvii, p. 322, 1878.

‖ W. H. Pickering, Photometric Researches, etc., p. 246.

¶ H. C. Vogel, Berliner Monatsberichte, 1880; p. 801.

photometry, as applied to so difficult an object as the arc-light, concerning which Vogel, whose measurements of this source of light, and of sunlight, daylight, and the light of the moon and of various fixed stars, are of uncommon accuracy, makes note that the limit of accuracy of his determinations of the electric light is about 16 per cent.

TABLE III.

A comparison of various measurements of the spectrum of the Foucault regulator.

Wave-lengths. λ	From measurements by A. Crova. Arc-light / Colza oil light.	From measurements by W. H. Pickering. Arc-light / Gas light.	From measurements by H. C. Vogel. Arc-light / Petroleum.
6760	0·59	----	----
6562	----	0·82	----
6333	----	----	0·71
6050	0·94	----	----
6000	----	----	0·88
5890	1·00	1·00	1·00
5600	1·19	----	----
5550	----	----	1·33
5230	1·76	----	----
5180	----	1·17	----
5170	----	----	2·08
4860	2·27	----	3·11
4640	----	----	4·16
4590	4·97	----	----
4550	----	5·88	----
4440	----	----	5·33
4260	----	----	6·66

These values, taken in comparison with those given in Table II, afford us abundant evidence that the light of arc-lamps with small carbons is very much whiter than that emanating from the large commercial lamps of the present day, with carbons of half inch diameter. This conclusion is quite in accordance with the results of recent investigations of the economy of the arc-light, in which it has been shown that the candle-power increases with the current-density.* Certain experiments upon the ratio between total radiation and luminous radiation from the electric arc, now in progress in the Physical Laboratory, point unmistakably to the same conclusion.

Daylight.

The method pursued in the determination of the color of daylight, was in every respect similar to that employed in the study of the lime and arc-lights. The rays falling upon

* Schreihage (La Lumiere Electrique, xxix, p. 585), has shown that the result of diminishing the cross section of the carbons of an arc-lamp from 254^{dmm} to 40^{dmm} was to increase the mean spherical candle-power from 161 candles to 471 candles, with corresponding increase in the efficiency of the lamp.

the block of magnesium carbonate were admitted through a four inch aperture in the opaque shutter which otherwise completely closed the only window of the spectrometer room. This window had a southerly exposure and the light reaching the magnesium-carbonate was received almost exclusively from the sky. Of the considerable number of comparisons which we made on different days, only two are presented in Table IV. One of these was made between two and three P. M. on a cloudless day of the summer of 1888, the other on the day following, when the sky was completely overcast with very heavy, dark, low-hanging clouds. Our other measurements all gave values lying between these extremes and, since they show no peculiarities which are not better exhibited by the latter, they have been omitted from the table.

Comparisons of daylight with artificial sources of illumination have likewise been made by O. E. Meyer * and H. C. Vogel,† and similar comparisons of the direct rays of the sun by Crova,‡ Meyer, Pickering, § Vogel, G. Müller, ‖ F. Exner ¶ and others.

The results given in Table IV, where our own measurements are placed side by side with those of Vogel, reduced to the same scale, exhibit in the most striking manner the enormous richness of daylight, as compared with any form of artificial light, in the shorter wave-lengths. In the extreme violet, (λ=4440 and 4260), according to the measurements of Vogel, day light by unclouded sky is relatively fifty and one hundred times brighter than a petroleum flame. Scarcely less surprising is the difference in quality between the daylight of clear and cloudy weather. The absorption due to moisture in the latter case begins to be important in the neighborhood of the F line, from which point it increases rapidly in amount to the end of the visible spectrum. Our curve of intensities for clear weather (see figure 3, curve VI) shows traces of this same absorption in the violet.

All the European observers, with the exception of O. E. Meyer, whose measurements of the electric arc and of day light and sunlight are widely at variance with those to which reference has been made, agree in finding the absorption of the shorter wave-lengths even more marked in the direct rays of the sun than in daylight by clouded sky. Thus Vogel, whose measurements may be taken as typical, gives for sun light the following values, which have been reduced to the same scale as those presented in Table IV.

* O. E. Meyer, Carl's Zeitschrift für Angewandte Elektricitäts-lehre, I, p. 320, 1879. † H. C. Vogel, l. c. ‡ A. Crova, l. c.

§ W. H. Pickering, Photometric Researches, etc., p. 246.

‖ G. Müller, Astronomische Nachrichten, ciii, p. 241, 1882.

¶ F. Exner, Repertorium der Physik, xxii, p. 605, 1886.

TABLE IV.

Daylight by clear and by clouded sky, compared with the light of a 16-candle incandescent lamp.

Sky Cloudless.				Sky Overcast.			
Measurements of H. C. Vogel (Reduced).		Measurements of Nichols and Franklin.		Measurements of H. C. Vogel. (Reduced).		Measurements of Nichols and Franklin.	
Wave-lengths.	Daylight / Petroleum.	Wave-lengths.	Daylight / Standard.	Wave-lengths.	Daylight / Petroleum.	Wave-lengths.	Daylight / Standard.
6330	0·50	6685	0·32	----	----	7530	0·13
6000	0·79	6080	0·75	6330	0·52	6685	0·45
5890	1·00	5890	1·00	600	0·84	6080	0·90
5550	2·00	5570	1·69	5890	1·00	5890	1·00
5170	5·00	5185	4·19	5550	1·78	5570	1·50
4860	10·52	4920	7·33	5170	3·80	5185	2·79
4640	22·22	4685	16·79	4860	7·77	4920	4·59
----	----	4500	21·37	4640	13·74	4685	6·45
4440	50·00	----	----	----	----	4500	9 08
4260	100·00	----	----	4440	17·80	----	
				4260	19·84	----	

TABLE V.

Sunlight, compared with a petroleum flame (reduced from the measurements of H. C. Vogel).

Wave-lengths.	Sunlight. / Petroleum flame.
6330	0·57
6000	0·75
5890	1·00
5550	1·31
5170	2·53
4860	4·87
4640	7·30
4440	11·93
4260	13·16

The only American observer, Mr. W. H. Pickering, has, however, obtained values for the relative brightness of the sun's rays which agree very closely indeed with those for day-light by unclouded sky, as observed by Vogel and by ourselves. Thus Pickering finds for the violet

$$\lambda = 4550\,;\ \frac{\text{Sunlight}}{\text{Gaslight}} = 23{\cdot}77 \text{ (reduced).}$$

Our value for the same region (see table IV), is,

$$\lambda = 4500;\ \frac{\text{Daylight}}{\text{Standard}} = 21{\cdot}37$$

Vogel's result, in nearly the same portion of the spectrum is,

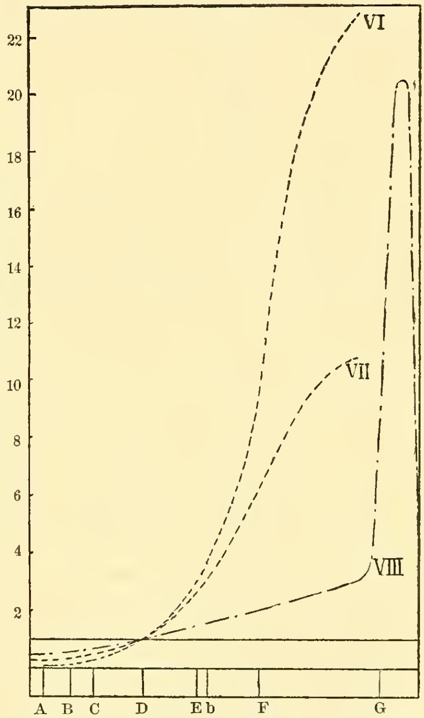
$$\lambda = 4640\,;\ \frac{\text{Daylight}}{\text{Petroleum flame}} = 22{\cdot}22 \text{ (reduced).}$$

These values have been brought to a common scale, as in all former comparisons, the region of the D line in both spectra being taken as unity.

It would not seem unreasonable to ascribe the difference in question, to the atmospheric conditions under which the observations were made.

The Incandescent Lamp.

3.



Curves of relative intensities in the spectrum of day-light. Curve VI is from measurement of day-light by unclouded sky, curve VII of day-light by heavily clouded sky. Curve VIII, introduced for comparison is same as curve III, figure 2, and represents the spectrum of the electric-arc. The horizontal line represents the spectrum of the standard incandescent lamp.

Our study of the incandescent lamp included the comparison of lamps of high and low resistance, heated to normal candle-power, and determinations of the color of the former in different stages of incandescence. The lamps in question were the Edison lamp which had been used as a standard throughout our investigation and a Bernstein lamp giving 16 candles at 20 volts.

The results, which are given in table VI (see also figure 4), show that the temperature of the lamp of low voltage was not so high as that of the Edison lamp at the same candle-power, and that the spectrum of the former was correspondingly of greater relative brightness in the red than in the violet.

Previous to the detailed study of the Edison lamp, the lamp was placed in the Bunsen photometer and the relation between electromotive force and candle-power determined for a range of brightness between 1 candle and 30 candles. It was then maintained successively at potentials corresponding to 4 candles, 10 candles, 16 candles, 22 candles and 28 candles, and its spectrum in each of those stages of incandescence was measured by the method already described.

TABLE VI.

Comparison of a Bernstein incandescent lamp at the same candle-power.

Wave-lengths.	Bernstein lamp. / Standard lamp.
7530	1·19
6680	1·08
6080	1·03
5570	0·97
5185	0·93
4920	0·91
4685	0·89
4500	0·87
4340	0·85

The results of these determinations are given in Table VII (see also figure 5). The brightness of the spectrum of the lamp at 16 candles is taken as unity throughout, and the intensity of the spectrum at other candle-powers is expressed in terms of the brightness of the corresponding region of the former.

TABLE VII.

An Edison lamp at various degrees of incandescence, compared with the same lamp at 16 candle-power.

Wave-lengths.	Intensity at 4 candles. / Intensity at 16 candles.	Intensity at 10 candles. / Intensity at 16 candles.	Intensity at 16 candles. / Intensity at 16 candles.	Intensity at 22 candles. / Intensity at 16 candles.	Intensity at 28 candles. / Intensity at 16 candles.
7530	0·34	0·71	1·00	1·18	1·56
6680	0·28	0·63	1·00	1·29	1·71
6080	0·23	0·58	1·00	1·34	1·80
5890			1·00		
5570	0·22	0·55	1·00	1·37	1·89
5185	0·19	0·53	1·00	1·38	1·97
4920	0·17	0·52	1·00	1·38	2·04
4685	0·16	0·51	1·00	1·39	2·12
4500	0·15	0·51	1·00	1·39	2·18
4340	0·14	0·51	1·00	1·39	2·24

This method of presentation enables us, by inspection of the table and curves, to see at a glance the changes which take place in the spectrum of the lamp as the candle-power is increased. With rising temperature the change is least in the extreme red, the rate of change increasing rapidly as we approach the violet end of the spectrum.

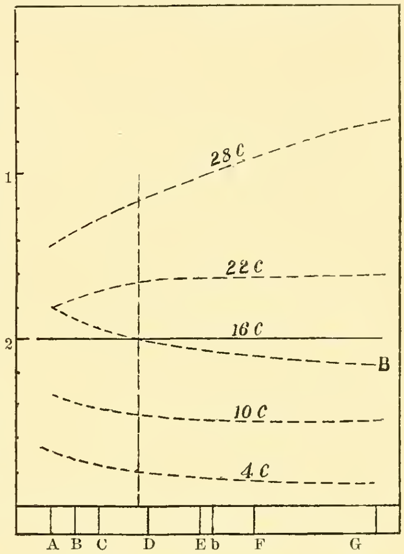
Thus the brightness of the spectrum in the neighborhood of the A line, when the lamp is raised from 4 candles to 28 candles, increases very nearly in the ratio 1:3·7; whereas the corresponding ratio for the neighborhood of the G line is approximately 1:22; intermediate regions giving values lying between these limits. In the yellow, (region represented by $\lambda = 6000$), this ratio has a value which is identical with that which expresses the change of candle-power.

In all regions toward the red from this particular wave-length, the brightness of the spectrum increases less rapidly, in all regions of shorter wave-length it increases more rapidly than the candle-power.

The position of this region, in which the brightness of the spectrum increases in direct proportion to the candle-power, is indicated in figure 4, by a vertical line.

It lies slightly toward the red from the position of maximum luminosity in the spectrum of the incandescent lamp, as determined for a lamp of the same type by Otto Schumann.*

4.



Curves of relative intensities in the spectrum of the incandescent lamp. Curves marked 4c, 10c, 16c, 22c, 28c, refer to the standard incandescent lamp at various temperatures. Curve B refers to a low voltage lamp at normal candle-power.

The location of this line is of especial interest because of the light it throws upon the results obtained with the Bunsen photometer when that instrument is applied to the comparison of sources of light differing in composition. The line in question does not divide the spectrum equally either in respect to the total energy of luminous radiation of the portions lying between it and the red on the one side and between it and the violet on the other, nor in respect to the total luminosity of those portions.

Suppose the case of four incandescent lamps, so constructed that when they give 16 candles each, their temperatures are respectively those of the Edison lamp upon which our measurements were made, when the latter gives 4, 10, 22 and 28 candles.

As measured in the Bunsen photometer these lamps would be found of equal candle-power, but they would differ greatly

* Otto Schumann, Elektrotechnische Zeitschrift, v, p. 220.

in color and the spectro-photometric examination of their spectra would give us a set of curves corresponding in character to those shown in figure 4. These spectra would be of the same brightness in the yellow ($\lambda=6000$), but at no other point within the limits of the visible spectrum. The lamps would differ in total energy of radiation, in the energy represented by their light-producing rays, and in total luminosity. With increasing incandescence the total energy of the regions lying beyond wave-length 6000, and also their luminosity, increase rapidly; and the corresponding decrease in regions between that wave-length and the red end of the spectrum is not sufficient to keep the energy and luminosity of the whole visible spectrum constant. It follows, therefore, that candle-power, as determined by means of the Bunsen photometer, affords us a correct measure neither of the light-giving energy nor of the luminosity of the source of light; the direction of the error always being such as to favor sources of a low degree of incandescence when compared with those of higher temperature.

The discrepancy between candle-power and luminosity, with increasing incandescence, is less marked than that between candle-power and energy of radiation, because luminosity depends very largely upon the less refrangible rays of the spectrum. Schumann's admirable study of the color and brightness of the incandescent lamp, to which reference has already been made, affords data for a comparison of candle-power and total luminosity of this source of light, luminosity being determined according to the method of Macé de Lepinay. Calculations based upon his measurements show that when the incandescence of a glow lamp is raised from 10 candles to 50 candles, its luminosity is increased in the ratio of 6 : 1 instead of 5 : 1. For light emanating from sources of higher temperature the discrepancy is still more marked. In the case of the electric-arc light, for example, the ratio of luminosity to candle-power is approximately 5 : 4 and in the case of day light it is probably commonly in excess of 6 : 4.

Every improvement, therefore in our methods of artificial lighting which makes it possible to raise the temperature of incandescence of the illuminant will be accompanied by a double gain. On the one hand a greater candle-power per unit of energy expended will be obtained, and on the other hand, the light-giving value per candle-power will be increased.

Every such step will render our present method of reference to the standard candle as a unit less satisfactory, and the time is probably not far distant when we shall have learned to measure the temperature of our illuminants and to express their light-giving value in terms of the temperature of the glowing material and the area of the illuminating surface.

ART. XIII.—*On the possibility of Hemihedrism in the Monoclinic Crystal System, with especial reference to the Hemihedrism of Pyroxene;* by GEORGE H. WILLIAMS.

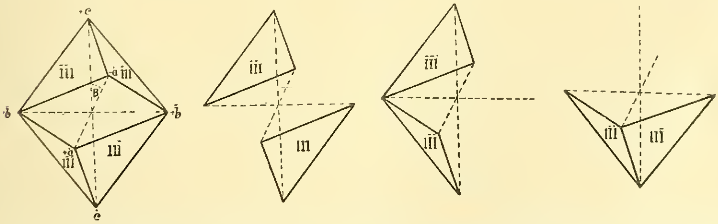
IN a recent "Note on some remarkable Crystals of Pyroxene from Orange Co., N. Y.,* I described an unusual monoclinic habit of this mineral which showed the planes of different forms grouped about opposite extremities of the vertical axis. These crystals were then called hemimorphic with reference to the vertical axis, although it was recognized that such an expression did not accord strictly with the accepted nomenclature, because in the monoclinic system the vertical axis is not an axis of symmetry.

During the past summer it was suggested to me by Professor Rosenbusch that these crystals might possibly be regarded as hemihedral rather than hemimorphic, and such upon more mature consideration appears to be the case. I therefore venture to refer once more to the Orange Co. crystals, both because their apparently anomalous form receives a new interest when viewed in this light, and also because they have been found, upon further investigation, to offer by no means an isolated instance of this peculiar development in pyroxene.

As they are at present used in crystallography, the terms *hemihedrism* and *hemimorphism* both express the independent occurrence of one-half of the planes belonging to a crystalline form. They differ, however, in the manner in which these planes are grouped; the former representing half the planes as occurring equally about both extremities of an axis of symmetry, while the latter implies the presence of all the planes of a form at one end of such an axis, and none of them at the other.

The most general holohedral form consistent with the symmetry of the monoclinic system is a hemipyramid ($\pm$P), composed of four planes, one in each of the four similar octants.

1. 2. 3. 4.



It is evidently possible to select one-half of these four planes in three and only three different ways:

* This Journal, III, xxxiv, pp. 275–276, Oct., 1887.

1. We may select two planes which are parallel ($\bar{1}\bar{1}1$) and ($11\bar{1}$); and, if the other pair of parallel planes, ($1\bar{1}\bar{1}$) and ($\bar{1}11$) disappear, there results a tetrapyramid composed of two planes, which is the most general form possible in the triclinic system (fig. 2). Such a form would be truly hemihedral because the planes are similarly grouped about each extremity of the axis of symmetry. A combination of such forms similarly developed would not, however, differ from a triclinic combination and this system may therefore be regarded as a kind of monoclinic hemihedrism. Orthoclase is sometimes quoted as an instance of this triclinic hemihedrism because its imperfect prismatic cleavage is often developed parallel to only one face of the prism. This was first noticed by Haüy and has been substantiated by many subsequent observers.

2. We may select the two planes which meet at an end of the axis of symmetry, $\bar{b}$, ($\bar{1}\bar{1}1$) and ($1\bar{1}\bar{1}$). If the corresponding pair, ($\bar{1}11$) and ($11\bar{1}$) should disappear (fig. 3) there would result, as Groth remarks,* not a hemihedral, but a hemimorphic form. By this method of selection those holohedral forms belonging to the orthodiagonal zone must remain unaltered, while all others, including the clinopinacoid, may occur with only half of their planes developed. The plane of symmetry here disappears as in the preceding case.

This case is illustrated by the crystals of several organic compounds, among which are tartaric acid ($C_4H_6O_6$),† cane sugar (sucrose, $C_{12}O_{22}H_{11}$)‡ and quercite (pentacid alcohol, $C_6H_{12}O_5$).§ These crystals have furthermore all been shown to be pyroelectric—a property which is especially characteristic of hemimorphic substances.

3. We may, as a last possibility, select two of the planes of the monoclinic hemipyramid which intersect in the plane of symmetry, ($1\bar{1}\bar{1}$) and ($11\bar{1}$). If the corresponding pair, ($\bar{1}\bar{1}1$) and ($\bar{1}11$), disappear (fig. 4) there results an apparent hemimorphism with reference to either or both of the axes in the plane of symmetry—vertical or clinodiagonal. The only holohedral form which cannot appear with only half its planes by this method of selection is the clinopinacoid. All others may be present with only half their planes, although of course both halves of a form may appear on the same crystal. If this be the case in the vertical zone there results apparent hemi-

* Physikalische Krystallographie, 2d Ed., p. 481. 1885.

† De la Provostaye, Ann. Ch. et Phys., III, vol. iii, p. 139. 1841.

‡ Wulff, Jour. für prakt. Chemie, vol. xxviii, p. 129, 1843. L. Wulff, in his recent article on the crystallization of cane-sugar (Zeitschr. für Kryst., vol xiv, pp. 552–562, 1888), finds that the face g, P$\breve{\infty}$ (011) generally occurs with only a single plane, which forces him to regard the substance as an instance of either monoclinic tetartohedrism or triclinic hemihedrism.

§ Lewis, Proc. Cryst. Soc., p. 51, 1882: cf. also Groth, Physikalische Krystallographie, 2d Ed., pp. 512 and 514.

morphism with reference to the vertical axis, as shown in figs. 5 to 8. It might, however, be the case that the forms of the clinodiagonal zone were fully developed, when the crystal would appear hemimorphic in the direction of the $\grave{a}$ axis.

This selection of the planes in reality satisfies all the conditions of hemihedrism since its planes are equally distributed about both extremities of the axis of symmetry. The hemihedrism is moreover inclined-faced, because its forms possess no center of symmetry;* or, in other words, their planes do not have others parallel to them. In this case alone of the three does the monoclinic plane of symmetry remain.

There is therefore possible in the monoclinic system:

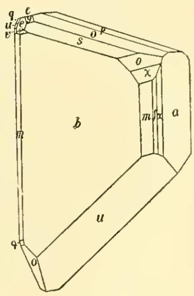
1. Parallel-faced hemihedrism. Triclinic system.
2. Hemimorphism.
3. Inclined-faced hemihedrism.

A similar suggestion has been offered by L. Wulff,† and in his recent paper on the crystallization of cane-sugar the same author has given figures very much like those here presented,‡ although I was not cognizant of his work until this article was ready for publication.

The theoretical possibility of such hemihedral and hemimorphic forms in the monoclinic system has, however, for mineralogists but little interest apart from their actual occurrence in nature. The first two are already well known and recognized; the third has heretofore lacked recognition on account of the want of examples, and it is the especial object of this paper to show that it is by no means uncommon on such an important mineral as pyroxene, while it may possibly occur on sphene.

The earliest recorded, as well as one of the most remarkable instances of this inclined-face hemihedrism in pyroxene which has come to my notice, is to be found in a perfectly developed crystal of diopside, probably from the Mussa Alp in Piedmont, figured and described by Hessenberg§ in 1856. His figure is here reproduced (fig. 5), drawn so as to show the clinopinacoid as the principal face. Here, as in all other cases, the prismatic zone is holohedral with the forms a, $\infty P\bar{\infty}$ (100); b, $\infty P\breve{\infty}$ (010); m, ∞P (110); f, $\infty P\breve{3}$ (130); and χ, $\infty P\breve{5}$ (150). The hemihedrism manifests itself as an apparent hemimorphism in the direction of the vertical axis, at one end of which are the forms p, $+P\bar{\infty}$ ($\bar{1}01$); θ, $+P\bar{3}$

5.



* For an explanation of this term, see Sohncke, Zeitschr. für Kryst., vol. xiv, p. 134, 1888.
† Ibid., vol. xiii, p. 499, 1888.
‡ Ibid., vol. xiv, p. 557, 1888. Pl. XI, figs. 3^a, 3^b and 3^c.
§ Mineralogische Notizen, No. 1. Pl. II, fig. 18.

($\bar{1}33$); *s*, $+P$ ($\bar{1}11$); *o*, $+2P$ ($\bar{2}21$); *λ*, $+3P$ ($\bar{3}31$); *y*, $+\frac{5}{3}P$ ($\bar{5}53$); *c*, $0P(001)$; *e*, $P\breve{\infty}$ (011); *z*, $2P\breve{\infty}$ (021); *σ*, $-\frac{1}{2}P$ ($\bar{1}12$); *u*, $-P(111)$; and *v*, $-2P$ (221). At the opposite extremity occur only the three forms *u*, *o*, and *λ*. The source of this remarkable crystal is not definitely given. It agrees in all respects with the well-known diopsides from Mussa Alp, except in the matter of attachment.

Inquiry has shown that inclined-faced hemihedrism is not altogether rare among the yellowish white pyroxene crystals from near Warwick, in Orange Co., N. Y. These are usually tabular, parallel to the base, and occur either singly or in groups, imbedded in crystalline limestone. A figure of one of these crystals given by DesCloizeaux,* shows above the forms *c*, *s*, *o*, *e* and *μ*, $-2\grave{P}2$ (211). At the lower end there are present *c*, *u* and *α*, $+\frac{3}{2}P\bar{3}$ ($31\bar{2}$).

6.

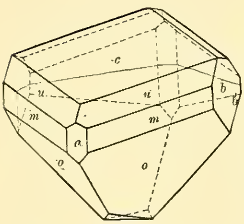
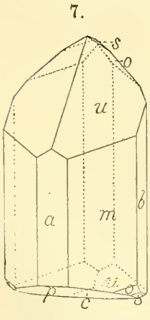


Fig. 6, taken from my above-mentioned "Note," shows a crystal with the usual combination above *c*, *s*, *o* and *u*, while below are the two halves of a crystal in twinning position showing only the two forms *o* and *p*. The crystal was carefully tested for pyro-electricity, but no trace of this property could be discovered even with a delicate Thomson electrometer.

For permission to use the following figure, 7, I am indebted to the U. S. Geological Survey, and also to Professor S. L. Penfield, of New Haven, by whom it was drawn. It represents a perfectly formed pyroxene crystal, 3½ inches in length, from Grassy Lake, near Rossie, St. Lawrence Co., N. Y., upon which the hemihedral distribution of planes is very apparent. At the upper end occur the planes *u*, very large, *s* and *o*. At the lower end are the forms *p*, *c*, *u*, small; *s* and *o*. In the prismatic zone are the pinacoids *a*, *b* and the prism *m*. This crystal was probably formed in calcite, as it is doubly terminated. It was collected by Professor Penfield during the summer of 1888, and is now deposited in the U. S. National Museum at Washington.

7.

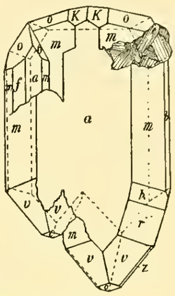


Prof. E. S. Dana has called my attention to the fact that certain of the tabular white pyroxene crystals occurring in the dolomite at Canaan, Conn., also show different forms at opposite extremities of the vertical axis. Indications of such a de-

* Manuel de Minéralogie, vol. i, p. 54. Atlas, fig. 58, 1862.

velopment are apparent on several of these crystals in the Johns Hopkins University mineral collection, but I am indebted to the kindness of Professor Dana for the opportunity of establishing it by an examination of a fine crystal from Canaan, belonging to the Yale University cabinet. This crystal, which is slightly over two inches in length, is represented in fig. 8. Its planes are for the most part broken or uneven from contact with the dolomite and the substance of the crystal is superficially changed to fibrous white hornblende (uralite), which renders measurement with a reflecting goniometer impossible. The size of the crystal, however, allowed of the satisfactory determination of most of the planes with a contact-goniometer. In this way the following forms were identified: prismatic zone: *a*, *f*, *m*, *b*. Upper extremity: *c*, large, *r*, $-\frac{5}{2}P$ (552); *o*, $K, +m\bar{P}n$ (?) Lower extremity: *c*, small; *h*, $-4P$ (441); *r*, *v*, *o*, *z*. The following approximate measurements of interfacial angles were obtained with a contact-goniometer, for comparison with which the corresponding values as calculated by von Kokscharow are also given:

8.



c : *r*	back above	126°	125° 26′		*c* : *o*	front above	114°	114° 40′
c : *r*	front below	125½°			*m* : *o*	back below	145½°	144° 36′
a : *r*	back above	133°	133° 24′		*c* : *v*	front below	129½°	130° 5′
a : *r*	front below	133° +			*h* : *m*	"	165° (*ca*)	163° 36′
c : *z*	"	132°	131° 24′		*f* : *m*	"	153½°	152° 52′

The positive hemi-orthopyramid, K, allowed of no definite determination as its planes were small and roughened by the projecting ends of little hornblende needles. It seems, however, to lie in the zone *o* : *o*, and may be the form, $+2P\bar{2}$ ($\bar{2}11$).

It is a striking feature of this crystal that a small portion of its upper half, represented on the left side of the figure, is of quite normal habit, being terminated only by the positive hemi-pyramid, *o*, as is the case below.

The paragenesis of the Canaan crystals is identical with those from Orange Co., N. Y., which are also superficially changed to tremolite. This is a point of some interest, since crystals from both localities show the same hemihedrism in spite of a wide difference in habit.

In a recent conversation with Professor C. W. Brögger, of Stockholm, I also learned that he had not infrequently observed a similar inclined-faced hemihedrism on aegirine crystals occurring in the nepheline rocks of southern Norway.

With such an amount of evidence there can therefore be little doubt that pyroxene illustrates a hemihedrism in the monoclinic system, producing an apparent hemimorphism in the direction of the vertical axis.

Hessenberg's well-known figures of sphene crystals from Rothenkopf in the Zillerthal, Tyrol, exhibit a similar hemihedral development which he at first interpreted as hemimorphism in the direction of the clinodiagonal.* Von Zepharovich, however, subsequently showed that some of these forms could be explained as twins,† and Hessenberg also expressed himself as convinced that even the simplest of these crystals were in reality contact-twins of the ordinary kind where one of the individuals was reduced to an almost invisibly thin lamella.‡

One of Hessenberg's figures is given on p. 385 of Dana's System of Mineralogy (f. 372). I have been permitted through the kindness of Mr. C. S. Bement, of Philadelphia, to examine his fine suite of sphene crystals from the Rothenkopf, which includes the finest crystal ever found there, figured in the Neues Jahrbuch für Min., etc., 1874, p. 828. These all appear to be contact-twins, and it is probable that Hessenberg's second explanation of their apparent hemimorphism or hemihedrism is the correct one. Nevertheless their peculiar habit is of interest in connection with the hemihedral development of pyroxene.

Petrographical Laboratory, Johns Hopkins University,
Baltimore, March, 1889.

Art. XIV.—*On the Earlier Cretaceous Rocks of the Northwestern portion of the Dominion of Canada;* by George M. Dawson, Assistant Director Geological Survey of Canada.

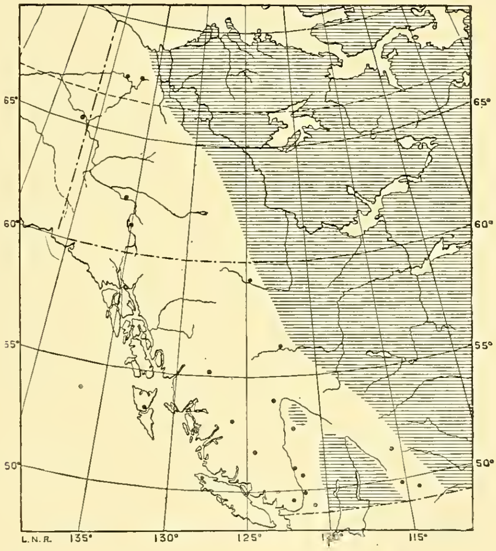
In the Report of Progress of the Geological Survey of Canada for 1872–73, the late Mr. James Richardson first described an important series of rocks occurring in the Queen Charlotte Islands, which Mr. E. Billings, on paleontological grounds, in an Appendix to the same report, characterized as probably lowest Cretaceous or Upper Jurassic. A further and

* Mineralogische Notizen, No. 6, p. 19, Pl. II, figs. 26–34, 1864. Neues Jahrbuch für Min., etc., 1874, p. 828. If the position of Dana be taken instead of that adopted by Rose and Naumann, as Hessenberg himself allowed to be more rational, these crystals become apparently hemimorphic in the direction of the vertical axis, like pyroxene.

† Sitzungsber. Ak. Wiss. Wien., vol. lx, p. 815, 1869.

‡ Mineralogische Notizen, No. 11, p. 19, Pl. II, figs. 16–18, 1873.

more detailed examination of these rocks, was subsequently made by the writer, of which the results were given in the Report of Progress for 1878–79; and in 1884, Mr. J. F. Whiteaves published a full account of the fossils collected, and reached the conclusion that the series (which is a very thick one) extended from about the horizon of the Gault upward to approximately that of the Lower Chalk.* The name "Queen Charlotte Islands Group" was proposed for the most fossiliferous member of the section (C), and it was further found that no distinct paleontological line could be drawn between this and two underlying members of the section, D and E.† These three lowest subdivisions of the Cretaceous section of the Queen Charlotte Islands, are here therefore referred to collectively, for purposes of description, as the Queen Charlotte Islands formation.



In reporting upon that portion of the Rocky Mountain range proper, which is included between the parallels of latitude of 49° and 51° 30′, the writer described the occurrence there of a very massive earlier Cretaceous formation, holding coals, and characterized by a peculiar flora,‡ which was examined and described by Sir J. Wm. Dawson. These Cretaceous rocks it was proposed to name the Kootanie series or formation.§

* Mesozoic Fossils, vol. i, part 3. † Trans. Royal Soc. Can., vol. i, sec. 4, p. 85.

‡ Annual Report, Geol. Surv. Can., 1885.

§ By Sir J. Wm. Dawson at the annual meeting of the Royal Soc. Can., May, 1885. Science, vol. v, p. 531. Trans. Royal Soc. Can., vol. iii.

The purpose of the present note is to call attention to certain facts recently developed respecting the equivalency of the Queen Charlotte Islands and Kootanie formations and to the importance of the earlier Cretaceous rocks of which they are representatives, over great areas of the western and extreme northwestern portion of the continent. These facts possess particular interest at the present time from their analogy to those lately developed by Mr. R. T. Hill respecting a similar earlier Cretaceous formation in the southwestern region of the United States.*

The region in which the Kootanie was first recognized as a distinct lower portion of the Cretaceous, embracing that portion of the Rocky Mountains above defined, with the adjacent foot-hills, has a length of about 140 miles with a width of forty miles or more. The Kootanie formation here constitutes a great part of the area of the several Cretaceous troughs or infolds and comes to the surface as well in several or many places in the foot-hills to the east. The Cretaceous rocks of this part of the mountains are known to extend upward from the Kootanie so far as to include the base of the Laramie. The thickness of the upper members of the series has not been ascertained, but that of the Benton (possibly including part of the Niobrara) is about 1400 feet, while the maximum known thickness of the lower part of the series, referable to the Dakota and Kootanie, is about 11,950 feet. Of this thickness, over 7000 feet is shown by its fossils to belong to the Kootanie, while the line between this formation and the Dakota remains to be drawn in a series of beds above, from which no fully distinctive fossils have been collected.†

In the report for 1885, above cited, it is stated that one of the characteristic fossil plants of the Kootanie had previously been found in northern British Columbia, at a distance of 580 miles to the northwestward of the part of the Rocky Mountains there under description. The flora of the Kootanie was characterized as Lowest Cretaceous and placed on approximately the same horizon with that of the Queen Charlotte Islands formation (more particularly of subdivision C., of that section) by Sir J. Wm. Dawson.‡

Up to this time no recognizable fossils other than plants had been obtained from the Kootanie, but marine mollusks have since been discovered by Mr. R. G. McConnell in beds which are (at least locally) at the very base of the formation and which underlie the principal plant-bearing beds by at least several hundred feet. These are referred to in Mr. McCon-

* See this Journal, vol. xxxiii, p. 291; vol. xxxiv, p. 287; vol. xxxvii, p. 282.

† Though fossil plants apparently referable to the Dakota have been found in the higher beds, in two places.

‡ Trans. Royal Soc. Can., vol. iii, sec. 4, p. 20.

nell's report,* and the identity stated, on the authority of Mr. Whiteaves, of three forms with species of the Queen Charlotte Islands formation. Mr. Whiteaves' subsequent detailed study of these fossils fully confirms and further carries out the correspondence between the two faunas, as explained by him in a report now in process of publication.† Thus the very important fact is established of the existence of an identical earlier Cretaceous horizon on the West Coast, and in, and even to the east of, the eastern range of the Cordillera System.

Turning now to the portion of the Cordillera region which intervenes between the above-mentioned widely separated localities, including that part of British Columbia to the south of the 56th parallel of latitude, we find there further evidence of the same great earlier Cretaceous formation.—The Iltasyouco beds (probably 10,000 feet in thickness) holding a fauna which was originally regarded as Jurassic, are now definitely referred to the Queen Charlotte Islands formation.‡ Further, the association of *Aucella Mosquensis*, var. *concentrica*, with the fossils of the last-mentioned formation in its typical locality, with the recent discovery by the writer of the same form, in great abundance, in beds of identical age in the northern part of Vancouver Island, leads Mr. Whiteaves to the belief that this species may be regarded as a characteristic one of the same general horizon.§ This view of the taxonomic value of the *Aucella* involves the conclusion that certain rocks in which it is the only abundant fossil, and for which provisional local names have been used in different parts of British Columbia, should likewise be regarded as representing inland extensions of the Queen Charlotte Islands formation, a conclusion in complete harmony with the stratigraphical and lithological evidence. The rocks referred to include the Tatlayoco Lake beds (7000 feet), Jackass Mountain beds (5000) and Skagit River beds (4400 or more) to which may be added (though as yet on little evidence other than lithological) the Nechacco series and the Cretaceous rocks known to hold coal on the upper part of the Skeena River.‖ To the south, in the vicinity of the West Coast, this earlier Cretaceous formation is doubtless represented by certain members at least of the Shasta group of California and Oregon.

In connection with the Yukon Expedition, in 1887 and 1888, important new observations bearing on the extent of the earlier

* Annual Report, Geol. Surv. Can., 1886, p. 17 D.

† Forming, part 2, Contributions to Can. Paleontology.

‡ Mesozoic Fossils, vol. i, p. 258.

§ A conclusion explained at length in the forthcoming publication by Mr. Whiteaves already referred to.

‖ These rocks may be found described in the reports of the Geological Survey of Canada as follows: 1875–76, p. 253, 1876–77, p. 90, 1877–78, p. 105 B., 1879–80, p. 102 B.

Cretaceous rocks have been made. At Rink Rapid, on the Lewes River (lat. 62° 20′ long. 136° 10′) and at Lake Labarge, further up on the same river, the writer found fossiliferous Cretaceous rocks which Mr. Whiteaves regards as probably also the same in age as those of the Queen Charlotte Islands formation.* Mr. McConnell has, further, discovered fossils belonging to the same fauna on Rat River (Rocky Mountains, lat. 67° 10′), on Porcupine River (lat. 67° 28′ long. 137° 47′) and on the main Pelly or Yukon River (lat. 65° 15′, long. 141° 40′). The characteristic *Aucella* above referred to is, however, the only species represented in two of these localities.

The various widely scattered observations above enumerated, now enable us to state, that a great earlier Cretaceous formation, beneath the horizon of the Dakota, is more or less continuously developed over a vast tract of country, the eastern edge of which lies to the east of the present line of the Rocky Mountains from the 49th parallel to the Arctic Ocean, and which is represented to the west as far as the vicinity of the mouth of Fraser River, the Queen Charlotte Islands, and in the Yukon Valley beyond the 141st meridian, in the interior of Alaska. Its existence may also be traced on the Alaskan Coast to the peninsula of Aliaska, in longitude 160° 31′ or farther.† It is impossible at present to define precisely the eastern margin of this formation, as in the area of the Great Plains sections are very seldom cut down to the base of the Cretaceous. From what is known, however, it appears probable that this line lies not far to the east of that of the Rocky Mountains, leading to the inference that some causal connection of an orogenic kind may exist between the eastern limit of these very massive Cretaceous accumulations and the position of this eastern member of the Cordillera. There is, however, in the southern interior of British Columbia, an extensive tract which includes the Selkirks and associated ranges, in which no Cretaceous rocks have been met with, and which it would appear, on this and other grounds, has been a land area throughout the Cretaceous period and a mountain system antedating those of the Rocky Mountains proper, the Coast Ranges of British Columbia and the Cascades of Oregon and Washington, in the flexures of which ranges Cretaceous rocks are involved. It is further probable that other yet undefined insular areas existed in the Cordillera region to the north and west, but the evidence now available shows, that to the north of the 54th parallel, in both the Triassic (" Alpine Trias ") and Cretaceous periods, the Pacific spread eastward in a more or less

* Annual Report, Geol. Surv. Can., 1887, pp. 146 B., 159 B.

† By collections made by Mr. W. H. Dall and others as detailed by Dr. C. A. White in Bulletin U. S. Geol. Survey, No. 4, 1884.

connected manner completely across the present position of the Cordillera belt.*

In the Queen Charlotte Islands, massive conglomerates immediately overlie that part of the section which has been referred to as the Queen Charlotte Islands formation. These, it has been suggested by Mr. Whiteaves, represent the horizon of the Dakota, and this reference is there strengthened by the fact that the conglomerates (2000 feet in thickness) are in turn overlain by shales holding *Inoceramus problematicus*. This occurrence of conglomerates appears, however, to have more than a local significance, for similar conglomerates are now known to occur in the same (overlying) position relatively to the earlier Cretaceous fauna in the northern part of Vancouver's Island, on the Lewes River, in the upper part or at the summit of the Tatlayoco, Jackass Mountain and Skagit series previously referred to, and are again found to overlie the Kootanie formation in the Rocky Mountains, forming there a portion of the thickness of beds between the Kootanie and Benton and consequently in all probability referable to the Dakota.

The constant or very frequent appearance of such massive conglomerates at or about the Dakota horizon, may fairly be taken to represent the initiation of an important and general subsidence, which seems to correspond as closely as possible with that referred to by Mr. Hill as the second great Cretaceous depression. It must be added, however, that in the northwestern portion of the continent, this second subsidence was not so profound as that described in the Arkansas–Texas region, and was interrupted, in the area of the plains, by at least one well-marked brackish-water and land epoch, represented by the Belly River and Dunvegan series of rocks.

The earlier Cretaceous rocks, here more particularly referred to, and named in widely separated portions of their extent the Kootanie and Queen Charlotte Islands formations, are again clearly analogous to Mr. Hill's Comanche formation, with which they have the same upward limit, and like it extend downward far beneath the base of the Cretaceous of the Interior Continental Plateau. In comparing the earlier Cretaceous rocks of these two portions of the continent, however, we find that though a distinct unconformity exists between the summit of the Comanche and base of the Dakota of the southwestern region of the United States, no such physical break is yet known as between the Kootanie or Queen Charlotte Islands formations and the Dakota; while the very great thickness of these formations, so far as it goes, may be regarded as tending

* Cf. on Triassic, Trans. Royal Soc. Can., vol. i, sec. 4, p. 144. Annual Report Geol. Surv. Can. 1885, p. 161 B.

rather to favor a belief in continuous sedimentation. Further, that while the base of the Comanche is described as equivalent to the Purbeck and Wealden, or lowest beds of the European Cretaceous, Mr. Whiteaves finds no evidence in the mollusks of even the lowest beds of the Kootanie and Queen Charlotte Islands formations of a horizon below that represented by the Gault in Europe. This can scarcely be regarded as divergent from the previous definition of the age of the same formations by their contained fossil plants, as the lower Cretaceous flora may be expected, from European and Asiatic analogies, to extend upward to the top of the Neocomian, between which and the Cenomanian the Gault may be said to be a transitional formation. The question, however, of the precise systematic position of these representatives of the earlier Cretaceous of the northwestern province of the continent, is one apart from that of their interrelation and general correspondence, which alone it is at present intended to point out. Finally, it may be noted, that while these formations mark the occurrence of a first Cretaceous subsidence in the northwestern portion of the continent, this subsidence has there been neither so great nor so continuous as in the case of the Comanche, a fact shown by the generally coarse, clastic character of the rocks, the comparative absence of limestones and the occurrence of beds of coal.

In this note it has been possible merely to outline the more interesting general results so far arrived at with respect to that part of the Cretaceous which underlies the Dakota horizon in British Columbia and in the western portion of the Northwest Territory. For details, some of which have important bearings on the general question, reference must be made to the various publications which have been cited and to forthcoming reports of the Geological Survey of Canada in which the facts more recently obtained will appear at length. The subjoined table presents in a diagramatic form the relations of the various formations above referred to, together with that of some overlying portions of the Cretaceous, not here specially alluded to, but which occur in the same region.

Geological Survey of Canada, April 20, 1889.

EXPLANATION OF MAP, p. 121.

The principal known localities of occurrence of the Earlier Cretaceous rocks, are indicated by the black dots. Nearly all of these represent places from which characteristic fossils have been obtained.

The eastern extension of the Pacific Ocean in the earlier part of the Cretaceous period is approximately shown by that of the unshaded part of the map.

TABLE ILLUSTRATING THE RELATIONS OF THE EARLIER CRETACEOUS FORMATIONS OF BRITISH COLUMBIA AND OF ADJACENT PARTS OF THE NORTHWEST TERRITORY.

Queen Charlotte Islands.	Comox, Vancouver Island.	Mainland of British Columbia.	Yukon District. (North of 60th parallel.)	Rocky Mountains Proper. (Between 49° and 51° 30′.)	Southern Alberta.
	Upper conglomerates, 320′ Upper shales, 776′ Mid. conglomerates, 1,100′ Middle shales, 76′ Lower conglomerates, 900′ Lower shales, 1,000′		Laramie of Lewes R.	Laramie (base).	Laramie, 5,750′
A. Upper shales and sandstones, 1,500′	Productive coal meas., 739′ (*Local base of Cretaceous.*)		(Intermediate formations probably represented, but not recognized.)	Pierre (including Fox Hill). Belly River. Benton (possibly with part of Niobrara, 1,400′).	Pierre (incl. Fox Hill), 830′ Belly River, 910′ Lower dark shales, 800′
B. Coarse conglomerates, 2,000′		Tatlayoco beds (7,000′), Nechacco beds (6,000′), Skeena beds, Skagit beds (4,400′ or more), Jackass Mt. beds (5,000′). All sandstones and quartzites, with shales, and generally coarse conglomerates ab've. "Porphyrite" series of Iltasyouco 10,000′ (probably passing up into above) of Tatlayoco, and possibly of Nechacco and Skeena.	Conglomerates of Rink Rapid, etc.	Dakota, apparently represented in part by coarse conglomerates, and including on Crow Nest Pass, 2,200′, of volcanic ejectamenta.	Dakota (probably). (*Local base of Cretaceous.*)
C. Lower shales and sandstones (with coal), 5,000′			Fossiliferous shales and sandstones, on Rink Rapid, L. Labarge, etc.	Kootanie formation, 7,000′ or more. Sandstones, shales, etc., with coal.	
D. Agglomerates, 3,500′					
E. Lower sandstones, 1,000′					
(*Local base of Cretaceous.*)		(*Local base of Cretaceous.*)	(*Local base of Cretaceous.*)	(*Local base of Cretaceous.*)	

Art. XV.—*A New Occurrence of Gyrolite;* by F. W. Clarke.

In the autumn of 1888, during a visit to the New Almaden Quicksilver Mine in California, Dr. D. T. Day of the United States Geological Survey was shown specimens of a mineral which was locally supposed to be white fluor spar. It occurred in well developed crystals lining crevice veins in the mine, and was easily recognizable as apophyllite. Dr. Day secured a good series of the specimens, and finally turned them over to me for examination. The largest crystals were about two centimeters in diameter, and fairly transparent, and grew out of crystalline masses of considerable thickness; the exposed definite faces nearly meeting at the center of the seam or vein. All of the specimens were saturated with bituminous matter, but except for that staining they were quite colorless.

In several of the specimens received the wall of the seam was distinctly shown, and between it and the crystalline apophyllite there was a fibrous layer from one to three centimeters in thickness. That layer was also colorless, except for bituminous staining, and on account of its relations to the apophyllite it appeared to deserve investigation. A sufficient quantity of the material having been selected, it was digested for about twenty-four hours with ether in order to cleanse it from bitumen, and then analyzed. I give the result in comparison with How's figures for a Nova Scotia gyrolite.

	Clarke.	How.
H_2O	14·60	15·05
SiO_2	52·54	51·90
Al_2O_3	0·71	1·27
Fe_2O_3		----
CaO	29·97	29·95
MgO	----	0·08
K_2O	1·56	1·60
Na_2O	0·27	----
F	0·65	----
	100·30	99·85
Less O	0·27	
	100·03	

It will at once be seen that the two analyses, except for the small amount of fluorine, coincide quite sharply, and establish the New Almaden mineral as gyrolite. The Nova Scotian gyrolite is also associated with apophyllite, from which species How supposed it to be derived.* In the present instance, however, the relative position of the two minerals in the vein suggests that the gyrolite is the older; and that the

* See this Journal, II, xxxii, 13.

apophyllite may have been formed from it by a partial solution and redeposition of its material through the agency of waters containing alkaline fluorides. The gyrolite is obviously not absolutely pure, but it agrees approximately with the formula $Ca_2Si_3O_8 . 3H_2O$. Its chemical structure and relations to apophyllite are not altogether clear.

Washington, May 24, 1889.

Art. XVI.—*On Action of Light on Allotropic Silver*; by M. Carey Lea.

Since my last communication to this Journal I have obtained the following results:

1. It was mentioned in that paper that the red gold-colored modification of silver was converted into a bright yellow-colored form by the action of light. Continued exposure seems to produce little further change so long as the substance is dry. But if the paper on which the silver is extended, is kept moist by a wet pad, with three or four days of good sunshine the change goes on until the silver becomes perfectly white, is apparently changed to normal silver:*—water, alone, tends to darken this form of allotropic silver, accordingly the portion of the paper that was protected for comparison, darkened, showing that the whitening effect was due wholly to light.

It thus appears that light can convert yellow or red-yellow allotropic silver to white.

2. Some pieces of very bright blue-green modification were exposed to light and with about one day's bright sunshine, they passed to a pure bright metallic gold-color.

It appears therefore that light can cause the blue-green modification to pass to the gold-yellow.

This change only occurs with a very brilliant form of the bluish-green substance which is obtained with a quick short washing. Specimens slowly and very thoroughly washed which when brushed over paper gave a more mat color, did not yield this result but became brownish, as described in the July number of this Journal. Nor can this result be obtained with the soluble form of allotropic silver described in the June number of this Journal.

Light therefore can change the bluish green to the yellow modification, and this last (with the aid of moisture) to white normal silver. The silver thus obtained is pure white, lustrous and metallic, resembling silver leaf. Organic compounds of silver reduced by light give gray or black silver devoid of luster.

* The pad used was of unbleached muslin which was boiled several times with distilled water to remove everything soluble before use.

Art. XVII.—*On Certain Porphyrite Bosses in Northwestern New Jersey;* by J. F. Kemp.

Across the northwestern portion of New Jersey the Hudson River shales extend in a broad band some six miles or more in width.* The general trend of the outcrop is northeast. To the northwest they run under the Oneida conglomerate forming Kittatinny range, and on the southeast are themselves underlaid by limestone of earlier age. West of Deckertown the shales have been the scene of extensive eruptive phenomena. Between them and the Oneida conglomerate the great elæolite-syenite dike† described by Professor B. K. Emerson‡ comes out, causing extensive contact metamorphism, and a mile or less east of this dike and wholly in the slates are to be seen the curious bosses or hillocks of eruptive rock referred to in the New Jersey Report for 1882, p. 67. Also, some ten miles southeast, at Franklin Furnace, we find the bed of franklinite intersected by the several dikes of mica-diabase described by Professor Emerson,§ and other evidences of eruptive rocks were found by Dr. N. L. Britton northwest of Franklin Furnace.‖ From these citations it will be seen that records of eruptive action are numerous in this district over an area ten miles or more in diameter.

Having been engaged in studying a collection of massive rocks for the N. J. Survey in 1886, the writer felt interested, now that the survey has lapsed, in pursuing the subject further, and was so fortunate, while doing the field work, as to have the aid of Mr. William S. Vanderhuff of Deckertown, whose thorough knowledge of the district it would require long residence to equal.

The accompanying map illustrates the region and has been imperfectly reproduced from Sheet No. 1, of the State Survey maps and afterward partly filled in with right line work to show the portion formed by the Oneida Conglomerate. The shales strike generally northeast where a strike can be observed, but as the eruptive rocks are neared it is difficult to satisfy oneself as to their bedding, for it has been largely destroyed by the baking influences to which the shales have been subjected.

There are in all some eight exposures. These are distributed in an irregular north and south direction as indicated by heavy lining on the map. The largest is in B2, the other seven in A5, B5 and B6. The great dike of Professor Emerson runs

* Cf. Geol. of N. J., Map, 1881.

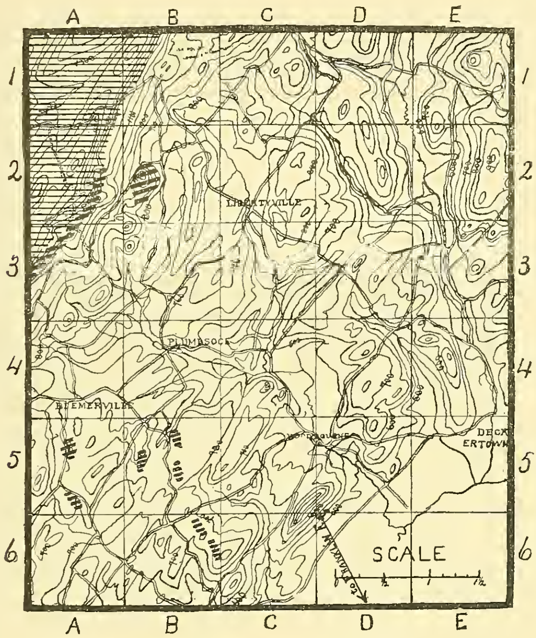
† Geol. Surv. of N. J., p. 144, 1868.

‡ This Journal, III, xxiii, p. 302.

§ Ibid., p. 376.

‖ Geol. Surv. of N. J., p. 110, 1886.

from A2 to A3. The exposure in B2 is a large hill which, in the words of the 1882 Report, p. 67, "rises very abruptly (33°) from the meadow to a height of 150 feet." This is the one on the farm of Mr. Rutan. Its outline viewed from the east is reproduced from a photograph in the figure below the map. The upper exposure in A5 is the one on the VanAuken farm and consists of "two low hills." The lower exposure in A5 is a low hill on the Howell farm. The westerly exposure in B5



is on the Stiver farm and consists of "two other but abrupt hillocks." The other four are not especially referred to in the report, but consist likewise of low hillocks or mounds. There are other spots which have clearly been subjected to the action of heat, but where no eruptive outcrop comes to the surface. The natural outcrops are not good and it is difficult to obtain specimens in which alteration is not far advanced, except where former prospect holes have been vainly sunk in the search for the precious metals. The pyrites disseminations in the contact shales have encouraged some such excavations.

What appears to be the original rock is generally a very finely crystalline ground-mass in which are developed numerous porphyritic crystals of biotite. Its composition is shown by analysis I in the following table. The crystals are often very thickly distributed through the mass and again are comparatively few. They run from microscopic dimensions up to two inches in diameter. The biotite is deep brown, almost black in color and well-nigh uniaxial, affording in convergent light an image, hardly, if at all, to be distinguished from a single cross and rings. As is to be expected it is optically negative. In the rock the mica is sometimes idiomorphic and sometimes in irregular masses. It frequently exhibits beautiful illustrations of crumpled and strained crystals and was evidently formed before solidification had set in. It alters concentrically from the edges.

Augite is especially abundant in the northern exposure, but less frequent in the others. It is greenish in tint, and exhibits well developed idiomorphic crystals bounded by the prism and pinacoids. In upper A5, it occurs altered in such a way as to resemble most closely serpentinized olivine crystals and on casual observation one would regard them as such. But by searching out the small unaltered fragments and testing the extinction angle they are seen to be augite. No hornblende whatever was found. Plagioclase seldom occurs in large crystals, but in the ground-mass is found by high powers to be present in quantity. In the available specimens it is generally in an advanced state of alteration and affords a light yellow, feebly refracting alteration product. Together with small masses of biotite, apatite needles and magnetite, it forms the ground-mass. The absence or very small amount of soda found in the analyses (see below), would indicate a plagioclase close to anorthite. Apatite is everywhere extremely abundant in well defined hexagonal crystals, often of unusual size. It constitutes one of the most remarkable features of the rock. Magnetite is abundant, without however showing indications of titanium. Pyrite is not infrequent. The ground-mass is an extremely finely crystalline base, composed of innumerable doubly refracting elements which are chiefly plagioclase, biotite and less abundantly augite. Two generative periods are thus clearly shown for the last two. In the majority of cases alteration is much advanced, yielding calcite in great quantity, so that the rocks often readily effervesce. In middle B5, titanite crystals are numerous but small.

An analysis of the biotite gave the results in column I; an analysis of the rock from B2, those in column II; another of the rock from upper A5, the results in column III.

	I.	II.	III.
SiO_2	34·61	40·47	31·8
Al_2O_3	15·74	11·86	18·78
Fe_2O_3	8·52	17·44	15·20
CaO	tr.	16·8	14·6
MgO	20·03	3·1	3·32
K_2O	17·14	4·21	5·074
Na_2O	tr.	1·90	1·10
P_2O_5			0·95
Loss on ignition	2·8	3·6	8·1
	98·84	99·38	98·924

The sulphur was not determined; a little is probably present from the pyrite. Spec. grav. of II, 3·102, of III, 2·939. No. III effervesced, No. II did not; alteration therefore lowers the spec. gravity.

Many surface fragments contain scattered through them in the greatest abundance pieces of shale which have become involved in the eruptive mass in its passage to the surface. Many fragments are little else than a kind of breccia of shale held together by a cement of porphyrite. They resemble nothing so closely as the fragments of rubbish that float about and adhere together on any standing liquid. The shale fragments have perfectly sharp edges and show no tendency to shade by contact fusion into the porphyrite.

Professor Emerson, in the paper on the elæolite-syenite dike referred to above, describes a large bowlder in the rear of Mr. Roloson's house near the syenite dike (this would be in the lower right-hand corner of A2), which is doubtless a stray piece of the B2 outcrop. The brief description given describes fairly well the latter, and some of the original sections which were studied by Professor Emerson have been kindly loaned the writer. They do not differ essentially from those of the rock in place, but the "square and hexagonal sections" which occur so abundantly in the rock in place have been determined by their high refractive power, by the absence of gelatinization such as would be indicated by successful staining which failed in repeated trials, and by the quite notable percentage of P_2O_5 in the second analysis above, to be apatite instead of nepheline. Its abundance, however, is, as stated above, one of the most remarkable features of the rock.

These masses have been described as bosses or knobs rather than dikes under which name the New Jersey report designates them because the large hill in B2 is nearly as broad as long and the other exposures resemble low knobs or blisters. It is possible that the mass of these hills under the soil may be baked shale with a backbone of eruptive rock in the form of a dike, but the peculiar color of the soil, and the irregular outline suggesting at once eruptive rock, and the general distribution of surface fragments, have led to the adoption of the different view. It seems probable that they have been occasioned by the same eruptive action which caused the syenite dike to the west, notwithstanding their great basicity and totally different character. The syenite dike itself varies much in character throughout its extent and still merits further study on its north and south extremities. Connecting these phenomena with the dikes at the southeast and south it seems as if there has been a longitudinal manifestation of eruptive activity in an irregular north and south line and that it occurred after the close of the lower Silurian Period.

These rocks are to be classed with the porphyrites according to the types systematized by Rosenbusch* and would perhaps be made most clear in their relations under the name biotite-augite-porphyrite. They appear to be in many respects very similar to those summarized by Rosenbusch (op. cit., p. 471) and described by Beyschlag, Schmid and others from various parts of Thuringia. With these they seem to agree quite closely in mineral composition, structure and alteration products.

Geological Laboratory, Cornell University.

ART. XVIII.—*On the great lava flows and intrusive trap sheets of the Newark† system in New Jersey;* by NELSON H. DARTON, U. S. Geological Survey.

SEVERAL years ago the writer commenced a systematic study of the Newark system in the New Jersey region, and several seasons were spent in an endeavor to determine the structure, and the relations of the igneous rocks. The results of these studies will be published during the latter part of this year as a bulletin of the U. S. Geological Survey, and it is the purpose of this paper to give only some general statements in regard to the nature of the more prominent trap masses.

The larger masses of igneous rocks in the Newark system in New Jersey constitute thick sheets enclosed in gently inclined soft sediments and their outcropping edges rise abruptly from the surrounding plains as long, narrow ridges generally bared of overlying strata on their gentler inner slopes, and presenting escarpments or steep slopes toward the underlying beds.

* Mikros. Physiog. Mass. Gest., Band II, pp. 446 and ff.

† This name, originally used by Redfield for the red sandstone of New Jersey has recently been revived by Russell (Am. Geologist, vol. iii, p. 178) and applied to the Jura-Trias of the entire Atlantic slope.

The long, level-crested ridge extending with palisadal front along the Hudson River northward from New York for thirty miles is a well known member of the series, and the Watchung or Orange Mountains some miles westward are other conspicuous instances. Sourland Mountain crossing the Delaware just below Lambertsville, Cushetunk Mountain east of Clinton and the line of ridges extending from south of New Brunswick to the Delaware and beyond, embrace the other large masses.

The earlier writers, from Pierce in 1819 to Rogers in 1836, expressed opinions in regard to the origin and nature of the trap masses, but they were so vague and contradictory that their significance is hardly noteworthy.

Rogers was the first to definitely recognize the evidence of intrusion and he considered all the trap masses subsequent in date to the enclosing sediments.

In 1846 Emmons described the palisade trap near the New Jersey-New York line and presented evidence indicating its intrusive nature and sheet-like structure.

Cook, in the Geology of New Jersey, 1868, described all the larger trap masses as intruded sheets, and as evidence of the intrusive nature of the Watchung Mountain outcrops, refers to the occurrence of indurated shales and limestones on the back of the mountain, northwest of Plainfield (at Feltville) and to their analogy in general relations to the Palisade and other intrusive traps.

Russell, in 1878, described in some detail the occurrence of what were supposed to be intensely altered shales and limestone on the inner side of the first Watchung Mountain at Feltville, and added great weight to the prevailing view that the Watchung and all the other trap masses were intrusive.

In 1882, Davis visited several typical localities in the New Jersey area for the purpose of determining the nature of the traps, and while he agreed with previous observers, Emmons, Cook, Credner, and Russell, in regard to the intrusive nature of the palisade trap, he stated his conviction that the Watchung traps were extrusive and similar in relations to some of the extrusive sheets which he had studied in the Connecticut valley. He found the base of the second Watchung trap resting on apparent tuff deposits at Little Falls and the conformable base and the amygdular and ropy-surfaced rock of the first Watchung trap exposed near Paterson. At the Feltville locality he found no traces of the alteration described by Rogers, Cook, and Russell, but on the contrary, it was seen that the vesicular, slag-like rock was overlain by unaltered shales with an intervening trap breccia at some points. This breccia alone was considered satisfactory proof of the extrusive nature of the sheet, and he stated his opinion that it could only have been formed on the surface of a pre-existent sheet of lava.

The writer's studies extending over the entire Newark area in New Jersey confirm Davis's suggestion and give rise to the following conclusions: The extrusive sheets, contemporaneous with the enclosing strata, include all the outcrops constituting the First and Second Watchung or Orange Mountain, and the ridges enclosed between them and the Archæan highlands, and the outlying outcrops near New Germantown. The intrusive sheets comprise those constituting the Palisades, Sourland Mountain, Cushetunk and Round Mountains, Lawrence Brook —Ten Mile Run Mountain—Rocky Hill—Pennington Mountain—Bald Pate and Jericho Hill series, and the outcrops at Point Pleasant, Snake Hills, Arlington, Martin's Dock, Neshanic, Belle Mountain, Granton and Brookville.

The extrusive sheets are characterized by their perfect conformity to the underlying strata, the deep vesicularity and alteration, or slag like aspect of their upper surfaces, the unaltered and undisturbed condition of the enclosing strata the presence of trap breccias at the contacts, the altered and frequently vesicular condition of the rock at their bases, the evidence of successive flows, their relations to anterior tuff deposits and their distinctive columnar structure and petrography.

The intrusive sheets are characterized by irregular lower contacts in which the trap cuts across the ragged edges of the strata for greater or less distances, the intense alteration in the enclosing strata, the increased density and fineness of grain and the bedded structure in the trap near the contacts, and the absence of vesicularity and breccias.

In the Watchung Mountains, erosion, glaciation and drift cover cause scarcity of outcrops of the original upper surfaces, but there are many localities scattered along their course in which deeply vesicular trap is exposed, and others in which unaltered and undisturbed strata outcrop very near the contact. The only actual overlap well exposed is in the ravine at Feltville, where the trap surface is in greater part vesicular and slag-like and the soft, red, argillaceous shales fill the irregularities, excepting at one point where there is an intervening trap breccia filling the interstices in a slag-like portion of the surface. Contacts of the Watchung traps with underlying strata are exposed at intervals along the outer sides of the ridges and absolute conformity prevails throughout. The trap is frequently vesicular and altered and lies on the unaltered or very slightly altered strata along a straight or gently sinuous line, in one case with a trap breccia intervening. At two points in its course the second Watchung trap is exposed overlying beds of loose eruptive materials apparently scoria and tuff, and at other localities the sheet is seen to be composed of successive flows, the base of one lying on the vesicular surface of a preceding flow, in one case with an intervening layer of trap breccia at some points.

In thickness the first Watchung trap varies from 450 to 650 feet, the second, from 600 to 850 feet, and the third, from 225 to 350 feet in the main, and the area enclosed by the outermost hooks is about 500 square miles, no doubt in greater part underlain by trap, so that the Watchung sheets represent lava-flows of no mean volume. Apparently the extrusions were continuous throughout, for excepting the intercalated breccia above alluded to, no intervening or overlapping sedimentary materials were discovered. The absence of fragmental volcanic deposits, excepting the local beds at the base of the second Watchung sheet, is a noteworthy feature, and the first extrusions were not attended by ejections of scoria, ash, etc., or, at most, in sufficient amount to extend to the present lines of outcrop. The eruptions which gave rise to the Watchung trap masses were no doubt very similar to those of some of the great lava-flows of the western part of the United States, which appear to have welled forth from long fissures without attendant craters, or the ejection of fragmental materials.

The great hooks characterizing the southernmost outcrops of the Watchung traps are entirely due to flexure, and the bowed course of their northern terminations and of Towakhow Mountain are due to the same cause.

The New Vernon trap, across the Great Marsh from the Watchung Mountains, is apparently an extension of one of the Watchung flows brought up by the partial quaquaversal which determines its crescentic course, and it is similar to them in every respect but not so well exposed for study, while the New Germantown traps farther southwestward, but at approximately the same horizon, are undoubtedly extrusive and may be remnants of another extension of the Watchung flows.

The Palisade trap is the best exposed instance of intrusion on a large scale in New Jersey and although it is in greater part an essentially conformable sheet throughout, the supply dike from which the sheet extends reaches the surface northwest of Hoboken and in Rockland County, New York, along the inner side of the ridge and is in part finely exposed in the two tunnels of the West Shore railroad.

For many miles along the Hudson River the Palisade sheet is exposed in contact with the underlying strata near the base of the formation, and while the relations are essentially conformable throughout, local irregularities are frequent in which the ragged edges of the strata are crossed laterally up or down for in one instance over 150 feet, and trap offshoots are sent down or out into the underlying beds. In the vicinity of Haverstraw the crescentic course of the dike causes a corresponding deflection in the line of outcrop, and although this is greatly aided by the structure of the outlying beds, the base of the sheet crosses the strata for several hundred feet in preserving its position above the surface. At its terminal outcrop, an occurrence of vesicular rock, suggests that the sheet was finally extruded. At its contacts with enclosing strata the Palisade trap becomes fine-grained, very dense and bedded in structure, and the sedimentary rocks are darkened and hardened often to a considerable distance.

A short distance west of the Palisade trap near the latitude of the city of New York, are the posterior trap masses of Granton and Snake Hills, similar structurally to the Palisade trap in consisting of a dike and a sheet extending up the dip.

While it seems probable that the Palisade trap continues southward to reappear in the series of outcrops which extend from Lawrence Brook through Rocky Hill and Pennington Mountain to Bald Pate and Jericho Hill on the Delaware, it is possible that it is due to an entirely separate intrusion. The trap of the series of outcrop from Lawrence Brook to Jericho Hill is similar to the Palisade sheet structurally and petrographically, and is apparently a continuous mass not reaching the surface in the gaps that isolate Pennington Mountain. It is heavily flanked with indurated shales and crosses the strike of the enclosing strata, both at intervals in its westerly course and in the hooked outcrop of Ten Mile Run Mountain.

Sourland Mountain consists of a thick sheet of coarse-grained diabase, heavily flanked by highly indurated shales, and follows the strike of the enclosing strata excepting in a local bowing near the center of its course where it crosses and recrosses the strata for a short distance. Cushetunk and Round Mountains are the remnants of a wide, thick, intrusive sheet considerably flexed, and eroded through at the anticlinals so as to give the singular horse-shoe shaped course to Cushetunk Mountain and isolation to Round Mountain. The indurated strata associated with this trap are crossed by it at some points, and along the western border for a short distance the edge of the sheet overlaps the Lower Paleozoic limestones and presents some evidence of having been extrusive.

The smaller trap masses along the Delaware, at Belle Mountain, Brookville, and Point Pleasant, are all local intrusive sheets intercalated between highly altered strata, and near Neshanic, Martin's Dock, and Arlington are other intrusive sheets, finely exposed in cross-section. The other trap masses in the New Jersey region are some small sheets and dikes near and northeast of Flemington, the dike so finely exposed near Blackwell's Mills, the dike (?) near Hackensack and the sheets south of New Brunswick.

The ages of the intrusive sheets of the formation are difficult to estimate. Davis has called attention to the raggedness of some of the contacts as evidence that the intrusion was effected before the development of joints by the uplift of the formation, and this certainly seems very probable.

As the stratigraphy of the Newark system of the New Jersey region is not worked out, the horizons of the trap masses are not known, and the sequence of their intrusion is indeterminable from any evidence now in hand. For the greater part of its course the Palisade trap lies just above the basal arkose, which is known to overlap the crystalline rocks in wells in Jersey City, and as the first Watchung trap lies on basal beds near Paterson, it might be suggested that the two sheets are not far distant in horizon, but in the absence of definite knowledge of the comparative age of the basal rocks at Paterson, and the structure and the configuration of the buried Triassic shores in the intervening region, the relative positions of the two sheets can only be conjectured.

At Lawrence Brook the supposed southward continuation of the Palisade trap is not far above the base of the formation, but in Ten Mile Run Mountain and Rocky Hill the strata are crossed, so that at the Delaware the sheet is apparently 10,000 feet above the Trenton gneisses, but probably there are intervening faults which might decrease this estimate very greatly.

Sourland Mountain trap is apparently high in the formation, but its exact or relative horizon cannot be determined until the stratigraphy and structure of the region has been worked out and the same is the case with the other traps of the Delaware region, and the Cushetunk and Arlington traps.

Art. XIX.—*Recent Explorations in the Wappinger Valley Limestones and other formations of Dutchess Co., N. Y.;* by W. B. Dwight. With Plate VI.

No. 7. *Fossiliferous Strata of the Paradoxides Zone at Stissing.*

The occurrence of fossiliferous Cambrian strata of the Potsdam group near Poughkeepsie, N. Y., and ten miles north of that city at Salt Point, has been described in previous papers of this series:* also the discovery by Mr. C. D. Walcott and myself, in a joint trip, of fossiliferous strata of the Olenellus horizon on the southern extremity of Stissing Mountain, 21

* This Journal, Feb., 1886, and July, 1887.

miles north of Poughkeepsie. It is the object of this paper to present a few of the prominent results of my more recent researches in the Cambrian and associated strata in that part of the county adjacent to Stissing Mountain.

The particular aim of these later investigations has been to ascertain the position and extent of the Olenellus strata, and their stratigraphic relations to the Hudson River shales of the region, and to the higher Cambrian strata whose presence a few miles to the southward had been already demonstrated.

The Olenellus quartzite and the overlying Olenellus limestone, rest upon the gneiss of Stissing Mountain around the entire circuit of its southern extremity and so continue northeastward for several miles along both its eastern and western flanks. At the southern extremity, about 21 miles northeasterly from Poughkeepsie, these strata cover the basal slopes of the mountain at an elevation of about 275 feet above the adjoining valleys and, conforming to these slopes, lie with a very gentle inclination to the south. On descending the slopes in southerly directions, the upper layers of the Olenellus limestone are found to run frequently into red shales which have not proved fossiliferous. In the fields which stretch southward and southwestward from the mountain, the rocks are to a great extent concealed by drift; but there are a sufficient number of outcrops to permit a continuous tracing of the limestones and calcareous shales (of whatever horizon they may be) for several miles, and to show that the dip rapidly increases, and the strike soon becomes the prevailing one of about N. 20° to 30° E. On account of the cover of drift, and the scarcity of fossils, it is at present impossible to determine exactly, along what lines the Olenellus group is succeeded by strata of later periods.

This mass of limestones of the Olenellus and to the southward probably of higher groups, which extends in the line of strike southwestward, is abruptly cut off on the west by a fault caused by the uplift of a belt of Olenellus quartzite, overlain on the west by a strip of limestone of the same age. West of this limestone are the shales of the Hudson River group. This fault begins at a point between two and three miles southwest of Mt. Stissing, where, however, only the limestone at first appears, faulting on the east (as well as the west) against Hudson River shale. This line of fault extends in a direction a little east of north to western flank of the mountain. One of the best places to observe it is one mile west from Stissing Station, on the road leading west beyond the corner of the McIntyre road, near Mr. Elias Turner's house. At this point the quartzite comes in, as a bold conspicuous ledge of white unfossiliferous rock. From this point northeastward, the quartzite faults against the Olenellus and associated limestones on the east, while it is bordered on the west by a belt, from 800 to 1000 feet wide in its outcrop of overlying limestone, partly at least of the Olenellus group.

After reaching the mountain, this belt follows along its flanks to Miller's Pond, during which course, the Hudson River shales on the west pinch out the limestone and rest against the quartzite for about 700 feet. North of Miller's Pond, the Olenellus belt begins to ascend the mountain flanks, until at a point about half a mile south of the "gap," the limestone entirely disappears, and the quartzite pressed upon by the Hudson River Shales stands out in bold white crags high up the mountain side,—at perhaps two-thirds of its height. North of this point, the Hudson River shales apparently rest directly upon the gneiss.

On the east side of Mount Stissing, the Olenellus belt does not tend at any point to climb its flanks; the tendency is rather to sheer away from them. The quartzite is here mainly on the west side of the belt. At a point, however, opposite to Attlebury Station, where there is a deep recess to the west in the outline of the mountain, there is a synclinal of limestone and calcareous shales lying west of the quartzite and filling up the gap.

At Mr. J. A. Thompson's house at the turn in the road northeast of Attlebury Station, the quartzite disappears in the meadows while the Olenellus limestone forms a bold escarpment along the base of the mountain, west of the road, for about half-a-mile farther north. Opercula of *Hyolithellus micans* occur in this limestone opposite Mr. Thompson's house. From this point the belt, much concealed by drift and alluvium, passes northeastwardly by and under the village of Pine Plains to the county line. There are outcrops of the quartzite in Mr. Henry Pitcher's swamp, north of the village, and on top of a hill belonging to Mrs. Henry Hoffman, and on the south side of the road close to the county line, near Mr. J. Weaver's house. There are outcrops of limestone in the plain near the north extremity of Stissing Mountain, which probably belong to this group, but this is uncertain. It may here be remarked that the Hudson River Shales mount to the summit of that part of the mountain lying north of the "gap," at least in its northern portion. Also that the only other place where I have found quartzite referable to the Olenellus group in this part of the county is a ledge in a ravine on Wing's farm a little southwest of the station at Willow Brook.*

* My explorations around Pine Plains were much facilitated by the generous assistance of Rev. A. Mattice, principal of Seymour Smith Institute.

Besides the strata already mentioned, there are limestones filling the eastern side of the valley east of the mountain, cropping out in Thomas's quarry on the northeastern edge of Pine Plains village, forming Mill Hill on its eastern edge, and other hills easterly as far as Bethel, and (in conjunction perhaps with the quartzite-limestone Olenellus belt,) passing north into Columbia County; also forming a belt about six miles long, and from a quarter of a mile to a mile wide in the Shekomeko valley, from Pulver's Corners on the north, to "The Square," two miles south of Shekomeko Station; also a very irregular strip about one mile and three quarters long and from a quarter of a mile to a mile in width, north of Bangall. All these outcrops I have searched and studied in detail, and have found them to be Cambro-Ordovician strata, much faulted against each other, and against the Hudson River Shales, especially in the Bangall strip. No Trenton outcrops have been found. Fossiliferous Calciferous strata occur at Attlebury Station, near the Moravian monument, at Bethel, and quite extensively at and south of Shekomeko.

The greater part of these limestones are Cambrian in appearance, passing very frequently into the calcareous shales characteristic of that zone in this county. But no fossils except those of the Calciferous strata have been found in any of the belts just named with the exception of a single fragment. This was found at the base of Mill Hill in Pine Plains Village, and may be either a Kutorgina or a Lingulepis. It is therefore at present impossible to determine the eastern edge of the Olenellus strata in the neighborhood of Pine Plains, or to distinguish, in this vicinity, the higher Cambrian strata, except in the single instance which will now be mentioned. It can scarcely be doubted, however, that the Potsdam zone is largely represented in connection with the Calciferous. The deep cutting on the railroad just north of Husted station is most probably in the Potsdam.

In July, 1887 the search in the limestones and calcareous shales immediately overlying the Olenellus limestone at the south end of Stissing Mountain was rewarded by the discovery of two or three fossils. No fossiliferous layer was then found; the organisms obtained were referred to the Potsdam zone which was to be expected in that position. It was not until the summer of 1888 that, by the discovery of a fossiliferous layer at this spot, the true significance of these important organisms began to appear.

The locality is in the first rock-cutting on the New York and Massachusetts Railroad, a little less than half a mile south of Stissing station. The organisms have been found chiefly in a thin layer of limestone and calcareous shales close to the ground and to the railroad track, near the southern end of the cut, and are more abundant in the shale. Roadmaster Joseph D. Neal very kindly put at my disposal a gang of the railroad employees to make the necessary excavation. Mr. Palmateer, who has charge of this "section," rendered very efficient service in conducting the work, and showed much skill in detecting fossils.

The species collected consists of a trilobite, a Leperditia, and a Kutorgina, all undescribed, and a Hyolithes, probably "Billingsi." As the latter has a large geological range, it would scarcely indicate the horizon, but the other organisms appear definitely to indicate the Paradoxides horizon in their character and affinities. Well defined specimens are very rare, and have been procured only by breaking up a large quantity of rock; but in certain thin layers, fragments of these fossils are very numerous. On account of the covering of soil, it is impossible to determine the boundary line between these Paradoxides beds, and those known to be of the Olenellus group, three quarters of a mile north on Stissing Mountain. It is probable however that the outcrop in the gulley at the station is of the latter group. It is equally impossible at present to determine the division line between these Paradoxides beds and the Potsdam strata doubtless overlying them, which latter are entirely similar in lithological characteristics.

No other locality of fossils of the Paradoxides horizon has yet been found. The only fossils of Paradoxides types previously reported from New York State, are those found by Mr. C. D. Walcott of the U S. Geological Survey, which he states that he is inclined to refer to the Paradoxides zone.* I have not been able to find any of these in the Stissing locality.

It may be observed that the stratigraphic position of the Stissing Paradoxides fauna is in harmony with the view which now seems likely to meet with general acceptation, that if the Olenellus and Paradoxides faunæ are not synchronous, the former should be regarded as the earlier deposit. It gives me pleasure to acknowledge the very kind and valuable assistance of Mr. C. D. Walcott in determining the relations of my specimens to typical Cambrian fossils.

A description of the species determined is here appended.

Hyolithes Billingsi ? Plate VI, fig. 1.

About half a dozen tubes of Hyolithes have been found in the calcareous shale: they are from eight to twelve millimeters in length, and from three to four in diameter at the aperture. Most of them are poorly preserved, showing little more than a

*This Journal, III, vol. xxxvii, 1889, pp. 385, 387.

black flattened cone. In one specimen, the shell shows considerable thickness. The one figured is the best one found, though it is the internal cast, the shell being entirely exfoliated. The shape is an acute cone very slightly convex on the visible surface, and with a few evident annulations in the upper half, the most marked one being next to the aperture. The shape of the transverse section is unknown, though it has been sought for by making cross-sections.

A single operculum has been found, but it is not sufficiently perfect to warrant its description. This fossil may be most safely referred to *H. Billingsi.* Specimens of the above named species, kindly loaned to me for examination by Mr. C. D. Walcott, show distinctly the annulations which appear in the Stissing fossils.

Leperditia ebenina, n. sp. Plate VI, figs. 2, 3 and 4.

Carapace jet-black, shining, subelliptical; about eight millimeters long, and five millimeters high in the largest specimens collected. Dorsal margin straight, or nearly so, somewhat shorter than the longest diameter of the carapace. Ventral margin arcuate; terminal margins well-rounded ventrally, but above sloping inward, in straight lines, to the dorsal margin; dorsal angles somewhat obtuse, not at all rounded.

The carapace in general is quite convex; in the largest specimens, as in one of those here figured (fig. 3), there is a broad and rather flat depression passing centrally from the dorsal to the ventral edge, leaving two terminal prominences; but as in such cases cracks are evident in the shell, and as the smaller specimens do not exhibit this feature, it is probably the result of compression. On account of the imperfection of the specimens, and the frequent distortion by pressure, it is not at present possible to determine the normal outlines of surface convexity.

The external surface of the carapace is very peculiarly ornamented. The entire border of each valve, in the form of a strip which is nearly two millimeters wide in the largest specimens, is covered with extremely minute contiguous pits. There are at least from 100 to 150 to a square millimeter. Within this finely-pitted border, the entire central portion is covered with much larger, separated pits, the interspaces being as wide as the pits themselves, or wider. Their disposition is very irregular, but they average about 15 or 20 to the square millimeter. There is a linear marginal groove extending along the ventral border; at its central point it is nearly one millimeter within the ventral margin, but it gradually approaches it toward each extremity until it coalesces with the terminal margins. The central portions of the internal surface of the valves are covered with well-defined scattered tubercles, corresponding apparently with the scattered pits of the external surface.

No eye-tubercle nor muscle-spot is visible. Further particulars, as to relative obliquity of the dorsal angles, etc., cannot be ascertained until more perfect specimens are collected. In specimen No. 175, the valve appears to be a little wider on the left-hand than on the right-hand ; it is therefore probable that the specimen is the right valve.

Found chiefly in the calcareous shale, but occasionally in the compact limestone. Some surfaces of the shale are black with its fragments, but owing to its brittleness no perfect specimens has been yet obtained.

Kutorgina Stissingensis, n. sp. Plate VI, figs. 5, 6, 7 and 8.

Shell black, phosphatic, slightly transverse ; width about three-tenths greater than the length. Those collected from the limestone are about eight millimeters in width ; specimens found in the calcareous shale are sometimes from eleven to twelve millimeters wide or even more. General shape, semicircular.

The cardinal margin slopes forward somewhat on each side of the beak, and makes obtuse angles with the lateral margins, on account of the incurving of the latter. It is shorter than the greatest width of the shell which is along a transverse line one-third of the distance from the beak to the front. Hinge-line not evident, but apparently a little curved.

The ventral valve has the beak elevated, pointed, and projecting somewhat behind the cardinal margin. From the beak the surface slopes down toward each lateral margin, and to the front margin, becoming sometimes slightly concave at the central portions of the shell. Along the cardinal border the shell is suddenly deflexed, making a distinct false area which, however, is separated into two parts by a vacant deltidial space under the beak. As the surface of this false area is exfoliated in specimens observed, it cannot be positively determined whether the surface ornamentation of the valve is extended over it. The edge between the false area and the upper surface of the valve is not sharp, but gently rounded.

The dorsal valve is depressed and nearly flat, beak low ; otherwise resembles the ventral valve, except that in specimens collected it appears a little more transverse.

The surfaces of both valves are covered with very fine, sharp, concentric ridges, traversed by striæ scarcely visible to the naked eye. Under a strong triplet these striæ prove to be very delicate longitudinal undulations radiating from the beak.

The concentric ridges are somewhat wavy as seen under a strong magnifier; they are semi-circular; a number of those lying nearest to the front margin, run out along the upper part of the lateral margins; but the remainder, and larger number terminate in regular order along the cardinal border. In front of the central portions of the shell, the concentric ridges, which number about 12 to 15 to a millimeter, are regularly concentric; but nearer to the beak the number, and the irregularity greatly increase. At a point about one-third the length of the shell, from the beak, there are twenty-five or more to the millimeter; as the radiating plications are numerons in this part, there is caused a complexity of curves, which under a powerful magnifier produces the effect of elegant and delicate basket work. The radiating undulations are very irregular in position and number, they are not thoroughly continuous from the beak, in specimens observed, but appear at irregular intervals singly or in groups; while apt to be crowded around the beak, they are rare near the front margin. On the best specimens, about 25 have been counted in the central parts of the shell just forward of the beak; had they extended in equal distribution around it, quite to the cardinal border, there would have been about 50. They are also unequal in breadth; where they are somewhat regular, the interspaces about equal the plications in width; these plications are multiplied by implantation.

The following internal markings are indicated by the study of a specimen (fig. 8,) which is supposed to be an umbonal fragment of a ventral valve of a *Kutorgina Stissingensis*, from the same locality.

The original specimen is a natural impression of the interior. The figure is drawn from a gutta-percha cast of the same, which therefore represents accurately the interior of the valve. In front of the deltidial groove, a thin medial septum extends toward the front. Lying close to this septum and divided by it, there is a posterior and an anterior pair of circular muscular impressions, separated from each other by a broad and low transverse ridge. Fine radiating lines extend out from along the septum, the front ones making a small angle with the latter, while the more posterior ones start out from the septum in a lateral direction, bnt are soon deflected into their proper radial position.

It is not quite certain that this latter fossil is identical with *K. Stissingensis.* It is an example of rather numerous organisms found at this locality, which for some time I supposed to be a new species of Lingulella, allied to *L. ella.* But as its surface-ornamentation appears to be quite exactly that of the *K. Stissingensis*, and for other reasons, I am now inclined to think that these little shells are either the young, or else fragmentary portions near the beak, of *L. Stissingensis.*

In the above description I have associated in the same species the specimens found in the calcareous shale, and those found in the compact limestone. There are some points of difference, especially in size; those in the shale are decidedly larger than those in the limestone, which may be due to more congenial sediment. The number found in the limestone however is too small to justify any strong conviction on this point.

Should it be ascertained hereafter that there are specific differences between these fossils, I should consider the specific name here given to belong to the specimens found in the limestone of which those corresponding to figs. 5 and 6 are the types.

Fragments of the front portion of this black shell are abundant and conspicuous in the shale, and in the absence of the associated fossils would readily be mistaken for fragments of *Lingulepis pinniformis.* Close inspection will however reveal this difference. The concentric ridges or laminae of *L. pinniformis* (at least as exhibited in Dutchess County, N. Y.) are feebly defined when magnified, and often run together obscurely; while those of *Kutorgina Stissingensis* as viewed with a strong triplet, are deeply cut, and in the front portions even, they are generally individualized with exquisite perfection.

This Kutorgina is related to *K. Labradorica* Billings; but the beaks are less elevated than the specimens figured of that species, and the peculiar surface ornamentation is different.

Olenoides Stissingensis, n. sp. Plate VI, figs. 9–15.

Body elongate ovate; in the single full-length specimen found, slightly over three centimeters in length.

Head large, semicircular, with apparently slight notches in the anterior outline, at the points of intersection with the facial suture. Eyes elongate and large.

Glabella elongate, its length in front of the occipital furrow, being nearly one and two thirds times its least width; a little expanded at the rounded anterior extremity, the sides slightly incurved along the posterior half, so that the shortest transverse diameter is a little in front of the posterior extremity. Dorsal furrow everywhere well defined, though not deep; inclined to be rather broad along the lateral edges. Glabellar furrows three, or in some specimens, four; the first pair are broadly and deeply impressed in the edges of the glabella, at a point about one-fourth of the longitudinal diameter from the posterior extremity; from here they pass very obliquely backward, shallowing and narrowing rapidly, until quite near to the posterior margin, they are joined by a shallow transverse furrow. The second pair arising from the central points in the edges are almost as oblique as the first pair and quite similar, except that they are slightly narrower, and considerably shorter, each one extending but a third of the distance across the glabella; the third and fourth furrows are very short and slight, often barely perceptible, and their direction is either directly transverse, or turned slightly forward.

Occipital furrow strongly defined at its outer extremities, where it terminates in pit-like depressions, but it is narrow, and very shallow toward the center.

Occipital ring, triangular, depressed convex, lower than the the glabella, very broad centrally, narrowing rapidly toward the lateral terminations; the postero-lateral margins pass directly to the fixed cheeks as elevated ridges, with only a slight transverse depression in the line of the occipital furrow. The occipital ring terminates posteriorly in an obtuse point. No occipital spine has been detected in specimens favorable for its exhibition if one were present.

The facial suture anteriorly passes obliquely forward and outward, in a sigmoid curve, from the anterior corner of the eye; from the posterior corner of the same, it runs nearly parallel to the posterior margin, until it turns and cuts this margin near the cheek-spine.

The fixed cheeks are broad, convex, elevated, but lower than the glabella; there is a deep furrow just within the well-marked palpebral-lobes; posterior limb with nearly parallel margins, and about as long as the shortest transverse diameter of the glabella; its furrow is broad and central at the inner end, but passes obliquely forward, as it vanishes before reaching the extremity. Front limb narrow, sloping upward from the dorsal furrow, elevated and rounding over at the margin; its contour is a curve of somewhat longer radius than that of the anterior outline of the glabella. Ocular ridge narrow and prominent, semicircular, extending anteriorly to the glabella at a point near the anterior end between the third and fourth furrows.

Free cheeks not well preserved in specimens collected; exclusive of the moderately long genal spine, their form is triangular, and the surface generally convex, rising towards the palpebral lobes. In the best preserved specimens there appears to be a narrow, flat, depressed margin, running down somewhat into the spine; from the anterior part of this margin, a deep furrow extends obliquely posteriorly, and inward, till it meets the posterior margin near the genal angle; it thus cuts off a strip of the convex portion of the cheek, which strip passes down into the spine to its point.

Hypostoma triangular, convex, well-rounded anteriorly, and the curved outline extending backward for more than $\frac{1}{3}$ of the distance along the sides; from this point, the sides are nearly straight, except at the posterior end, where there is an expansion into a broad, rounded, well-marked annulation, whose outlines are everywhere curved. Between the ring and the main body is a transverse, linear, deeply impressed furrow. There is a pair of short faint furrows, together forming a V, just in front of the posterior transverse furrow on each side.

From the central point of the front edge, a broad moderately deep furrow, extends a short distance backward, rapidly contracting to a vanishing point; it obscurely divides the anterior part of the hypostoma into two lobes. There is anteriorly, a narrow, rounded margin whose contour conforms to that of the front edge of the principal mass. It is uncertain from the partially imbedded specimens, whether or not, this margin extends also along the sides.

The thorax contains eight segments. Axis well-elevated, strongly convex, rate of taper regular, about one part in six. Each segment is of about the same width as the corresponding pleural segment, exclusive of the free spinous portion.

A linear furrow, deeply impressed, passing from one posterior corner to the other, traverses each segment through its central point. This furrow thus presents the shape of an arc convex anteriorly. Immediately behind its central and highest point there is a tubercle, or perhaps the base of a spine. All that portion of each segment lying within, and posterior to the furrow, presents a visible contrast to the anterior portion by some slight difference in the texture of its surface, which, for one thing, is a little the rougher; in the two specimens collected, it is also of a darker color. The pleural segments are depressed convex, and extend out very nearly at right angles to the central line of the axis, until the free spinous portions are reached. Each of the pleuræ consists of a broad, flat depressed portion or furrow, flanked by narrow, well-defined marginal ridges. The furrow is broad at its inner end, and continues of equal width for half the distance, when it rapidly draws down to a point. The posterior pleural ridge is almost perfectly straight through its entire length; the anterior ridge is straight for about half its length, while it lies appressed against the posterior ridge of the next segment in front; from this point it is at first gently, then rapidly recurved until it meets in an acute point the posterior ridge of its own segment. All the narrowing of the pleuræ is thus effected from the anterior side. The pleural segments are prolonged into flat, acute, recurved spines, with broad contiguous bases; their length is about two-thirds that of the main segments; their inner, concave edges appear to be continuations of the posterior pleural ridges.

Pygidium of moderate size, triangular; axis strong elevated, obconical; with at least two well-impressed transverse furrows near the anterior end, forming there two conspicuous annular lobes, and apparently in some specimens, another faint furrow still farther to the rear. No tubercles detected. The lateral lobes consist of an inner depressed-convex portion, much lower than the axis, traversed by two or three oblique furrows corresponding with the spines, the posterior one, however, quite faint, and a perfectly flat and moderately broad margin from which three flat and acute spines extend backward. These much resemble the pleural spines, but have a less graceful appearance from the tendency of their edges to run into straight lines. The two posterior spines, one on each side, are about as far apart as the width of the axis of the pygidium at its anterior end; the border of the posterior margin which unites them, is nearly or quite a straight line.

Quite a number of specimens have been collected of the glabella and pygidium of this trilobite, in which the features as here described are quite constant. Only one has been found (fig. 5) which exhibits the contour of the complete cephalic shield, and two which show the thoracic segments.

On account of the imperfection of the head and pygidium of the more complete specimen, No. 180 (which I will consider, in any event, the type of the species "*Stissingensis*"), there might be doubt concerning its specific identity with the others. Specimen No. 182 is a link, however, which seems to remove all question from the evidence. The name assigned to the species is that of Mount Stissing, near whose base it occurs.

The close affinity of this trilobite to the type *Olenoides Nevadensis*,* Meek, is very evident and interesting. The main points of difference are: (1) The more slender and tapering thoracic axis. (2) The shape of the axial thoracic segments, and the arrangement of the furrow in these segments. (3) The broad, flat pleural thoracic spinous processes. (4) The different structure of the pygidium.

The glabella and fixed cheeks are also considerably unlike those of "*Ogygia serrata*" Rominger, which Mr. C. D. Walcott, after careful comparison of specimens, considers to be identical with *Olenoides Nevadensis*.† From the calcareous shale, and rarely in the compact limestone.

8. *Discovery of Calciferous Fossils in the Millerton–Fishkill limestone belt; also in a belt near Rhinebeck.*

The Hillsdale-Copake belt of the original Taconic limestone, dividing just south of Copake, enters the northeast corner of

* See Bulletin No. 30, U. S. Geological Survey, Plate xxv, fig. 7.

† This Journal, III, vol. xxxvi, 1888, p. 165.

Dutchess Co., in two main belts, the western or Pine Plains—New Hamburg belt, and the eastern, or Millerton-Fishkill belt. Associated with these are a few shorter parallel belts of limestone. The western one has been considerably altered by metamorphic action, but the metamorphic alteration has been much greater in the eastern belt where the limestones are frequently found coarsely crystallized and marble-like, while the associated shales often merge into micaceous or hydro-micaceous schists, or even become gneissoid. These facts were clearly set forth by Professor J. D. Dana, in 1879,* as also the fact that Lower Silurian fossils had been discovered in the western belt, while no definite species of fossils had been made out among the signs of organisms found in the eastern one.

Recently the writer visited the northern end of the Millerton–Fishkill belt, for the first time, in the work of exploration, entering it from the central part of the Shekomeko Valley. The limestone was reached at the eastern base of the high ridge of argillite and micaceous schist which is the southern extension of Winchell Mountains. At once the presence of fossils was discovered in a limestone ledge on the farm of Mr. Edward Clark. The locality is a little less than a quarter of a mile from the village of North East Center, on the Shekomeko road, and scarcely more than one and a half miles, in a straight line, from Millerton railway station. It is about five hundred feet northerly from the road, and but slightly elevated above the surface; the portion exposed is about one hundred and fifty feet long and sixty feet wide, with a strike N. 11° E. (true) and dip 35° westerly.

The rock is a fair sample of the much altered limestone of this eastern belt; its color varies from gray to white, and in many spots it is rather brittle, or inclined to crumble under blows of the hammer. In some cases, where the mass of the rock is grayish, the fossils in it are quite white, making a fine contrast. This fossiliferous limestone is frequently filled with films which very strongly resemble micaceous or hydro-micaceous films; but as I have not had time to examine them carefully I do not venture to assert that they are any other than films of gypsum.

The limestone in this ledge is filled with organic remains, some of which are fairly well defined, appearing in relief on the weathered surfaces;—many of them are distorted by pressure. The so-called Calciferous fucoids are abundant and of the same peculiar forms elsewhere observed in this formation. *Ophileta complanata* (which according to Prof. R. P. Whitfield is identical with *O. compacta*), is present in numerous

* This Journal, vol. xvii, May, 1879.

specimens, though not generally well preserved. I obtained four or five good specimens of it about $2\frac{3}{4}$ centimeters in diameter. Specimens resembling *O. sordida* were observed, but I suspect that they are simply distorted forms of *O. complanata*, as the gain in the size of the whorls is moderate.

An Orthoceras was found, conspicuous in its relief upon the weathered surface. It is about five centimeters long, and one and a third wide; the rate of taper is moderate; the septa number about seven to a centimeter: they are quite oblique, but this may be due to distortion. The siphuncle is two millimeters in diameter; the shape of the cross-section, and position of the siphuncle cannot be known because of the distortion, nor can its species be at present determined. Fragments likely to be those of *Cyrtoceras Vassarina* were also noticed.

No other limestone outcrops were seen in the vicinity, as the rock is extensively covered by drift in this part of the State, though a more careful search would doubtless reveal other localities. Similar fossils were found in adjoining walls indicating a considerable area of the fossiliferous strata. The limestone belt here has a width of about two miles, its eastern edge skirting the base of Indian Mountain in the Connecticut border. Throughout this width there appears to be a general similarity in the lithological characters so far as these could be observed in the rather scarce outcrops. The strata from the village of North East Center are continuous northerly to Millerton and to the north county line, becoming a white and crystalline friable marble in the quarry of the A. H. Maltby furnace, north of Millerton. The belt was also cursorily examined south as far as Amenia, and found to be of a similar character.

These facts show that the Calciferous, which is clearly indicated by the fossils, is at least one of the most prominent components of the Millerton–Fishkill limestone belt. Trenton strata are very likely to be present, but were not observed. No indications of Cambrian strata were noticed between Millerton and Amenia but the search has not yet been thorough. The shales and schists associated with these limestones, and passing sometimes from argillite, without interruption, into hydro-micaceous schist, hold evidently the same stratigraphic position as the shales and schists which are associated with the similar western limestone belts of the county. It is therefore not easy to see how they can be referred to any other horizon than that of the Hudson River Group.

It may be well to announce here that the writer has also found, recently, Calciferous fossils in one of the short belts of limestone lying a few miles east of Rhinebeck village. The fossiliferous locality is at Eighmyville three miles northeast of

Rhinebeck. This limestone has been mentioned by Mr. S. W. Ford, as probably Cambrian, and it contains in considerable quantity what certainly appears like the Potsdam conglomerate of Dutchess and Columbia counties. But the presence of the Calciferous there in a very characteristic form is now beyond doubt.

NOTE.—Since the above paper was written, Mr. C. D. Walcott's article on the "Position of the Olenellus Fauna," in the July number of this Journal, has been published. In this paper he very justly calls attention to the fact that the fauna here described belongs to the type of the Middle Cambrian of the interior (as of the Rocky Mountain region) rather than to that of the typical Paradoxides of the Atlantic coast; and that, from its position, the Hudson Valley fauna serves in a measure to connect the two.

EXPLANATION OF PLATE VI.

CAMBRIAN FOSSILS FROM STISSING, N. Y.

Natural size, except where otherwise noted. All are from the Calcareous shales, except those represented by figs. 5, 6, and 15, which are from the limestones.

Fig. 1. *Hyolithes Billingsi* (?) cast of interior, showing three or four slight annulations; the anterior one more prominent than the others.

Fig. 2. *Leperditia ebenina*, n. sp., enlarged to 2 diameters; fragment of (right?) valve, showing the line of the hinge, and a sloping dorsal angle, also the outer belt of minute contiguous pits, and the inner tract of larger separated pits. The ornamentation indicates that the complete carapace must have been at least one-sixth longer than the fragment.

Fig 3. *L. ebenina* enlarged to 2 diameters: lacking the cardinal margin; showing perfectly the peculiar surface-pitting, and the ventral furrow.

Fig. 4. *L. ebenina*, interior view of a central fragment of a valve; showing the separated tubercles, corresponding to the separated pits of the central exterior.

Enlarged to 2 diameters.

Fig. 5. *Kutorgina Stissingensis*, n. sp., enlarged 2 diameters; a natural cast of the dorsal valve.

Fig. 6. *K. Stissingensis;* enlarged to 2 diameters; ventral valve; with a side view of the elevation.

Fig. 7. Gutta percha cast of a natural impression of the interior of the umbonal region of a ventral valve, referred to *K. Stissingensis;* showing a medial septum from which fine striæ diverge, and muscular impressions, enlarged to 3 diameters.

Fig. 8. *K. Stissingensis*, cardinal view; showing false area, deltidial opening, and the rounded edge between the false area and the main surface of the valve; enlarged to 2 diameters.

Figs. 9. and 10. *Olenoides Stissingensis*, n. sp.; the glabella. Fig. 9 from an artificial cast, Fig 10 with a side view of the elevation.

Fig. 11. *O. Stissingensis*, pygidium.

Fig. 12. *O. Stissingensis*, pygidium, with four attached thoracic segments.

Fig. 13. A free cheek, associated with *O. Stissingensis.*

Fig. 14. Hypostoma of *O. Stissingensis.*

Fig. 15. *O. Stissingensis*, full length, showing eight thoracic segments; details of the glabella obliterated or distorted by compression.

Art. XX.—*Silicic Acids;* by George F. Becker.

The silicic acids usually assumed to be needful to account for the natural silicates are ortho-, meta-, poly-, and disilicic and these are represented by the formulas H^4SiO^4, H^2SiO^3, $H^4Si^3O^8$ and $H^2Si^2O^5$. Professor P. Groth, however, points out* that polysilicic acid may be regarded as compounded of disilicic and metasilicic acids, since $H^2Si^2O^5+H^2SiO^3=H^4Si^3O^8$. This method of viewing these compounds has the advantage of reducing the acids to three in number. On the other hand polysilicates (orthoclase and albite) are among the most abundant substances in the accessible portion of the earth, while disilicates are extremely rare, and are commonly considered as being represented only by petalite and milarite. The latter is known in but one locality, and petalite is very sparsely distributed. If disilicic acid is really a constituent of the alkaline feldspars, it seems strange that it should not more often appear independently. The other hypothetical component of polysilicic acid is little less common than polysilicic acid itself.

The series of acids may be simplified in another way to which I have seen no reference. Orthosilicic and polysilicic acids may be conceived as united to form metasilicic acid, for

$$H^4SiO^4+H^4Si^3O^8=4H^2SiO^3.$$

On this hypothesis also the acids are reduced to three, and, furthermore, the acids supposed to unite are each very abundant in nature. This is a distinct advantage. There seem also some grounds in the behavior of the silicates favorable to this view of their constitution. It is known that the metasilicates of a metal are more stable than the orthosilicates. Now if a molecule of an orthosilicate combines with a molecule of a polysilicate, the union of the two must be attended with the liberation of heat and the compound must be more stable than its proximate constituents. In so far the behavior of the metasilicates accords with the hypothesis.

Again, the most important metasilicates are the amphiboles and pyroxenes, and, as Groth remarks, these two series afford most remarkable examples of the crystallization of the same substances in forms belonging to three different crystallographic systems, yet presenting extraordinary similarity in their angles. Such relations seem more readily reconcilable with the hypothesis that these ferro-magnesian minerals are double compounds of two acids than with the theory that they are substitution products of a single acid. One can easily im-

* Tabell. Uebersicht der Min., 1882, p. 75.

agine diopside (for example) as a calcium salt of A combined with a magnesium salt of B, and tremolite as a magnesium salt of A in combination with a calcium salt of B. Uralitization would then be represented as an interchange of bases between the two acids. The modulation from one crystallographic system to another is no doubt due to substitution, however these metasilicates may be regarded, but the dimorphism which extends throughout the two series yielding pyroxenes and amphiboles of similar composition, shows that the basic molecules are united with the acid groups in two distinct ways and, in the non-aluminous members of the series, it is difficult to see how this can be unless the acid is complex.

Were the metasilicates and particularly the pyroxene-amphibole group to be considered as ortho-polysilicates they would present a close parallelism to the composite feldspars. Nearly all mineralogists now accept the theory of isomorphous mixtures of anorthite and albite. The former is of course an orthosilicate and the latter a polysilicate. These isomorphous mixtures would seem to represent in reality some slight chemico-physical reaction between the components for, if no energy were depotentialized in the formation of the mixtures, these would have no tendency to form, and if energy is dissipated by the union of albite and anorthite, some action (perhaps comparable to solution) must occur. That these isomorphous mixtures should be accompanied in nature by double salts of the same acids, but in part containing different bases, seems very natural. The hypothesis that the metasilicates are double salts evidently does not preclude the theory that they too are sometimes isomorphous mixtures.

The studies of Messrs. Brush and E. S. Dana on the spodumene of Branchville* show that when this pyroxene undergoes decomposition, a part of the lithium is replaced by sodium, and that the mineral breaks up into eucryptite and albite. This decomposition can be neatly exhibited in accordance with the hypothesis here suggested by means of structural formulas similar to those which Prof. F. W. Clarke has so effectively employed. Spodumene† and its decomposition-products may then be represented by

$$
\begin{array}{lll}
\;\;\;\diagup Si^2O^6 \equiv Li^3 & \;\;\;\diagup Si^3O^8 \equiv Na^3 & \;\;\;\diagup SiO^4 \equiv Li^3 \\
Al - Si^2O^6 \equiv Al & Al - Si^3O^8 \equiv Al & Al - SiO^4 \equiv Al \\
\;\;\;\diagdown Si^2O^6 \equiv Al & \;\;\;\diagdown Si^3O^8 \equiv Al & \;\;\;\diagdown SiO^4 \equiv Al \\
\text{Spodumene.} & \text{Albite.} & \text{Eucryptite.}
\end{array}
$$

so that two molecules of spodumene, as here written, are resolved into one molecule each of the other minerals when one

* System of Mineralogy, App. III.

† Amer. Chem. Journ., vol. x, No. 2.

half of the lithium is replaced by sodium. In this case metasilicic acid actually breaks up into polysilicic and orthosilicic acid. Were the process of decomposition to be reversed, or were albite and eucryptite, together with some appropriate lithium compound, to be mingled under the physical conditions which prevailed when the spodumene formed, this pyroxene would be regenerated. This case consequently appears to demonstrate that a metasilicate, one indeed of a peculiarly important group of metasilicates, may be produced by the union of orthosilicic and polysilicic components.

It remains to be considered how disilicic acid is to be regarded. If the synthesis of molecules is practicable, the resolution of molecules is also feasible. Why then may disilicic acid not be considered as a polysilicic acid from which orthosilicic acid has been isolated? This process would be represented by

$$3H^4Si^3O^8 - H^4SiO^4 = 4H^2Si^2O^5.$$

Were such really the process by which disilicic acid is produced, one would expect to find some hints of it in the occurrence of the disilicates. As a matter of fact, petalite occurs at the original locality in Sweden with lepidolite, which is an orthosilicate similar in composition to petalite. Tschermak regards lepidolite as a mixture principally composed of the silicate (Li, K) $AlSiO^4$. If the formula of petalite is (Li, Na) $Al(Si^2O^5)^2$, as it is usually written, then two molecules of petalite might combine with the lepidolitic compound and they would yield three of a polysilicate (Li, K, Na) $AlSi^3O^8$, which is simply an orthoclase containing lithium. Such orthoclases are known to occur at various localities. It is also well-known that among the decomposition products of orthoclase, orthosilicates (muscovite, kaolin) are most abundant. These facts evidently suggest that petalite may have resulted from the separation of such a feldspar into two compounds.

The resolution of orthoclase into orthosilicates and other compounds is in progress in all parts of the world. Were disilicic acid strongly electronegative and its compounds of a stable character, one would expect therefore to find disilicate minerals frequently associated with decomposing granite. This expectation is not realized nor does it seem probable that the absence of such compounds is due to their solubility, for microscopical study shows that the separation of silica accompanies the decomposition of the feldspar in most cases.

Such facts seem to me to throw much doubt on the true character of the mineral petalite and these doubts are not resolved by study of the data. Some of the analyses must be considerably strained to give the formula usually accepted;

various formulas have been proposed, and Damour found the composition variable in the same specimen. Professor J. D. Dana* also suggests that a portion of the silica may be basic. On the whole it appears to me that the constitution of this mineral and of the allied milarite is insufficiently established, and that it is not as yet necessary to assume for them an acid not known to exist elsewhere.

The hypothesis that the silicates can be reduced to two series and their combinations would greatly simplify the discussion of eruptive magmas. This supposition would cover nearly the same ground as Bunsen's famous suggestion of a normal pyroxenic and a normal trachytic magma, afterwards more or less differently developed by Durocher and others. Magmas would then be composed of substitution products (acid, normal or basic) of polysilicic and orthosilicic acids.

U. S. Geol. Survey, San Francisco, March, 1889.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Vapor Density of Hydrogen fluoride.*—Thorpe and Hambly have confirmed by further experiments the opinion expressed by them a year or more ago that the process of breaking up by heat of the molecular grouping of hydrogen fluoride in the state of vapor, is analogous to that of acetic acid vapor, and that there is no evidence that a molecule corresponding to the formula H_2F_2 exists through any appreciable range of temperature. The commercial aqueous acid was purified by adding to it a strong solution of potassium permanganate and then potash, and redistilling from a platinum retort. The acid potassium fluoride was prepared either by adding the theoretical quantity of pure potassium carbonate to the hydrofluoric acid in a platinum dish, or by adding to the normal potassium fluoride the required quantity of the acid. The residue after evaporation was fused, and yielded on cooling a white opaque mass only slightly hygroscopic. About 40 grams of this salt were placed in a platinum-iridium retort, fitted, by grinding, to a condensing tube and receiver made of the same alloy. The condensing tube which was 50 cm. long was immersed in a mixture of calcium chloride and ice, which gave a temperature of $-25°$. The receiver was similarly cooled. To determine the vapor density, a platinum vessel of known weight and of a capacity of 288·6 c. c., was placed in a bath of glycerol at the required temperature and connected with the receiver containing the liquefied hydrogen fluoride. On surrounding this receiver with water at 25°, the liquid rapidly volatilized

* System of Mineralogy, 5th Edition.

and filled the vessel with its vapor. The temperature of the bath and the reading of the barometer being noted, the vessel was withdrawn from the bath, allowed to cool and weighed, the necessary corrections being applied in calculating the result. The experiments were made at temperatures varying from 26·4° (which is about 7° above the boiling point of hydrogen fluoride under normal pressure) to 88·1°. The vapor density was found to vary from 25·59 at the lower temperature, corresponding to a molecular mass of 51·18, to 10·29 at the upper temperature, corresponding to a molecular mass of 20·58. The results of the 14 experiments are given in a table, from which values a curve has been plotted, showing the law of the vapor density variation. From this it appears at once that the process of dissociation is a perfectly continuous one, and that if such a molecule as H_2F_2 exists, it must be formed only during a transition process and be capable of persisting only in the presence of definite proportions of molecules both more and less complex than itself. At about 32° the density apparently corresponds with H_2F_2, but the curve gives no indication of statical equilibrium in the neighborhood of this temperature such as would be manifest were such a molecule capable of an independent existence. "At temperatures below this point, the vapor-density gradually increases in a regular manner until at 26·4°, the lowest temperature observed, the vapor-density becomes 1·773 (air=1) equivalent to a molecular mass of 51·2 (H_3F_3=60); as it is heated the vapor behaves like a mixture of a complex molecule H_xF_x or of H_xF_x and H_yF_y molecules with a gradually increasing number of molecules of HF, the process of dissociation being perfectly continuous until the temperature increases to about 60° when the density becomes approximately normal; that is, corresponds to a vapor consisting wholly of HF molecules."—*J. Chem. Soc.*, lv. 163, April, 1889.

G. F. B.

2. *On the decomposition of Potassium chlorate by heat, in presence of Manganese dioxide.*—McLeod has studied the nature of the reaction which takes place in the ordinary method of preparing oxygen by heating a mixture of potassium chlorate and manganese dioxide. He concludes that the mechanism of the action of the manganese oxide on the chlorate is probably as follows: First, the formation of permanganate, chlorine and oxygen according to the reaction $(KClO_3)_2 + (MnO_2)_2 = K_2Mn_2O_8 + Cl_2 + O_2$; since chlorine is certainly evolved at the commencement of the action. Second, the permanganate is decomposed by the heat, producing manganate, an oxide of manganese and oxygen; a reaction which may be written in the ordinary way $K_2Mn_2O_8 = K_2MnO_4 + MnO_2 + O_2$. The third stage is not quite so clear. It is very improbable, the author says, that the manganate is transformed into permanganate by the oxygen from the chlorate, for in certain of the experiments in which permanganate and chlorate were heated together, manganate remained in the residue. He regards it as more likely that the manganate is acted on by more chlorine produced by the action of the peroxide on fresh

chlorate thus, $K_2MnO_4 + Cl_2 = (KCl)_2 + MnO_2 + O_2$. Indeed he has found that on passing chlorine into the residue obtained by heating potassium permanganate, this residue being heated in the vapor of mercury, the chlorine is absorbed and oxygen is evolved. But here however the action goes further, the manganese being also transformed in part into chloride. That this change does not take place in the preparation of oxygen is evident from the fact that the solution obtained by extracting the residue with water does not contain manganese; and moreover, manganous chloride in presence of potassium chlorate at a high temperature is immediately converted into an oxide with evolution of chlorine. The absorption of the chlorine by the manganate too accounts for the very small quantity of chlorine finally obtained, amounting in the author's experiment to only 6 per cent of the peroxide as a maximum, and this in an exceptional case; the probable average being not over one per cent.—*J. Chem. Soc.*, lv, 184, April, 1889.
G. F. B.

3. *On the synthesis of Formic aldehyde.*—JAHN has succeeded in effecting the direct synthesis of formic aldehyde in a very simple manner. In the course of his investigations upon the volumetric determination of hydrogen by means of palladium he observed that the presence of carbon monoxide exerted a disturbing action upon the occlusion of the hydrogen. Attributing this effect to the possible direct union of the carbon monoxide with the hydrogen under these conditions, he repeated his experiments with suitable modifications and passed a mixture of carbon monoxide and hydrogen over palladium sponge, and then through potash bulbs containing water. Although very little condensation took place, apparently, the water acquired a weak odor of aldehyde; and the solution, obtained from two liters of the gas mixture, gave very distinctly the reducing action characteristic of aldehyde and produced an excellent silver mirror. In view of the synthesis of the sugar formose $C_6H_{12}O_6$ by Loew by the action of calcium hydrate on formaldehyde, this synthesis of the latter substance makes it possible to build up a glucose very directly from its elements.—*Ber. Berl. Chem. Ges.*, xxii, 989, May, 1889. G. F. B.

4. *On the identity of Seminose and Mannose.*—A short time ago Reiss showed that a constituent of certain seeds, hitherto supposed to be cellulose, afforded on hydrolyzation a sugar, to which he gave the name seminose. Although its hydrazone showed the closest similarity with that of mannose, yet its behavior with lead acetate led Reiss to regard it as a different sugar. E. FISCHER and HIRSCHBERGER have re-examined the behavior of mannose with lead acetate and have found that contrary to their earlier statement, this sugar is precipitated by lead acetate, and therefore agrees in this regard with seminose. The authors have produced mannosoxime by the action of hydroxylamine hydrochlorate on mannose, and have found its melting point to be between 176° and 180°; Reiss having found 176° for the melting point of seminosoxime. So also the not quite pure

phenyl-hydraxone from mannose fused at 188°, while that from seminose fused at 185°–186°. It seems probable, therefore, that seminose is identical with mannose, thus confirming the view of the authors that mannose exists in the vegetable kingdom in the form of its anhydride.—*Ber. Berl. Chem. Ges.*, xxii, 1155, May, 1889. G. F. B.

5. *On the Synthesis of Uric acid.*—The determination of the constitution of uric acid analytically has promptly been followed by its synthesis. Although Horbaczewski first produced this substance artificially by fusing together urea and glycocine, yet the reaction was complicated, the yield small, and the stages could not be traced. BEHREND and ROOSEN have now succeeded in building up this substance by a series of simple steps all clear and distinct as to their results. As the starting point, isobarbituric acid was employed; a substance already synthesized by Behrend as follows: (1) by the action of aceto-acetic ether upon urea, an ether of β-uramidocrotonic acid is produced; (2) by saponification with potash, the potassium salt of the corresponding acid is obtained, the acid itself splitting into its anhydride and water; (3) this anhydride called methyl-uracil, when treated with fuming nitric acid, yields nitro-uracil-carbonic acid; (4) this, on boiling with water, loses a molecule of carbon dioxide and produces nitro-uracil; and (5) nitro-uracil by reduction with tin and hydrogen chloride, gives partly amido-uracil and partly isobarbituric acid. By the action of bromine water, isobarbituric acid is oxidized to iso-dialuric acid, the ureide of dioxy-pyroracomic acid,

$$\begin{array}{lll} NH & - & CHOH \\ | & & | \\ CO & & C<^{OH}_{OH} \\ | & & | \\ NH & - & C \end{array}$$

And by heating the isodialuric acid with an equal weight of urea and six times its weight of sulphuric acid on a water bath for five minutes, the uric acid falls as a reddish crystalline powder, which becomes white after washing, dissolving in potash solution and reprecipitating. The yield is about 30 to 32 per cent of the theoretical. The artificial uric acid is identical in its properties with the natural product. This synthesis therefore confirms the constitution of uric acid given by Fischer and Medicus

$$\begin{array}{lllll} NH & - & C & - & NH \searrow \\ | & & \| & & \\ CO & & C & - & NH \nearrow CO \\ | & & | & & \\ NH & - & CO & & \end{array}$$

—*Liebig's Annalen*, ccli, 235, April, 1889. G. F. B.

6. *Crystallized Tungsten;* by ROBERT N. RIDDLE. (Communicated).—In an attempt made in May, 1888, to investigate tungsten alloys of iron, a mixture of powdered Lake Superior hematite and tungsten trioxide in proportion to yield when reduced 75 per cent iron and 25 per cent tungsten, with enough carbon to reduce them both to metal, was put into a graphite crucible, together with sufficient borax to flux the mass, and was intensely heated in a coke fire for several hours. The fire was then banked,

and the crucible allowed to cool gradually through the night. The button, weighing about six ounces after removing the slag, was found to be covered with small, very brilliant crystalline faces. Pieces of the alloy were then broken up, and digested for several days, in hot hydrochloric acid. The crystals unaltered and but very slightly dimmed, remained separated from the mass of the alloy. Except on the one face, the crystals were not brilliant enough to be measured by the reflecting goniometer. Such as could be obtained appeared to be like trigonal prisms, and were inferred to belong to the triclinic system. Their hardness was above 7, so that they easily scratched quartz, and they were quite brittle. Specific gravity, 15½ to 16. Color, steel gray. Analysis showed 99½ to 98 per cent tungsten, with trace to 2 per cent iron. Carbon was probably present but was not determined. After pulverizing, and heating for three days with concentrated hydrochloric acid, the tungsten was not acted on, and the hydrochloric acid contained no tungstic acid. An alloy of tungsten with nickel shows even more tendency to form the crystals of tungsten.

University of Pennsylvania.

7. *Influence of Solar radiation on Electrical phenomena in the Atmosphere of the Earth.*—Sv. Arrhenius concludes, from a series of investigations, that the air irradiated by ultra violet light conducts like an electrolyte. On Peltier's hypothesis that the earth is charged negatively Arrhenius endeavors to explain the electrical phenomena of the earth as the result of solar radiation. The solid and liquid particles suspended in the air carry the electricity which they obtain from the earth by conduction when the air becomes a conductor under the influence of the sun's rays. Feeble electrical currents exist in the air as a result of this carrying process. On cloudy days the fall of potential is much lower than on bright days. Hail is for the most part negative, while snow is occasionally positive because it occurs at periods when the sun's action is the weakest. These facts the author thinks support his theory. The positive fall of potential noticed in morning fogs he believes is due to the sun not having acted on the fog. A table of Quetelet is referred to which shows, from many years' observations, that the monthly mean of the strength of atmospheric electricity is the less the greater the monthly mean of the solar radiations measured by the actinometer. Thunder storms result from the effects of solar radiation, and are most frequent in hot countries, in the summer, and in the afternoons. The lagging of the maximum occurrence of thunderstorms behind the maximum of solar radiation the author attributes to the time required for the charge and the coalescence of individual drops. Cyclonic storms, occurring at night and in winter, are supposed to be brought from southern regions. The yearly and daily periods of atmospheric electricity are in accordance with this theory. Since the greater part of the active solar radiation is absorbed in the upper regions, these must conduct better than the lower layers of air. Since these upper layers of air are moving strongly from west to east round the earth, a conductor would be obtained under the influence of the sun's rays

which would rotate about a magnet—the earth. By unipolar induction electromotive forces must be set up which would drive the electricity in the higher atmosphere from the equator to the pole. The auroræ boreales and the daily variations of terrestrial magnetism would be referred to these phenomena.—*Phil. Mag.*, July, 1889.—*Meteor. Zeitschrift*, v, 297, 1888. J. T.

8. *Disruptive discharges in gases.*—M. WOLF concludes from his investigations that:

(1) The electrical force required for disruptive discharge in different gases, between spheres of 5 cm. radius at a distance of 0·1 cm., increases with the pressure of the gas between 1 and 9 atmospheres.

(2) The increase of electrical force for an increase of pressure up to one atmosphere is for simple gases, oxygen, hydrogen, nitrogen and atmospheric air, inversely proportional to the mean wave-length of the gas molecule.

(3) With carbonic acid gas the product of the increase of electrical force, for one atmosphere increase of pressure, into the mean wave-length is noticeably smaller (about one-half) than with simple gases.

(4) One or more discharges are needed before the normal resistance of the gas is reached. The resistance also is smaller in comparison with that of later discharges the higher the pressure of the gas.—*Ann. der Physik und Chemie*, No. 6, 1889, pp. 306–315. J. T.

9. *Selective reflection of Metals.*—H. RUBENS has carried out at Strassburg and in Berlin under Kundt a research upon this subject. The apparatus consisted of a spectroscope, the eye-piece of which was replaced by a bolometer. By a mechanical arrangement a standard lamp could replace the metallic mirrors from which the light was reflected, and thus a comparison could be made, the lamp being placed in the position of its virtual image. The ratio of the heat measures gave the selective absorption of the mirror under examination for the wave-length λ.

The following table exhibits the results:

	Silver.	Gold.	Copper.	Iron.	Nickel.
0·45 μ	87·0	43·4	53·0	58·7	61·7
0·50 "	88·3	56·1	54·8	57·7	61·0
0·55 "	90·3	71·1	70·0	56·1	62·1
0·60 "	92·7	80·5	77·7	57·6	63·4
0·65 "	93·3	85·3	80·7	59·6	65·8
0·70 "	94·5	90·3	83·3	61·4	67·8
0·80 "	95·2	92·4	85·4	63·6	70·4
0·90 "	95·8	95·2	87·3	64·7	73·1
1·00 "	96·5	96·8	88·9	69·0	77·4
1·15 "	97·0	97·3	89·5	72·3	80·4
1·40 "	97·4	97·0	91·3	74·3	81·7
1·65 "	97·7	97·0	93·0	78·4	83·9
2·00 "	97·3	95·4	93·9	80·5	84·5
2·3 to 2·7 μ	97·0	89·0	95·0	86·6	88·0
2·7 to 3·2 "	98·3	84·2	96·4	89·6	91·7

—*Ann. der Physik und Chemie*, No. 6, 1889, pp. 249–268. J. T.

II. Geology and Mineralogy.

1. *The Tertiary Volcanoes of the Western Isles of Scotland;* by Prof. John W. Judd, Q. J. Geol. Soc., Jan. 9, 1889.—A brief notice of this important paper by Prof. Judd, prepared from an abstract of it in the Geological Magazine of February last, is published on page 412 of the last volume of this Journal. The following are additional facts from the paper. Prof. Judd states that his memoir of 1874 was the outcome of five years' of personal investigation, and that the region has since been his frequent field of study. The present paper reviews the opinions held before 1874, commends strongly the conclusions of Macculloch with reference to the region, points out the divergences of later writers, and then the results of his own researches, confirming in the main Macculloch's views. One of the most important points brought out in that paper was the earliest establishment of the fact that "in a particular area there exists a complete transition of granitic into glassy rock, both in the acid and basic series," that is, "of granites and gabbros into pitchstones and tachylytes," thus establishing the true relation of the so-called *Plutonic* rocks to the *Volcanic*"—making it in that case a relation of identity as regards age, and of difference, but only small difference, in conditions of crystallization. The conclusion was then doubted by most geologists, and rejected by many; but now it is adopted by Prof. Geikie in his memoir on the same region and has gained general acceptance.

In the same paper of 1874, Prof. Judd presented the conclusion, now sustained by Prof. Geikie, that there were five well-marked centers of eruption—namely, Mull, Ardnamurchan, Rum, Skye and St. Kilda—where the eruptions were on a vast scale, attaining great thickness, with great numbers of dikes; "the largest of these intrusive masses, especially the nearly horizontal sheets, consist of gabbro and granite, while the smaller ones, the dikes and the peripheral portion of the great bosses and sheets, pass into dolerites, basalts and 'felstones' that are exactly similar to the materials of the lava-currents;" that "the basic intrusions tend to form wide-spread sheets, while the acidic ones assume those more bulky and lenticular forms for which the name 'laccolites' has since been proposed by Gilbert."

The Tertiary age and subaerial origin of the "Plutonic" and Volcanic rocks were shown in the paper of 1874, and these points also have been sustained by Prof. Geikie in his memoirs, the facts proving that "many of the rocks occurring among the Tertiaries present all the characters which would, if found among older rocks, cause them to be classed as 'porphyrites,' 'melaphyres,' 'diabases.'"

Prof. Judd does not admit that the evidence points to the conclusion that the acidic rocks of the Western Isles are of younger age than the more basic ones, and now holds that the interval between the acidic and basic outflows has no special importance as a period of quiescence, but that the change was a gradual one. He says: "Some of the 'felstones' are augite-andesites and labradorite-andesites, but little more acidic in character than the olivine-basalts of the great plateaus; and there are abundant examples of lavas of more or less acidic type having been erupted from the central vents from time to time, while the basalts were being ejected. But as I have formerly shown, while the extremely liquid basalts flowed to distances of 40 or 50 miles from their point of origin, the less fluid acidic lavas seldom flowed to distances of more than ten miles and are consequently found confined to the flanks of the volcanoes from which they issued."

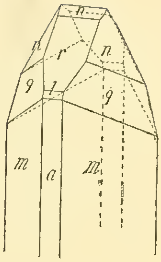
The paper treats at length of the question whether the great centers of eruptions were volcanic centers with subordinate fissures of eruption, or merely regions of grouped dikes, and sustains, as before, the former of these conclusions. He refers to the eruptions of Hawaii as favoring the view that very small angles of flow are the ordinary method with basaltic lava-streams. These angles over Mt. Loa and Kilauea vary, in general, from seven degrees to one, and on Oahu and Kauai, in the deep-cut gorges, usually from five degrees to one, and less than one.

2. *On the Genus Tubicaulis of Cotta;* by Dr. G. Stenzel, Prof. Realgymnasium at Breslau. 50 pp. 4to, with 7 plates, Mitth. Museum, Dresden, 8th Heft. Cassel, 1889, (Theodor Fischer).—This memoir is a full discussion of the fossil tree-ferns of the *Tubicaulis* type, both historical and descriptive, and a defining of species and genera pertaining to it. The *Tubicaulis Solenites* of Cotta, a Permian species, is illustrated by transverse sections on plates 1 and 2, and species of other genera on the following plates. The genera differ in the characters of the internal leaf-stems with their leaf-bundles. The genus Asterochlæna of Corda includes the Devonian species *Asteropteris Novaboracensis* of Dawson. Other genera described are Zygopteris and Anachoropteris of Corda. The earliest species are two of Asterochlæna in the Devonian; the larger number occur in the Permian.

3. *Faune du Calcaire d'Erbray* (*Loire Inférieure*), par Charles Barrois. 348 pp. 4to, with 17 plates. Mém. de la Soc. Geol. du Nord, Tome iii, April, 1889.—M. Barrois, after a stratigraphical account of the region, gives detailed descriptions of 200 species of fossils, with a critical discussion of many questions that come up in connection with them. The faunas of other Devonian regions of Europe are also brought into comparison, so that the work has geologically a continental importance. The relations to the American Devonian, with which he is familiar, are also considered. The figures on the seventeen plates are excellent.

4. *Notes on Epidote and Hanksite;* by Dr. C. Bodewig. (Communicated).—Epidote. The epidote which I bought last summer at Manitou Springs at the foot of Pike's Peak offered at first sight nothing worth publishing. A closer investigation showed that we have here the interesting case of a normally developed epidote.* While the epidote of other localities is developed

* Artini has recently described similar crystals from Elba.—Eds.



in the direction of the ortho-axis, that of Pike's Peak shows a prismatical development. It occurs with calcite on a base of altered pyroxene or amphibole. The crystals are 2–5^{mm} in length and breadth, and though the planes do not allow of accurate measurements, the latter are sufficient to identify the planes. The figure shows the habit of the crystal, which is a twin, with *a* as the twinning plane. The planes identified are *a* (100, T), *c* (001, M), *u* (210), *m* (110, *z* of most authors), *e* (10$\bar{1}$), *i* (102), N ($\bar{3}$04), *r* ($\bar{1}$01), *l* ($\bar{2}$01), *n* ($\bar{1}$11), *q* ($\bar{2}$21). Some of the measured angles are:

	Calc.	Meas.			Calc.	Meas.
$\bar{1}10 \wedge \bar{1}\bar{1}0$=	109° 56′	109° 50′		$\bar{1}00 \wedge \bar{4}03$=	64° 29′	64° 14′
$\bar{1}00 \wedge \bar{2}10$=	35 29½	35 26		$\bar{1}00 \wedge \bar{1}11$=	69 4	69 13
$001 \wedge 00\bar{1}$=	50 46	50 50	twin	$\bar{1}11 \wedge \bar{1}1\bar{1}$=	41 52	41 57
$101 \wedge 100$=	30 23	29 54		$001 \wedge \bar{1}11$=	75 11	75 27½
$\bar{1}00 \wedge \bar{1}01$=	63 42	63 25		$001 \wedge \bar{2}21$=	89 42	89 54

Hanksite.—A pyramidal crystal with polished planes, and in habit resembling figure 1 on p. 66 of the last volume of this Journal, gave the axial ratio $a : c = 1 : 1{\cdot}00564$, and the following measurements:

	Meas.	Calc.		Meas.	Calc.
oo (pyr.)	=*44° 31′		*mo*	=67° 44′	67° 44½
co	= 49 15½	49° 16′	*ms*	=23 12	23 17½

With HCl the substance effervesces; the solution tested with $BaCl_2$ gave only a comparatively small precipitate of $BaSO_4$. A new chemical investigation of the bright crystals may therefore be necessary. The only one in my possession is not pure enough for a chemical analysis.

5. *Plattnerite from Idaho;** by J. D. Hawkins and Edwin N. Hawkins. (Communicated).—In the early part of June, Mr. A. Chanute, Vice-President of the Globe Smelting and Refining Co., collected a specimen of plattnerite from the "As You Like" Mine, near Wallace, Shoshone Co., Idaho, which he gave to us for examination and analysis. The specimen, of the size of a large duck's egg, was superficially coated with limonite, and was of a nodular structure; color iron-black, streak chestnut-brown. The fracture was uneven, and showed a dense structure; hardness between 5·5 and 6, fusibility 2, and very easily reducible to metallic lead. The mean of three close determinations of the specific gravity of the mineral in powder was 7·25. This specific gravity seems to be more in accordance with the specific gravity of Massicot (8·0) than that given by Wheeler (9·46). Two analyses, on 1 and 0·5 grams respectively gave the following results:

PbO_2	90·99			91·03
ZnO	·07			(·07)
Insoluble in HCL.	2·96	{ SiO_2	2·68	3·00
		{ Al_2O_3	·28	
Fe_2O_3	5·69			5·86
	99·71			99·96

* Compare p. 79 of the July number.

The specimen was found in a fissure vein in quartzite rock, 100 feet below the surface. As all the lead of the surrounding country exists as galenite, the conclusion seems to follow that the mineral is a direct alteration from the sulphide.

Laboratory of The Globe Smelting and Refining Co., July 18, 1889.

6. *The Minerals of New South Wales, etc.*, by A. Liversidge, M.A., F.R.S. 326 pp. 8vo. London, 1888, (Trübner & Co.).—A thorough, well digested work on local mineralogy such as Professor Liversidge has given us is of great value to the mineralogical student. The author has already published two earlier memoirs on this subject, but this third edition has a much wider scope and constitutes an independent work. The subjects of the metals, as gold, silver, copper, tin, are treated with especial fullness and have more than a local interest. The author has also included the results of his own original work on many of the species. A large and well executed colored mineral map forms the frontispiece to this unusually handsome volume.

7. *Eighth Annual Report of the State Mineralogist of California*, for the year ending October 1, 1888. William Irelan, Jr., State Mineralogist. 948 pp. 8vo. Sacramento, 1888.—The present issue is the most extended of the series, and gives a detailed account of the mineral resources of the State, arranged according to counties. The number of subjects noticed will be appreciated from the fact that an index of 50 pages is needed to record the names of the different mines, mills, etc., which are mentioned in the volume.

III. Botany and Zoology.

1. *Beiträge zur Kenntniss der Oxidationsvorgänge in lebenden Zellen;* by Professor Pfeffer, of Leipzig. pp. 141, (from the fifteenth vol. of the Abhandl. der math-phys. Classe der Konigl. Sächsischen Gesellschaft der Wissenschaften. No. V. 1889.)—Professor Pfeffer presents the results of a systematic investigation regarding the action on vegetable cells, of peroxide of hydrogen. The experiments are characterized by his usual thoroughness and breadth of examination. He is led to believe that neither the substance referred to, nor any similar substance furnishing active oxygen, arises in living cells. The same is true of cell-sap. Hence the processes of oxidation in the living cell are effected in some other way than by simple imbibition into the protoplasm. G. L. G.

2. *Biologia Centrali-Americana*, or Contributions to the knowledge of the Fauna and Flora of Mexico and Central America. Edited by F. Ducane Godman and Osbert Salvin. Botany. Introduction (Vol. I, pp. ix–lxi) by W. B. Hemsley. Commentary on the Introduction and Appendix, (Vol. I, pp. lxii–lxviii) by Sir J. D. Hooker, and Appendix (Vol. IV, pp. 117–332) by W. B. Hemsley, 1888.—Mr. Hemsley's important addition to existing knowledge regarding Geographical Botany possesses a high degree of interest to American students. It contains analyses of

statistics and comparisons which have not before been attempted owing to scarcity of material. Although it is impossible to give within the narrow limits of this review even a partial idea of the facts upon which Mr. Hemsley's conclusions are based, the endeavor will be made in a future notice to indicate his method of exposition and to state the general results which he has reached. The present short mention can only give a few citations from Sir Joseph Hooker's "Commentary" above referred to, in order to outline two views relative to the primary divisions of the vegetation of the globe. In contrasting the two views, it may be well to keep in mind the practical division made by Mr. Thiselton Dyer, namely, into "Northern, Tropical, and Southern."

Mr. Hemsley's Introduction, with which the Commentary deals, comprises about 50 pages. It is devoted mainly to the presentation of general statistics regarding phanerogamous vegetation, its division into regions, and, especially, a contrast of the flowering plants of Mexico (including those of Central America) with those of India. The approaching completion of Hooker's "Flora of British India" renders this contrast for the first time possible. The areas contrasted are within nearly the same parallels of latitude, namely, 9° N. and 35° N. but they are separated by about 180° of longitude, the American 80° to 115° W., the Asiatic 70° E. to 95° E.

Of these widely separated regions, Sir Joseph Hooker says in his interesting commentary on Mr. Hemsley's work, "Each presents a hot and moist tropical, a temperate, and a frigid climate. It is impossible to find in the Old and New Worlds respectively, two areas more similar as to physical features, or in which the vegetation of their respective continents is more fully represented; and yet the comparison of their floras shows that with an almost total diversity of species genera and of many natural orders, the proportion of monocotyledonous to dicotyledonous plants is nearly the same in each; that the number of natural orders is only 12 fewer in Mexico; that the number of species in each differs by only 2000 (11,626 in Mexico, 13,647 in India); that the average number of genera in each order is nearly the same in each (11 in Mexico and 13 in India) that the average number of species in each genus even more nearly coincides (6·4 in Mexico and 6·0 in India), and more singular still, that the percentage of endemic species in each differs by only 2 per cent. It is instructive to observe that these marked resemblances in proportions do not arise out of a resemblance in the elements from which they are derived; for, turning to the natural orders that contribute most largely to the Flora of each area, they are very differently represented as to the number of species in each. Compositæ, which take the first place in the Flora of the globe and of Mexico, are reduced to the sixth place in India. Leguminosæ, which are second to Compositæ alone, are second in both Mexico and India, but Orchidaceæ, which hold the third place in the world and in Mexico, are first in India; Rubiaceæ, the fourth in the world are the seventh in Mexico and fifth in India; grasses are fifth in the world and in Mexico, but only third in India. Descending in the systematic scale to the lowest terms of the series, the differences between the elements of the two Floras become greater and greater until genera are reached; thus as Mr. Hemsley shows, only 25 to 26 per cent. of these are common to the two regions. As yet data do not suffice to ascertain the exact number of species common to India and Mexico, but it may not exceed 600 of the 25,273 which is approximately the sum of the species of both Floras." Sir Joseph does not discuss the nature or the origin of these striking likenesses and unlikenesses, but passes in his commentary to a brief account of what he conceives to be the primary Floras of the globe. He limits the primary botanical divisions of the globe to two, the Tropical and the Temperate, and for these primary divisions he suggests the name, Botanical Empires. The regions "next in importance to the two primary are in my view seven,—two north temperate, of the Eastern or Old, and Western or New World, respectively; two tropical, corresponding to the above; and three south temperate (America, Africa, and Australia)." For these regions he proposes the term Kingdom. With regard to "the exact geographical limitations of any of these seven botanical areas, such are possible only where geographical features present insuperable obstacles to the further spread of the plants that characterize them. Where two are conterminous, there is always a neutral ground, often a very broad one, and this neutral ground may itself present a Flora which may be regarded as either tropical or temperate."

Mr. Hemsley on the other hand, with the same statistics before him, proposes a different division. He thinks it possesses certain advantages over that suggested by Wallace for the distribution of animals:—these regions are the following,—(1) Northern, (2) Neotropical, (3) Palæotropical, (4) Andine, (5) Cape, (6) Australian. "The anomalous Sandwich Islands Flora and the fragmentary Antarctic Flora would be unattached in this as in the other."

Mr. Hemsley has given in the appendix a very valuable account of the distribution of the more prominent natural orders, and closes his work by a recapitulation of the dominant features of the Flora of Mexico and Central America, and remarks on its probable derivation. To them we hope to recur later. G. L. G.

3. *A Hand-book of Cryptogamic Botany;* by ALFRED W. BENNETT, M.A., B Sc., Lecturer on Botany at St. Thomas's Hospital, and GEORGE MURRAY, Senior Assistant Dept. Botany British Museum. 472 pp., 12mo, with 378 illustrations. London, 1889. (London and New York: Longmans, Green & Co.)—This small Hand-book covers all departments of cryptogamic botany. The parts on Vascular Cryptogams, Muscineæ, Algæ and Schizophyceæ are by Mr. Bennett, and those on Fungi, Mycetozoa and Schizomycetes by Mr. Murray; but the authors hold themselves "severally responsible for the whole contents of the volume."

This compact, well-printed volume contains a mass of details on the different orders of cryptogams, which will make it a valuable reference book for instructors and higher students. But the somewhat encyclopædic arrangement and lack of what may be called general perspective make it unsuited to the large class of students whose knowledge of the subject is elementary. The chief merit of the work is in the unusually full account of Algæ which are copiously illustrated. The part on Fungi is a condensation of other well-known treatises, and the condensation has been carried so far that this portion of the work seems to be crowded into a space quite disproportionate to its relative importance. The attempt of the authors to reform the terminology in common use on the basis of conformity to what they assume to be the rules of English etymology, is by no means to be commended. To let well enough alone should be the rule in science as elsewhere. W. G. F.

4. *Bathymetric conditions as to growing corals and other species of Tizard and Macclesfield Banks, in the China Sea*, by Commander W. U. Moore, R. N. and P. W. Bassett-Smith, Esq., Surgeon R. N.—The facts here cited are from a Report from the Hydrographic Department of the Admiralty, published in March last. On the Tizard bank it was found that live corals in blocks, and of more or less vigorous growth, occurred as far as a depth of 13 fathoms; and in small fragments, as far down as 32 fathoms; but at greater depths than this, no evidence of living corals was obtained with the dredge and swabs used, which "might drag over low blocks of Astræa or Porites without detaching species." "A living specimen of Astræa was found in one of the deepest parts of the lagoon at a depth of 45 fathoms, amongst fine green sand."

Where the section of soundings was through a part of the elevated rim of reef, which reached to the surface of the water, or when it was near such a part, a steep declivity was found somewhere on the slope between 7 and 30 fathoms. The lagoon banks were apparently crowned with dead coral; the floor was covered with sand, and the slope down to it was very gradual.

On the Macclesfield bank, coral was found living as far down the slope as 44 fathoms; it may extend farther, as the work was here suspended. There is no steep declivity at a moderate depth as in the Tizard bank, but there is an extraordinary drop between 65 and 115 fathoms.

5. *The Coral Reefs of the Hawaiian Islands ;* by A. Agassiz. Pp. 121 to 168 of vol. xvii of Bulletin Mus. Comp. Zool. Harvard College, with 13 plates. Cambridge, April, 1889.—In this paper Mr. Agassiz discusses the character of the Coral reefs, the elevated reefs, and the results of deep borings in the Hawaiian group. His views and conclusions are an important contribution to the subject of the origin of Coral reefs and islands.

6. *The Fisheries and Fishery Industries of the United States.* Prepared through the coöperation of the Commissioner of Fisheries and the Superintendent of the Tenth Census, by G. Browne Goode, Assistant Secretary of the Smithsonian Institution and staff

of Associations: Section V. *History and Methods of the Fisheries*, in two volumes with an atlas in quarto of 255 plates, volume ii, 882 pp., 4to. Washington, 1887.—The two quarto volumes just issued, one of plates, bear the date 1887, in which year they were ready for the printers, and, like vol. i, were therefore prepared under the active coöperation and superintendence of the late Commissioner Spencer F. Baird, whose name is at the head of the title page. The associate authors with Mr. Goode in the preparation of the volumes of Section V, are nineteen in number, all able in their departments. The subjects treated in the volume just issued are the Whale Fishery, the Blackfish and Porpoise Fisheries, the Seal and Sea-Otter Industries, the Turtle and Terrapin Fisheries, the Crab, Lobster, Crayfish, Rock-Lobster, Shrimp and Prawn Fisheries, the Leech Industry and Trepang Fishery, and the Sponge Fishery and Trade.

The Fish Commission has done a great work for the various industries represented, and incidentally a great work for science in the explorations of the ocean's depths and their species. It is a department in which economical and scientific investigations necessarily go hand in hand, and its results are vastly more important than is generally appreciated.

7. *Darwinism:* an exposition of the Theory of Natural Selection, with some of its applications; by Alfred Russell Wallace, LL.D., F.L.S., etc., 494 pp., 12mo, with maps and illustrations. London and New York, 1889 (Macmillan & Co.).—Dr. Wallace, who shares with Darwin the credit of first bringing forward and illustrating the principle of Natural Selection, is the best exponent of the subject living. His own travels and observations over all the world have given him a fund of facts in all departments of science which his familiarity with species, and clear-sighted vision, enable him to use to great advantage in the illustration of the subject. On some important points he diverges from Darwin, and this renders the work more discriminating and of much greater interest. The enquirer as to evolution, desiring to know what it is, and where it tends, should begin with Dr. Wallace's work.

IV. Astronomy.

1. *Researches on the Spectrum, Visible and Photographic, of the Great Nebula in Orion.*—Mr. Huggins has communicated to the Royal Society, in his own name and that of Mrs. Huggins, some important observations upon the spectrum of the nebula in Orion. In 1882 he described a new bright line in a photographic spectrum of the nebula, to which he assigned a wave-length of about 3730. Owing to the necessity of using a wide slit a more exact value could not be given.

On the 5th February, 1888, he photographed the spectrum with a narrow slit and found the same line and a pair of less conspicuous lines on the less refrangible side of the strong line. The continuous spectra due to two of the four bright stars or the *trapez-*

ium are also present; across which are at least four groups of bright lines of which the greater number can be traced into the nebula for some little distance from the stellar spectra. Mr. Huggins is led to infer that the stars of the trapezium are not optically projected on the nebula but are physically bound up with it and are very probably condensed out of the gaseous matter of the nebula; also that the nebula as a whole may not be at a distance from us greater than that which we should attribute to such stars if they occurred alone in the heavens.

On the 28th of February of this year he obtained another photograph, using a narrow slit, and was astonished not to find the strong line near 3730. He found, however, the pair that was on the less refrangible side of it, and two other pairs in the more refrangible region of the spectrum.

Mr. Lockyer, in his *Researches upon the Spectra of Meteorites*, has inferred that of seven nebular lines then known three belong to hydrogen and three to magnesium. One of these latter lines, near 5005, is in the visible spectrum, and Mr. Huggins has tested a part of Mr. Lockyer's inference by direct comparison of the magnesium spectrum with that of the nebula. From these, and from various observations of other astronomers, Mr. Huggins concludes "that the remarkable spectrum of the gaseous nebulæ has not been produced by burning magnesium." H. A N.

V. Miscellaneous Scientific Intelligence.

1. *Elizabeth Thompson Science Fund.*—The following circular has been issued by the Trustees of this fund, of whom Dr. H. P. Bowditch is President:

This fund, which has been established by Mrs. Elizabeth Thompson, of Stamford, Connecticut, "for the advancement and prosecution of scientific research in its broadest sense," now amounts to $25,000. As accumulated income is again available, the trustees desire to receive applications for appropriations in aid of scientific work. This endowment is not for the benefit of any one department of science, but it is the intention of the trustees to give the preference to those investigations *which cannot otherwise be provided for*, which have for their object the advancement of human knowledge or the benefit of mankind in general, rather than to researches directed to the solution of questions of merely local importance.

All applications should be forwarded to the Secretary of the Board of Trustees, Dr. C. S. Minot, Harvard Medical School, Boston, Mass., U. S. A.

It is intended to make new grants at the end of 1889.

*** The trustees are disinclined, for the present, to make any grant exceeding five hundred dollars ($500); preference will be given to applications for smaller amounts.

2. *The Assayer's Manual: an abridged treatise in the docimastic examination of ores, and furnace and other artificial*

products, by BRUNO KERL; translated from the German by W. T. BRANNT. Second American edition, edited with extensive additions by F. LYNWOOD GARRISON. 354 pp. 8vo. Philadelphia, 1889, (Henry Carey Baird & Co.).—This standard and well known work on assaying appears now in its second American edition, increased in completeness and value by the large amount of new and useful matter added by the editor. It gives a clear and concise statement of the methods employed in assaying. The first quarter of the work is devoted to a general discussion of the mechanical manipulations, the chemical processes, assay furnaces, implements and reagents, and the remainder gives the special methods applicable to the different metals. The figures are models of clearness and the whole execution reflects credit upon the publishers as well as upon the editor.

Catalogue of Fossil Fishes of the British Museum, Part I, containing the Elasmobranchii by Arthur S. Woodward, F.G.S., F.Z.S., 474 pp. 8vo, with 17 plates. London, 1889.

La Nouvelle Guinea, IIIe Notice, Le Fleuve Augusta, by Prince R. Bonaparte. 16 pp., with a map. Paris, 1887; and IVe Notice, Le Golfe Huon, 62 pp., with maps.—By the same: Note on the Lapps of Finmark, Paris, 1886, 12 pp.

Glaciation of British Columbia and adjacent regions, by G. M. DAWSON (Geol. Mag., Aug., 1888).

OBITUARY.

JOHN PERCY, M.D., F.R.S.—Dr. Percy, of the Royal School of Mines, the distinguished metallurgist, author of an invaluable series of treatises upon metallurgy, died June 19, 1889, at the age of seventy-two.

MARIA MITCHELL.—Miss Maria Mitchell, the astronomer, died at Lynn, Massachusetts, on the 28th of June, having nearly finished her seventy-first year. The interest which her father, Mr. Wm. Mitchell, of Nantucket, had in mathematics and astronomy, and his telescope, led to the development of similar tastes in the daughter. From the age of eighteen to thirty-eight she was librarian of the Nantucket Athenæum; but her spare time was given to mathematical studies and astronomical observations, and in October, 1847, she made the discovery of a comet, for which she received a comet gold medal from the King of Denmark. In her later astronomical work she devoted herself particularly to the study of the satellites and surface of Jupiter. In 1865 Miss Mitchell became Professor of Astronomy and Director of the Observatory at Vassar College, Poughkeepsie, N. Y., a position she held, with honor to the institution, until January, 1888.

Miss Mitchell was early elected a member of the American Academy of Arts and Sciences of Boston. The degree of LL.D. was conferred on her by Dartmouth College in 1852, and by Columbia College in 1887. On her return from Europe, where she went in 1858 to see observatories, and met with a welcome from many astronomers, she found a welcome back in the form of a telescope purchased for her by American friends.

APPENDIX.

Art. XXI.—*Notice of Gigantic Horned Dinosauria from the Cretaceous*; by Professor O. C. Marsh.

The remarkable reptiles which the writer recently described, and placed in a new family, the *Ceratopsidæ*,* prove to be more and more wonderful as additional specimens are brought to light. There appear to be two or three genera, and several well-marked species, already discovered, and the object of the present paper is to notice briefly some of their characteristic features so far as investigated.

Triceratops horridus, gen. nov.

The animal described by the writer as *Ceratops horridus*† possesses some remarkable characters not before known in the *Dinosauria*. In addition to the pair of massive horn-cores on the top of the skull, there is a third horn-core on the nose. This is median, as in the Rhinoceros, and is placed on the end of the nasals, which are firmly coössified to support it.

The edentulous premaxillaries are compressed anteriorly, and are strongly coössified with each other and with a third bone in front, which corresponds to the pre-dentary bone below, the whole forming a projecting beak, like that of a tortoise. Over all, there was, evidently, a huge horny covering, like the beak of a bird.

The bone in front of the premaxillaries has apparently not before been observed in any vertebrate, and may be called the rostral bone (*os rostrale*). It is analogous to the pre-nasal ossification of the pig, and of the *Dinocerata*.

Other portions of the skull show features not before seen in the *Dinosauria*. There is a huge occipital crest, extending backward and outward. In the present specimen, this is bent downward at the sides, like the back part of a helmet, thus affording, in life, strong protection to the neck.

* This Journal, vol. xxxvi, p. 477, December, 1888.
† *Ibid.*, vol. xxxvii, p. 334, April, 1889.

The lower jaws are massive, and were united in front by a strong pre-dentary bone. This is pointed anteriorly, and its surface marked by vascular impressions, showing that it was covered with horn, and fitted to meet the beak above.

The skull appears to have been at least two metres in length, aside from the horny beak. It represents a genus distinct from the type of the family, which may be called *Triceratops*. This interesting specimen, which has recently been received at the Yale Museum, was discovered by Mr. Charles A. Guernsey and Mr. E. B. Wilson, in the Laramie formation of Wyoming.

Triceratops flabellatus, sp. nov.

A second specimen of still greater dimensions has since been found at another locality of the same formation, by Mr. J. B. Hatcher. The skull, lower jaws, and a considerable portion of the skeleton, were found together. A striking peculiarity of this skull is the occipital crest, which extends upward and backward, like an open fan. Its margin was armed with a row of horny spikes, supported by separate ossifications, some of which were found in position.

The skull as it lay in the rock measured more than six feet in length, four feet in width, and the horn-cores about three feet in height. These dimensions far surpass any of the *Dinosauria* hitherto known, and indicate to some extent the wonderful development these reptiles attained before their extinction at the close of the Cretaceous.

Triceratops galeus, sp. nov.

A much smaller species is represented by various remains probably from the same horizon, in Colorado. In this species, the nasal horn-core is especially characteristic. It is compressed longitudinally, and its apex is pointed, and directed well forward. It is on the extremity of the nasals, and is thoroughly coössified with them. In front, at the base, it shows indications of union with the premaxillaries, but this connection was slight.

The type specimen was found in Colorado, by Mr. G. H. Eldridge, of the U. S. Geological Survey. The known remains indicate an animal about twenty-five feet in length.

The bison-like horn-cores figured in this Journal (vol. xxxiv, p. 324), probably belong to a member of this group, as already suggested by the writer.* They were sent to him from a locality in which he had himself collected Mastodon remains and other Pliocene fossils. As they agreed in all anatomical

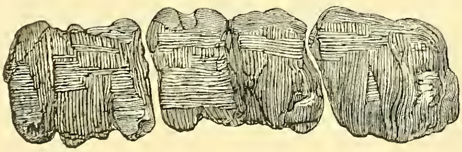
* This Journal, vol. xxxvii, pp. 334.

characters with the remains of cavicorn mammals from that formation, they were referred to the genus *Bison*, under the name *B. alticornis*. The writer has since learned that they were found in the Denver beds, which, although regarded as Tertiary, are probably Cretaceous. Under these circumstances, this well-marked species may be known as *Ceratops alticornis*, until additional remains make certain its true nature.

Nodosaurus textilis, gen. et sp. nov.

Another new member of the *Stegosauria*, from a lower horizon in the Cretaceous, was discovered several years since, in Wyoming, and is now in the Yale Museum. The skull is not known, but various portions of the skeleton were secured. One characteristic feature in this genus is the dermal armor, which appears to have been more complete than in any of the American forms hitherto found. This armor covered the sides closely, and was supported by the ribs, which were especially strengthened to maintain it. In the present specimen, portions of it were found in position. It was regularly arranged in a series of rounded knobs in rows, and these protuberances have suggested the generic name.

Near the head, the dermal ossifications were quite small, and those preserved are quadrangular in form, and arranged in rows. The external surface is peculiarly marked by a texture that appears interwoven, like a coarse cloth. This has suggested the specific name, and is well shown in the cut below.



Dermal ossicles of *Nodosaurus textilis*, Marsh. Natural size.

The fore limbs are especially massive and powerful, and are much like those of the Jurassic *Stegosaurus*. There were five well-developed digits in the manus, and their terminal phalanges are more narrow than usual in this group. The ribs are T-shaped in transverse section, and thus especially adapted to support the armor over them. The caudal vertebræ are more elongate than those of *Stegosaurus*, and the middle caudals have a median groove on the lower surface of the centrum.

The animal when alive was about thirty feet in length. The known remains are from the middle Cretaceous of Wyoming.

New Haven, Conn., July 24th, 1889.

Art. XXII.—*Discovery of Cretaceous Mammalia.* Part II; by Professor O. C. Marsh. (With Plates VII and VIII.)

In the last number of this Journal, the writer announced the discovery, in the Cretaceous, of many remains of *Mammalia*, and gave brief descriptions, and figures, of some of the more important forms secured.* The present article is a continuation of the same subject, and contains notices of other new species from the same localities, together with some additional information in regard to those first described. In a future article, the relations of these various forms to each other, and to other Mesozoic Mammals will be discussed.

Cimolomys digona, sp. nov.

A species of this genus, somewhat larger than those described, is represented by various remains, the most characteristic of which is the tooth figured on Plate VII, figures 1–4, which may be considered the type specimen. The crown is elongate, rounded in front, and angular at the posterior corners. It is apparently from the left side, and has nine cones in the outer row, and ten in the middle row. In the inner row, there are eleven cones, the posterior ones being minute. The square end of the crown indicates that it adjoined another tooth behind it. This specimen is from the Laramie of Wyoming.

The remains now known of this genus represent a distinct family, which may be called the *Cimolomidæ*.

Selenacodon brevis, sp. nov.

A second smaller species of this genus is indicated by a number of teeth, one of which is figured on Plate VII, figures 9–12, and may be regarded as the type. This tooth is an upper molar, apparently from the left side, and the form of its crown is well shown in the figures named. The front of the crown is rounded and narrow, while the posterior end is broad, and slightly concave, indicating another molar behind it. The valleys between the rows of cones are less deep than in the larger species, a typical molar of which is shown on the same Plate, figures 5–8.

The specimens representing the present species were found in Wyoming, in the Laramie.

* This Journal, vol. xxxviii, pp. 81–92, plates ii–v, July, 1889.

Stagodon nitor, gen. et sp. nov.

The present genus is based on a number of molar and premolar teeth, some of which were found together, but may pertain to separate individuals. The striking character of all the molar teeth secured is the resemblance of their crowns to a drop of viscous fluid, and this is shown in the figure of the type specimen, Plate VII, figures 22–25. This is probably a lower molar, as it has but two fangs.

The premolar represented on Plate VII, figures 17–21, has the same general rounded character, but the form shows its position. This tooth has a portion of the maxillary attached to it. It represents a larger species, which may be called *Stagodon tumidus*.

These remains evidently represent a distinct family, which may be called the *Stagodontidæ*. They are from the Laramie of Wyoming.

Platacodon nanus, gen. et sp. nov.

A number of peculiar teeth, very diminutive in size, have been found in the Laramie. Although evidently mammalian, it is impossible at present to make out their exact affinities. The three teeth represented on Plate VIII, figures 4–12, were found together, and apparently form a series from one jaw. They may be considered as the type. They resemble somewhat, in form, the flattened molars of *Chrysochloris*, but they are more probably premolars. Their main features are well shown in the figures. They indicate an animal about as large as a shrew, and are from the Laramie of Wyoming.

Oracodon anceps, gen. et sp. nov.

A number of peculiar teeth, mostly premolars, represent a very distinct genus, the affinities of which are doubtful. The type specimen is shown on Plate VIII, figures 13–16. It is apparently a lower premolar from the right side, and was implanted by two strong fangs. The crown consists of one main cone, with two small tubercles behind, placed transversely, and three in front. Two of the latter are in the same row with the main cone, and one smaller is on the inner side. The top of the main cusp is worn, mostly on the outside.

This specimen is from the Laramie of Wyoming.

Allacodon lentus, gen. et sp. nov.

The present genus, which appears to be nearly allied to *Allodon* of the Jurassic, is represented by a number of teeth, several of which were found together. The upper molar shown on Plate VIII, figures 22–26, may be taken as the type. The upper molars secured resemble the corresponding teeth of *Allodon*, but the cones are more pointed, and there is no true basal ridge.

The tooth represented in figures 27–31 of the same Plate may pertain to the same individual as the type. The premolar with three cones, represented in figures 17–21, is referred to the same species, and may belong with the type specimen.

A second, very diminutive, species is represented by several teeth but little larger than those of the Jurassic forms. The type has a crown with four cones, nearly equal. This species may be called *Allacodon pumilus.* All the known remains of this genus were found in Wyoming, in the Laramie.

These fossils evidently belong to the family named by the writer, the *Allodontidæ*, which includes the American genus *Allodon*, and *Bolodon* from the Jurassic of England.

Halodon formosus, sp. nov.

A diminutive species, apparently of this genus, is represented by several specimens, of which the fourth premolar figured on Plate VIII, figures 36–39, may be taken as the type. The crown of this tooth is very low, and elongate. There are eight ridges on the outer side, and twelve tubercles along the upper margin, the two anterior and the two posterior ones having no ridges connected with them.

The lower incisor represented on the same Plate, figures 32–35 probably belongs to this species.

The known specimens are from the Laramie of Wyoming.

Didelphops (*Didelphodon*).

The name *Didelphodon*, proposed by the writer in Part I, for a genus of mammals allied to the modern opossums, proved to be essentially pre-occupied, and was changed in the *errata* to *Didelphops.* A specimen of this genus, apparently belonging to *D. vorax*, has one character that distinguishes it strongly from the genus *Didelphys.* The palate is perforated by a large median aperture. This is not due to imperfect ossification, as seen in the palate of the opossum, and other existing marsupials, but the opening has a well-defined thickened margin. This orifice appears to have been functional, and may represent the posterior nares. If functional, the vacuities in recent forms are probably remnants of the same cavity.

The allied genus *Cimolestes* may be distinguished from *Didelphys* by the fact that the teeth in the lower jaw form a continuous series, there being no diastema.

The fossils here briefly noticed are from the same horizon in the Laramie as those previously described by the writer. Most of them are from the same localities, which have been very carefully explored by Mr. J. B. Hatcher and party. In this work, important aid has been rendered by Dr. C. E. Beecher, assistant in the Yale Museum.

New Haven, Conn., July 25th, 1889.

Explanation of Plates.

Plate VII.

Figures 1–4.—Upper molar tooth of *Cimolomys digona*, Marsh.

Figures 5–8.—Upper molar of *Selenacodon fragilis*, Marsh.

Figures 9–12.—Upper molar of *Selenacodon brevis*, Marsh.

Figures 13–16.—Premolar of *Cimolomys digona*.

Figures 17–21.—Upper premolar of *Stagodon tumidus*, Marsh.

Figures 22–25.—Lower molar of *Stagodon nitor*, Marsh.

Figures 26–29.—Upper incisor of *Dipriodon robustus*, Marsh.

Plate VIII.

Figures 1–3.—Lower incisor of *Selenacodon brevis*.

Figures 4–6.—Tooth of *Platacodon nanus*, Marsh.

Figures 7–9.—Tooth of *Platacodon nanus*.

Figures 10–12.—Tooth of *Platacodon nanus*.

Figures 13–16.—Lower premolar of *Oracodon anceps*, Marsh.

Figures 17–21.—Upper premolar of *Allacodon lentus*, Marsh.

Figures 22–26.—Upper molar of *Allacodon lentus*.

Figures 27–31.—Upper molar of *Allacodon lentus*.

Figures 32–35.—Lower incisor of *Halodon formosus*, Marsh.

Figures 36–39.—Lower premolar of *Halodon formosus*.

Note.—The figures enlarged from natural size have the increase given in diameters over each cut.

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[THIRD SERIES.]

Art. XXIII.—*On the Feasibility of Establishing a Light-wave as the Ultimate Standard of Length;* by Albert A. Michelson and Edw. W. Morley.

In the problem of making a light wave a practical standard of length, it is desirable to use as an intermediate standard a metal bar bearing two plane surfaces at the greatest distance apart at which interference (between two pencils having this difference of path) is accurately measurable. Some preliminary experiments have shown that in the case of the green mercury wave the distance may be a fourth of a meter. To keep well within limits, however, it is safe to say that an intermediate standard one-eighth of a meter long is entirely practicable. Such a distance will contain about a quarter of a million waves. The fractions of a wave present no especial difficulty; but to find the whole number when it is so large is not so simple a matter.

The following plan has been adopted and it is believed that by its means the chances of error are reduced to a minimum.

A series of intermediate measures were constructed alike in all respects save that the distances between the two planes were made very nearly 2^{-11}, 2^{-10}, 2^{-9}, 2^{-8}, 2^{-7} of a meter.

A description of one of these will answer for all. It consists of a brass bar provided with two sets of brass studs against which are pressed by spiral springs two silvered glass pieces two cm. square and about 0·6 cm. thick. The reflection takes place from the front surface, and the distance between these surfaces was adjusted as follows:—

The plane-parallel glasses are pressed by springs against three brass studs which are adjusted by filing away the studs to within a few waves of the desired length, and till the angle between the planes was less than half a second. The former operation was effected by the instrument described at the meeting of the National Academy in New Haven, which for want of a better term may be called the "interferential comparer." And the latter by the "refractometer" also previously described.

The relation between these intermediate bars which, commencing with the shortest (about half a millimeter), shall be designated *A B C D E F G H I*, was then determined with a mean error of a fifth of a wave, as described below, by the "comparer," and the last one compared directly with a standard meter. Thus the absolute length of *A* was found to be 0·4891 mm. ± 0·0001 mm. This was divided by the wave-length of sodium light taken from Rowland's tables and $2A$ was thus to contain 1659·1 ± ·2 of the longer sodium waves (λ=5896·08). *A* was then placed in the refractometer and the correct fraction found to be ·01 instead of ·10; so $2A=1659{\cdot}01\lambda_D$. With this corrected value of the length of *A*, *B* was found to contain 3314·22 waves, and, when corrected by the refractometer, 3314·27 waves.

Similarly *C* was found to contain 6617·84 waves, and when corrected, 6617·90. *D* contained 13237·00, corrected, 13236·99; and *E* contained 26472·08, corrected, 26472·18.

The same process was repeated for other kinds of light to diminish the chances of error. Besides yellow sodium and red lithium, the three bright radiations of mercury in a vacuum tube were used; namely, a moderately bright double line in the yellow, a very brilliant line in the green, and a fainter one in the violet.

The approximate wave-lengths of these were found by direct comparison with the solar spectrum and Rowland's maps as follow:

	Na_1	5896·08
	Na_2	5890·1
	Li	6707·8
Hg	Y_1	5769·8
	Y_2	5790·6
	G	5460·6
	V	4358·5

In the case of sodium it is somewhat difficult to obtain good results because the two series of interferences overlap, and especially so because they are of unequally varying intensities. When the flame is bright the intensities are nearly equal—but then the light is not sufficiently pure. When the light is faint Na_2 is nearly twice as bright as Na_1. Hence to find the fraction corresponding to Na_2 a correction of one-third the phase-difference between the two was added. The sodium flame gave good interference rings with E the longest standard used; but when longer standards are used it will be better to use the vacuum tube.

The lithium flame gives very indistinct interference circles but is valuable as a check on account of its great wave-length.

The yellow mercury light has the inconvenience of being double; but the two radiations are of nearly equal intensities. When, however, the phase-difference amounts to nearly half a wave it may be necessary to add or subtract half a wave from the observed result.

The brilliant *green* line gives beautifully clear circles even with a difference of path of half a million waves, so that in all probability *this will be the wave to be used as the ultimate standard of length.* So far as mere errors of setting are concerned, it is easy to obtain results consistent to a fiftieth of a wave, and with care to a hundredth.

The violet is also perfectly clear but the light much fainter. Its short wave-length makes it very valuable as a check.

As has been elsewhere shown the refractometer gives precisely the same interference phenomena as two surfaces enclosing a plate of air. One of these surfaces corresponds to one of the mirrors on the standard; the other to the *image* of another mirror. This image will be called the "reference plane."

The standard, A, let us say, which has already been carefully adjusted for length and parallelism is placed in the refractometer and the distance of the reference plane adjusted till the interference rings are equally distinct on the upper (rear) and the lower (front) surfaces of A. Then the reference plane is made to bisect the (extremely small) angle between the upper and lower surfaces. This is accomplished by adjusting till there is no alteration in the diameter of the rings on either surface when the eye is moved vertically or laterally (if the angle is zero); or till the alteration is equal and opposite on the two surfaces.

This adjustment is effected by means of the sodium flame, without the observing telescope. Temperature and barometric pressure are then taken. The reference plane is then moved by a fine adjustment till the central spot is black (phase = zero) on the upper (mirror) and the diameter of the first ring measured by the Troughton micrometer; and the telescope is then lowered and the width of the first ring on the lower surface measured. Then the phase difference at the lower surface is adjusted to zero, and diameter of first ring measured; and then the telescope is raised and width of first ring on upper mirror is measured.

The square of the ratio of two successive measurements on the mirror farthest from the reference plane will be the required result, and should agree, except in sign, with the corresponding result for the nearer mirror.

The following is a specimen observation:

March 12. *A* Sodium, T = 17°·0, B = 74·55^{cm}

	Upper Mirror.		Lower Mirror.	
	557	zero	542	----
	----	274	zero	600
	572	zero	554	----
	----	260	zero	588
Means	564	267	548	594

$$\left(\frac{267}{564}\right)^2 = 0·22 \qquad -\left(\frac{548}{594}\right)^2 = -0·86 = +0·14$$

$$0·14$$

Final mean = 0·18
— 0·19 = corrections for therm., barom. and phase.
Final result = ·99

The mercury light was obtained by passing sparks from an induction coil through an "end on" vacuum tube enclosed in a galvanized iron box heated by a Bunsen burner. Before passing to the refractometer it was analyzed by a single carbon-disulphide prism. By moving the source, yellow, green, or violet light could be examined at pleasure.

The comparison of intermediate bars is effected as follows:

The bar, *B*, let us say, is held on a fixed support attached to the bed of the comparer, and *A* is held on a movable carriage so that the two are side by side with their lower mirrors in the same plane. The reference plane is adjusted to make a small horizontal angle with the surfaces of *B* (the vertical angle being adjusted to zero) and then the surfaces of *A* are adjusted to parallelism with *B*. The carriage holding the combination equivalent to the "reference plane" is then released from all contact with adjusting screws. The fringes in white light under these conditions are vertical lines on the lower surfaces. The distance (in fractions of a fringe) between the central black fringes and marks on each mirror is noted.

The reference plane is now moved back till it coincides with the upper mirror on *A* when the fringes in white light appear on this surface and the position of the central black fringe is again noted.

Next *A* is moved back till the *lower* mirror coincides once more with the "reference plane" and finally the latter is moved back till it coincides with the *upper* mirrors of both A and B *if* B *is just twice* A. If not, the fringes and fractions in the difference are noted.

In the actual experiment the fringes always were adjusted to move to the right (in the observing telescope) when the reference plane was moving from the observer.

The following table gives the final results from the observations on E in wave-lengths. After the first series was completed all the standards were altered in length and adjustment. Series III was taken by another observer.

Ser. I	5896·08	6707·98	5460·85	5790·70	4358·42
Ser. II	5896·08	6708·00	5460·85	5790·67	4358·42
Ser. III	5896·09	6708·00	5460·85	5790·68	4358·41
Mean	5896·083	6707·993	5460·850	5790·683	4358·417

The arguments for the accuracy of these results are as follows:

1st. In every step of every series the mean difference between observation and calculation is less than it is when the whole number selected is either greater or less.

2d. In every step of every series the maximum difference between the greatest and least values of the errors is less than it is when the whole number selected is either greater or less.

3d. In every step of every series the difference between the errors of the longest and shortest waves, namely, lithium and violet mercury, is less than it is when the whole number is either greater or less.

4th. In every step of every series the number selected as agreeing most nearly with the results of observation differs less than six tenths of a wave, and usually less than three tenths of a wave from the number found by the comparer.

5th. In every step the results of the three independent series agree within 0·15 of a wave.

It may be considered reasonably certain therefore that the number of waves in the distance between the two planes of the standard E is known to within about one part in a million. It is also reasonably certain that the distance may be increased at least eight fold and hence the error reduced to less than one part in eight millions.

These results have been attained with apparatus having many imperfections and inconveniences. With better appliances and with the benefit of the experience gained it is hoped the last trace of uncertainty may be removed and the whole operation of establishing a material standard a meter long whose length in light waves is known to within one part in one million, and perhaps one in ten millions may be accomplished with ease and certainty.

POSTSCRIPT.

As has been previously stated, the only serious source of error to be feared in this method is a mistake in the whole number of waves in one or more of the "intermediate standards."

Notwithstanding the cumulative evidence just cited, it must be admitted that such a mistake may have occurred—and the numbers given in the table would require further and independent confirmation before being accepted as final.

Some months after the preceding paper was read a letter was received from Professor Rowland giving numbers for the relative wave-lengths of sodium and mercury lines by the grating method, as follows:

The upper line repeats the means of the preceding table corrected to agree with the latest of Rowland's tables by adding $\frac{1}{80000}$; the lower are Rowland's figures.

	Na_1	Hg	Hg_1	Hg_3
M. & M.	5896·157	5460·918	5790·755	4358·470
R.	5896·156	5460·94	5790·86*	4358·49

* Marked "poor reading."

In view of this final and almost complete confirmation these results may be taken not merely to prove the feasibility of the method, but as an accurate and reliable measurement of the relative wave-lengths of these radiations. As the whole number of waves used in this work was but a tenth of the number to be used in the final work—and as the relative error will be diminished in this proportion, nearly, it would seem that the claim made for the possible degree of accuracy attainable by this method of measurement has already been justified.

ART. XXIV.—*The Carboniferous Echinodermata of the Mississippi Basin;* by CHARLES R. KEYES.

DURING the deposition of the Lower Carboniferous rocks, life throughout the interior of North America was remarkable for the immense development and expansion of piscine and echinodermatous types; and among the latter especially, for the culmination of crinoidal and blastoidal forms. Not only was the development of the Crinoidea phenomenal in the number of species, but the extensive numerical representation of individuals was most astonishing. So prolific was crinoidal life at this period that the disjointed skeletal remains form great beds of what may be appropriately denominated a crinoidal breccia; which, however, is not always compact, but frequently full of interstices, with scarcely any finer and cementing materials; while throughout are disseminated broken and shattered calyces, fragments of arms, and portions of stems. Other parts of the formation exhibit thick beds of compact massive limestone alternating with layers of less durable composition. In some of the thin, sandy or clayey partings, lying half imbedded in the surface of hard limestone are often myriads of stemmed feather-stars, perfect as the day when they were entombed—forms of wondrous beauty and rare delicacy, gracefully and intricately intertwined like some rich flowing arabesque; and depicting accurately and distinctly the conditions of their surroundings when they waved to and fro in the quiet depths of the great Carboniferous sea.

Composed of regular plates, definitely arranged and frequently highly ornamented, delicate arms and characteristic stems, these organisms were admirably adapted for recording all marked changes in the physical conditions of their habitat. The testimony of the crinoids, corroborating the stratigraphic evidence, points to a slow and very gradual alteration of the sea-bottom. The long period of quietude over the broad Mississippi basin imposed especially favorable conditions of environment for a wide geographic and geologic dispersion of the various species. And the great uniformity of these conditions over extended areas is amply attested by the occurrence of identical species in localities as widely separated geographically as eastern Iowa and the Lake Valley region of New Mexico; or as central Illinois and the southern prolongation of the Appalachians in Alabama. But notwithstanding the extensive distribution of many species, the large majority of Paleozoic echinoderms was very limited in space and especially in time. Those species therefore which experienced a wide dispersion form valuable and reliable criteria for synchronizing horizons far removed from one another. The equivalency, however, of strata of distant localities can at best be only approximately determined from paleontological data alone. As has been suggested by Williams,* the biologic sequence in any limited region is not indicative of the genetic succession of the inhabitants, but merely the sequence of occupants within that particular area. The gradual oscillation and change of habitat to which the Carboniferous echinoderms of the Mississippi basin were subjected would tend to make their migrations extend through longer periods of time and their specific existence more protracted than the stratigraphy of any one place would indicate. And thus certain species would become extinct in one region and be completely replaced by very different forms; while in distant localities the migratory species would continue to flourish in all their wonted vigor.

* Proc. Am. Association Ad. Sci., vol. xxxiv, p. 232, 1885.

Echinodermatous life during the Lower Carboniferous was preëminently crinoidal and blastoidal: the former greatly predominating in the earlier part, and the latter conspicuously present in the later portion of the period. So marked is the contrast between the faunal features of the middle and upper portions of the Lower Carboniferous that Wachsmuth and Springer* have suggested that the Burlington and Keokuk deposits could very appropriately be called the "crinoidal limestone"; while the St. Louis and Chester are manifestly a "blastoidal" division.

In the subjoined synoptical† table are arranged the principal Carboniferous genera of the Pelmatozoa, and their distribution through Paleozoic time. Inasmuch as the synonymy of the species has been worked out more carefully and accurately than in any other group of fossils, the table is especially reliable for the consideration of problems of distribution during geologic times. The figures in the various columns refer to the number of species of each genus at present known from the respective beds. In cases where species existed through more than one epoch they are referred to the division in which they occur most abundantly. The faunas of the Upper and Lower Burlington limestones are so well marked that for convenience the species of each are considered separately. The abbreviations are: L. S.=Lower Silurian, U. S.=Upper Silurian, D.= Devonian, W.=Waverly or Kinderhook, L. B.=Lower Burlington, U. B.=Upper Burlington, K.=Keokuk, L.=St. Louis, C.=Chester, M.=Coal Measures.

The genera enumerated in the accompanying synoptical table, while characteristically Carboniferous, are very unequally distributed in time. In nearly every instance each genus exhibits: (1) a gradual expansion after its first appearance, shown by the differentiation of species occurring in each epoch; (2) a culmination, marked not only by a larger number of species and a great numerical increase of individuals, but also by a remarkable development and specialization of various structural characters, and by a more or less wide distribution in space; and (3) a decrease in the number of species, and a very apparent decline in physical energy, generally terminating in a more or less abrupt extinction of the group. The culmination of crinoidal‡ life generally was in the middle

* Proc. Acad. Nat. Sci. Phila., 1878, p. 229.

† The table is based chiefly upon the extensive collections of Messrs. Wachsmuth and Springer. The echinoderms other than crinoids and blastoids have purposely been omitted for the reason that at the present time perfect confusion exists throughout. However, as accurately as can be determined from all available sources the omission affects in no way the general conclusions arrived at, in regard to the Pelmatozoa alone.

‡ It must be borne in mind that the terms Crinoidea, Crinoids and their derivatives are limited to ordinal application, equally with Blastoidea and Cystidea, which are included under Pelmatozoa. There is a general practice prevalent of applying the name Crinoidea to all stemmed echinoderms, thus making the term co-extensive with Pelmatozoa, while in reality it is only a subdivision of the latter.

Synoptical Table of Carboniferous Echinodermata.

Genera of Pelmatozoa.	Pre-Carboniferous.			Lower Carboniferous.						U. C.
	L. S.	U. S.	D.	W.	L. B.	U. B.	K.	L.	C.	M.
Crinoidea.										
CAMERATA.										
Gilbertsocrinus	----	----	2	----	3	2	1	----	----	----
Rhodocrinus	----	----	3	3	6	2	2	1	----	----
Agaricocrinus	----	----	----	2	4	7	6	----	----	----
Alloprosallocrinus	----	----	----	----	----	----	1	----	----	----
Periechocrinus	----	3	----	----	2	1	----	----	----	----
Megistocrinus	----	----	9	2	2	1	----	----	----	----
Actinocrinus	----	----	----	4	21	6	5	----	----	----
Teleiocrinus	----	----	----	----	----	9	----	----	----	----
Steganocrinus	----	----	----	1	3	1	----	----	----	----
Amphoracrinus	----	----	----	1	2	----	----	----	----	----
Physetocrinus	----	----	----	----	2	3	----	----	----	----
Strotocrinus	----	----	----	----	----	2	----	----	----	----
Batocrinus	----	----	----	1	8	12	15	5	----	----
Eretmocrinus	----	----	----	----	7	8	5	----	----	----
Dorycrinus	----	----	1	1	5	4	3	----	----	----
Platycrinus	----	----	2	6	23	13	5	7	1	----
Eucladocrinus	----	----	----	----	----	2	----	----	----	----
Dichocrinus	----	----	----	2	7	6	4	2	----	----
Talarocrinus	----	----	----	----	----	----	----	1	4	----
Pterotocrinus	----	----	----	----	----	----	----	----	10	----
ARTICULATA.										
Ichthyocrinus	----	5	----	----	1	1	----	----	----	----
Taxocrinus	2	----	5	4	2	1	4	2	----	----
Forbesiocrinus	----	----	----	----	----	1	2	----	2	----
Onychocrinus	----	----	----	1	----	2	3	1	2	----
Nipterocrinus	----	----	----	----	1	1	----	----	----	----
INADUNATA.										
Larviformia.										
Allagecrinus	----	----	----	----	----	----	----	----	1	----
Symbathocrinus	----	----	1	1	2	2	1	----	----	----
Belemnocrinus	----	----	----	----	2	2	----	----	----	----
Atelestocrinus	----	----	----	----	1	1	----	----	----	----
Vasocrinus	----	----	2	----	1	----	1	----	----	----
Baryocrinus	----	----	----	----	2	3	15	2	----	----
Cyathocrinus	3	4	----	1	5	5	9	----	----	----
Fistulata.										
Poteriocrinus	----	----	2	----	3	1	----	----	----	----
Scaphiocrinus	----	----	1	3	5	9	14	7	11	----
Scytalocrinus	----	----	----	----	----	1	4	3	5	----
Decadocrinus	----	----	5	4	2	2	2	1	2	----
Woodocrinus	----	----	1	1	1	2	3	1	----	----
Zeacrinus	----	----	----	----	1	5	1	----	6	----
Hydreionocrinus	----	----	----	----	----	----	----	----	3	4
Cromyocrinus	----	----	----	----	----	----	----	----	2	----
Eupachycrinus	----	----	----	----	----	----	----	----	4	2
Graphiocrinus	----	----	----	----	5	2	1	----	----	----
Agassizocrinus	----	----	----	----	----	----	----	----	9	1
Calceocrinus	2	3	3	----	1	1	2	----	----	----
Catillocrinus	----	----	----	----	----	1	2	----	----	----
Blastoidea.										----
Schizoblastus	----	----	----	1	3	2	1	----	----	----
Cryptoblastus	----	----	----	----	1	1	----	----	----	----
Granatocrinus	----	----	----	1	----	2	----	----	----	----
Heteroblastus	----	----	----	----	----	----	----	1	----	----
Pentremites	----	----	----	----	----	2	----	4	28	----
Mesoblastus	----	----	----	----	----	----	----	1	----	----
Codaster	----	2	9	----	----	1	1	----	----	----
Metablastus	----	----	----	----	----	1	2	2	----	----
Orophocrinus	----	----	----	----	3	----	----	----	----	----
Tricœocrinus	----	----	----	----	----	----	1	4	----	----
Phanoschisma	----	----	----	----	1	----	----	----	----	----
Troostocrinus	----	----	----	----	----	----	----	1	----	----

of the Lower Carboniferous. At the close of the Keokuk epoch one-half of the Carboniferous genera had become extinct. The great group Camerata had passed away, with the exception of the Hexacrinidæ and a few depauperate forms of several other genera whose existence was quickly brought to a close. A large proportion of the genera in the extensive section Inadunata had disappeared; of those groups which survived to the close of the period, a diminutive species *Allagecrinus* (a single specimen only being at present known) was the sole representative of the branch Larviformia; while of the great group Fistulata only the typical genus (including four subgenera) of the Poteriocrinidæ extended through the entire Lower Carboniferous. And the widely distributed *Calceocrinus* which began back in the Lower Silurian became extinct just before the beginning of the St. Louis.

Wachsmuth and Springer* have shown that in the expansion and geological development of the various groups of crinoids the modification of specific characters was very gradual and corresponded in a striking manner with the changes by growth in the individual. Another suggestive fact is that usually the more generalized types of the various groups are the more persistent, often having a considerable range both in time and space. The expansion of the several families is also frequently indicated by the relatively rapid development, in some supra-generic groups, of certain structural features which soon become curiously differentiated Perhaps nowhere in any zoological group is its culmination better or more clearly defined, in accordance with the suggestions already made, than in the Crinoidea. The remarkable multiplicity of specific and generic types, appearing in rapid succession during the middle Lower Carboniferous; the extreme and phenomenal specialization of particular anatomical structures; the great increase in size; the ponderous character of the test; and the marked structural changes in many minor particulars are of peculiar biological significance. Toward the close of the Keokuk nearly all the specialized forms became extinct; and with a very few exceptions only the more generalized types continued through the Lower Carboniferous—only such forms as were ordinally related to living crinoids.

If the crinoids formed a prominent faunal feature of the earlier part of the Lower Carboniferous, the blastoids were equally conspicuous during the latter portion of the period. In the Burlington and Keokuk the Blastoidea, although represented by more genera than in the St. Louis and Chester, were for the most part rare individually; and their presence was rendered still less noticeable by the great preponderance of

* Proc. Acad. Nat. Sci. Philad., 1878.

associated crinoids. During the St. Louis and Chester the blastoids were greatly in the ascendancy. This was due partly to an immense expansion in the order itself, and partly to a further marked numerical decrease of the crinoids, which had already become astonishingly reduced. Though the blastoids, in number of genera, were not as abundant in the latter, as in the former, part of the period, individually they were exceedingly numerous.

Recent investigations show that the divisions of the Lower Carboniferous as generally recognized in the continental interior are not as clearly marked by abrupt changes in faunal and lithological features as current opinion considers, and as has been very strongly urged, particularly by some of the earlier geologists. It is now conceded that some of the present divisions of the Lower Carboniferous as presented throughout the region in question, could be very appropriately united. That several of these divisions are very closely related cannot be questioned. There is conclusive proof,* at least so far as the most characteristic faunal group is concerned, that the Burlington and Keokuk are more closely related than the two limestones (upper and lower) of the former division. Investigations instituted among the Gasteropoda and Brachiopoda afford like evidence as to the near relationship of the two formations as usually designated.

From a comparison of the Crinoidea occurring in the Upper and Lower Burlington, and Keokuk limestones it is quite apparent, as first observed by White† and afterwards more fully discussed by Wachsmuth and Springer‡ that the forms of the three horizons present some marked differences. Those species from the lower Burlington are of small size, delicately constructed and ornamented; in the upper division of the Burlington the peculiar delicacy pervading the lower bed forms is absent, or has assumed a ruder character; while in the Keokuk the crinoids are characterized by large size, rough massive construction, bold rugged ornamentation, and a conspicuous exaggeration in many structural details. The last consideration is of great interest. For it appears that in general the exaggeration of various structural features is indicative of important biologic changes in that particular zoological group in which such extreme developments take place; and as has been shown in other orders this extravagant and undue acceleration in growth is relatively very rapid, but of short duration, and usually terminates in the abrupt extinction of the group; or as in some cases results in a very great diminu-

* *Vide* Wachsmuth and Springer, Transition Forms in Crinoids, Proc. Acad. Nat. Sci. Phila., 1878.

† Jour. Boston Soc. Nat. Hist., vol. vii, pp. 224, 225.

‡ Loc. cit.

tion of vitality. It would seem then that a general amplification of the various anatomical structures in any faunal group marks its culmination; and this fact is peculiarly significant in its application to fossil crinoids, for the middle of the Lower Carboniferous was preëminently the climax of crinoidal life.

The abrupt extinction of a large proportion of crinoidal forms towards the close of the Keokuk is certainly suggestive of a series of decided and wide-spread changes in the geographic and bathymetric extent of the great interior sea. White* has already shown that at least in some portions of the Mississippi basin there were very considerable alterations in the coastal contour of this broad shallow gulf, during the latter part of the Lower Carboniferous; and it is known that there were even greater changes in the coast line in other parts of this region during the same period. During the Keokuk the waters over portions of Iowa, Illinois, Missouri and Indiana became greatly diminished in depth and the land of the same area was considerably extended. While the St. Louis beds were being deposited the sea again encroached upon the land, extending in some places more than two hundred miles northward beyond the former Keokuk waters. Over an extensive portion of the interior sea the conditions of environment during the Keokuk and St. Louis epoch presented some notable differences, as is amply attested by even a casual comparison of the faunæ of the two divisions. In some parts of Indiana and Illinois the organic remains of the former are characterized by a certain luxuriancy of individual growth, apparent not only in one, but in the majority of the zoological groups represented. In the latter division the animal forms, in many cases, are strikingly depauperate. It is not only a depauperation among a few types that is discernible, but a great diminution in vitality is manifest in forms genetically related to those occurring in the Keokuk.

The Lower Carboniferous of the Appalachian area seems to present two easily determinable divisions. In the Mississippi basin this double nature of the Lower Carboniferous does not appear to be clearly defined. The combined physical and paleontological evidence would indicate that the Lower Carboniferous throughout the interior of North America is broadly divisible into three sections; the lower comprising chiefly shales and sandstones, and the two upper principally limestones. If, in the correlation of the Lower Carboniferous strata of the Appalachian and Mississippi regions, the latter is to be considered double as the former it does not appear advisable to draw the line of division between the Burlington and Keokuk, for reasons already stated. In accordance, there-

* Geology Iowa, vol. i, p. 225, *et seq.*

fore, with the salient statigraphical and faunal features as presented, the evidence in considering the dual character of the Lower Carboniferous in the continental interior indicates that by far the two most widely separated of the five generally recognized divisions are the Keokuk and St. Louis.

Recapitulating, it appears that in the Lower Carboniferous of the Mississippi basin: (1) the most characteristic faunal group was preëminently dual in its general aspect, the Crinoidea greatly predominating during the first part, and the Blastoidea during the latter portion, of the period; (2) that a large proportion of the genera of echinoderms became extinct toward the close of the Keokuk; (3) that, of the crinoidal genera represented in the St. Louis and Chester, nearly one half of the number did not occur in the earlier epochs; (4) that among the Crinoidea in general the abrupt and extensive differentiation in certain anatomical features toward the end of the Keokuk are suggestive of decided changes in the biological and physical conditions of environment; (5) that the faunas of the Burlington and Keokuk are very closely related genetically, the two being practically continuous; (6) that if the members of the Lower Carboniferous of the Mississippi basin are to be synchronized with the two divisions of the Appalachian Lower Carboniferous, the line of demarkation is far more apparent at the close, than at the beginning, of the Keokuk epoch.

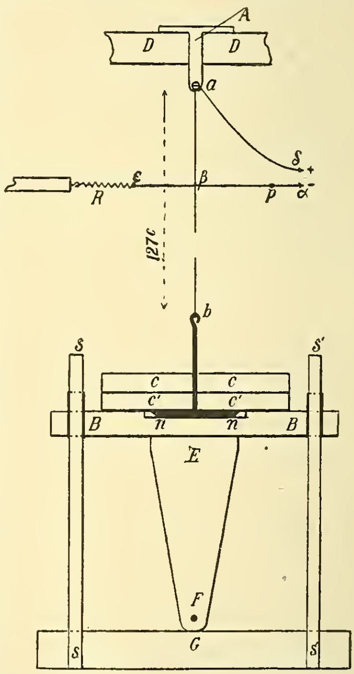
Art. XXV.—*The Energy Potentialized in Permanent Changes of Molecular Configurations*; by Carl Barus.*

1. In the following work a soft annealed wire is stretched by a known weight falling from an initial position (strain minimum), to the lowest position compatible with the given adjustment (strain maximum). If the wire remains sufficiently soft throughout the experiment the recoil is nearly zero. Hence the energy expended in stretching is to this extent easily measurable; and if also the heat evolved during stretching, be measured, the difference between the work done on each centimeter of wire and the heat produced per centimeter of wire is the energy potentialized; i. e. the energy which permanently manifests itself as tensile strain. Using the nomenclature of Maxwell's theory of viscosity, the numerical datum, thus obtained, is an expression for the amount of change in the history of the typical molecular configuration, the dates being taken immediately before and immediately after the tensile stress is applied.

* In my paper, this Journal, xxxvii, page 346, Table II, exchange traction and torsion. In the fourth line below read conductivity for resistance.

Now it is clear that the strain-effect of a given amount of work done must depend on the dimensions of the material. It must be supposed variable with the extension produced in case of a given sectional area, as well as with the section of the stretched wire in case of a given extension. At the outset it is difficult even to conjecture in what respect these strains, though of a given class, may differ in essential details. There is, however, a more interesting phase of these experiments: the strain-effect of a given amount of work done on centimeters of wire will vary, cæt. par., with the material acted upon. From this point of view the prosecution of the present research promises to lead to results bearing directly on the nature (form and mutual relations) of the molecules sustaining strain.

2. In figure 1, *CC C′C′*, the weights (P=40 kg to 60 kg) by which stretching is to be done are supported on a suitable trap-door, *BB*; and the fall of *BB*, when released, is guided by the upright slides *ss*, *s′s′*, fixed in the firm base, *G*, of the apparatus. I took pains to adjust the soft wire *ab* to be acted on, as nearly straight and free from initial tensile strain as possible. It was firmly fastened above to a heavy cross-timber of wood, *DD*, the lintel of a framework which in form and purpose closely resembled a gallows. The screw clamp at *a* in the vertically adjustible brass torsion-circle *A*, the axle of which passes snugly through *DD*, secures the upper end of the wire. The lower end is lapped around the hook of the weight pan, *bnn*, then wound around the wire and soldered, care being taken to avoid such loops and kinks as might change form during stretching.



A thermo-couple, $\alpha\beta\alpha\delta$, originally of platinum/platinum-iridium, with its junction β tied on with silk thread on the upper half of the wire *ab*, enabled me to measure the change of temperature due to stretching. In later experiments more reliable devices were adopted, cf. § 5. Changes of length were measured with Grunow's cathetometer, two fiducial marks having been painted on the wire *ab* about 70 ^{cm} apart. At a given signal the catch-board EF of the trap-door BB was jerked away, by aid of a rope tied at F and manipulated by an assistant.* Simultaneously with the stretching I read off the temperature-increment in terms of the excursion of the needle of a sensitive mirror-galvanometer, and as soon as this was taken, I made the final length measurement with the cathetometer. From these both δL and δl, i. e. the length-increment of the whole wire and of the part between the fiducial marks, respectively, were derived.

δL varied between 8^{cm} and 20^{cm}, δl between 6^{cm} and 11^{cm}, L being about 12^{cm}.

3. In Table 1, I have systematized the results of the measurements. Here ρ_s and ρ_h denote the radii of the wire before and after straining, and are computed from gravimetric measurements. P is the stretching force; $\delta l/l$ the longitudinal extension produced, and measured between fiducial marks on the wire with the cathetometer. $E = P\delta L/L = P\delta l/l$ is the work done on centimeter of length; t the observed increment of the temperature of the wire resulting. Finally $r = E_t/E$ indicates the part of the applied work which is converted into heat, the remainder $(E - E_t)/E$ being potentialized. The table contains both $P\delta L/L$, and $P\delta l/l$, the latter being usually greater in consequence of errors of experiment which need not here be considered.

The heat corresponding to $t°$ being $Amct$, where A is the mechanical equivalent of the water-gram-degree in ergs, m the mass of the wire per centimeter and c its specific heat. I was obliged to take c from tables and also for want of data to disregard the variations of c during straining. Density, Δ, was measured before and after stretching.

TABLE 1.—*Energy potentialized in tensile strains. First method.*

Metal	$2\rho_s$ / $2\rho_h$	P	$\delta l/l$	$P\delta L/L$	$P\delta l/l$	t	$r = E_t/E$
	cm	g	(cm)	megalergs	megalergs	°C	
Brass	·1662	60,000	·129	7·5	7·7	4·3	0·40
$\Delta = 8{\cdot}42$	·1546		·163	9·3	9·8	4·1	·30
			·151	9·0	9·1	3·9	·31
			·168	9·9	10·1	4·3	·31
			·153	9·1	9·2	6·0	·45
			·160	8·9	9·6	7·0	·52
Mean			·154	8·95	9·24	4·9	·38
Iron	·1362	50,000	·087	4·26	4·35	3·8	0·47
$\Delta = 7{\cdot}68$	·1310		·091	4·33	4·56	4·0	·47
			·084	4·17	4·22	4·3	·54
			·087	4·26	4·36	3·5	·43
Mean			·0875	4·25	4·37	3·9	·48
Copper	·1630	40,000	·147	5·58	5·88	6·0	0·77
$\Delta = 8{\cdot}87$	·1514		·148	5·51	5·92	5·1	·65
			breaks	----	----	5·5	----
			·153	5·90	6·12	5·3	·65
Mean			·149	5·66	5·98	5·5	·69

* Mr. Ernest L. Howard had the goodness to give me much efficient service during the course of the present experiments.

4. A few words on the errors involved are essential. Comparison of the values of $P\delta L/L$ and $P\delta l/l$ shows that the work lost upon kinks and flaws together with that spent upon the frame-work is not seriously large so far as the present purposes are concerned. This is also true of the energy elastically potentialized, as may be found by direct tests. The satisfactory measurement of the thermal datum t, however, is much more difficult. Apparently the graduation of the thermo-couple is simple: for it is merely necessary to make preliminary observation of the throw of the needle of a ballistic galvanometer produced by given increments of temperature. The use of such graduation is, however, only permissible if the temperature of the wire remains constant during the period of oscillation of the needle. These conditions are never rigorously given; whereas even in case of jacketed wires it is a question whether they are sufficiently given. The temperature of the wire increases very rapidly to a maximum, and then decreases by radiation, etc., reaching the original thermal value in a few minutes. Again the cooling effect of the metallic wires of the thermo-couple cannot easily be allowed for, neither can it be considered negligible even in case of filimentary wires. Finally the error of heterogeneity is of serious consequence; for the thermoelectric measurement is virtually a thermal exploration of the metal lying very near the point-junction. Hence since the wire near such a point may be imperfect by reason of flaws or composition so that more or less work is done here than at other parts of the wire, it follows that the temperature thermoelectrically obtained is not a mean datum for the wire taken as a whole.

Unfortunately the combined effect of the errors stated will usually be the cause of too small a value of t. Some assurance of the approximate truth of the results in Table 1 may, however, be obtained by observing that the experiments made are to some extent differential in kind. For instance, caet. par., about as much heat is evolved in the copper wire for an expenditure of only $\frac{2}{3}$ the work applied to the brass wire. Sections and thermo-couple are here the same and similarly adjusted.

The importance of the thermal datum is such, however, that special corroborative measurements are essential. To obtain these, the above method was modified in such a way that the wire was stretched successively in equal amounts. One end of it was fixed and the other fastened on the circumference of an iron drum of small radius, $\rho = 0{\cdot}9^{cm}$. By revolving the latter the wire is stretched and the friction of the axle sufficient to keep it so. I chose successive angles of revolution, π, by which extensions $\delta L/L = {\cdot}054$ each, were easily produced, and could usually be repeated 4 or 5 times.

The results of these experiments showed no essentially new points of view. Hence I will omit them in favor of the work of the next paragraph.

5. The errors discussed in § 4 induced me to repeat the work with a thorough change of method, so far as the thermal measurements are concerned. To obtain the data of table 2, the thick wire *ab*, figure 1, was itself used as one of the elements of the thermo-couple. The other element was a filimentary wire $\alpha\beta\varepsilon$, passing from a fixed point *p* in connection with the terminal of the galvanometer, once around the wire to be stretched (junction, β), and thence to an insulated spiral spring, *R*, to keep it tense. At the point, β, where the thin wire lapped around the thick wire, both were carefully brightened and good electrical contact was further insured by stiffening the spring *R* as much as the thin wire permitted. The upper end *a* of the wire to be stretched placed in connection with the other terminal δ of the ballistic galvanometer completed the circuit. In this way the heat generated by stretching acts at once at the thermoelectric junction of the thick and the filimentary wire, while the latter may be chosen so thin as to produce only negligible cooling. Indeed in virtue of friction the discrepancy is apt to be in the opposite direction.

In this arrangement* a special error is introduced by the change of thermoelectric constants due to stretching, but this error, for the present purposes at least is negligible in comparison with the thermoelectric powers copper/ iron, or brass/ iron, being not greater than a few per cent.

The notation of table 2 is the same as that in table 1. E_p the mean energy stored in the wire per centimeter of length has been added.

TABLE 2.—*Energy potentialized in tensile strains. Second method.*

Metal	$2\rho_s$ $2\rho_h$	P	$\delta l/l$	E	t	E_t/E	E_p
	cm	g	(cm)	megalergs	°C		megalergs
Brass	·166	60,000	·199	11·8	9·1	0·55	5·0
	·155		·191	11·5	9·0	·56	
			·182	10·9	8·8	·58	
Copper	·163	40,000	·153	6·12	6·8	0·81	1·3
	·151		·153	6·12	6·1	·72	
			·153	6·12	6·8	·81	
			·143	5·72	6·0	·76	
			·143	5·72	6·3	·80	
Iron	·136	50,000	·084	4·21	4·0	0·51	2·2
	·131		·086	4·28	3·9	·49	
			·089	4·47	4·3	·51	
Iron	·136	40,000	·032	1·26	0·8	0·36	0·9
			·031	1·23	0·5	· 22	

* After making these experiments, I found that a similar method of thermoelectric measurement has recently been employed by Wassmuth (Wiener Sitzber., xcii, (2), p. 52, 1888). Wassmuth's purposes are distinct from mine.

A comparison of the results of table 2 and table 1 shows that the latter substantiates and emphasizes the results of the former. In table 2, moreover, the measurements of the effects produced by stretching the same metal are in very much better accord. It is not improbable that the variations of E_t/E for the same metal in table 2 may be due to actual differences of hardness or composition of the annealed wires.

In case of iron two values of P occur, and the metal exhibits striking differences of behavior in the two experiments. It appears that more energy is potentialized during initial than during final stages of strain. For $P = 40$ kg, the small value of t is only measurable as a superior limit. Moreover the extension is here so small that the error due to resilience may be 5 per cent.

6. To summarize it appears that as much as one-half of the work done in stretching up to the limit of rupture may be stored up permanently; that the amount of work thermally dissipated varies considerably with the metal acted upon, being very large for instance in case of copper (75 per cent), smaller in case of brass (60 per cent) and of iron (50 per cent); that in case of the same given metal the work done is very largely potentialized during incipient stages of strain, and very largely dissipated during final stages of strain. When stress of a given kind is applied to different metals, the total amount of energy which can be stored per unit of section, per unit of length up to the limits of rupture, may therefore be looked upon as a molecular constant of the metal. Table 2 shows that in case of a wire about $\cdot 16^{cm}$ thick stretched nearly to the limits of rupture, at least 5 megalergs per centimeter will have been stored in case of brass, and about 1 megalerg per centimeter in case of copper. In iron $\cdot 14^{cm}$ thick at least 2 megalergs per centimeter are potentialized under the same conditions.

Art. XXVI.—*Contributions to Mineralogy, No.* 44; by F. A. Genth.

1. *Gadolinite.*—In the fall of the year 1888, Dr. A. E. Foote sent me for identification a shining black mineral which he brought from Burnett County, Texas. A preliminary examination, which I made, proved it to be *Gadolinite*, which, excepting that from Colorado, described and analyzed by Mr. L. G. Eakins of the U. S. Geological Survey, had never been observed in this country. Since it became known that the mineral brought from Texas by Dr. Foote was gadolinite, large quantities have been obtained, some in crystals, weighing from

seven to eleven pounds. I am indebted to Mr. W. Earl Hidden for some from Llano County, Texas, and give in the following the results of my analyses of this, as well as that received from Dr. Foote.

It has a black color; in thin splinters it is translucent with a dark bottle-green color; the fine powder is greenish-gray; fracture conchoidal to splintery. Sp. gr. = 4·201 (Burnett Co.) to 4·254 (Llano Co.). Heated to low redness, it begins at once to glow vividly through the whole mass and swells up into ragged fragments of a grayish-white color, only superficially melted. The fine powder is soluble in dilute acids, even after ignition. The best solvent I found to be dilute sulphuric acid (1 : 20) in which it dissolves in the cold after repeated shaking, leaving only a minute, somewhat flocculent, reddish residue of ferric oxide and a little quartz which were mechanically mixed with the gadolinite.

The Texas gadolinite is altered into a brownish-red mineral of waxy luster, finally into a reddish or yellowish-brown earthy substance. Neither could be obtained in a state of purity, but I will give below a partial analysis of the former. *Tengerite* (?) or yttrium carbonate in thin, white crystalline incrustations is found between the cracks of the gadolinite. There was only enough obtainable to show their composition by qualitative tests.

In the analyses of the Burnett Co. gadolinite I, *a* and *b*, it was dissolved in hydrochloric acid, in those of the Llano Co. mineral II, *a* and *b*, in dilute sulphuric acid and the mechanically admixed ferric oxide and silica separated by filtration. The other separations were made in the usual manner. The cerium oxide was separated from the oxides of didymium and lanthanum by oxydizing the almost neutral nitric acid solution with bromine, and precipitation of the boiling solution with sodium acetate. This was repeated five times, when, finally, the filtrate gave only traces of oxides which could be precipitated with oxalic acid and the ceric oxide showed a pale salmon color. The oxides, separated from the cerium were chiefly didymium oxide, and lanthana in smaller quantity. The oxides of the metals of the yttrium group gave almost white salts, with only a very faint rose color of that of erbium. The separation of glucina and alumina from ferric oxide was effected from a solution of citric acid and ammonia by precipitating the iron as ferrous sulphide, which method I found to give the most satisfactory results. The little alumina was separated from the glucina by precipitating the nearly neutral solution and re-dissolving the precipitate in a strong solution of sodium hydrate and, after the dilution with much water, precipitating the glucina by continuous boiling. After acidulation of the alkaline solution the alumina was precipitated by ammonium hydrate. The alumina, separated in this manner, after dissolving it in hydrochloric acid, and treatment of this solution with sodium hydrate, did not yield a trace of glucina on continuous boiling of the dilute alkaline solution.

The following results were obtained:

	I. Burnett County.		II. Llano County.	
	a	*b*	*a*	*b*
SiO_2	22·87*)	23·40*)	22·80	22·92
Al_2O_3	0·28	0·33	0·31	0·29
Ce_2O_3†)	2·65	2·76	2·66	2·85
$(Di,La)_2O_3$	5·22	5·17	5·01	5·33
$(Y,Er)_2O_3$	44·35	44·65	44·45	44·30
MnO	0·22	not det.	0·18	not det.
FeO	13·69*)	13·58	12·93	13·03
BeO	9·24	9·32	9·19	9·34
MgO	0·07	0·08	0·11	not det.
CaO	0·64	0·54	0·71	0·78
Na_2O	0·20	not det.	0·23	not det.
K_2O	0·15	" "	0·12	" "
Ignition	0·72	" "	0·79	" "
Insoluble in dil. H_2SO_4	not det.	" "	0·93	0·92
	100·30		100·42	

Decomposed Gadolinite from Llano Co.

Spec. grav.	= 3·592
Ignition	9·30
Quartz	1·03
SiO_2	22·11
$(Ce,Di,La,Y,Er)_2O_3$	39·20
Fe_2O_3	14·53
BeO	6·03
MnO	0·22
CaO	5·58

2. *Cacoclasite.*—At the meeting of the Mineralogical and Geological Section of the Academy of Natural Sciences of Philadelphia, November 26th, 1883, the late Professor H. Carvill Lewis described under the provisional name "cacoclasite," peculiar white and grayish-white crystals, imbedded in blue cleavable calcite, associated with graphite, pyroxene, wollastonite, cubical spinel, pyrrhotite, etc., at Wakefield, Ottawa County, Quebec, Canada. They are nearly square prisms with truncated angles, the general appearance being

* Includes the Fe_2O_3 and SiO_2, insoluble in dilute sulphuric acid.

† Mr. L. G. Eakins informed me that he had found ThO_2 in the Texas gadolinite. As I had not tested for it, I examined the ceric oxide, left from the four analyses, and found it to contain 3·22 per cent of ThO_2.

that of a partly altered scapolite. They are tetragonal with $O \wedge 2 = 129\frac{1}{2}°$. The following planes have been identified: *O*, *i-i*, 2, 2-*i*, 2-2, 6-3, the last two hemihedral. Almost entire absence of cleavage, luster vitreous to resinous; H.=5–6; Spec. gr.=3·050–3·057.

An analysis, made by Mr. Reuben Haines gave, after deducting admixed calcite:

		Oxygen ratio.	
SiO_2	= 36·74	0·612	= 6
Al_2O_3	19·79	0·190	2
Fe_2O_3	1·33		
CaO	38·16	0·736	7
MgO	0·77		
Na_2O	0·32		
K_2O	0·17		
P_2O_5	2·49		
H_2O	0·23		

Quantivalent ratio of bases (*in which he includes* P_2O_5—F. A. G.) to SiO_2=9 : 6=3 : 2, thus making the mineral a subsilicate.

Professor Lewis concludes his article thus: "The species appears to be isomorphous with sarcolite, but its very different physical and chemical characters indicate either a distinct species or a pseudomorph. The absence of cleavage and the heterogeneous microscopic characters argue pseudomorphism. Chemically it is allied to gehlenite. The temporary name 'cacoclasite,' referring to its imperfect cleavage was suggested. The specimens are still under investigation."

I have no information that anything in addition to the above was done by Professor Lewis, and as the whole tenor of his communication leaves a great deal of doubt about the nature of this mineral, I have, at the suggestion of Professor G. Christian Hoffmann, chemist and mineralogist of the Canada Geological Survey, made a few experiments with excellent material which he had given me for this purpose, also with a crystal which Dr. A. E. Foote kindly presented to me, and give in the following the results of my investigation.

The calcite, in which the cacoclasite crystals are imbedded, is of a pale blue color and shows perfect cleavage, producing cleavage crystals up to 10^{mm} in size; the cacoclasite crystals vary from 3^{mm} to about 50^{mm} in diameter; their surface is glossy and has the appearance, as if the crystals had undergone a partial melting or vitrification. They are more or less rounded, the planes, *without exception*, are not smooth but deeply corrugated and grooved in an irregular manner. It is remarkable that this peculiarity must have existed, before the calcite was deposited upon the same, because, when broken off from the cacoclasite, it shows the reverse of the grooves and corrugations of the latter.

For investigation two crystals were used, the best one of Professor Hoffmann's (I) about 12^{mm} in size, was almost white, but had a little pyrite in the center, that from Dr. Foote, (II) about 18^{mm} long had a slightly brownish white color, but the interior was of a uniform grayish white color. Finely granular, like sugary quartz and of the same luster, crystal I was slightly coarser than II. Spec. grav. of crystal I=3·337, of crystal II =3·222.

They were broken into small fragments from 2 to 3^{mm} in diameter and carefully examined for their purity, but none showed any admixture of blue calcite or other minerals.

By qualitative analysis it was found that although no calcite could be found by a strong lens, both crystals contained a carbonate, probably that of calcium, a phosphate, probably apatite, and a considerable quantity of *free* quartz. In the quantitative analysis the latter was determined by fusing the finely powdered mineral with microcosmic salt, dissolving in hydrochloric acid and boiling the remaining silica with dilute sodium hydrate, as long as it extracted soluble silica.

In crystal I the remaining SiO_2 was 23·44 per cent; this on being fused with sodium carbonate etc., etc., gave *pure* SiO_2= 23·04 per cent present as *quartz*, with little alumina and calcium oxide. Crystal II treated in the same manner gave 11·84 per cent of silica which contained 11·63 per cent of *pure* SiO_2 present as *quartz*. The analyses gave the following results:

	I.	II.
H_2O	= 1·04	2·28
CO_2	6·73	4·25
SiO_2	31·52	32·67
P_2O_5	2·19	3·36
Al_2O_3	17·34	19·63
Fe_2O_3	0·51	0·39
MgO	trace.	0·49
CaO	40·95	36·38
Na_2O	trace.	0·31
K_2O	trace.	0·20
	100·28	99.96

Deducting the CO_2 as calcium carbonate, the P_2O_5 as apatite and the free quartz, we get:

$CaCO_3$	= 15·20	9·66
$Ca_5F[PO_4]_3$	5·05	7·74
SiO_2	23·04	11·63
Apparent admixtures	43·29	29·03

The remaining constituents would give the following composition:

	I.	Molecular ratio.		II.	Molecular ratio.	
H_2O =	1·83	0·102	= 2	3·22	0·179	about 3
SiO_2	14·89	0·248	5	29·67	0·495	8
Al_2O_3	30·45	0·296	6	27·68	0·270	5
Fe_2O_3	0·90	0·006		0·55	0·004	
MgO	----			0·69	0·017	12
CaO	51·93	0·927	18	37·47	0·569	
Na_2O	----			0·44	0·008	
K_2O	----			0·28	0·003	
	100·00			100·00		

Although these analyses, especially I, show a simple molecular ratio between the constituents, they do not represent the constitution of any known mineral and are evidently mixtures, the actual nature of which, however, we have no means to determine. From all this, cacoclasite cannot be considered a good species, but a mixture of quartz, calcite, apatite and other unknown minerals in various proportion, which have the form of scapolite and have resulted from its alteration.

3. *Monazite.*—At the Villeneuve Mica Mine, Ottawa County, Quebec, Canada, an interesting variety of monazite has lately been discovered, of which Professor G. Ch. Hoffmann sent me a specimen.

It has a reddish-brown color, indistinct cleavage and little or slightly waxy luster. The specific gravity of the purest cleavage pieces was found to be =5·233. The analysis gave:

H_2O	= 0·78
SiO_2	0·91
ThO_2	12·60
P_2O_5	26·86
Fe_2O_3	1·07
Ce_2O_3	24·80
$(LaDi)_2O_3$	26·41
$(YEr)_2O_3$	4·76
MgO	0·04
CaO	1·54
	99·77

Chemical Laboratory,
Philadelphia, 111 S. 10th st., April 29, 1889.

ART. XXVII.—*On the Period of Rotation of the Sun;* by HENRY CREW, Ph.D., Instructor in Physics in Haverford College.

PETERS* was probably as early as anyone to remark that the period of rotation of the sun, without farther limitation, was a meaningless term. In a series of observations on sun spots, taken at Naples during the years 1845–6, he found, among his results, discrepancies larger than could be explained by errors of measurement; but what is more striking, these discrepancies were always in one direction. In short, he showed that each heliocentric latitude has its own period of rotation.

The law, according to which this velocity varies with the distance from the equator, Carrington† has placed beyond doubt. His work, however, is all confined to the photosphere or the immediately underlying region in which the sun spots have their seat.

A few years later Braun and Hornstein,‡ independently, discovered in the magnetic elements a pretty well marked variation, having a twenty-six-day period. This at once suggested a means of getting the rotation period of the solid (?) nucleus of the sun. For Braun (Phil. Trans., 1876), from two years' observations, finds that the large disturbances of the horizontal component of the earth's magnetism were nearly all confined to the days on which one of three solar meridians was presented to the earth. But this needs confirmation, for the total number of disturbances observed was not large. However, the *phase*§ of this disturbance, unlike those of the annual and secular variations, is the same in all parts of the earth, seeming to indicate that we have here to deal with solar action which is direct and not intermediate. On the other hand, solar temperatures appear to preclude the possibility of the sun being a permanent magnet. So that the region of sun whose period Braun and Hornstein and, later, Liznar,‖ have determined remains completely unknown, but with the probability of its being below the photosphere.

A fairly pronounced twenty-six-day variation in the daily range and height of both the thermometer and the barometer has been known for a long while. But no theory, in any degree tenable, has been offered to explain the connection of this variation with the sun. We are, therefore, also unable to assign this period to any definite solar height. But there are reasons (Encycl. Brit., art. *Meteorology*) for thinking that it is the rota-

* Proc. Amer. Assoc. Adv. Sci., ix, p. 87, 1855.
† Carrington, Observations on Solar Spots, London, 1863.
‡ Hornstein, Ber. Akad. Wien., lxiv, p. 62, lxvii, p. 385, 1873.
§ Braun, C. R., lxxvi, p. 698.
‖ Liznar, Ber. Akad. Wien., Bd. 91, p. 454.

tion period of the same part of the sun as that given by magnetic variations. In this case the three particularly active solar meridians, discovered by Braun, would appear to be essentially regions of great thermal, rather than magnetic, activity. That these variations are due primarily to the direct heating effect of the sun is the basis on which Faraday, Christie, De la Rive, and Stokes have each with varying success explained the subject of terrestrial magnetism.

But if the rotation period is to be determined from barometric and magnetic disturbances, then regions of special solar activity must be assumed to be persistent. Evidence of this from other sources is doubtful, though the observations of Sporer on sun spots and Wilsing on faculæ would seem to indicate that these outbursts have a tendency to recur at the same place

Doppler's principle has already been applied by Zöllner, Vogel, and Young, to the determination of the relative velocities of the extremities of a solar diameter. Here we have under investigation probably a different part of our luminary, viz: the seat of selective absorption for the Fraunhofer lines, a layer of considerable thickness mixed up with and extending into the photosphere. So that this method probably gives the period of a region higher than that of the sun spots.

Later, Wilsing,* of Potsdam, has measured, by means of photography, the daily angular motion of a large number (1012) of persistent faculæ. Since these are seen as elevations in passing over the sun's limb and give brighter spectra† than surrounding portions of the solar surface, there is reason for thinking that the period thus obtained by Wilsing is that of a region some distance above the photosphere.

There are, then, at least four distinct solutions of the problem in hand:

(*a*) The observation of sun spots, giving the period of the lower parts of the photosphere for various latitudes. The data in our possession are here limited to a zone extending a little less than 45° on each side of the equator.

(*b*) The observation of the meteorological (including magnetic) elements, giving the period of an unknown region, possibly of the more solid interior, possibly of the region of the great uprushes around the spots.

(*c*) The measurement of the difference of refrangibility of light coming from the eastern and western limbs of the sun, suggested by Zöllner.

Since the accuracy of this method varies as the cosine of the latitude, observations are, at present, of no value for parallels higher than 75°.

* Wilsing, Publicationen des Astrophysikalischen Observatoriums, 1884.
† Lockyer, Chemistry of the Sun, p. 105.

(*d*) The observation of faculæ, giving the period for a layer probably a few hundred miles higher than the photosphere. Present data extend from 24° S. to 33° N.

Each of these methods gives the synodic period.

The object of the work communicated in this paper is to measure the rotation for a zone some 60° wider than any hitherto observed, and to verify or disprove the conclusion which appeared to follow from some observations made a year ago.* The measurements then at hand gave for the daily angular motion, θ, of any point on the sun's absorbing layer, as a function of the heliocentric latitude, χ,

$$\theta = 838' \, (1 + 0{\cdot}00335 \, \chi),$$

which makes the velocity a minimum at the equator, the place at which, for sun spots, it is a maximum.

There was also, apparently, a systematic error† in the first series, depending either upon the heating of the spectroscope or upon some cause which varied with the date of observation. This, I hope, has been eliminated in the second set of measurements, which are here given.

They were made with the same instrument, viz: the large spectrometer of the Johns Hopkins University, but with the three modifications which follow.

The method of shifting the sun's image across the slit was so changed that almost any solar latitude could be observed at any time.

This was accomplished by a device suggested by Professor Rowland. The brass ring which held the condensing lens was furnished with a metal arm, not unlike the handle of a palm-leaf fan. This arm was pinned to a brass collar, larger than the lens and surrounding it. This pin was the axis, parallel to the optical axis of the lens, about which the lens rotated through a small arc, throwing the image of the sun, now with its eastern, now with its western, limb on the slit. But this collar, besides having adjustable stops to limit the motion of the lens, could also be rotated in its own plane, and clamped in any azimuth, thus changing the direction of the motion of the image across the slit. To make this latter change was the only purpose of this part of the apparatus. For a reflecting prism was inserted between the condensing lens and the collimator, and by rotating this, any desired portion of the sun's limb could be made tangent to the slit. This having been done, the image would, in general, no longer move at right angles to the slit; so the device above described was used to counterbalance the effect of the prism on the

* Crew, this Journal, Feb., 1888.

† Discussion of this in Observatory, April, 1888.

direction of motion. The prism was by Steinheil and gave very perfect definition.

The Fahrenheit heliostat, with two mirrors, used in the first series, was replaced by a better instrument of the Foucault pattern.

Two of Professor Rowland's gratings were used. That designated as "No. 1," I had used before. It was four inches long, ruled with 14,436 lines to the inch, and gave superb definition in the 4th order. The other, "No. 2," was a six-inch grating, with 7218 lines to the inch, and gave fair definition in the 8th order.

The objectives of the collimator and telescope had each a clear aperture of six and one-half inches. The angle between their optical axes remained constant, the grating being movable.

In the first series, the grating was so placed that its normal and the diffracted ray were both on the same side of the incident ray, a position which shall be denoted by "right;" while, in the second series, the normal and the diffracted ray were on opposite sides of the incident ray, a position called "left." This change, as we shall presently see, has a very decided effect on the result.

The method of observation was very simple. The adjustment of the instrument having been tested as accurately as could be, by setting on an atmospheric line, the cross hairs were then set on the solar line whose displacement was to be measured, and the micrometer read. The sun's image was then shifted by a cord convenient to the observer at the eyepiece, and the micrometer read for the opposite limb. Ten settings of this kind were made in succession, and then a new latitude was chosen.

Formula.

The value of the relative linear velocity of the two limbs at the equator, $v'—v''$, was computed from the following formula which, together with the method of obtaining the heliocentric latitude, was sufficiently discussed in connection with the first series.*

$$v' - v'' = \frac{c\ V \Delta}{\lambda \cos \chi} \cdot \frac{1}{\cos h} \cdot \frac{\sqrt{1 - \sin^2\chi \cos^2\chi}}{\cos \chi \quad \cos \theta} + 2\alpha \sin \varphi$$

* Professor Oliver has been kind enough to call my attention to an error in the formula as used in the computation of the first series, viz: the omission of the factor "2" from the last term of the right-hand member, the effect of which was to make the result there given some three per cent smaller than it should have been.

The corrected value from the *previous* measurements is

$$v' - v'' = 2{\cdot}565 \text{ mi. per sec.}$$

and daily angular motion at equator = 838′.

Where
- c = value of one revolution of the micrometer screw in Ångström's units.
- V = velocity of light, in miles per second.
- Δ = displacement measured in micrometer revolutions.
- λ = wave length of line whose displacement is measured.
- χ = heliocentric latitude.
- h = half the angle subtended at the center of the sun's image by that portion of the slit covered by the sun's image.
- θ = inclination of the plane of the solar equator to the ecliptic.
- φ = angular semi-diameter of the sun as seen from the earth.
- α = linear velocity of the earth in its orbit, in miles per second.

Observations.

The following table includes all the observations made, except three in which a radial slit was used. The difficulty of setting on the end of such a line is so great that these have been discarded, and only those made with a tangential slit are retained.

These observations are arranged in the order of their solar latitudes, given in column 7.

Column 6 gives the difference between the readings of the micrometer, on the eastern and western limbs of the sun respectively. The relative equatorial linear velocities, computed from the above formula, will be found in column 8.

In column 9 is given the average discrepancy (in per cent) among themselves of the ten settings which make up each observation. May it not be that local currents—solar gusts—have something to do with the large irregularities in this column?

Column 10 gives the quadrants in which lay the extremities of the solar diameter under observation. This, together with the latitude, completely determines the points at which the slit was made tangent.

Each weight in column 11 is the product of the cosine of the latitude by a number depending on the definition and the grating, and was determined from notes taken at the time of observation.

Six of the observations were made by Mr. Louis Bell, Fellow in Physics of the Johns Hopkins University; the others by the writer. Neither of us, at the time, had the slightest idea in what latitude we were observing. The value of the mean relative equatorial velocity thus obtained is

$$v'-v''=2{\cdot}173 \pm 0{\cdot}028 \text{ mi. per sec.},$$

a velocity some 15 per cent less than that obtained in the first series, viz: 2·565 mi. per sec. But this, as Professor Young has

TABLE I.

1 No. of obs.	2 Date.	3 Mean time of obs.	4 Line.	5 Grating.	6 Displacement. Δ	7 Heliocentric latitude χ	8 $(v'-v'')$ $-2a\sin\phi$	9 Ave'g. discrepancy.	10 Direction of diameter measured.	11 Weight.
		H. M.			Rev.	°	M.p. sec	%		
1	July 6	12 12	5166·4	No. 1	0·0905	4·4	2·165	6	N.W.-S.E.	50
2	June 18	11 09	5914·3	2	0·1121	8·1	2·099	6	N.W.-S.E.	20
3	July 11	10 58	5166·4	1	0·0824	8·9	1·990	11	N.E.-S.W.	50
4	June 19	11 36	D_1	1	0·1076	14·3	2·100	13	N.W.-S.E.	10
5	"	11 50	"	"	0·1116	15·2	2·187	11	N.W.-S.E.	20
6	July 6	11 54	5166·4	"	0·0843	16·3	2·095	8	N.W.-S.E.	40
7	July 3	11 24	5914·3	"	0·1089	17·5	2·188	10	N.W.-S.E.	20
8	June 18	11 52	"	2	0·0990	18·3	1·932	12	N.W.-S.E.	20
9	June 16	11 33	D_1	"	0·1224	18·5	2·410	14	N.W.-S.E.	10
10	July 11	10 39	5166·4	1	0·0764	21·9	1·966	11	N.E.-S.W.	45
11	June 19	12 14	D_1	"	0·0993	24·0	2·056	9	N.W.-S.E.	18
12	July 3	11 36	5914·3	"	0·1023	24·3	2·150	14	N.E.-S.W.	27
13	July 3	12 24	"	"	0·1050	24·4	2·210	15	N.W.-S.E.	36
14	June 18	10 56	"	2	0·0881	24·8	1·799	12	N.W.-S.E.	18
15	July 3	12 36	"	1	0·0995	25·1	2·106	12	N.W.-S.E.	27
16	June 18	12 06	"	2	0·0966	25·6	1·985	8	N.W.-S.E.	18
17	June 19	12 54	D_1	1	0·1044	30·4	2·289	17	N.W.-S.E.	18
18	June 18	12 34	5914·3	2	0·0802	32·5	1·763	10	N.E.-S.W.	24
19	July 6	12 24	5166·4	1	0·0749	32·8	2·131	12	N.W.-S.E.	40
20	June 18	12 22	5914·3	2	0·0920	39·3	2·202	13	N.W.-S.E.	8
21	"	11 21	"	"	0·0871	39·6	2·101	10	N.W.-S.E.	16
22	July 3	11 10	"	1	0·0681	43·1	1·786	11	N.W.-S.E.	21
23	"	12 03	"	"	0·0866	43·6	2·291	11	N.E.-S.W.	14
24	July 11	1 06	5166·4	"	0·0415	45·7	1·420	23	N.E.-S.W.	35
25	June 18	1 45	"	2	0·0567	45·8	1·534	13	N.E.-S.W.	21
26	July 6	11 21	"	1	0·0625	49·6	2·300	6	N.W.-S.E.	36
27	"	12 56	"	"	0·0406	56·6	1·762	15	N.W.-S.E.	25
28	July 11	11 30	"	"	0·0414	57·1	1·824	18	N.W.-S.E.	25
29	June 18	1 32	"	2	0·0513	58·8	1·872	16	N.E-.S.W.	15
30	July 6	11 05	"	1	0·0457	58·9	2·112	15	N.W.-S.E.	25
31	June 19	12 45	D_1	"	0·0621	60·0	2·347	18	N.E.-S.W.	10
32	July 6	10 49	5166·4	"	0·0276	62·3	1·418	19	N.W.-S.E.	25
33	July 6	1 11	"	"	0·0248	72·1	1·932	30	N.W.-S.E.	18
34	July 3	10 58	5914·3	"	0·0300	72·7	1·941	25	N.W.-S.E.	9

pointed out, is just what one would expect, since all the settings of the *first* series were made with the grating "right," and all those of the *second* with the grating "left." For the heating effect of the sun on the slit-plate will, in the first case, introduce an error with a positive sign, and in the second case, with a negative sign; *but these errors will not be equal in amount.*

I attempted to detect any heating effect by observing atmospheric lines, and, failing to discover any motion when the image was rapidly shifted from one jaw of the slit-plate to the other, I conclude that this effect would be negligible in measuring the displacement. But this is not true, because, in the latter case, the sun has more time to heat the plate.

When we consider that, if the whole differences between the two results were due to the heating of the slit-plate, the displacement of an atmospheric line on the micrometer would be only $\frac{1}{1000}$ of the distance between D_1, and D_2, it will not be surprising that it was not detected by direct observation of the motion.

Without knowing what displacement of the slit by heat would be required to harmonize the two results, I computed the amount of this error as follows: Of two thermometers, placed one on either side of the slit, that in the sun's image indicated at the end of one minute (the average time of a complete reading), an excess of 10° C. over the other.

If the angle of incidence be denoted by i, the angle of diffraction by r, the order of the spectrum by n, the wave-length by λ, and the grating space by e, then

$$\sin i + \sin r = \frac{n\lambda}{e} = \text{constant.}$$

$$\therefore dr = -\frac{\cos i}{\cos r} di$$

where di is the *angular* displacement of the slit and dr is the resulting *angular* displacement at the micrometer. When the eastern limb of the sun was on the slit the displacement was always in a direction opposite to that when the western limb was observed, so that these effects were added. Not only so, but since the increment di is negative when the grating is "right," dr will be positive and the reading of the micrometer will be too large. If now the grating be turned "left," di will be positive, and hence the micrometer reading too small.

There were 20 revolutions of the micrometer to the centimeter, and the ratio of the focal length of the telescope to the collimator was 1·08; so that if we call the micrometer error dm and the *linear* displacement of the slit ds, then

$$dm = -20 \times 1{\cdot}08 \times \frac{\cos i}{\cos r} ds \text{ micrometer revolutions.}$$

The condensing lens had a clear aperture of 8^{cm} with a focal length of 135^{cm}, thus giving an image of $1{\cdot}25^{cm}$ diameter. The jaws of the slit-plate were of blackened brass, were a little wider than the sun's image, and expanded toward the slit. If we assume that the expansion took place throughout that part covered by the image, then for 10° C.:

$$ds = \pm 1{\cdot}25 \times 10 \times 0{\cdot}000019 = 0{\cdot}000238 \text{ centimeters.}$$

$$\therefore dm = \pm 0{\cdot}0052 \times \frac{\cos i}{\cos r} \text{ micrometer revolutions.}$$

For either grating in the position "right," the value of $\frac{\cos i}{\cos r}$ was approximately, for all lines observed, 0·84.

$$\therefore dm = + \overset{\text{rev.}}{0{\cdot}0044}$$

But in the position "left," $\frac{\cos i}{\cos r} = 1{\cdot}19$,

$$\therefore dm = - \overset{\text{rev.}}{0{\cdot}0062}$$

The divergence between the first series and the second, due to this cause, would therefore be that produced by a difference of $\overset{\text{rev.}}{0{\cdot}0106}$ in the micrometer readings. Now the mean value of the displacement due to rotation, for latitudes less than 30°, was $\overset{\text{rev.}}{0{\cdot}099}$; for latitudes between 30° and 75°, was $\overset{\text{rev.}}{0{\cdot}060}$. So that the heating effect would explain for lower latitudes a divergence of 11 per cent, and for higher latitudes, a difference of 18 per cent between the results of the first and second series. It is thus fully competent, on the assumptions we have made, to explain the discrepancy between a velocity of 2·565 mi. per sec., obtained in the first series, and 2·173 mi. per sec., obtained in the second.

Dividing this error in the ratio $\frac{0{\cdot}0044}{0{\cdot}0062}$, we have for a final value

$$v' - v'' = 2{\cdot}403 \pm 0{\cdot}026 \text{ mi. per sec.},$$

which corresponds to a sidereal period of 26·23 days, or a daily angular motion of 824′.

It is to be observed that this result is independent of any assumption as to *how much* the slit is heated. The divergence between the two series has simply been divided in the ratio of $\frac{\cos i}{\cos r}$ for the position "right" to $\frac{\cos i}{\cos r}$ for the position "left."

To determine the change of angular velocity with latitude, I have drawn through the observations of the *second* series the straight line which most nearly represents them, and find by the method of least squares its equation to be:

$$\theta = 802'(1 - 0{\cdot}00206\, \chi^\circ)$$

where θ is the daily angular motion, and χ the heliocentric latitude, expressed in degrees. This would indicate acceleration as we approach the equator. The *first* series gave:

$$\theta = 838'\,(1 + 0{\cdot}00335\, \chi^\circ).$$

Since the error due to heating affects the higher latitudes more than the lower, in the ratio of the secants of the latitudes; and since it enters the two series with opposite signs, the coefficients of χ, in any accurate work, *ought* to have opposite signs, always provided there was in reality no very marked change of angular velocity with latitude.

Combining these two expressions:

$$\theta = 823' \, (1 + 0{\cdot}00065 \, \chi^\circ).$$

The co-efficient of χ is too small to put much stress upon, when we consider the necessarily large errors in the observations from which it was derived. As it stands, however, it indicates that points in latitude 45° rotate in 18 hours *less* time than points at the equator, while Carrington's expression for sun spots,

$$\theta = 865' \, (1 - 0{\cdot}191, \sin^{\frac{7}{4}} \chi^\circ)$$

would make the rotation period at 45° some $2\frac{1}{2}$ days *longer* than at the equator. The difference between the two is quite marked. Can it indicate that the spectroscope measures the velocity of regions, corresponding in some degree to upper or lower "trades," the angular velocity of each of which would *decrease* from the equator to poles?

But it is not easy to think of any cause competent to produce "trades" on the sun, since no certain difference of temperature* between equator and pole has ever been discovered. The evidence afforded by these observations, therefore, is, that *no certain variation of period with latitude has been detected by the spectroscope.*

Wilsing (l. c., p. 436) has examined the motion of faculæ with reference to this same phenomenon, but failed to find any "drift" or change of velocity with latitude.

The following table may, I think, be considered as fairly representing the best determinations of the *sidereal* period of points on the equator.

From Barometer and Thermometer.	*Hornstein*—from daily range of barometer at Prague during the year 1870,	24·12
	Braun—from daily average of barometer at Singapore, 1841–1845,	24·13
	Van der Stok†—from daily average of barometer,	24·10
	" " range " "	24·11
	" " average " thermometer,	24·10
	" " range " "	24·14
	Von Betzold‡—from thunderstorms in Bavaria and Wurtemberg,	24·12

* Young's *Sun*, p. 264.

† Van der Stok: Natuurkundig Tijdschrift voor Nederlandsche-Indie, Deel 48. The observations extend over 7740 days, were made in the tropics where the amplitude is large, and are entitled to great weight.

‡ *Nature*, April 11th, 1889.

Variation of Magnetic Elements.	*Hornstein*—variation of magnetic elements at Prague and St. Petersburg during 1870,	24·51
	Braun—variation of magnetic elements at Greenwich and Makerstown during five years, between 1844 and 1870,	24·18
	Liznar—magnetic disturbances (storms),	24·29
Photosphere Equatorial values.	*Carrington*—from sun spots—seven years' observations,	24·97
	Sporer— " " "	24·60
	Wilsing—from faculæ,	25·23
	Crew—by spectroscope, equatorial value,	26·23

It will be observed that the lowest value by any one method is higher than the highest of the next preceding. May this not correspond to a physical fact, viz: that as we pass from the more central portions of the sun, up through the photosphere, faculæ, and absorptive layer, there is a gradual decrease of angular velocity?

Haverford College, April 16, 1889.

Art. XXVIII.—*The "Grand-Gulf" Formation of the Gulf States;* by Lawrence C. Johnson.

The group of clays, sands, sandstones and quartzites called the Grand-Gulf formation by Dr. Eugene W. Hilgard, has a boundary as yet undefined in Texas and Louisiana, and is little better known in the States east of the Mississippi River. Dr. Hilgard considers it of fresh water origin, and upon good grounds; but of what precise age no one has been bold enough to advance a definite opinion. Fossils are rare: a few *Uniones* have been found, and in places, there are many leaf impressions. It cannot be older than *Miocene*, and is as certainly not Quaternary.

The sandy clays, and quartzose sandstones of this formation are so peculiar in structure, colors and general appearance that they are easily recognizable, and cannot well be mistaken for any other in these States, much less for any of the calcareous groups northward of it. By all observers it is agreed that the strata next in this direction, are of Dr. Hilgard's Vicksburg Formation. The trend of the northern boundary of the "Grand Gulf"—from the vicinity of the place giving it its name, in Claiborne County, Miss., is southeastward at such an angle that at the Alabama line it has a breadth only half as great as on the Mississippi River, that is: allowing an average of twenty miles for the coast formations, it is about sixty miles in width next to Alabama, against one hundred and twenty-five on the meridian of Vicksburg. No critical surveys of it having been made and its eastern extension is only conjectural.

Adjoining the Great River, the "Grand Gulf" formation is covered first by the sands and gravels called by Dr. Hilgard "the Orange Sand;" and this is overlain by his "Port Hudson" and lœss. At a dip, estimated as between twenty and thirty feet to the mile, the average thickness must approximate two hundred feet.

Though a geological examination of this obscure portion of our Gulf terranes has only commenced, the relation of the "Grand Gulf" to the underlying and overlying formations, having within the last three or four years been called in question, some recent observations on the line of the calcareous Eocene outcroppings may be of general interest.

As already intimated, there is no dispute as to later strata. The so-called "Orange-Sand," at least to the west, covers the "Grand Gulf" to unequal depths. Many sections in Claiborne, Jefferson and Adams Counties, Miss., on the smaller tributaries of the Mississippi, exhibit the great gravel beds assigned by Dr. Hilgard to his "Orange Sand," resting upon it, as the lœss there rests upon the gravel. Underlying it, we are not so fortunate as to possess many satisfactory exposures. The relations here were rather an inference on the part of Dr. Hilgard, founded upon general principles, and not from instances of actual visible contact. It has even been said that no locality shows exactly the relative position of the two, so as to prove conclusively Dr. Hilgard's hypothesis. Mr. Otto Meyer thought he saw a contact of these in a cut of the Vicksburg and Meridian Railway, near Pelahatchie, Miss., and he regarded it as proof of his hypothesis that the "Grand Gulf" is the older, and that the superposition is the other way.

Having traced the course of the Eocene rocks across several counties of Mississippi, and seen the exposures on almost all of these small rivers and railroad cuts, I have no doubt whatever of the correctness of Dr. Hilgard's views. Had no locality of actual contact been found, the evidence would still be satisfactory, for in every instance in this State, and in Alabama, and in Louisiana, where the stratification could be observed of either of these formations, the dip has been found uniformly southward.

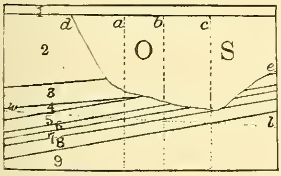
To set all questions aside, at least one point of actual contact has been found. As a general rule, the streams of this region run southward, and cut across the structure of the formations, but they fail to make many bluffs, and these not at points to expose the strata and their relative positions. On Chickasawkay River, however, the bluffs, which extend in almost unbroken series for more than twelve miles between Shubuta and Winchester, display every layer from the former in the middle of the Jackson formation to Brown's Bend in

Wayne County, three miles southeast of Waynesboro, where the Grand Gulf stands alone, with clean cuts of its peculiar clays and quartzitic rocks, to a thickness of seventy feet. The most southern three miles of these exposures are particularly instructive.

Beneath the surface actually visible at Brown's Bend lie two beds of clay, very sandy, very compact, and of a greenish-yellowish color, mottled with pink, on the whole of a cast seen only in the Grand Gulf formation, and indescribable. They are six to eight feet in thickness each, and have a layer of sand, one foot deep, intercalated between them. Beneath this double bed of clay, lies another layer of sandy material, about two feet thick, containing lumps and fragments possibly of organic origin but not recognizable. This much, unseen at the Bend itself, crops out half a mile farther north ; and still a little farther, all these layers, the double-bedded clay and attendant sands, appear above water at a low stage, with sufficient of the underlying strata fully to explain the nature of the unstratified sand beneath the clays.

The first that comes to the surface beneath the above described clays and sands, is about four feet thick, and a very compact sand made up as it were of fucoidal stems like tangled roots. Beneath this lie four to six feet of a dark crumbling sand filled with spines and fragments of Echinoderms and decayed remains of Ostrea. One mile up the river from Brown's Bend, at Trigg's Old Ferry, all these fossiliferous layers may be seen well above water, together with the next underlying, which at this point consists almost exclusively of gigantic oyster shells. At Cochran's Ferry, a few hundred yards still farther north, ten feet of this great Ostrea bed are visible at low water, and other Vicksburg fossils are discoverable scantily among the oyster shells.

A general section may be made to show the structure from Brown's Bend to Cochran's Ferry, one and a half miles, as follows:



OS. Stratified Orange Sand; 1, sandy soil with pine woods, old terrace, 10 ft. thick; 2, gray sandy clay, 60 feet; 3, compact whitish sand, becoming sandstone in places, 20 ft.; 4, clays, 10 feet; 5, clayey sands, no distinct fossils, 6 feet; 6, fucoidal hard sands, 2 feet; 7, compact sands, with fragments of *Ostrea* and other shells, 3 feet; 8, dark sands, with fragments of Echinoderms, 5 feet; 9, bed of *Ostrea gigantea* and *O. Vicksburgensis*, etc., over 10 feet of it, probably 30 to 40 feet; two miles to the north this mingles with the Vicksburg limestone of Huggins Bluff having *Orbitoides Mantelli* and *Pecten Poulsoni; a*, line of calcareous Eocene; *b*, Trigg's Old Ferry; *c*, Cochran's Ferry; *d* to *e*, line of very old erosion filled in again with the so-called Orange Sand; *w l*, water line.

At Trigg's Old Ferry, by means of a small spring branch, which comes pouring out of the sands a short distance to the west, everything has been washed away and again covered, so as to alter and hide the original bluff down to the compact fucoidal sands, which a full stage of water would protect and conceal. And at the other point mentioned where the fossiliferous layers are first seen beneath double-bedded joint clays, quite a bold spring branch comes in with like effect; for it has cut through all the layers down to low water and by stealing out in preference the soft, sandy layers, has so let down and distorted the lay of the clays, that it is difficult to determine the dip. On occasion of the first visit the writer supposed it to be the same as that of the calcareous beds. Upon further observation, he is satisfied that it is less. That is: putting the dip of the Vicksburg rocks at thirty feet to the mile—and it cannot be less—the Grand Gulf is probably about twenty feet and can scarcely be more. To settle this exactly will require further and more careful observation.

This layer of the Vicksburg formation, in which the great oysters abound, may be followed up the river more than two miles, and cannot be much less than forty feet in thickness. Echinoderms and corals become more common in the lower portions of it, and with them, among other things, are conspicuous the great tubes of *Aspergillum* or some kindred *Tubicola*—all forming a transition of Rotten limestone, before passing to the hard bluffs of *Orbitoides* rocks, constituting so much of the river bed for the next six miles.

All the eastern bank of the river is made of a kind of second-bottom, from one to three miles in width, having a few low places through which the river runs at high water, and many sandy knolls over which the water never rises. In some of these branches, and in all the wells dug in this flat, the Rotten marl, having shells of *Ostrea Vicksburgensis*, is found near the surface. Along the foot of the hills eastward there are sand hills and benches, evidently remnants of an olden terrace.

The older terrace constitutes wholly the western bank of the river and its towering bluffs. At Cochran's Ferry the bluff cannot be less than one hundred feet high, and consists entirely of soft sands, resembling "Orange Sand." Though so near the terrace of compact clays at Brown's Bend, these sands at Cochran's have not the faintest resemblance to the Grand Gulf strata of the hills to the west and south. Evidently there has been a great erosion, and refilling at this point and for some miles farther north; all which may be gathered from the section herewith exhibited.

These notes are offered, not with a view to controversy, or to re-open a discussion: It can hardly be said, that there is a serious doubt in the premises, but as a statement of facts, and an attempted description of a locality in itself interesting, and worthy of a visit.

Art. XXIX.—*Radiant Energy and Electrical Energy;* by John Trowbridge.

The relations between radiant energy and electrical energy are daily becoming more important, and the experiments of Hertz on Electrical Rays lead one to ask whether the doctrine of the conservation of energy can guide us in answer to the question, what are the transformations of energy in a dielectric submitted to rapidly alternating electrical stress?

Hertz has also shown that ultra violet waves of light exercise a marked influence upon the striking distance of the electric spark. E. Wiedemann attributes this effect to a selective absorption of the metals between which the spark is passed. Thus platinum terminals show the effect in a more marked degree than the terminals of other metals, and it is well known that platinum exercises a marked selective absorption for violet rays. This explanation of the phenomenon observed by Hertz may however be only a partial explanation. The question still remains, do ultra violet rays exert any effect upon a dielectric which becomes manifest in changes of electrical stress? Or, to put the question in another form, are the shorter waves of electrical energy passing between the plates of a condenser, separated by various dielectrics, absorbed by the dielectric, or is this the case for the long waves only? It is well known that a dielectric is under stress when submitted to rapidly alternating electrical charges. Under the supposition that an electrical wave or disturbance in the ether carries heat and light waves; or that there is a close correspondence between the phenomena of light and heat waves and electrical waves, we are led to ask if there are not transformations similar to those Alexander Graham Bell has shown to exist in substances submitted to the action of rapidly interrupted waves of energy in the form of heat. The Radiophone shows that the long waves of energy become absorbed in passing through various substances. The transformation of energy is shown by a musical note which is that of the wheel employed to interrupt the beam of light which falls upon the substance under examination. The effect is evidently due to the long waves of energy which we call heat. The effect might have been anticipated; for Balfour Stewart had shown that a body subjected to changes of temperature undergoes a change not only at its surfaces, but also throughout its interior. The rapidity of these changes, however, had not been suspected until the invention of the Radiophone.

In the case of the Dolbear telephone, electrical oscillations are transmitted from one plate of an air-condenser to another.

With this instrument we have no guide or indication of the size of the electrical undulations which are transformed while creating a stress in the dielectric which separates the two plates of the condenser. I was led, therefore, to examine the specific inductive capacity of well known insulators in order to perceive if any relation exists between such inductive capacities and the selective absorption of radiant energy which these substances may exhibit. The first substance selected was naturally paraffine. In order to examine its selective absorption a layer of it in the melted condition was contained between quartz plates. In order to keep it melted the plates were imbedded in sand, an aperture being left for the passage of light, and placed over a Bunsen burner. Light passing through the paraffine was then examined by means of a spectroscope provided with quartz lenses and a quartz prism. It was found that the paraffine transmitted the ultra violet rays certainly as far as wave-length 3400. There was evidence that absorption of the ultra violet rays began in the neighborhood of this wave-length. Thin sheets of vulcanite were next examined. These transmitted light through the extent of the visible spectrum from the extreme limit of the red to the beginning of the blue region of the solar spectrum. It was opaque to the blue and the violet.

The following table gives a comparison of the specific inductive capacities of the substances examined and the range of their selective absorption in the ultra violet.

Dielecric.	Specific inductive cap.	Limit of transmission.
Glass	3·243	about 3800
Paraffine	2·32	about 3400
Ebonite	3.15	opaque
India rubber...	3·24	opaque
Quartz	4·6	below 2000
Iceland spar. ..	8·4	below 2000

Boys has lately called attention to the remarkable insulating qualities of quartz.

From the above table we are apparently justified in drawing the conclusion that the long waves of electrical radiation, the existence of which has been shown by Hertz, behave like the long waves of radiant energy which we term heat waves, and perform work in the dielectric when transmitted in an alternating manner through it. The short waves of electrical energy if they are analogous to the short waves of light are apparently not absorbed by the dielectric when this dielectric approaches perfection as a dielectric. The theory, therefore, that electrical attraction may be due to extremely rapid vibrations of the ether which cause attraction of bodies, much as a pith ball is attracted to a vibrating prong of a tuning fork, is apparently not supported by the new theory that very short electrical wave-lengths are closely related to very short wave-lengths of light: for we should expect that there would be an absorption of these extremely quick oscillations of light or electricity when the attraction between the conductors, insulated by a dielectric, increases. Calling K the specific inductive capacity of the medium between two plane conductors, S the area of the opposed surfaces, c the distance between the plates B and A the potentials of the plates, we have total energy $Q=\frac{KS}{8\pi c}(B-A)^2$. This evidently increases with the value K. The relations between electric conductivity and opacity have been discussed by Maxwell, vol. ii, p. 798. Calling V the velocity of propagation, K the resistance in electromagnetic measure, of a plate whose length is l, breadth b and thickness z. The proportion of the incident light which will be transmitted by this plate will be of the form

$$\varepsilon^{\frac{-4\pi\mu l V}{b R}}$$

This proportion evidently increases with the value R.

Jefferson Physical Laboratory.

Art. XXX.—*Note on the fossil Spider Arthrolycosa antiqua* Harger; by Charles E. Beecher.

In the March number of this Journal for 1874, Mr. O. Harger described and illustrated a fossil spider from the lower Coal Measures of Illinois,* under the new generic and specific designation of *Arthrolycosa antiqua.*

While examining the type specimen in connection with preparing a series of fossils to illustrate Dana's Manual of Geology, it became evident to the writer that all the features of the fossil had not been observed at the time of the original publication. The specimen was then studied and figured in the condition in which it was first discovered, and had never been sufficiently cleaned, nor had the appendages been exposed by removing the superincumbent matrix. This has now been accomplished, and results render it necessary to make some modifications and additions to the original description, as well as to give an illustration of the specimen in its present state. These changes are quite important as *Arthrolycosa* is one of

* Notice of a new Fossil Spider from the Coal Measures of Illinois, viii. 219–223.

the oldest of the spiders, and the original figure has been copied into text books and general works on Paleontology.

A re-examination of the type was make by Professor Samuel H. Scudder in 1884,* and the only change from the original description suggested by him was in the character of the appendages then considered as the palpi. The conclusions reached were the following (*loc. cit.*): "Having reason, by its undoubted relationship to other forms of Anthracomarti, to doubt the forcipulate character of the palpus, . . I find on close examination that not only is the joint in question not chelate, but it terminates by a straight transverse suture, and is followed by a portion of another, apparently short terminal joint."

The specimen now shows that these members are not the palpi, but are the anterior pair of legs. The true palpi have been exposed, and the full number of cephalothoracic appendages revealed, including the normal number of eight legs, the palpi, and the mandibles.

Figure 1 represents the specimen as it now is, and the original illustration, figure 3, is introduced for comparison.

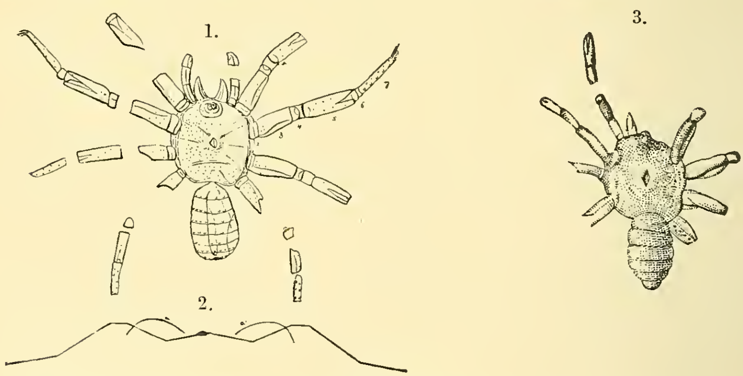


Figure 1.—Dorsal aspect of type; natural size.
Figure 2.—Profile showing elevation of cephalothorax and position of legs. *a*, *a*,′ profile of palpi.
Figure 3.—Original illustration.

The cephalothorax is subcircular in outline, with a slight sinus in the posterior margin for the insertion of the abdomen. It measures about 10^{mm} in diameter. The surface gradually rises toward the center, which is occupied by a deep rhomboidal pit marking the point of attachment for the muscle moving the sucking stomach. From this point, radiating grooves extend to the margin, indicating the ventral coxal

* Proceedings of the American Academy of Arts and Sciences, 1884. A contribution to our Knowledge of Paleozoic Arachnida, p. 15.

elements, and near the center of the posterior half, there is a sharp transverse ridge extending about two-thirds across the body. The anterior border presents a conical elevation measuring 3^{mm} in transverse diameter, and showing on its summit two oval prominences in which the ocelli were undoubtedly located. Two of them seem to be distinctly marked and are represented in the figure, while the others are obscurely shown and are not delineated.

Both mandibles are well preserved, and consist apparently of a short basal joint and a strong arched angular grooved terminal portion. Their position and character seem to indicate that they were moved vertically as in the Territelariæ (*Avicularia* = *Mygale*), and not laterally as in the majority of spiders. They project 3^{mm} beyond the margin of the carapace, and extend downward a distance of at least $1{\cdot}5^{mm}$.

The palpi are shorter and more slender than the legs, and to all appearances simply terminated, except that the inner edge of the extremity is marked by a small excavate area which may indicate the male palpal organs. Three or four joints can be made out, each being marked by a longitudinal ridge. Entire length observed, 6^{mm}.

The four pairs of ambulatory appendages differ little in character and can be homologized, joint for joint, with the Tetrapneumones. The two anterior pairs are somewhat more robust than the others, but present the same general features. Beginning with the distal joint as preserved on the second pair of legs, it is found to measure 6^{mm} in length and is elongate and slender in form, ending in some obscurely defined bristles and claws. The surface is strongly marked by pitted pustules, probably indicating the bases of the stronger hairs. The next, or sixth joint, is short, not longer than wide, and without ornament. The fifth segment is stout, measuring 7^{mm} in length and 2^{mm} in width, and furnished on its distal half with a triangular groove extending to the anterior articular face; surface with a few scattered capillary pits. The fourth and second segments are short and robust, resembling the sixth, while the third is similar to the fifth, but shorter and furnished with a flattened margin instead of a triangular groove. As the specimen presents only the dorsal aspect, the coxal elements of the limbs cannot be described.

The abdomen is as long as the cephalothorax, but only a little more than half the width of that portion. It is ovoid in form, very much constricted anteriorly where it joins the cephalothorax, and gradually widens posteriorly to the fifth segment. The specimen preserves seven segments which gradually decrease in length from the first to the seventh. Each is ornamented with a single row of nodes on its posterior border, and in addition, the last somite shows a depressed central area which may correspond to the spinneret, but otherwise, no abdominal appendages can be detected. The longitudinal lines represented in the figure have been produced by the folding of the test, due to compression in the rock.

Considerable interest is attached to the position and association of the specimen. From the figure and profile, it is seen that all the elements of the spider are in nearly their natural position, having undergone but slight distortion, while its perfection indicates that it is not a shed skin which is preserved, but that the actual animal was entombed.

In the same concretion are fragments of the broad leaves of a rush-like plant, and it is not improbable that they furnished a float upon which the spider was carried out from the land so that its remains are found mingled in the same beds with marine organisms.

With the additional evidence furnished by the original specimen, the systematic position of this form is open to revision.

It has been generally recognized as the type of a new family, Arthrolycosidæ, as first established by Mr. Harger. Professor Scudder placed this family at the beginning of the order Anthracomarti. The characters of the order as enumerated by him are: "Body somewhat depressed, the cephalothorax and abdomen distinctly separable. Cephalothorax usually made up in large part of more or less wedge-shaped pedigerous segments, the arrangement of which corresponds to that of the coxæ. Abdomen forming a single mass and composed of from four to nine distinct joints. Palpi not much longer than the legs and simply terminated."*

With the exception of *Arthrolycosa*, all the families of this order comprise species which have the abdomen larger than the cephalothorax, and divided longitudinally into well defined areas. The cephalothorax is composed of distinct wedge-shaped pedigerous segments, while in *Arthrolycosa*, it is formed of a single piece, not more divided into coxal elements than in the living species of Tetrapneumones.

The palpi of the Anthracomarti are said to be "not much longer than the legs," and, in this respect, *Arthrolycosa* differs in having short stout palpi, about twice as long as the mandibles, and reaching to the fourth segment of the anterior legs. The arrangement of the eyes and mandibles is also quite distinct in the two groups.

On account of these important differences, it seems necessary to exclude the genus from the order Anthracomarti, and at present, a strict interpretation of any of the orders will not admit this form.

*Bulletin U. S. Geol. Surv. No. 31, Systematic review of our present knowledge of fossil insects, including Myriapods and Arachnids. Washington, 1886.

The marked resemblance between the recent *Avicularia* (*Mygale*) and the fossil appears to be grounded upon more than trivial characters. *Avicularia* and allied forms, constituting the Tetrapneumones, with four air sacs in the abdomen as among the Scorpions, eight ocelli, two pairs of spinnerets, and vertically acting mandibles, form a division of the Araneina of much greater significance than a family, and this fact has been recognized in the separation of the order into the Tetrapneumones and Dipneumones. The first division embraces the suborder Territelariæ including the families Theraphosidæ and Atypidae, (Tarantulas and large hairy spiders), and the second is divided into six suborders and thirteen families, to which belong all the true spiders.

The similarity of organs used for sight, locomotion, and procuring food, is of much greater importance than the external segmented or unsegmented nature of the abdomen, which structurally and primarily is truly segmented, as shown by the anatomy, embryology and phyllogenetic history. Taking this view, it is seen that a slight extension of the characters generally ascribed to the Araneina, in the single direction of the segmented nature of the abdomen, will admit *Arthrolycosa* and place it in the division Tetrapneumones. From present information, there seems to be no marked characters which would exclude it from forming a family in the suborder Territelariæ.

Mr. J. H. Emerton previously called the attention of Mr. Harger to the general affinities between *Arthrolycosa* and *Mygale* (*Avicularia*) as noted at the end of the original description. At that time, however, the apparent forcipulate character of what was termed a palpus outweighed all other considerations.

Yale University Museum, June, 1889.

Art. XXXI.—*On the Paragenesis of Allanite and Epidote as Rock-forming Minerals*; by Wm. H. Hobbs, Ph.D.

The interesting discovery of Messrs. Cross and Iddings,* of the U. S. Geological Survey, that the mineral allanite or orthite occurs widely distributed as a constituent of many varieties of rocks, has placed this mineral in the list of important accessory rock-constituents, and called the attention of American geologists to its distinguishing characters. In Europe, allanite, or orthite, which is the term commonly used in Germany for the same mineral, had already become recognized as one of the rarer constituents of a few rock species. As early as 1860, K.

* Cross and Iddings, Wide-spread Occurrence of Allanite as an accessory constituent of many Rocks, this Journal, III, xxxii, p. 108, Aug., 1885.

von Fritsch* described this mineral in the granitite of Ilmenau in the Thuringian Forest. Vom Rath† recognized it as an important accessory constituent of the tonalite of Mt. Adamello. Interesting occurrences are mentioned by Liebisch‡ in the granite porphyry of Erdmannsdorf and other localities in Lower Silesia, and by Törnebohm§ in an amphibole-biotite granite from Eastern Siberia. Our knowledge of the optical properties of allanite has been much advanced by the investigation of this mineral in the granite of Pont Paul near Morlaix, Finisterre.‖

The occurrence of allanite and epidote as constituents of the same rock has been several times observed, and by two investigators these minerals have been found so intergrown, as to add evidence of isomorphous character to that already known to exist in the similar crystal form and analogous chemical composition.

In 1854, Blomstrand¶ described from Wexio in Sweden crystals of pistazite arranged radially about cores of allanite; and somewhat later Ewald Becker** mentioned inclusions of orthite in the epidote of a granite from Striegau. Messrs. Cross and Iddings†† observed apparent inclusions of epidote in allanite. It is further stated in many text-books‡‡ that cores of allanite in epidote and cores of epidote in allanite, occur at Sillböhle in Finland. After some search I am unable to designate the original paper by Nordenskiöld, but through the courtesy of Professor Wiik of Helsingfors, I have a copy of the catalogue to the mineral collection of the Helsingfors University§§ in which the interesting intergrowths are figured. A similar intergrowth has been recently found by Törnebohm‖‖ to characterize the epidote-gneiss of a considerable portion of Wermland. "Small crystals which have been taken for orthite and which are crystallographically similar and oriented like their host, occur in the epidote."¶¶

* Geognostische Skizze der Umgegend von Ilmenau im Thüringer Walde. Zeitsch. d. d. Geol. Ges., xii, 105.

† Beiträge zur Kenntniss der eruptiven Gesteine der Alpen, I, ibidem, xvi, 255, 1864.

‡ Ueber die Granitporphyre Niederschlesiens, ibid., xxix, 725, 1877.

§ Vega Expedition IV, 115–140, Stockholm, 1884. Ref. Neues Jahrb. f. Min., etc., 1885, i, 429.

‖ Michel Lévy et Lacroix. Note sur un gisement français d'allanite, Bull. soc. minèr. de France, xi, No. 2, 64, Feb., 1888

¶ Blomstrand, Oefvers. af akad. Förhandl., 1854, No. 9, p. 296. Ref. Journ. f. prakt. Chem., lxvi, 156.

** Ewald Becker, Ueber das Mineralvorkommen im Granit von Striegau insbesondere über den Orthoklas und dunkelgrünen Epidot, Breslau.

†† Loc. cit.

‡‡ Dana, Brooke and Miller, etc.

§§ F. J. Wiik, 1887, p. 27, pl. II, fig. 7.

‖‖ Törnebohm. Mikroskopiska bergartsstudier, XIII Epidotgneiss. Geol. För. i Stockholm Förhandl., 1882, No. 75, vi, 189.

¶¶ Ref. Cohen, Neues Jahrb. f. Min., etc., 1883, i, 245.

While engaged in the study of the geology of a section of the Johns Hopkins University map, two epidotic minerals were found to play an interesting rôle as accessory constituents of the porphyritic granite of Ilchester. A short notice on the geological relations of the rocks of this area, together with mention of parallel growths of epidote and allanite, appeared in April, 1888.* After a further examination of these interesting intergrowths, it is my purpose in the present paper to consider them more fully in connection with what has already been said concerning epidote and allanite.

The Ilchester granite, in which they occur, is one of the youngest of a series of eruptions in the gneiss and crystalline schist of eastern Maryland. It is a medium to coarse-grained rock, with a porphyritic aspect caused by the large microcline crystals scattered through the holo-crystalline to granophyric ground-mass. This ground-mass contains as essential constituents, varying proportions of monoclinic and triclinic feldspar, and biotite By the more or less complete replacement of biotite by hornblende, the granitite develops facies of hornblende granite. Besides allanite and epidote the only important accessory constituent is a colorless mica. Throughout the entire area of the section studied, the granite shows evidence of "stretching" in its more or less perfect "parallel structure," and in the broken character and disturbed optical properties of the constituent minerals.

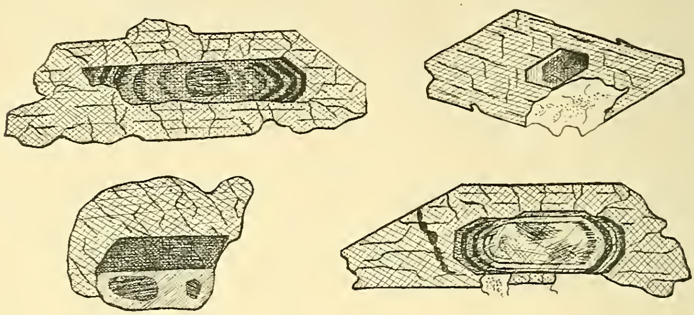
The epidote is macroscopically visible in the rock, generally as yellow columnar crystals one to three millimeters in length, though it is often without crystalline form. A brownish kernel is frequently visible within the epidote, and when prismatic planes are developed upon the latter, the perfect parallelism of the corresponding faces of the two minerals can be observed. The junction of the included mineral with its host appears as a sharp line, owing to the difference in color of the two minerals. The included mineral shows no distinct cleavage, is very brittle, and is found in some specimens of the granite decomposed to a brown powder. The brittle character of this mineral has prevented its removal from the matrix and examination with the goniometer.

Under the microscope its isomorphous relation to epidote is strikingly shown in many instances by the parallelism of the bounding planes of the two minerals and its distinct character

* Wm. H. Hobbs, On the rocks occurring in the neighborhood of Ilchester, Howard County, Maryland; being the detailed study of the area comprised in sheet No. 16 of the Johns Hopkins University map. Johns Hopkins University Circulars No. 65. (Preliminary notice of a dissertation for the degree of Doctor of Philosophy).

marked by a beautiful zonal structure absent in the epidote. The forms observed were M (001), r ($\bar{1}01$), T (100), and somewhat imperfect terminal planes, the symbols of which could not be determined. When not too deeply colored the long

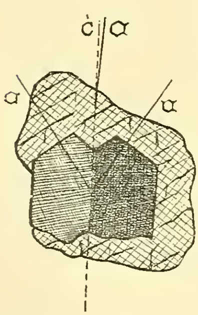
1.



Sections of intergrowths in the Ilchester granite, × 50.

sections yield an optic axis, which shows the plane of the axes to be the clino-pinacoid (010). Such sections therefore extinguish the light parallel and perpendicular to the long axis (b). The index of refraction is strong, while the double refraction is feeble, the interference colors between crossed nicols being of the first order, even when the slides are above the usual thickness. The dispersion is very strong, making indistinct the extinctions in polarized light. Twins parallel to the ortho-pinacoid were rarely observed. A chance section of such

2.



Section of twinned allanite crystal with mantle of epidote, × 5.

a twin appears in fig. 2. The symmetry of extinction with reference to the composition seam and the form of the section, are evidence that the plane of the section, lies nearly or quite perpendicular to the axis b. In either individual the axis of maximum elasticity makes an angle of 36° with the vertical axis, but in the absence of cleavage and perfect planes, it was impossible to determine whether this axis of elasticity lies in the obtuse or in the acute angle β. The surrounding epidote is allotriomorphic and a single individual, but orientated like one of the included crystals, as is shown by its axis of maximum elasticity, which makes an angle of 3° with the twinning plane of the inclusion. The pleochroism of the included mineral is one of its most marked characters, and has been determined to be as follows: $\mathfrak{a}$ light yellowish-brown, $\mathfrak{b}$ chestnut-brown, and $\mathfrak{c}$ dark greenish-brown. The absorption is like epidote $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$.

These characters belong to the mineral allanite and a comparison shows that they are the same as are possessed by the allanite of the Ten Mile Region of Colorado.* Further comparison with slides from the epidote-gneiss of Wermland in Professor Rosenbusch's collection shows that in this case, as in the Ilchester granite, we have to do with parallel intergrowths of allanite in epidote.

Since publishing my first notice of these intergrowths, the suggestion has been made that the surrounding mineral may not be epidote, but that it may be allanite whose color and optical differences are to be accounted for by slight differences of chemical composition; in other words that we have to do with a case of zonal structure in allanite. The characters of the epidote require therefore careful consideration.

The examination in thin section under the microscope shows the epidote to possess, in the majority of cases, the prismatic planes, M, *r*, and T. The longer sections of these crystals exhibit cleavage lines parallel to the longer axis, and yield in converging polarized light an optic axis, which often appears on the edge of the field. The plane of the optic axes is perpendicular to the ortho-diagonal and the optical angle is large. The cross-sections of crystals show an imperfect cleavage parallel to M (001), and a poor cleavage parallel to T (100). The cleavage angle measured 115°. The angle of maximum elasticity lies in the acute angle β and makes with the vertical axis an angle of 3° to 3° 3′. The pleochroism is distinct and as follows: $\mathfrak{a}$ nearly colorless, $\mathfrak{b}$ light straw-yellow, $\mathfrak{c}$ siskin-green The absorption is written $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$.

By the use of the Thoulet solution a quantity of epidote together with some admixed allanite and titanite was separated from the rock, and ·45 gram obtained pure by the tedious process of picking out the fragments of allanite and titanite, their darker brown color serving to distinguish them. I am indebted to the U. S. Geological Survey for an analysis of this powder by Dr. W. F. Hillebrand. Special examination was made to determine the presence or absence of the rare earths, but no trace of any was discovered. The material used in this examination necessitated a determination of the alumina by difference. The amount of ferrous oxide was not determined. The water was determined by loss on glowing. The results of Dr. Hillebrand's analysis are given under I. An analysis of the Untersulzbach epidote by Ludwig is introduced under II by way of comparison.

* The sections of the biotite-porphyrite of this region were kindly loaned me by Dr. Cross of the U. S. Geol. Survey.

	I.	II.
SiO_2	37·63	37·83
Al_2O_3	[20·86] difference	22·63
Fe_2O_3	15·29	15·02
FeO		0·93
MnO	0·31	----
CaO	22·93	23·27
MgO	0·31	----
H_2O	2·23	2·05
P_2O_5	0·44	----
	100·00	101·73

If we consider the phosphoric oxide as due to inclusions of apatite, and disregard the traces of manganese and magnesia, the analysis corresponds very closely with the formula $2H_2Ca_4Al_6Si_6O_{26}+H_2Ca_4Fe_6Si_6O_{26}$.

The peculiar intergrowths that have been described are characteristic of the Ilchester granite throughout the twenty-five square miles of the section studied.* Colorless inclusions, probably apatite, as well as biotite, are occasionally found in the allanite. With little doubt, the latter is one of the earliest separations from the magma. The origin of the epidote is not so easily settled, but the "stretched" character of the granite is in favor of a metamorphic origin through pressure. Against such a view is the discovery by Professor Williams that the Woodstock granite, which is particularly rich in these intergrowths, shows no evidence of cataclastic action.

In conclusion I would gratefully acknowledge obligation to my much honored teachers, Professor Williams of the Johns Hopkins University in Baltimore, and Professor H. Rosenbusch of Heidelberg, Germany.

After the foregoing article left my hands, there was brought to my notice the recent important paper of Lacroix on Pyroxene-gneiss and Wernerite Rocks (Contributions à l'étude des gneiss à pyroxène et des roches à wernerite, Bull. de la Soc. française de Minéralogie, tome xii, No. 4, April, 1889). The author describes similar epidote-allanite intergrowths in the pyroxene-amphibole gneiss of Finisterre (pp. 138–9, fig. 21); in the pyroxene-wernerite gneiss of the Lower Austrian Waldviertel (p. 157, pl. I, fig. 5); and in the wernerite gneiss of Odegården in Norway (p. 210). M. Lacroix has found the same properties to characterize the allanite and epidote of these localities as have been determined for the Ilchester intergrowths, specimens of which he has used for comparison. He considers the epidote primary in all the occurrences described by him (p. 353).

* I am informed by Prof. Williams that he has found such epidote-allanite intergrowths to be characteristic of the surrounding Ellicot City and Woodstock granites, but wanting in the Guilford granite which occurs farther to the south.

Art. XXXII.—*A new locality of the Camptonite of Hawes and Rosenbusch;* by Frank L. Nason.

In Hitchcock's "Geology of New Hampshire," Part IV, "Mineralogy and Lithology;" also in this Journal, vol. cxvii, p. 147, Dr. G. W. Hawes describes a "group of dissimilar eruptive rocks in Campton, N. H." Dr. Hawes calls these dikes respectively, diabase, olivine diabase, diorite and syenite. There are five dikes in all: one each, of the first three and two of the syenite. One of these dikes which Dr. Hawes has called a diorite, Professor Rosenbusch, in his last edition of the "Mikroskopische Physiographie der Massigen Gesteine," p. 333, has called Camptonite after the locality where it was first observed.

In the summer of 1885, the writer, while crossing the Green Mountains along the line of the Rutland and Burlington R. R. between Rutland and Bellows Falls, Vt., encountered a peculiar rock in a cut near the station called Summit. This rock was observed to occur in the form of a dike cutting across the quartzite and the gneisses of the Green Mountains. The dike, however, had a N. W. dip, strike N. E., S. W., while the country rocks dipped S. E. The dike is about six feet in width. Near its outer boundaries the contact with the rocks through which it broke prevented the coarse crystallization which took place in the center. It does not appear on the surface or either side of the cut. Careful search was made for it but without success. The reason is assumed to be that the dike rock is much more susceptible to weathering than the country rock. The hope of tracing the dike to some central chimney or throat was thus abandoned.

The macroscopic description given by Dr. Hawes of his dike No. 2, answers almost perfectly for this dike, save that the Summit dike is darker and richer colored, the porphyritic crystals of hornblende are fresher and of a larger size than the New Hampshire specimens which I have seen. The crystals of hornblende also appear to be more numerous in the Summit dike than in the other. It is also mottled near the contact with large crystalline nodules of calcite and occasionally of feldspar. Magnetite, menaccanite and pyrite also occur.

Microscopically the rocks present no striking differences save what a macroscopic study would suggest. In some of the mottled spots of the Summit dike, however, are cavities filled with true glass into which project well-developed lath-shaped crystals of feldspar.

About twenty rods above this dike, toward the Summit station, is another dike with the same dip and strike, but wholly different in appearance from the first dike. This dike corresponds to Dr. Hawes' diabase dike No. 1. It has large amygdaloid cavities which are filled with chlorophane (?), calcite, stilbite and apophyllite. The rock is much finer grained than the first dike and shows no porphyritic crystals. The microscope shows it to consist principally of augite crystals, with a small proportion of hornblende and biotite in a feldspar magma. The feldspar is not well crystallized. The rock is badly decomposed.

In the dike first referred to as being similar to Dr. Hawes' diorite, the microscope shows that there are present a few crystals of pyroxene. This makes the two dikes at the Summit the reverse of each other. The writer feels more certain of the identity of these two dikes with the diorite and diabase of Dr. Hawes since he (the writer) made a partial chemical analysis of the Summit rock which agreed almost exactly with the analyses published in the papers cited above.

I have not time to make a thorough microscopic study of the above rocks, but shall be glad to furnish material to any one who wishes to undertake it. I have no doubt, however, that such a study would only confirm the present opinion that the Summit dike is identical with the Camptonite.

Laboratory State Geol. Survey of New Jersey.

ART. XXXIII.—*A Determination of the value of the B. A. unit of Resistance in Absolute measure, by the method of Lorenz;* by DR. LOUIS DUNCAN, GILBERT WILKES and CARY T. HUTCHINSON.

THE work here reported upon was done at the Physical Laboratory of the Johns Hopkins University during the spring of 1888.

Lord Rayleigh's modification of Lorenz's original method was used: in this, as is well known, a measured part of the current flowing through the inducing coils is balanced by the current induced by the rotation of the disc.

The apparatus employed is that designed by Professor Rowland for his determination of the ohm undertaken for the United States Government. A detailed description of it is contained in his forthcoming report, so only a few words will be given to it here. The induction coils, four in number, were wound in square channels cut in heavy flanges, cast on the exterior of a hollow brass cylinder open at both ends. The coils were respectively 30·171, 9·786, 10·545, and 30.775 cms. from the mean plane of the disc, itself placed as nearly as possible midway between the ends. The cylinder is about 66 cms. long, 100 cms. in diameter, and 1cm. thick; it is thus the longest ever used in work of this kind. The flanges and cylinder were cast in one piece, and the tooling was all done without once removing the casting from the lathe. The walls of the channels were left very thick to prevent spreading during the winding of the coils. The radius of the disc was so chosen that an error in its value should enter as slightly as possible in the value of the coefficient of induction.

The disc was brass, 21·5 cms. radius and ·5 cms. thick. It was fixed to a brass axle, 3 cms. diameter, turning in bearing boxes, carried by suitable framework fixed inside the cylinder. There was a cone of grooved pulleys toward one end of the axle, used for getting different speeds of the disc. The motor for running the disc was in the adjoining room about 10 meters from the disc. The speed obtained varied from 26 to 47 revolutions per second, higher than has usually been used.

The current was taken from the edge of the disc by three brushes which bore on it at angular distances of 120°; each brush was made of three or four brass strips of different lengths soldered together at one end; each strip in every brush touched the disc, one brush occupying a length of 2 cms. or more on the edge. The strips were made of various lengths in order to avoid systematic vibrations. For the contact at the center, a conical counter-boring was made in one end of the axle, and a brass point was pressed into it constantly by a stiff spring. The counter-boring in the axle, the point, the brushes and the edge of the disc were all carefully amalgamated before each observation; particular care was given to this. The insulation resistance of the coils was found to be from six to ten megohms.

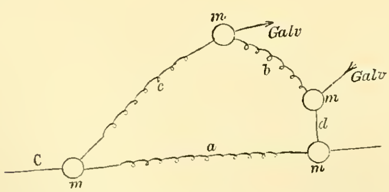
The arrangement for getting the speed differed from that generally employed. As the quantity desired is the average speed during the time of an observation it seemed that a chronograph, if sufficiently accurate, would give this better than any other means, besides furnishing at a glance the history of the systematic variations of the speed, while the galvanometer showed the abrupt changes. The spot of light of the galvanometer was usually very steady, showing that there were no sudden changes. Every hundredth revolution of the disc was recorded on the chronograph; to accomplish this, one end of the axle was connected to an ordinary speed counter, consisting of a worm wheel and endless screw, which rested on a board fixed to receive it. The worm wheel carried a small brass pin, which made contact every revolution with a brass strip fixed near it, thus closing the chronograph circuit. The strip was adjustable and the contact was always made as slight as possible consistent with certainty. The length of this contact about $\frac{1}{80}$ sec., while the clock break was nearly twice this.

The connection of the axle with the endless screw was made in this way: A small hard rubber screw with square head was fitted in the end of the axle and was joined to the screw of the speed counter by drawing over both a piece of pure rubber tubing with thick walls, about 2 cms. long. This connection is easily made, permits no slipping, and absorbs vibrations so completely that even for comparatively high speeds no fastening is required to hold the counter down to the board; but for the very high speeds we used, it was necessary to secure it to the rubber bed on which it lay by rubber bands, in order to ensure perfectly uniform contact between the pin and the spring.

The chronograph was a large and excellent instrument by Fauth; the drum was about 18 cms. diam. and in this work, revolved in 30 secs.; the length of a second was thus nearly 2 cms.; the sheet could be read with rough means to $\frac{1}{2}$ mm. ($=\frac{1}{40}$ sec.,) and was actually read much closer. As each observation lasted five minutes, even this gave an estimation of the mean speed to $\frac{1}{6000}$.

The galvanometer was a low resistance one of the Thomson reflecting type; a small piece of wire, which dipped in a light oil, was hung from the needle and acted as a damper; with this the needle was found to be sufficiently sensitive and to come nearly to rest in about 12 secs. after reversing the current through it.

The resistance "*a*" in the figure, through which the main current flows, is a large one ohm coil of German silver wound about a skeleton cylinder of glass rods, and is about 30 cms. high and 15 cms. in diameter. The ends of the coil are soldered to copper blocks which form the bottoms of mercury cups. It is placed in an earthenware jar filled with a special light oil known to be a good insulator and is provided with a stirring paddle. Resistance "*b*" is a one ohm coil by Elliott of the usual form; this is put in a large glass jar and surrounded with water. Resistance "*c*" is taken from specially made "comparators;" each consists of ten coils of the same nominal value wound together in a copper cylinder 6 cms. diameter; they are properly insulated, etc., and protected by a



larger concentric cylinder. The terminals are soldered to the copper bottoms of mercury cups, arranged in two circles around the hard rubber ring which closes the annular space between the inner and outer copper cylinders. The inner cylinder is filled with water. The connections of the ten coils can be varied at pleasure: they can all be thrown in series, in parallel, or in any intermediate arrangement. There were two comparators used, with the coils 100 and 10 ohms respectively.

To keep the temperature constant, spirals of lead pipe were placed around the Elliott coil and in the inner cylinders of the comparators, through which there was a constant flow of water from the city supply. This answered its purpose admirably; the temperature varied only a degree or so from day to day even. The water, was of course, allowed to flow some hours before beginning observations.

The terminals of all resistances were brought to large mercury cups (*m*, *m*) each having an amalgamated copper disc lying on the bottom. The main current did not flow through any part of the circuit of the induced current; a short bridging piece (*d*) is used, as Lord Rayleigh found necessary.

The resistances used were all compared several times by different observers with the standard: this was a Warden Muirhead 10 ohm coil, whose value was determined at the Cavendish Laboratory in 1887; it was 9·99416 B.A. units at 16·5°, with temperature coefficient of ·000292 per ohm per degree.

In taking the observations, the aim was to adjust the resistances first so that there should be only a small deflection; after a number of galvanometer readings for this "balanced" arrangement had been taken, the resistance "*c*" was changed so as to give a deflection of 10 divisions (say); readings were taken for this "unbalanced" arrangement; the original "balanced" was then restored and readings taken. If nothing had changed sensibly since the beginning of the experiment, the average deflections for the two "balanced" would agree; of course, this condition was only approximated to. The "unbalanced" set gives the data for correcting for the small deflection of the "balanced."

Each experiment then consists of the galvanometer, speed, and temperature readings pertaining to the three arrangements of resistances: these three arrangements are called "A," "B," and "A′" in the order taken, irrespective of the magnitude of the deflections. In general, R_1 and R_3 (subscripts 1, 2, 3, refer to A, B, A′, respectively: R is the "effective" resistance) are the same, and the corresponding deflections are small; B is in this case used to correct both R_1 and R_3, and the mean of the corrected values is used. When, however, the deflection for

A happens to be undesirably large after beginning the experiment, B is made to give a small deflection, and A′ made as nearly as may be the same as A. We have in this case to apply the mean of two corrections to R_2, one from A and the other from A′.

In each arrangement, as A, the current is reversed four times; it is kept in the same direction for one minute at a time, and five galvanometer readings at equal intervals of time are taken each minute; this gives then 25 galvanometer readings, and occupies five minutes. The set B is begun as quickly as possible after A. The chronograph record is started by dropping the pen on the revolving drum only a few seconds before the first galvanometer reading, and an effort is made to use that portion of the record beginning exactly with the readings, the record is stopped at the instant of the last reading by lifting the pen. Temperature readings are taken before, after and often during the set. The resistance carrying the main current is constantly stirred and the others frequently. After A′, the temperature of the cylinder and disc is noted.

Variety was given to the different experiments by using different pairs of induction coils, inner or outer, and by varying the speed and direction of rotation. Sometimes, too, an experiment was repeated with everything the same, except that the resistance "*c*" would be made up of different coils.

The coefficients of mutual induction for the two pairs of coils as used by Professor Rowland are:—

Coils 1+4, M= 60292·5
" 2+3, M=102030·2
Diameter disc =42·1334 at 17°.

Before beginning these experiments, the disc was slightly turned off in order to smooth the edge; the diameter was measured by two observers, and was found to be

43·1201 at 17° C.

The formulæ expressing the effect on M of small changes in the quantities entering in its expression are,

$$\text{for } 1+4, \quad \frac{dM}{M} = \cdot015\frac{dA}{A} + 1\cdot912\frac{da}{a} - \cdot927\frac{db}{b}$$

and

$$\text{for } 2+3, \quad \frac{dM}{M} = -0\cdot95\frac{dA}{A} + 2\cdot12\frac{da}{a} - 0\cdot17\frac{db}{b},$$

where A=mean radius of the coil,
a=radius disc,
b=distance of mean planes of disc and coil.

The corrections, calculated by these formulæ, due to the change in "a" give

for 1+4, M= 60257 at 17°
and " 2+3, M=101964 "

Let ρ=ratio of the BA unit to the ohm,

$R=\frac{ab}{a+b+c}$=" effective " resistance,

N=No. revolutions per second.

$D=D_S-D_N$=difference of mean deflections, D_S and D_N, for the two positions, S and N, of the reversing key ; i. e. D would be the mean deflection for either direction of current, if no irreversible effects existed.

Then will

$$\frac{1}{\rho}=\frac{1}{MN_{1\cdot3}}\left\{ R_{1\cdot3}-\frac{\frac{N_{1\cdot3}}{N_2}R_2-R_{1\cdot3}}{\frac{N_{1\cdot3}}{N_2}D_2-D_{1\cdot3}}D_{1\cdot3}\right\} \qquad (1)$$

and

$$\frac{1}{\rho}=\frac{1}{MN_2}\left\{ R_2-\frac{\frac{N_{1\cdot3}}{N_2}R_2-R_{1\cdot3}}{\frac{N_{1\cdot3}}{N_2}D_2-D_{1\cdot3}}D_2\right\} \qquad (2)$$

(1) is used when $D_1 < D_2$
(2) " " $D_1 > D_2$.

The double subscripts, as $R_{1\cdot3}$, means that the two quantities R_1 and R_3 are to be used in turn; that is to say, each formula above is really double: first, we use the sub 1's, and then the sub 3's. It was found more convenient to calculate the values of ρ_1 and ρ_3 this way and average them, than to apply an average correction. Indeed, when the speeds N_1 and N_3 are different, this is the only way.

The following table gives the data and results of these experiments; the (+) direction of rotation is, —Zenith, North, Nadir, South.

Experiments Nos. 1, 2, 3, 6, 14A′, 17A′ and 22 were interrupted by divers accidents and never completed; in No. 19, there is confusion in the notes making the sign of the deflection doubtful; Nos. 21, 23 and 24, give values of ρ from 2 to 10 per cent out, due to some error in the record of resistances used. This accounts for all the experiments begun.

The average of all the above is ·98622; without No. 27, which differs about twice as much from the mean as any other observation, the average is ·98634. The great divergence of No. 27, is in itself reason enough for giving it less weight; but in addition, the chronograph sheet shows that the speed here was very irregular, increasing, decreasing and increasing

Table of Experiments.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Descp.	Coils.	Rotat'n.	N.	D.	R.	Correction.	Corrected resist.	M.	ρ.
4 A	1 and 4	+	35·648	+ 4·74	·00220207	−·00002110	·00218097	60266	
B			·701	− 6·71	215435	--------	------	------	·98620
A′			·715	+ 6·04	220216	−·00002215	217991		
7 A	2 and 3	+	·720	−10·76	365835	−·00000828	------	101979	
B			·966	+ 2·60	372638	--------	371810	------	647
A′			----	------	------	--------	------		
8 A	"	+	·752	+10·15	372859	−·00003345	369514	"	
B			·929	− 6·15	369317	--------	------	------	658
A′			36·055	+ 0·37	372859	−·00000127	372732		
9 A	"	−	·268	+ 5·24	372837	+·00001695	374532	"	
B			·162	+12·51	369392	--------	------	------	725
A′			·347	+ 7·99	372837	+·00002712	375549		
10 A	"	+	·514	+ 2·16	376476	+·00000513	377007	"	
B			·462	+14·39	372933	--------	------	------	758
A′			·503	+ 1·94	376476	+·00000486	376962		
11 A	"	+	35·373	+ 4·12	365589	+·00000559	366188	101974	
B			·365	− 9·70	367517	--------	------	------	490
A′			·497	+14·96	365589	+·00001999	367588		
12 A	"	+	·066	− 8·19	365680	+·00000560	363586	"	
B			·134	+ 1·64	363026	--------	------	------	541
A′			34·959	−11·91	365680	+·00000551	363577		
13 A	"	−	35·053	+ 0·53	362375	−·00000230	362145	"	
B			·099	+ 7·10	365710	--------	------	------	724
A′			·200	− 2·49	362375	+·00001137	363512		
14 A	"	−	34·249	− 9·08	362865	+·00000267	------	"	
B			·184	− 2·56	352873	--------	353140	------	710
A′			----	------	------	--------	------		
15 A	"	−	·621	−14·88	352932	−·00000282	359439	"	
B			·752	+ 0·81	359721	--------	------	------	594
A′			·844	− 8·84	357139	−·00000297	359424		
17 A	1 and 4	+	·999	+ 0·42	213697	+·00000154	213851	60232	
B			·928	− 6·20	215248	--------	------	------	710
A′			·715	− 5·47	213697	−·00001939	211758		
18 A	"	−	·767	− 6·23	210691	−·00000604	212373	60263	
B			·745	+ 2·07	212977	--------	------	------	583
A′			·731	− 6·05	210691	−·00000562	212415		
20 A	"	+	26·630	+ 0·52	162529	+·00000156	162685	60265	
B			·943	− 6·54	169446	--------	------	------	659
A′			·744	+ 2·77	162529	+·00000817	163346		
25 A	"	−	40·486	+ 0·55	247395	+·00000351	247746	60267	
B			·626	+20·29	235649	--------	------	------	472
A′			·450	+ 0·32	247395	+·00000206	247601		
26 A	2 and 3	−	·033	− 2·88	411309	+·00002574	413883	101970	
B			·478	+17·48	402846	--------	------	------	651
A′			·537	+ 0·74	419576	−·00000654	418922		
27 A	"	+	·933	+ 1·15	422586	+·00001644	424230	"	
B			·906	+ 8·81	411344	--------	------	------	372
A′			41·130	+ 2·65	422586	+·00003836	426422		
28 A	"	+	26·833	+ 2·19	274840	+·00002602	277442	"	
B			·654	+12·75	260443	--------	------		
A′			·861	+ 2·31	274840	+·00002711	277551	------	653
29 A	"	−	25·885	− 0·25	267436	−·00000151	267285	"	
B			26·076	− 9·30	274869	--------	------		
A′			·240	+ 5·94	267436	+·00003557	270993	------	745
30 A	"	−	30·024	+ 1·59	308948	+·00000925	309873	"	
B			·125	+19·12	299648	--------	------		
A′			·220	+ 5·30	308945	+·00003193	312138	------	762
31 A	"	+	29·831	− 3·05	306612	+·00001857	308469	"	
B			30·053	+13·41	318928	--------	------		
A′			·504	+ 0·13	311446	−·00000078	311368	------	601
32 A	"	+	47·531	+ 1·51	492544	−·00000882	491662	"	
B			·514	−18·56	480642	--------	------	------	551
A′			·545	+ 0·74	492544	−·00000444	492100		
33 A	1 and 4	+	·513	+ 0·53	290981	−·00000234	290747	60271	
B			·869	+15·12	299749	--------	------	------	457
A′			·457	+ 0·83	290981	−·00000363	290618		

again; this is the only occurrence of such irregularity. Therefore giving it about one-third weight, we find as the most probable value

1 B. A. UNIT = ·9863 OHMS.

A determination of the "Mercury Unit" was recently made by Messrs. Hutchinson and Wilkes (Johns Hopkins University Circulars, May, 1889), who found the value to be

·95341

taking this with the above number for the B. A. unit, we have as the length of the mercury column corresponding to the ohm,

106·34 CMS.

ART. XXXIV.—*The Properties of Allotropic Silver;* by M. CAREY LEA.

THE three forms of allotropic silver which were described in the June number of this Journal—the blue soluble and the blue and the yellow insoluble—are not to be understood as the only forms which exist, but as the best marked only. The substance is protean, and exhibits other modifications not yet studied. No other metal than silver appears to be capable of assuming such a remarkable variety of appearances. Every color is represented. I have obtained metallic silver blue, green (many shades of both), red, yellow and purple. In enumerating these colors I do not refer to interference colors produced superficially by reagents, also wonderfully brilliant, but to body colors. As a single instance of coloration the following may be mentioned. I recently obtained a solution of allotropic silver of an intense yellow brown. A little solution of disodic phosphate changed this to bright scarlet (like Biberich scarlet) presently decolorizing with formation of a purple precipitate. Washed on a filter this changed to bluish green. The colors I have met with in this investigation can only be compared with the coal-tar products, of which one is constantly reminded by their vividness and intense colorific power.

Two of the insoluble forms of allotropic silver, the gold-colored and the blue, show in many respects a close relationship and almost identical reactions. There are other respects in which they differ strikingly and amongst these, in stability. Blue allotropic silver (dark red whilst moist, becoming blue in drying) is very stable. It may be exposed for weeks in a moist state on a filter, or be placed in a pasty condition in a corked vial and so kept moist for months, without alteration.

The gold-colored form on the contrary, tends constantly to revert to ordinary silver. This is especially the case whilst it is moist, so that from the time of its formation, it must be separated from its mother water and washed as rapidly as possible, otherwise it loses its brilliancy and purity of color and changes to a dark dull gray form of normal silver. On the filter, its proper color is pure black with a sort of yellow shimmer (the gold color appearing as it dries) often, especially if allowed to become uncovered by the water during washing, it will change superficially to gray.* But if the washing is done rapidly with the aid of a filter pump and a pressure of four or five inches of mercury, the allotropic silver obtained, when allowed to dry in lumps, or brushed over paper or glass, is at least equal to pure gold in color and in brilliancy. With the blue product such precautions are wholly superfluous.

Of the facility with which the gold colored form is converted into normal silver, I have recently had a somewhat singular proof. I brought with me to my summer home a number of specimens in tubes, some recently prepared, some dating back as far as two and a half years, together with other tubes containing specimens of white silver spontaneously formed from the gold colored. On opening the box no tubes of gold colored silver were to be found, all had changed to white. But the same box contained pieces of paper and of glass on which the same material had been extended; these were wholly unchanged and had preserved the gold color perfectly. Apparently the explanation was this, the mere vibration caused by the jarring of a journey of 600 miles by rail and steamboat had had no effect in changing the molecular form, but the material contained in the partly filled tubes had been also subjected to *friction* of pieces moved over each other, and this had caused the change. To verify this explanation I prepared fresh material, filled three similar tubes each one quarter full, but in one forced in cotton wool very tightly to prevent frictional motion. These tubes were packed in a small box and sent over 2400 miles of railway. The tubes with loose material came back much altered, one was nearly white, and as the change has been set up will probably in a few days be entirely so,† another with loose material was also changed but not as much as the first mentioned. The tube filled up with cotton came back unaltered. So that continued friction of pieces sliding over each other will cause a change to take place in a few days which otherwise might have

* When well washed, this form can also be preserved for a time in the moist condition in a corked vial, as I have lately found.

† Has since become so.

required years or might not have occurred at all. The permanency of this substance is greatly influenced by moisture, so that when simply air-dried before placing in tubes it is less permanent than when dried at 70° or 80° C. in a stove. Tubes placed in the same box containing the blue form remained unaffected by the motion, though only partly filled and allowed to move freely.

When gold-colored allotropic silver is gently heated in a test tube it undergoes a remarkable change in cohesion. Before heating, it is brittle and easily reduced to fine powder. After heating it has greatly increased in toughness and cannot be pulverized at all.

Both the gold-yellow and the blue forms resemble normal silver in disengaging oxygen from hydrogen peroxide.

These two forms though differing so much in color and stability and differing also in specific gravity and in their mode of formation, have many properties in common, not possessed by ordinary silver, and differentiating them strongly from it. They show a vastly greater sensitiveness to reagents, and are also sensitive to light. The ability to form perfect metallic mirrors by being simply brushed in the pasty condition over glass was mentioned in a previous paper.

Many substances which react little if at all with ordinary silver, attack the gold-colored and the blue allotropic silver with production of very beautiful colors due to the formation of thin films and resulting interference of two reflected rays. In my previous papers I called this the "halogen reaction" because first obtained by the action of substances which easily parted with a halogen. But I have since found that many other reagents will produce the same or similar effects. These are

Sulphides. Paper brushed over with either the gold, the copper colored, or the bluish green substance exposed to the vapor of ammonium sulphide, or immersed in a dilute solution of it, assume beautiful hues, though less brilliant than those obtained in some other ways.

Potassium permanganate in dilute solution produces blue, red and green colors.

Potassium ferricyanide in moderately strong solution gradually attacks allotropic silver with production of splendid blue, purple and green coloration.

Phosphorous acid produces gradually a rather dull coloration.

The color reaction is produced finely by substances which readily part with a halogen such as ferric and cupric chlorides, sodium hypochlorite, hydrochloric acid to which potassium bichromate has been added, and by corresponding, bromine and iodine compounds. In some earlier experiments I obtained effects of the same sort, but in much weaker degree with alkaline haloids. But with purer products, the results have been different. There is at first some darkening, but no true color reaction and the allotropic silver appears to be gradually converted into normal, so that it is no longer capable of giving the brilliant color reaction with potassium ferridcyanide, but, like normal silver, takes a pale and faint coloration only.

The perchlorides of platinum, gold and tin do not give the color reaction, though by analogy one would expect that they should, since they can lose chlorine with formation of a lower chloride.

Action of Light.—In a previous paper was mentioned the remarkable fact that the gold- and copper- colored forms of allotropic silver can be converted first into yellow and finally into white normal silver by the continued action of light. The earlier specimens of the blue form became brown by exposure, but purer ones since obtained are likewise converted into yellow by exposure, becoming continually lighter as the action is continued. The conversion from the darker shades to a bright yellow with full metallic luster is very easy, but when the previous paper was written I had been only able to obtain the white by keeping the paper, on which the silver was coated, moist by a wet pad and by exposing for five or six days. Since then I have obtained the gold-colored silver in a more sensitive form, giving a perfectly white product by exposure dry for half that time.

The white silver thus obtained has all the character of ordinary silver and does not show the color reaction with ferric and cupric chloride, potassium ferridcyanide, etc. Just in proportion to the exposure to light, the ability to give this color reaction diminishes, so that after a day's exposure, when the exposed part has become bright yellow, the color reagents scarcely affect this yellow, whilst the protected part becomes intense blue, purple, or green. In this way it is easy to observe the gradual effect of light as it changes the allotropic silver, finally converting it into what resembles in every way, and is undoubtedly, ordinary silver.

July, 1889.

ART. XXXV.—*On Ring Systems and other Curve Systems produced on Allotropic Silver by Iodine;* by M. CAREY LEA.

ALLOTROPIC silver, in its moist and plastic state, may be brushed over paper and gives on drying a continuous and brilliant coating resembling metallic leaf.* When a small crystal of iodine is placed on paper that has been thus coated, a system of colored rings of remarkable beauty is obtained. A funnel or beaker should be inverted over the paper to prevent distortion by irregular currents of air. One form of distortion, however, produced by a slight current in one direction, gives interesting results. If the paper with the crystal on it is set near a closed window, the slight current which makes its way through, affects the air under the glass enough to carry the iodine vapor principally in one direction and there result oval or pear-shaped curves of great elegance and much variety according as the air currents are stronger or weaker. Another method is to place a bell glass, not fitting too closely, over the paper and to set it where it will be influenced by the draught created by a fire, or even by a gaslight.

That iodine is capable of producing interference rings (Nobili's rings) on metallic surfaces has long been known, and Robert Hunt has described their formation on surfaces of normal silver. I have made these for comparison, pressing gummed paper on silver leaf, bringing to a smooth surface by gently rubbing after drying. The contrast between the pale and faded-looking effects produced on normal silver, and the lustrous and glowing hues given by the allotropic, is very striking.† One cannot help wishing that this splendid coloration could be made to do service for obtaining natural colors by photographic processes.

As to the durability of these products, I cannot yet speak with positiveness. Protected from light and air they endure for several months at least. Both the bluish green insoluble silver B, and the gold-colored C produce these effects; the gold-colored is the better suited of the two.

July, 1889.

* Described in this Journal, June, 1889.

† I was desirous of having some of these curve systems reproduced in color printing for this Journal, but on conferring with an experienced color printer, found that he could give no assurance of a successful result. The colors are transparent, and yet have a metallic brilliancy, a combination almost impossible to imitate in printing.

ART. XXXVI.—*Notes on some Native Iron Sulphates from Chili;** by JAMES B. MACKINTOSH.

IN March, 1887, I received from Dr. Thos. Egleston a series of the native iron sulphates from South America, which I analyzed for him, as there were some minerals among them which he was not able to identify and which he regarded as probably new. It is with his permission that I now give the results of my analyses and the conclusions to which they lead. My results confirm his opinion as to the novelty of some of the specimens analyzed.

Among the series of specimens were several of well known species, of which I also made analyses. These I will give first, with but little comment, as they do not afford much that is new, and then take up the new varieties in turn.

1. *Coquimbite.*—Of this species I had three varieties, as described below, which gave the following results:

	I (No. 1). Amethystine crystalline transparent.	II (No. 2). Amethystine massive translucent.		III (No. 10). White massive opaque.
Specific gravity	2·07	2·086		----
SO_3	43·40	42·90		42·32
Fe_2O_3	22·17	26·10		28·10
Al_2O_3	4·39	1·65	SiO_2, Al_2O_3 }	0·91
Na_2O	0·25	0·27		----
CaO, MgO	traces	traces		----
H_2O (difference)	[29·79]	[29·08]		[28·67]

All lead to the same formula, Fe_2O_3, $3SO_3$, $9H_2O$. The water expelled at 110° in the three samples was 5, 6, and $5\frac{1}{3}$ molecules respectively. It is interesting to notice that the most crystallized and transparent specimen is the poorest in iron and richest in alumina, while the most opaque and non-crystallized is the richest in iron.

2. *Copiapite* (No. 6).—The specimen analyzed was massive, yellow, with specific gravity = 2·118. The analysis gave

SO_3	39·03
Fe_2O_3	29·16
FeO	1·56
Na_2O	0·31
H_2O	[29·94]

* Recent contributions to our knowledge of the iron sulphates of South America have been given by Frenzel, on amarantite and hohmannite, Min. petr. Mitth., ix, 397, 1887; and by G. Linck on coquimbite, copiapite, quenstedtite, stypticite, roemerite, halotrichite, Zeitschr. f. Kryst., xv, 1, 1888.

The formula corresponds to

$$91\{2Fe_2O_3, 5SO_3, 18H_2O\}+22\{FeSO_4, H_2O\}+5\{Na_2SO_4, H_2O\}$$

The water lost at 110° C. is 1124 out of 1663 molecules represented in the above formula or about 12 out of each molecule of $2Fe_2O_3$, $5SO_3$, $18H_2O$ or $\frac{2}{3}$ of total H_2O. Readily soluble in water before and after heating to 110°.

3. *Roemerite* (No. 8).—Brown, crystalline; specific gravity 2·15; analysis gave:

		Ratio.
SO_3	40·19	50·24
Fe_2O_3	19·40	12·125
FeO	9·52	13·22
Na_2O	0·14	0·226
H_2O	[30·85]	171·39

After subtracting SO_3 corresponding to Na_2O present, the molecular ratio is 4 : 0·97 : 1·058 : 13·7 or nearly 4 : 1 : 1. At 110° C. most of the H_2O is expelled with simultaneous oxidation of part of the ferrous iron. The net loss amounts to 11·8 molecules of H_2O, leading to the formula FeO, Fe_2O_3, $4SO_3$, $13·7H_2O$ ($12H_2O$ Tschermak, $15H_2O$ Linck). Readily soluble in water—after heating only partially soluble.

4. *Amarantite* (No. 3).—Red, crystalline, with sp. gr. = 2·005; associated with copiapite. Analysis:

		Ratio.
SO_3	36·15	2·0
Fe_2O_3	35·69	0·987
Al_2O_3	0·21	0·009
Na_2O	0·51	0·036
H_2O	[27·44]	6·75

Hence the formula corresponds to

$$Fe_2O_3, 2SO_3, 7H_2O$$

When heated to 110° C., 3·48 molecules of water are expelled and the residue leaves a slight insoluble basic salt on solution in water.

5. We will now consider some minerals which have not yet been described and which are of seemingly definite formula. The first of these (No. 9) occurs associated with copiapite and amarantite, but quite distinctly separated from them, in pulverulent orange flakes which are arranged in parallel tabular layers. It shows no crystalline structure, which might be expected if it was a direct alteration of amarantite, and there is a sharp line of demarcation between the minerals on the same specimen with no appearance of a transition state. Analysis gave:

		Ratio.
SO_3	41·24	2·001
Fe_2O_3	41·22	1·000
H_2O	[17·54]	3·78

Formula Fe_2O_3, $2SO_3$, $4H_2O$

Water lost at 110° C. = 0·304 molecule, leaving a residue containing 3·48 molecules. The result of heating this mineral is the same as of heating amarantite. They only differ by 3 molecules H_2O, but there is no apparent structure like amarantite to indicate that the one is a direct product of dehydration of the other.

6. *Ferronatrite* (No. 11).—The analysis of this mineral I have recently completed, having received it from Prof. Egleston only a short time since. It occurs in stellate groups of a pale, whitish green color, forming nearly spherical nodules; it is in general similar to pale wavellite in appearance. It is associated with copiapite and coquimbite. Analysis:

		Ratio.
SO_3	50·25	6·281
Fe_2O_3	17·23	1·077
Al_2O_3	0·43	0·042
Na_2O	18·34	2·958
K_2O	0·40	0·042
SiO_2, etc., insoluble	2·00	
H_2O	11·14	6·189
	99·79	

Formula $3Na_2O$, Fe_2O_3, $6SO_3$, $6H_2O$

Water lost at 110° = $5\frac{1}{2}$ molecules, the residue dissolves readily in water. This mineral is somewhat similar to sidero-natrite, Na_2O, Fe_2O_3, $3SO_3$, $6H_2O$, to urusite, $2Na_2O$, Fe_2O_3, $4SO_3$, $8H_2O$ and to bartholomite, $2Na_2O$, Fe_2O_3, $4SO_3$, $2H_2O$, but differs from them in being soluble in water and being a neutral instead of a basic salt. It is quite analogous, however, to Kröhnkite,* the double sulphate of sodium and copper if we can consider that the copper may be replaced by its equivalent in ferric iron without destroying the analogy. The relationship is clearly shown by the formulæ, taking 3 parts of Kröhnkite.

Kröhnkite	$3(Na_2O$, CuO, $2SO_3$, $2H_2O)$
Ferronatrite (new mineral)	$3Na_2O$, Fe_2O_3, $6SO_3$, $6H_2O$

7. Associated with these minerals are several white pulverulent sulphates which are apparently alteration products, but which nevertheless possess some points of interest. Of these the first gives the following results on analysis. White, pulverulent (No. 4), sp. gr. not taken. Analysis:

* Cf. Darapsky, Jahrb. f. Min., i, 192, 1889.

		Ratio.
SO_3	38·00	6·25
Fe_2O_3	12·16	1·00
FeO	22·51	4·114
Na_2O	0·58	1·124
H_2O (by difference)	26·75	19·55

Formula $3FeO, Fe_2O_3, 5SO_3, 18H_2O + FeO, SO_3, H_2O$
or $4FeO, Fe_2O_3, 6SO_3, 19H_2O$

Water lost at 110° C.$=$9·61 molecules. This cannot be regarded as a mixture of $4FeSO_4$, Aq. and (Fe_2O_3, $2SO_3$, Aq.) because it is *perfectly white* and not red or yellow-brown, which would be the case if it was a mixture containing amarantite or No. 9. Another argument in favor of its individuality seems to be the loss of one-half its water at 110° C. It bears a certain similarity to copiapite, which suggests that it may be a product of partial reduction of, or of action of ferrous sulphate on, copiapite. This view does not seem to me to be far fetched, since the analysis of the copiapite, quoted above, shows the presence of a small quantity of ferrous sulphate. If we write copiapite $2Fe_2O_3, 5SO_3, 18H_2$ it is seen that by the substitution of 3FeO for $1Fe_2O_3$ in the above formula, with simultaneous addition of another molecule of $FeSO_4$ we would arrive at the formula adopted, viz:

$$3FeO, Fe_2O_3, 5SO_3, 18H_2O + FeO, SO_3, H_2O$$

8. Two other white powders associated with these minerals have given the following figures:

	A.	Ratio.	B.	Ratio.
SO_3	47·90	599	45·61	570
FeO	30·81	428	35·05	487
Fe_2O_3	5·64	35	5·14	32
Al_2O_3	0·65	6	----	---
Na_2O	4·42	71	0·33	5
H_2O (difference)	10·58	588	13·87	770

These both have as their chief constituent a ferrous sulphate with one molecule of water, as shown below:

A $428(FeSO_4, H_2O) + 71Na_2SO_4 + 40(2Fe_2O_3, 5SO_3, 4H_2O)$
B $487(FeSO_4, H_2O) + 5Na_2SO_4 + 16(2Fe_2O_3, 5SO_3, 18H_2O)$

In the first of these this monohydrated ferrous sulphate amounts to about 70 per cent of the material and in the second to about 78 per cent. This same compound also appears in the copiapite analysis. This form of ferrous sulphate is far more stable than melanterite, which, indeed, changes into this form very readily by loss of water when protected from oxidizing influences.

SCIENTIFIC INTELLIGENCE.

I. Physics.

1. *Electrical Waves in Conductors.*—In continuation of his work upon electrical waves, or surgings, as Lodge expresses it, Hertz has examined experimentally the theoretical conclusions of Maxwell, Heaviside, Poynting and others in regard to the distribution of an electrical current upon the surface and through the section of a wire carrying it. It is well known that a steady current distributes itself through the cross section of the conductor. When the current however is oscillatory in its nature the distribution ceases to be uniform through the section, and when the current changes its direction many millions of times a second the electricity glides upon the surface of the conductor or spreads inward from the surface, according to laws analogous to those governing the increase of temperature from the surface of the earth to its interior. The slower the changes of current the deeper the penetration of the electricity into the interior of the wire. Hertz finds the theoretical conclusions fully justified by his experiments. His apparatus was similar to that employed in his earlier researches. Electrical waves of three meters long were produced. Their nodal points were detected by the spark method. In one experiment a space along the wire upon which the electrical oscillations were produced was replaced by two strips of thin metal connected at their ends with the wire. Between them was a stretch of insulated wire with a spark interval between the ends. No spark jumped across these ends when the wire was almost entirely surrounded by the tin foil, the wire being then in the center of the conductor. When, however, the smallest portion of the wire was outside, the tin foil sparks appeared. In order to make these sparks disappear it was merely necessary to wrap the exposed portion of the wire with tin foil and connect this with the main leading wire. In this case, we have brought the wire back into the interior of the conductor. In another experiment the conductor, which was of very thick copper of 1·5 meters in length, had interposed two metal discs, separated by a short interval. In the interval were two knobs for the passage of sparks. Sparks passed freely when the waves were produced. When, however, the discs were connected by wires passing through corresponding holes in the discs, near the edges and opposite to each other, the spark decreased in length. When wires connected the edges of the discs outside the wires passing through the holes, the sparks decreased still more in length, and when a number of wires connected a number of holes, and wires were placed outside these wires along the edges of the disc, no spark passed in the interior of the cylindrical cage, although the resistance of the exterior wires was greater than the interior wires. The electricity passed along the exterior wires and not through the interior ones. By means of a similar

arrangement thin cylinders of various metals enclosed a portion of the wire upon which the electrical waves were excited. These thin cylinders protected the inner wire from electrical disturbances. Thin deposits of silver on glass cylinders which allowed light to be seen through them did not entirely shield the inner wire. When the thickness of the silver layer increased to only $\frac{1}{100}$ of a millimeter all sparks disappeared in the spark detector, showing that the electrical disturbance was entirely on the surface of the conductor. Instead of saying, therefore, that electrical waves are propagated through the wires, we should say that they glide along the surface of the wire. Further experiments are added which conclusively show that the electrical waves are confined to the surface of the conductor, and that they are greatly influenced upon two neighboring conductors by the character of the intervening space and by surrounding objects. Hertz concludes with the observation that, according to former ideas, he classed among conductors those substances which allowed the passage of electricity, and among insulators those that did not permit this passage. According to the new interpretation of electrical oscillations or waves, all electrical waves are propagated through insulators, and good conductors oppose the quick oscillations of these waves. The terms conductors and insulators therefore should change places.—*Ann. der Physik und Chemie*, No. 7, 1889, pp. 395–408. J. T.

2. *Disintegration of Surfaces by means of the Ultra Violet rays.*—PHILIPP K. LENARD and MAX WOLF, by means of Helmholtz's modification of Aitken's apparatus (Wied. Ann., xxxii, p. 1, 1887), show that the ultra violet rays exert a remarkable effect in producing dust from metallic surfaces. As a source of light sparks from a Ruhmkorf coil were used, it having been shown that these sparks are richer in violet rays than other sources of light, and have the advantage of not causing heat and are therefore to be preferred to the voltaic arc formed between carbon and zinc, which has been used by some observers. The presence of the dust was shown by the vapor produced in a suddenly exhausted receiver according to the method of Aitken, and also by the coloration of a jet of steam. The latter method Helmholtz had shown to be very sensitive, showing by changes of color the presence of metallic dust. All metals examined when negatively electrified showed metallic dust under the influence of ultra violet rays. Quartz and gypsum also showed disintegration. Fluids also when negatively electrified gave forth finely divided particles.—*Ann. der Physik und Chemie*, No. 7, 1889, pp. 443–456. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Eruption of Baldai-san, in northern Japan, on July* 15, 1888.—This eruption, noticed in vol. xxxvi of this Journal, is reported on by Mr. Y. KIKUCHI in the third volume of the College of Science Journal of the Imperial University, of Tokyo. The facts were briefly these:

The mountain of Baldai-san was an extinct volcano, but had one steaming fissure. On the 14th of July, at 10 A. M., the spring at the Spa on the mountain became dry. The next morning, the 15th, it was full again. At 7 h. of that morning, light earthquake-like rumblings were noticed; at 7 h. 30 min., there were loud and heavy shocks; at 7 h. 45 min., the eruption began, about 120 yards from the steaming fissure. A dense column of steam and dust shot up with tremendous noise. 15 to 20 explosions occurred of a minute or more each, and the vapor and dust were projected to a height of 4000 to 14000 feet, and spread into a canopy of much greater height, making pitchy darkness around. About the crater, a tempest raged of hot blasts of steam, wind, thunder, lightning, volcanic dust and falling stones, and, for five minutes, rain; the prostrated trees fell with their heads away from the crater. Within fifteen minutes of the outbreak a land-slide started from the summit, probably promoted by the shower of water, stones and rock-masses, and descended with terrific speed, burying the Nagase valley with its villages, and devastating an area of 27 square miles. Some of the masses transported by the land-slide were over 30 feet each way.

The violence was ended in less than an hour, when the darkness became that of twilight on a rainy evening; and in five hours the dust-fall had wholly ceased. The dust was drifted southeastward to the seacoast, where, 62 miles from the volcano, the area covered was 30 miles wide; but the deposit made there only traces of a film over the surface, and was but a foot deep on the leeward slope of the mountain. This dust was not ordinary glassy volcanic ashes, but like dust from abraded volcanic rock. There was no flow of lava.

Mr. Kikuchi concludes from the absence of any lava-flows and the character of the dust, that no lava was concerned in the eruption. In that case, unlike the explosive eruptions of Krakatoa and Tarawera, the vapor producing the explosions was generated above the level of liquid rock, the opened fissure permitting entrance of water only to a depth short of that where fusion existed. The chief rending and projecting force of the explosion would, in any case, have been below at the depths where the sudden generation of the vapor took place; and from the subterranean region, the rocks and stones, and the dust that abrasion could make, would have been thrown into the air to fall around, the lighter part to be drifted by the winds as it fell. The steam, after escaping into the air, would have already expended the chief part of its energy and could therefore have produced comparatively little effect on the outside walls or the summit peaks of the mountain. There would have been undermining by the ejections, and a corresponding loss to the mountain from subsidence; and there could not have been the supposed "blowing away" of even the millionth part of "2782 million tons" from the summit, the amount estimated as lost by the mountain.

Such an eruption is a *semi-volcanic* explosive eruption, supposing no lava concerned. But those fifteen to twenty explosions, a minute or more in duration, with their throws of dust and steam and apparent regularity of interval, suggest that possibly lava was concerned. For they are very like the explosions and projectile action of confined accumulations of steam on breaking through viscid lavas.

From an analysis and the optical characters of the rocks of the volcano it was made to consist chiefly of labradorite and augite. An analysis by Professor T. Wada, Director of the Geological Survey, obtained, Silica 59·56, alumina 16·10, Fe_2O_3 6·28, FeO 3·62, Mn_3O_4 1·80, lime 6·32, magnesia 3·08, soda 3·09, potash 0·80, phosphoric acid 0·18, loss by ignition 0·44=100·67. J. D. D.

2. *Mastodon or Elephas with fragments of charcoal at Attica, Wyoming Co., N. Y.*—The Report for 1887 of the State Museum of New York, contains an account, by Professor J. M. Clarke, of the discovery of bones at Attica, including a tusk and ribs, and a portion of the zygomatic arch, associated with fragments of charcoal and a piece of pottery. They were obtained from a bed of unlaminated clay, 1 foot 5 inches thick, lying beneath, 1 foot 7 inches of clayey muck and loam and 2½ feet below the natural surface. Another place, about one hundred yards distant, charcoal and the pottery were found at the bottom of a deep accumulation of muck, under which was a bed of compact clay. The depth below the natural surface of the ground was four feet. The vegetable mould was continuous between the two localities.

3. *Illustrations of the Fossil Fishes of the Devonian Rocks of Canada;* by J. F. WHITEAVES, F.G.S. Part II. *Descriptions of species from the Upper Devonian rocks of Scaumenac Bay.* 20 pp. 4to, with plates V to X. Montreal, 1889. Trans. Roy. Soc. Canada, vi.—Part I of Mr. Whiteaves appeared in 1887. This second part describes and finely figures the species *Glyptolepis Quebecensis*, *Eusthenopteron Foordi*, *Cheirolepis Canadensis*, *Bothriolepis Canadensis*, *Acanthodes affinis*, *Phaneropleuron curtum*, *Cephalaspis Campbelltonensis*, *Coccosteus Acadicus*, *Ctenacanthus latispinosus*, *Homacanthus gracilis*.

In the Annals and Magazine of Natural History for August, p. 183, Mr. A. Smith Woodward remarks that the species of Ctenacanthus and Homacanthus are in every respect closely like the spines of the Acanthodian genus *Climatius*, as elucidated by Egerton and Powrie, and names them provisionally *Climatius latispinosus*.

4. *Brief notices of some recently described minerals.*—MICHEL-LÉVYTE. Barium sulphate crystallizing, according to the determination of A. LACROIX, in the monoclinic system. It occurs in lamellar masses in a crystalline limestone near Perkins' Mill, Templeton, Quebec. Three cleavages are noted: a (100) easy, also b (010, plane of symmetry) vitreous, and c (001); the angles are $ab=bc=90°$, $ac=77°–78°$. Polysynthetic twinning, with a as the twinning plane, gives rise to numerous hemitropic bands observed on b. The optic axial plane is normal to b, and the

bisectrix probably coincides with the orthodiagonal axis; axial angle about 90°. Mean refractive indices 1·6413 for yellow, and 1·6305 for green. Specific gravity, 4·39. The composition is that of normal barite, $BaSO_4$. The close similarity between the two substances in cleavage form makes a more thorough knowledge of their relation to be desired. The mineral is named after M. Michel Lévy.—*C. R.*, cviii, 1126, May 27, 1889.

FLINKITE. A hydrous manganese arseniate from the Harstig mine, Pajsberg, Sweden, described by A. HAMBERG. It occurs in orthorhombic crystals, tabular parallel to the base, often grouped in feather-like aggregates. Hardness, 4·5. Specific gravity, 3·87. Color, greenish brown. An analysis gave:

As_2O_5	Sb_2O_5	Mn_2O_3	Fe_2O_3	MnO	CaO	MgO	H_2O
29·1	2·5	20·2	1·5	35·8	0·4	1·7	9·9 =101·1.

For this the formula $4H_2O.4MnO.Mn_2O_3.As_2O_3$ is calculated, which brings it very near synadelphite. Named after the Swedish mineralogist G. Flink.—*Geol. För. Förh.*, xi, 212, 1889.

DAVIESITE. A new oxychloride of lead from Sierra Gorda, Chili, named by L. FLETCHER after Thomas Davies of the British Museum. It was observed associated with percylite and caracolite in minute prismatic crystals. These are clear and colorless and have an adamantine luster. The axial ratio is $a:b:c=$ 1·2594 : 1 : 0·6018. A qualitative analysis was impossible, but the crystallographic examination showed that the mineral was not to be united with any of the other known lead oxychlorides.—*Min. Mag.*, viii, 171, May, 1889.

DUDGEONITE. A hydrous arseniate of nickel named by HEDDLE after Mr. Dudgeon who discovered it at the Pibble mine, near Creetown, Kilcudbrightshire, Scotland. It is a dull, loosely coherent earthy mineral of grayish white color with spots of pale pink or green, and resinous luster; hardness, 3–3·5. An analysis gave:

As_2O_5	NiO	CoO	CaO	H_2O
39·33	25·01	0·76	9·32	25·01=99·43.

This corresponds to an annabergite with one-third the nickel replaced by calcium.—*Ibid.*, p. 200.

HYDROPLUMBITE. A name given by HEDDLE to a supposed lead hydrate known on a single specimen, probably from Leadhills It is inferred to be $3PbO.H_2O$, but the examination is too incomplete to allow of any definite conclusion.—*Ibid.*, p. 201.

PLUMBONACRITE. A name suggested by HEDDLE for a hydrous lead carbonate from Wanlockhead, near the hydrocerussite of Nordenskiöld. An analysis gave:

CO_2	PbO	H_2O	Insol.
4·76	92·85	2·01	0·78=100·40.

ANTHOCHROITE. A silicate of magnesium, calcium and manganese from Jakobsberg, Sweden, described by L. J. IGELSTRÖM. It occurs with braunite in massive forms, having a fine granular or indistinctly crystallized structure. The color is rose-red or violet; the hardness, 5 to 6. An analysis gave:

SiO_2	MnO	CaO	MgO	Al_2O_3, Fe_2O_3	Alk.
51·6	3·4	23·3	13·5	1·4	[6·8]=100.

It seems to belong with the pyroxenes.—*Jahrb. Min.*, ii, 36, 1889.

PLEONECTITE. A partially examined mineral from the Sjö mines, Grythyttan parish, Sweden. It occurs in narrow veins with arseniopleite; color, grayish white; luster, greasy; hardness, 4. Qualitative trials led to the conclusion that it was an antimonio-arseniate of lead, carrying some chlorine.—*Ibid.*, p. 40.

5. *Lehrbuch der Mineralogie* von Dr. C. HINTZE. Erstes Lieferung, pp. 1–160, Leipzig, 1889 (Veit & Co.).—The publication of the first part of a new Descriptive Mineralogy which promises to be, when completed, the most exhaustive work ever written, is an event of no small importance to those interested in this science. This great labor has been undertaken by Prof. C. HINTZE, of Breslau, and if the whole can be carried through with the same care, accuracy and thoroughness exhibited upon each page of this first part it will be a monumental work, reflecting great credit upon its author and of great value to all workers in mineralogy. The plan as announced contemplates the issue of two or three parts yearly (at 5 marks each), the completion of the whole in two volumes being accomplished in three or four years. The present part forms the opening portion of the second volume and is devoted to a part of the silicates, namely, those of the olivine, willemite, eulytite, garnet, phacelite and topaz-andalusite groups. Some idea of the fullness with which the species are treated will be gathered from the fact that 13 pages are given to olivine, 26 pages to topaz, etc. With topaz, for example, we have first the crystallographic characters, the axial ratio, list of forms, calculated angles, etc.; then the physical characters and optical constants very fully given with references to the original papers; then a review of the history of the species with respect to its names, composition, etc.; then follows a general statement of method of occurrence, with a very minute description of all the important localities, with an account of the crystals from each and references to the authors who have treated of them. The figures of crystals are scattered through this part of the text as referred to. An account of the artificial mineral and a list of analyses, including also alteration products closes a most complete and interesting chapter. Very little attempt is made at condensation, and if this takes something from the compactness of the whole it certainly adds to the clearness of presentation.

The portion of the work at hand is too small to allow of a satisfactory judgment in regard to the general classification to be adopted, but it seems to follow the usually accepted methods. Danburite is placed with topaz and andalusite, etc., though the chemical composition does not show the same analogy that exists in the form; nephelite, however, is not included with the related silicates $KAlSiO_4$, $LiAlSiO_4$ $NaAlSiO_4$ since it deviates from the unisilicate formula. We are surprised to find this last group named after Scacchi's "phacelite," while the fact that Scacchi's mineral was described two years earlier under the name of *Kaliophilite*, is overlooked. The appearance of the succeeding parts of this great work will be looked for with interest, and it cannot fail to receive the cordial reception which it deserves.

6. *Mazapilite.*—The new mineral from Mazapil, Mexico, described by KOENIG (see this Journal, xxxvii), proves upon further examination to be a calcium-iron arseniate near arseniosiderite. An analysis gave:

As_2O_5	Sb_2O_5	P_2O_5	Fe_2O_3	CaO	H_2O
43·60	0·25	0·14	30·53	14·82	9·83=99·17.

The mineral occurs in prismatic orthorhombic crystals, which are black in color and only translucent and blood-red on the thinnest edges; the specific gravity is 3·582.—*Proc. Acad. Nat. Sci. Philad.*, 45, 1888–9.

III. BOTANY AND ZOOLOGY.

1. *Ueber Entstehung und Wachsthum der Zellhaut*; EN. ZACHARIAS (Pringsheim's Jahrb., xx, 2, p. 107).—The root-hairs of Chara fœtida were used as materials, and the process of growth by which the cell-wall is formed and grows, was followed out step by step on living cells. The new formation begins with the appearance of minute granules out of which minute rods are produced which become wider and longer and finally unite to constitute a coherent membrane. Between these rods one may see at first some protrusions of protoplasm, but then later withdrawn. But the origin and chemical relations of the granules which are seen at the outset are as yet undetermined. Growth in thickness is demonstrated to take place by the mechanical apposition of new rods, and also by intercalation. Growth in superficies is believed to be explained best by a combination of the two theories of intussception and of apposition. G. L. G.

2. *Volvox* has been investigated afresh by L. KLEIN (Pringsheim's Jahrb., xx, 2, p. 133).—The following are his conclusions: I. *Volvox aureus* and *V. globator* vary extremely with regard to the size and number of the individual cells, the size and number of the colonies produced, and the number of the oospores and bundles of antherozoids. But, on the other hand, the size and shape of the oospores of both are constant. 3. The protoplasts are enveloped by a thick gelatinous membrane which does not exhibit a cellulose reaction. The inner space of the colonies is filled with jelly, not with water. 11. Physiologically, a volvox-colony is to be recognized as a community comparable to a colony of bees so far as a division of labor is concerned. 13. The change in the distribution of sex coincides, as a rule, with the time of year. Thus, in spring *Volvox aureus* has predominately non-sexual colonies, and those with pure diœcism; in summer the antherozoids are only in those colonies which are otherwise vegetative; in late summer and autumn there are also the families which are monœciously protozynous. In general the sexual relations are more complicated than was previously supposed. G. L. G.

3. *Zur Kenntniss der fixen Lichtlage der Laubblätter;* by G. KRABBE (Pringsheim's Jahrb., xx, 2, p. 211).—The experiments were confined principally to the leaves of Phaseolus and lead to the following general conclusion which is somewhat at variance with those recently announced by Väehting. The position of the leaf with respect to light cannot be explained on the basis of a simple combination of heliotropism, epinasty, etc.; it is the result of a *special* heliotropic property of leaves. G. L. G.

4. *Flora*, oder *Allgemeine botanische Zeitung.*—This well-known journal, now in its 72d year, changes its place of publication. Hereafter it is to be edited at Marburg by Prof. K. Goebel. The number for March 1 begins the new volume. It contains (1) an interesting paper, by the editor, on the young forms of plants, (2) a criticism by Prof. Pfeffer on the researches by Loew and Bokorny, (3) notes on *Hypoxis decumbens* by Ludwig, (4) the genus Crenacantha (certain algæ placed by Hausirg near Draparnaldia), (5) (6) papers by J. Müller on Sandwich Island and Argentine Lichenes, (7) Widmer, notes on the red primroses of the Alps, (8) Loesener, some new plants from Brazil, and, finally, two reviews.

The second number, May 15, has (1) Schenck, on the aerial roots of *Avicennia tomentosa* and *Laguncularia racemosa*, (2) on the liquefaction of gelatine by moulds, Hansen, (3) the sandflora of Mainz, by Jännicke, (4) Weisse, on the mechanical theory of leaf arrangement in axillary buds, (5) short notes giving information relative to a botanical journey of Bornmüller in Asia Minor, (6) Lichenologic notes by Müller, and, lastly, four reviews, one of them being an appreciative notice of the Botanical Gazette.

The foregoing list serves to indicate the wide range covered by the journal under its new editor. It should receive hearty encouragement. G. L. G.

5. *The utilization by plants of free atmospheric nitrogen.*—At the close of a very interesting article in the Berichte der Deutschen Botan. Gesellsch. for June 25th, Prof. Frank, after having reviewed certain points in dispute between Helbriegel and himself, says: "All plants use as nitrogenous food at least in their young state, and up to a certain degree of development, compounds of nitrogen, especially nitrates, which they take from the soil; under a favorable condition of development they can also assimilate free nitrogen from the air. The gain from the latter depends in amount on the energy and duration of this assimilation; for instance, in the Leguminosæ it is especially marked. * * * * Just as we attribute the carbon of humus and of peaty soil to the carbonic acid of the air, we must attribute the nitrogen of arable land to the nitrogen of the air, both of these having been acquired through the intervention of the vegetable world." G. L. G.

6. *Monographiæ Phanerogarum Prodromi nunc continuatio, nunc revisio Editoribus et pro parte auctoribus* ALPHONSO et CASIMIR DE CANDOLLE. *Vol. Sextum. Andropogoneæ, auctore*

EDUARDO HACKEL. (Paris, pp. 716, 2 plates.)—About 60 pages of this volume are given up to an instructive review in German, of the principal feature of this tribe of grasses, and the characters which the author has used in his revision. The second plate exhibits graphically the supposed relations of the genera, regarded from the point of view of development. In the main line of descent stand Miscanthus, Erianthus, Pollinia, and farther on, in the same straight line Andropogon, while there branches off from Pollinia an oblique line with Ischnæum, Rottboellia, and Ophiurus. Elionurus and Cleistachne are given off on either side of Andropogon, or, rather, its sub-genus, while Sorghum comes in the Cleistachne offshoot. G. L. G.

7. *Angewandte Pflanzenanatomie;* by DR. A. TSCHIRCH, (vol. I, pp. 548.) Wien, 1889.—This work gives the principal applications of Vegetable Histology to the Arts, especially to Pharmacy, Agriculture, and Technical Industries. The first volume confines itself to a general sketch of general anatomy considered from almost every point of view. The book is copiously illustrated with woodcuts, many of them original, and all of remarkable clearness of outline. The paper is much heavier than we usually find in German books, and, in this case, it contributes greatly to typographical excellence. It forms the best practical work of reference for the laboratory that we have yet seen, covering all the ground thoroughly in a careful survey. A second volume, which is to deal with the more important drugs, fibres and the like, is in preparation. This work can be unreservedly recommended to all who have to examine the tissues of plants for any purpose whatever in the arts. G. L. G.

8. *Report on the Mollusca from dredgings of the Steamer "Blake," under the Supervision of* ALEXANDER AGASSIZ; by W. H. DALL. Part II, the Gastropoda and Scaphopoda. 492 pp. 8vo, with 31 plates.—Bulletin Mus. Comp. Zool., vol. xviii. Part I was published as No. 6 of vol. xii.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Soaping Geysers.*—Mr. ARNOLD HAGUE, in a paper read before the American Institute of Mining Engineers, in February last, gives the results of some trials of the effect of soap in the waters of geysers in hastening geyser action. The discovery with regard to it was made by a Chinese laundryman at the Upper Geyser Basin, who found that the soap produced an eruption in every way similar to that of the ordinary working of a geyser. Mr. Hague's experiments proved that geyser-action could be forced in a number of ways, but most conveniently by the use of soap. Lewis's concentrated lye in half-pound packages was used in the trials. The more powerful geysers in general did not respond to the influence. Old Faithful, the interval between whose eruptions is about 65 minutes, or generally between 57 and 72, afforded no positive results. With the Bee Hive, whose eruptions

vary greatly in interval, from a few hours to weeks and months, there was rarely success, but sometimes twice in a day. The Giantess, which is only 400 feet from the Bee Hive, has a large basin without a cone or mound, and varies from 12 to 20 days in its very copious and long-continued discharges, never was found to yield to artificial methods of hastening action. With some other geysers there was frequent success.

Mr. Hague concludes that the acceleration of action takes place when the waters are in a super-heated condition. He remarks that the experiments of Dr. William Hallock have shown that this is a common condition in some geysers. "If in one of these super-heated basins a handful of sinter pebbles be thrown, or if the surface of the water be agitated by the rapid motion of a stick or cane, or even by lashing with a rope, a liberation of steam takes place, which is liable to be followed by a long boiling of the water, and the boiling may lead to geyser-action. The laundryman's spring is only a hot spring, and never acts as a geyser without treatment with soap,—with one exception, in which, stirring it vigorously with a pine bow for nearly 10 minutes, produced a play to a height of 20 feet.

When soap is used the viscosity produced appears to be the principal cause that hastens geyser-action. The waters are too dilute and not of a nature to be chemically changed by the lye.

Mr. Hague observes, in closing his paper that the desire of tourists to soap a geyser during their trip through the Park grows annually with the increase of travel, so much so that there is a steady demand for the toilet-soap of the hotels. If visitors could have their way, the beautiful blue springs and basins of the geysers would be in the suds constantly throughout the season. Throwing anything into the hot springs is now prohibited by the government authorities. It is certainly detrimental to the preservation of the geysers, and the practice cannot be too strongly condemned by all interested in the National Reservation.

2. *Proceedings of the Colorado Society*, vol. iii, Part I, 1888. 186 pp. 8vo.—This number of the Proceedings of the Colorado Society contains among its articles, Mineralogical papers by W. F. Hillebrand, H. S. Washington, F. F. Chisholm and S. G. Eakins; papers on the Denver Tertiary formation by W. Cross and G. H. Eldridge; on the Tertiary Dinosauria in Denver beds, by G. L. Cannon, Jr.; on the Tertiary of the Huerfano River Tertiary, by R. C. Hills; on the Quaternary of the Denver basin, by G. L. Cannon, Jr.

3. *The Chemistry of Photography*; by Raphael Meldola, F.R.S. 382 pp. London and New York, 1889, (Macmillan & Co. —Nature Series).—The perfection of modern methods in photography has made the processes largely mechanical and reduced to a minimum the necessity of a knowledge of its scientific principles. It still remains true, however, that the worker who will attain the best success must have a thorough knowledge of the chemistry of the various processes, such, for example, as can be

gained from this attractive little volume. The subject is presented here in the form of nine lectures, originally delivered at the Finsbury Technical College in 1888, and this form makes it the more readable and gives it less the character of a text-book.

4. *Ostwald's Klassiker der exakten Wissenschaften.* Nos. 1, 2, 3. Leipzig, 1889 (Wilhelm Engelmann).—The publication of this valuable series of scientific classics is a real service to the scientific student. The numbers thus far issued are:

No. 1. Ueber die Erhaltung der Kraft von Dr. H. Helmholtz.

No. 2. Allgemeine Lehrsätze in Beziehung auf die im verkehrten Verhältnisse des Quadrats der Entfernung wirkenden Anziehungs- und Abstossungs-Kräfte von Carl Friedrich Gauss.

No. 3. Die Grundlagen der Atomtheorie; Abhandlungen von J. Dalton und W. H. Wollaston (1803, 1808).

On the Classification of the Early Cambrian and Pre-Cambrian formations, by R. D. Irving, pp. 367 to 454 of the Seventh Annual Report of the Director of the U. S. Geol. Survey, Washington, 1888.—This very valuable paper is the last work of the able geologist. It makes manifest the greatness of the loss which the Government Survey experienced in his decease.

The Faults in the Triassic formation near Meriden, Conn., by Wm. Morris Davis. 24 pp. 8vo, with 5 plates. An important paper in the discussion of the origin of the Triassic trap ejections of the Connecticut valley.

The English Sparrow, *Passer domesticus*, in North America, especially in its relations to Agriculture. Prepared under the direction of Dr. C. Hart Merriam, Ornithologist, by Walter B. Barrows, Assistant Ornithologist, U. S. Dept. Agric., Washington, D. C., 1889.

Catalogue of Fossil Reptilia and Amphibia in the British Museum. Part II, containing the orders Ichthyopterygia and Sauropterygia; by R. Lyddekker. London, 1889.

Etudes sur les couches Jurassiques et Crétacées de la Russie; by Prof. A. Pavlow, with 3 plates of figures of fossils Relates especially to the beds at the junction of the Jurassic and Cretaceous.

The Mineral Wealth of British Columbia, with an annotated list of localities of minerals of value; by G. M. Dawson, D.S., F.G.S. Geol. and Nat. Hist. Survey of Canada, Part R, Ann. Rep. for 1887. Montreal, 1888. (Dawson Brothers.)

Discovery of fossil-bearing Cretaceous strata in Anne Arundel and Prince George Counties, Maryland, by Prof. Wm. B. Clarke, Johns Hopkins University Circular, No. 69, 1889.

A Manual of Chemistry for the use of Medical Students, by Brandreth Symonds, A.M., M.D., Assist. Physician to Roosevelt Hospital. 154 pp. 12mo. Philadelphia, 1889. (P. Blakiston, Son & Co.)

Cercle Chromatique de M. Charles Henry, presentant tous les complements et toutes les harmonies de Couleurs, Paris, 1888. (C. Verdin). Rapporteur Esthétique de M. Charles Henry, permettant l'étude et la rectification esthétique de toute forme. Paris, 1888. (G. Séguin).

OBITUARY.

ELIAS LOOMIS.—Professor Elias Loomis, the eminent meteorologist, connected since 1860 with the Faculty of Yale College, died in New Haven on the 16th of August, at the age of seventy-eight. A notice of his life and scientific work is deferred to another number.

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VOL. XXXVIII. OCTOBER, 1889.

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THIRD SERIES.

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[THIRD SERIES.]

Art. XXXVII.—*On the Origin of Normal Faults and of the Structure of the Basin region;* by Joseph LeConte.

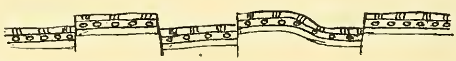
I have already, in a previous paper (Am. Geol., vol. iv, p. 38), given reasons for thinking that the general structure of the earth is that of *a solid nucleus* constituting nearly its whole mass, a solid crust of inconsiderable comparative thickness, and a subcrust liquid layer, either universal or over large areas, separating the one from the other. In this paper I assume such a general constitution. I assume also that the crust rests upon the subcrust liquid as a *floating body*. We may well assume this because, broken as we know the crust to be, if it were not so it would long ago have sunk into the subcrust liquid. I have also, in the previous article already alluded to, shown that this condition of flotation would be the necessary result of the increasing density of the earth as we go down. I now wish to apply these two assumptions to the explanation of Normal Faults and of the origin of the Structure of the Basin region.

Crust-fissures and great faults.—Leaving aside the small fractures called joints which affect rocks of all kinds and in all places, the crust of the earth, as is well known, is everywhere traversed by great fissures more or less parallel to one another in the same region, often hundreds of miles in length, and passing entirely through the crust into the subcrust liquid beneath, by which the crust is broken into great oblong crust-blocks many miles in extent and through which the subcrust liquid is often outpoured on the surface in the form of lava sheets. The walls of such fissures do not remain in their original position but are always slipped, one side being heaved and the other dropped.

Such displacements are called *faults*. The amount of vertical displacement is often enormous, especially in the Basin and Plateau regions. The vertical displacement on the north side of the Uinta Mountains according to Powell is 20,000 ft., that on the west side of the Wahsatch according to King is 40,000 ft. In the Plateau region according to Dutton there are faults extending for 200 miles with a vertical displacement of 2000 to 12,000 feet. It seems impossible to account for such faults, unless there be a subcrust liquid.

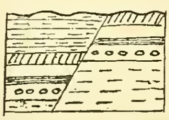
The displacement of these enormous crust-blocks did not take place all at once, nor by uniform motion, but by a succession of slight slippings, each doubtless attended by an earthquake. This is by far the most common cause of earthquakes. If it were not for erosion, of course every fault would be marked by a great cliff of height equal to the displacement. But in every case the resulting cliff has been greatly lessened, and in many cases entirely destroyed by erosion. If, however, the rate of slipping has been greater than the rate of erosion a cliff will be formed; and if the time since the displacement was finished be not too great, the cliff will still remain. The faults of the Basin and Plateau region are on an enormous scale and are of comparatively recent origin, in fact are still growing. For this reason fault-scarps form a very conspicuous feature of this region.

Law of Faults.—If fissures be vertical so that the crust-blocks are rectangular prisms, then one block may sink bodily lower and another float bodily higher, giving rise to level tables

1.

Ideal section showing the general structure of the Plateau region.

separated by fault-cliffs (fig. 1). This structure is so common in the Plateau region that it may well be called Plateau-region structure. In such cases the fissures being vertical we can have no distinctive names for the two walls. But in nearly all cases the fractures are more or less *inclined*, and therefore we have

2.



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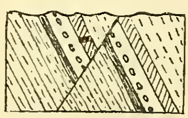
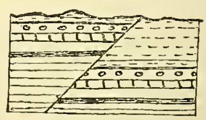


Normal Faults.

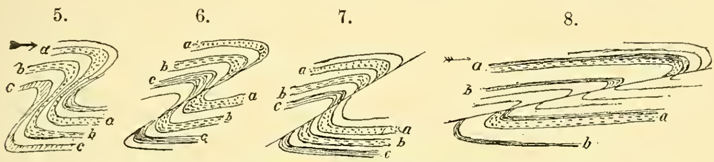
4.



Reverse Fault.

an upper or *hanging* wall and a lower or *foot wall*. Now in by far the larger number of faults we find that the *foot wall* has gone up and the hanging wall dropped down. These therefore are called *normal faults* (figs. 2 and 3). In many cases however, especially in strongly folded and crumpled strata whether in existing mountains or in the places of extinct mountains, we find faults in which the hanging wall has slidden upward and forward over the foot wall. These therefore are called *reverse* faults (fig. 4).

Theory of Faults.—The explanation of the *reverse* faults seems obvious enough. They occur, as we have already said, mostly in strongly folded regions. Such folds can only be produced by lateral pressure. The pressure when extreme often produces overfolds. If such overfolds break, the dip of the fissure will be toward the direction from which the pressure came and the hanging wall be *pushed* forward and upward over the footwall by the sheer force of the lateral thrust (figs. 5, 6



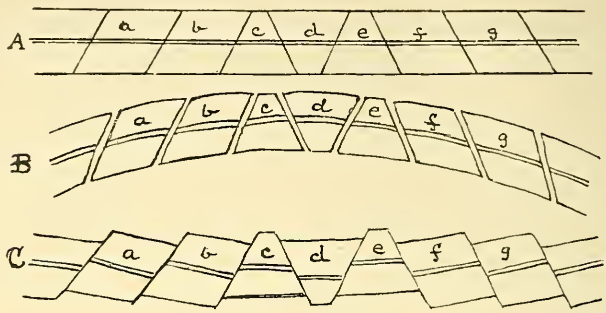
Diagrams showing made of formation of reverse faults.
(After DeMargerie and Heim.)

and 7). Extreme examples of this are found in the Scottish highlands in which the plane of displacement is nearly or quite horizontal. These are called by Geikie *thrust-planes* (fig. 8).

But the explanation of normal faults which are by far the most common is not so obvious. I will give very briefly what seems to me the simplest explanation—an explanation which I have used in my class lectures for many years.

Suppose then the earth-crust in any place to be *not crowded together* by lateral pressure, as in the formation of mountains of the Appalachian type, but *uplifted into an arch* by intumescence of the subcrust liquid. Such local intumescence of the subcrust liquid may be the result (*a*) of elastic force of steam incorporated in the magma in more than usual quantity by the access of water from above, or (*b*) of hydrostatic pressure transferred from a subsiding area in some other perhaps distant place. Such an arch being put upon a stretch would be broken by long fissures more or less parallel to one another and to the axis of uplift into oblong prismatic crust-blocks many miles in extent. After the outpouring of liquid lava or the escape of elastic vapors had relieved the tension, these crust-blocks would again be re-adjusted by gravity. If the blocks are *rectangular* prisms, some may float bodily higher and some sink bodily lower, giving rise to level tables separated by fault cliffs as in the Plateau region already explained. But if the fissures are more or less *inclined*, as is more commonly the case, then it is evident that the crust-blocks will be either rhomboidal (*a*, *b*, *f*, *g*,)

9.



A. Crust broken into blocks. B. Crust arched and blocks separated. C. Crust re-adjusted by gravity.

or wedge shaped (*c*, *d*, *e*, fig. 9 A). These in the arching of the crust would be separated from one another, fig. 9 B. But after the relief of tension by outpouring of lava or by the escape of steam, they would of course readjust themselves by gravity in new positions. Now by the laws of flotation how would such blocks adjust themselves? It is quite evident that every rhomboidal block would tip over on the *overhanging side* and heave up on the obtuse angle side producing in every case *normal* faults, and every wedged-shaped block would sink bodily lower or float bodily higher according as the base of the wedge were upward or downward, producing again in every case *normal* faults (fig. 9 C). A thick board sawn in the manner represented in fig. 9 A and the separated blocks placed together and floated on water would take exactly the positions represented in fig. 9 C. The explanation is complete. Of course erosion will modify the fault-scarps thus formed, by sculpturing their faces and by reducing their heights and slopes or even in some cases effacing them altogether. But if the fracturing and faulting have been geologically recent and on a large enough scale they may still remain and give rise to very conspicuous orographic features.

It is in this way that the orographic features of the Basin region have been formed; and the scale has been so grand and the features are so conspicuous that the resulting structure has been appropriately called *Basin structure.* The Basin region, according to the researches of King, Gilbert and Russell, is traversed by numerous north and south ridges several thousand feet high, with intervening valleys which are now or have been occupied by lakes. Although greatly modified by contemporaneous igneous ejections and subsequent erosion, these mountains consist essentially of gentle monoclinal slopes terminated by fault-scarps. They are in fact a succession of tilted and displaced crust blocks (fig. 10). The simplest and

Fig. 10. Basin structure, (after Gilbert.)

most beautiful illustration of this structure is found in the northern part of the Basin region in S. E. Oregon. In this region, as Russell has shown, the country rock consists of level sheets of lava outpoured during the later Tertiary period. These have been subsequently broken by parallel N. and S. fissures into rhomboidal and wedge-shaped blocks, which, readjusting themselves by gravity, have tilted or else sunk bodily lower, or floated bodily higher, so as to make a succession of normal faults. Moreover, the event has been so recent and the scale so grand that the uptilted side of each block forms a mountain ridge and the down dropped side a valley, on which has often accumulated a lake (fig. 11). Where the

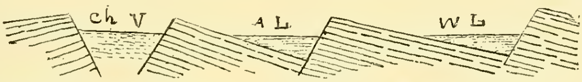


Fig. 11. Sketch section showing structure of S. E. Oregon, (after Russell.) W. L.—Warner Lake. A. L.—Albert Lake. Ch. V.—Chewaukan Valley.

inclination of contiguous fissures are in opposite directions, so as to form wedge-shaped blocks, these, as already explained, will drop down or heave up bodily. Some of the most conspicuous valleys are formed in this way—as for example Chewaukan Valley in Oregon, and Surprise Valley in N. E. California.

Geological age of these events.—I have already shown in a previous article (this Journal, vol. xxxii, p. 167, 1886), that the Sierra Nevada is a great crust-block 300 miles long and 50–60 miles wide heaved and slipped on the eastern side, forming there a great fault of 15,000–20,000 feet vertical displacement, and that this took place at the end of the Tertiary, accompanied with floods of lava. The evidence of this is found in the relation of the new to the old river-beds. The rivers displaced from their old beds by the lava have since that time cut far deeper than before, although cutting far less time.* Now,

* There is another evidence of the comparative recency of the origin of the Sierra in its present form, to which attention is now drawn for the first time. It is well known that *slates* overlying the axial granite are found forming the very crests of the Sierra. Furthermore, the deepest biting into the granite is found twenty miles westward of the crests in the region of the domes about the margin of the Upper Yosemite. This would be impossible if the crest had been in its present position ever since Jurassic times. When these mountains were first formed at the end of the Jurassic, the crest was probably about the region of the Domes. The tilting of the Sierra crust-block transferred it eastward to, or a little beyond, its present position Since that time it has been migrating westward by erosion. But the recency of this event is shown by the fact that these once flanking slates now forming the crest have not yet been removed.

this event seems, as shown by Russell to have been coincident with the formation of the Basin ridges, and both of these with the formation of the great fault-scarp on the western side of the Wahsatch range.

How the Basin system was formed.—Now regarding the Sierra and Wahsatch as belonging to the Basin system, we may imagine how the whole system was formed. At the end of the Tertiary the whole region from the Wahsatch to the Sierra, inclusive, was lifted by intumescent lava into a great arch, the abutments of which were the Sierra on the one side and the Wahsatch on the other as shown in the dotted line

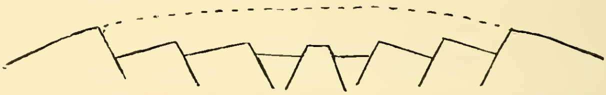


Fig. 12. Ideal section, showing mode of formation of Basin system.

(fig. 12). The arch broke down and the broken parts readjusted themselves by gravity into the ridges and valleys of the Basin region, leaving the raw faces of the abutments overlooking the Basin and toward one another. It must not be supposed, however, that this took place at once, but *gradually;* the lifting, the breaking down and the readjustment going on together *pari passu;* each readjustment probably giving rise to an earthquake.

Process still going on.—There are many evidences that the process of adjustment of these crust-blocks is still going on. In the Sierra we find evidence in the still deepening channels of the rivers and especially in the occasional readjustment of the walls of the eastern fault of the Sierra block. The Inyo earthquake of 1872 was undoubtedly produced in this way. Gilbert also finds evidences of recent movement of the Wahsatch block in the faulted terraces of Lake Bonneville; and in this fact foresees the probability of destructive earthquakes here in the future. In the Basin region, both in Nevada and in S. E. Oregon, Russell finds evidences of the same in faulted lake terraces. Finally, during a camp of two or three weeks in 1887 in Warner Mountains, where the structure described by Russell is finely displayed, I found abundant evidences of local subsidence still in progress. Many small lakes in that region, probably of the type produced by block-tilting, have apparently been formed during the present century. In Blue Lake, for example, I found stumps of pines standing in water fifty or more feet deep, rotted off level with the surface, *but perfectly sound below.*

Two kinds of mountains.—I must not be understood as maintaining that the Sierra, the Wahsatch and the Basin ranges were entirely formed at the end of the Tertiary. Some of the

Basin ranges, for example those of S. E. Oregon, were indeed wholly formed at that time and in the manner already explained. But the Sierra, the Wahsatch and many of the Basin ranges existed before that time. The Sierra was born from the sea by the folding and upswelling of thick sediments at *the end of the Jurassic.* Many ranges in the Basin region were formed at the same time and in the same way. The Wahsatch was similarly formed, probably about the end of the Cretaceous. But at the end of the Tertiary the greatly eroded land surface previously formed in this region was arched and broken and readjusted, forming these ranges *in their present condition*, as already explained.

In an article published in 1872,* entitled "Theory of the formation of the greater features of the earth's surface." I showed that mountain ranges were formed by lateral pressure acting upon thick sediments folding and swelling up the mass along the line of yielding. In another article published in 1878,† I further developed the same views and tried to show that even the Basin ranges—claimed by Gilbert as belonging to a different type and formed in a different way—were no exception; that *they also* were formed by lateral pressure; only that in this case the crust of the earth being rigid would not yield by mashing, but only by arching—the blocks of the broken arch readjusting themselves to form the orographic features already described; and therefore that mountain ranges are all of one type and formed in one way, viz: by lateral pressure. I now feel compelled to modify this statement. It is evident from the *character of the faults* i. e. normal instead of reverse faults, that the arch was not formed by lateral *pressure* but by *tension of lifting.* Therefore, I now believe that mountain ranges are of two types: (1.) Those formed by lateral crushing and folding, and (2.) those formed by adjustment of crust-blocks. The one produces reverse faults, the other normal faults. The best types of the one are the Appalachian, the Alps, and the Coast ranges of California; the best types of the other are the Basin ranges. Very often the two types are mixed, or one is superposed on the other—the one or the other predominating. This is the case with the Sierra, the Wahsatch, and to some extent with many of the Basin ranges.

Note.—Since writing the above my attention has been called to the fact that Hopkins, in his "Researches in Physical Geology" (Phil. Trans. for 1842, p. 53), gives a similar explanation of normal faults in the case of *wedge-shaped blocks,* but he says nothing of the far more common case of rhomboidal blocks.

* This Journal, vol. iv, p. 345–460.
† This Journal, vol. xvi, p. 95.

ART. XXXVIII.—*On the Circular Polarization of certain Tartrate Solutions*—II; by J. H. LONG.

MY first experiments on the circular polarization of tartrate solutions were described in the number of this Journal for November, 1888, volume xxxvi, page 351. (See also Chemical News, December, 1888, page 313). It was there shown that the rotation of solutions of potassium sodium tartrate is changed by the addition of various inactive salts, being increased by salts of potassium and ammonium, and decreased by salts of sodium, lithium and thallium, with the decrease in the last case especially marked. In this paper I describe experiments carried out with other tartrates. In these later investigations I have employed the large Landolt polariscope made by Schmidt & Hænsch using the 400^{mm} tube. As the specific gravity of the solutions tested was found in nearly every case I have usually employed in the reductions, the formula

$$[a] = \frac{10^4 a}{LPD}$$

instead of the simpler one

$$[a] \doteq \frac{10^4 a}{LC},$$

where a is the observed angle of rotation, L the length of the tube in millimeters, C the concentration, or number of grams of active substance in 100^{cc}, all weights being reduced to vacuo, D the specific gravity of the solution referred to water at 4°, and P the per cent, by weight, of active substance in solution.

Potassium Antimony Tartrate, $K(SbO)C_4H_4O_6 . \frac{1}{2}H_2O$.

For a study of this salt a preparation from Schuchardt was purified by several crystallizations. The tests, at 20°, gave,

$c = 2,$	$a = 11°.236$	$[a] = 140°.688$
c 4,	a 22·545	$[a]$ 141·144
c 5,	a 28·207	$[a]$ 141·273
c 6,	a 33·880	$[a]$ 141·404

In calculating $[a]$ a slight correction has been introduced because of the fact that the measuring flask employed in making the solutions held $100·17^{cc}$ instead of 100^{cc}.

It will be noticed that there is a slight increase in the specific rotation by increase in concentration. By increase of temperature there is, however, a decrease. For $t = 28°$ I found $[a] = 139°·92$, taking into consideration the change in density of solution.

The values for the specific rotation are slightly higher than found by Landolt for similar solutions.

Having established the value of the specific rotation, for the salt employed, I next sought to determine the variations in this when various inactive substances were dissolved with definite amounts of the potassium antimony tartrate. All attempts to prepare solutions with iodides, even in small amount, failed because of more or less rapid precipitation of oxyiodide. This did not take place with pure chlorides or bromides. I likewise found it difficult to prepare stable solutions with any potassium salt. Even potassium chloride and nitrate gave crystalline precipitates on standing but a short time, except when added in very small amount. Much better results were obtained with sodium and ammonium salts. The data obtained can be best shown in tabular form, and hence they will be presented in that way. The first column in the table below shows the amount of inactive salt dissolved with 5^{gm} of the tartrate in 100^{cc} at 20° C. The second column gives the observed rotation for the tube 400^{mm} in length. The third column gives the specific rotation calculated by the formula $[a] = \frac{10^4 a}{LC}$, and corrected for the error of the flask. In the fourth column is given the change from the normal specific rotation of the active salt, and in the last column it is shown in several cases how this varies by increase in the amount of the inactive salt.

Formula and amount of inactive salt.		Observed rotation a	Specific rotation $[a]$	Deviation from normal.	Change in this.
		°	°	°	
NaCl	5gm.	28·075	140·613	— ·660	
NaCl	10	27·738	138·925	— 2·348	1·688
NaCl	15	27·460	137·532	— 3·741	1·393
NH_4Cl	5	28·188	141·179	— ·094	
NH_4Cl	10	27·965	140·053	— 1·220	1·126
$NaNO_3$	5	28·025	140·363	— ·910	
$NaNO_3$	10	27·718	138·825	— 2·448	1·538
$NaNO_3$	15	27·427	137·367	— 3·906	1·458
NH_4NO_3	5	28·155	141·013	— ·260	
NH_4NO_3	10	27·865	139·561	— 1·712	1·452
NH_4NO_3	15	27·620	138·334	— 2·939	1·227
$NaC_2H_3O_2.3H_2O$	5	25·745	128·944	— 12·329	
$NaC_2H_3O_2.3H_2O$	10	24·676	123·589	— 17·684	5·355
KCl	2	28·200	141·238	— ·035	
KNO_3	2	58·205	141·264	— ·009	
KBr	5	27·945	139·953	— 1·320	

The last three solutions were clear when used, but on standing a few hours a crystalline precipitate separated out.

Attempts were made to prepare solutions containing salts of thallium with the potassium antimony tartrate, but only very dilute ones could be obtained.

In the above table it will be observed that without exception the specific rotation is decreased by addition of inactive salts, this decrease being especially marked in the case of sodium acetate. In the preparation of the solution with this salt it was observed that heating must be avoided as this produced a precipitate in a short time. It was also noticed that a solution with 15^{gm} of sodium acetate gave a crystalline precipitate after standing. The mixture, therefore, is not a very stable one, and the greatly decreased rotation indicates that some change has taken place, even before a precipitate appears. The precipitation by acetates has been pointed out before, but attention has never been especially called to it.

It will also be noticed that the nitrates of sodium, and ammonium produce a greater change than do the corresponding chlorides, and finally that when several solutions with the same inactive substance were tried the rate of increase in the deviation from the normal specific rotation is a diminishing one with the concentration.

Thallium Tartrate, $Tl_2C_4H_4O_6 . \frac{1}{2}H_2O$.

This salt was prepared from the sulphate which was first converted into the hydrate by means of solution of barium hydrate. The hydrate was neutralized with solution of tartaric acid, the point of neutrality being shown by disappearance of reaction with phenol-phthalein. The salt thus made was purified by several crystallizations and was shown by analysis to have the above composition, which agrees with the formula found by Lamy and Des Cloizeaux (J. B. 1868, p. 254).

5 grm. of the salt in 100^{cc} polarized in the 400^{mm} tube at 20° gave

$$a = 0°{\cdot}950$$

from which $[a]$ $4°{\cdot}758$

Another solution was polarized at 19° and at 28°·4 giving

$$a_{19} = 0°{\cdot}915 \qquad a_{28{\cdot}4} = 1°{\cdot}139$$

$$[a]_{19} = 4°{\cdot}582 \qquad [a]_{28{\cdot}4} = 5°{\cdot}704$$

From the mean of the observations we have

$$[a]_{20} = 4°{\cdot}729$$

This gives a marked increase by temperature.

To test the effect of addition of inactive salts I prepared six solutions containing, with 5 grm. of the tartrate, compounds of sodium and potassium, and one with thallium sulphate, and polarized them as before. The results are given in the table below:

Formula and amount of inactive salt.		Observed rotation a	Specific rotation $[a]$	Deviation from normal.
$NaNO_3$	5gm.	1°·640	8°·214	+3°·485
$NaC_2H_3O_2 . 3H_2O$	5	1·405	7·037	+2·308
Na_2SO_4	5	1·679	8·409	+3·680
KNO_3	5	1·420	7·112	+2 383
$KC_2H_3O_2$	5	1·510	7·563	+2·834
K_2CO_3	5	1·830	9·166	+4·437
Tl_2SO_4	2	0·912	4·568	−0·161

We find here that without exception the potassium and sodium salts produce a marked increase in the rotation. In the case of potassium carbonate the rotation is nearly doubled and suggests at once the behavior of potassium tartrate as the active body. The combined tartaric acid in 5 grams of thallium tartrate is equivalent to that in 2 grams of potassium tartrate, and supposing that amount of this salt in solution we can write the specific rotation

$$[a] = 22°·90$$

The actual specific rotation of the anhydrous salt is given by Landolt for C = 11·6 as

$$[a] = 28°·48$$

while a slightly lower value is given by Krecke. It seems possible, therefore, to account for this large rotation by assuming the presence of some neutral potassium tartrate. The other inactive salts experimented with do not seem to have as great a decomposing power on the tartrate, if this assumption may be considered the correct one. It will be noticed that the thallium sulphate decreases the rotation slightly.

Thallium Bi-tartrate, $HTlC_4H_4O_6$.

This salt was prepared by treating thallium carbonate with an excess of tartaric acid. As it is but slightly soluble it was easily freed from the excess of acid by crystallization and washing with water.

I investigated only one solution, having a strength of 1^{gm} in 100^{cc}, and found

$$a = 0°·48 \qquad t = 20°$$
$$[a] = 12°·02$$

Thallium Sodium Tartrate, $TlNaC_4H_4O_6 . 4H_2O$.

This beautiful salt is readily produced by mixing solutions of the acid thallium tartrate and sodium carbonate in equivalent proportions and allowing to crystallize after sufficient concentration. Large crystals resembling those of Rochelle salt are formed. They are, however, liable to break down by loss of water of crystallization, unless kept in a perfectly close bottle. The salt is readily soluble. The results of the tests are shown in tabular form.

gm. in 100 cc.	D^{20}_{4}	P	a °	$[a]$ °
5 gm. $TlNaC_4H_4O_6 . 4H_2O$	1·0317	4·8379	1·810	9·065
10 " " "	1·0652	9·3710	3·075	7·701
15 " " "	1·0992	13·623	4·188	6·992
20 " " "	1·1311	17·651	5·186	6·492

A marked decrease in the specific rotation by increase of concentration is shown. This is best illustrated by a curve obtained by plotting the concentrations as abscissas and the specific rotations as ordinates, which will be found below.

In order to find the effect of change of temperature I prepared a solution containing 10^{gm} of the anhydrous salt in 100^{cc}.

Direct tests gave

$$a_{18.4} = 3°·362 \qquad a_{28} = 3°·780$$
$$D^{15}_{4} = 1·0791 \qquad D^{30}_{4} = 1·0741$$

from which were calculated

$$[a]_{20} = 8°·595$$
$$[a]_{28} \quad 9°·490$$

we have here an increase of over 10 per cent for only 8° of temperature, which is somewhat remarkable.

The influence of the presence of inactive salts was shown by testing three solutions at 20°. One containing in 100^{cc} 10^{gm} of the tartrate and 5^{gm} of sodium sulphate (anhyd.) gave $[a] =$ 10°·192; the second containing 10^{gm} of the tartrate and 5 ^{gm} of thallium sulphate gave $[a] = 5°·494$, while the third, made by mixing equal volumes of the other two, gave $[a] = 8°·139$.

Thallium Lithium Tartrate, $TlLiC_4H_4O_6 . H_2O$.

This salt was prepared from pure thallium bitartrate and lithium carbonate, and was readily obtained in large crystals which were found by analysis to possess the above formula. Four solutions were tested, the results given in the table below show a great similarity between the behavior of this salt and that of the preceding one, which is likewise indicated by a curve, plotted as before.

gm. in 100 cc.	D^{20}_{4}	P	a °	$[a]$ °
5 gm. $TlLiC_4H_4O_6 . H_2O$	1·0347	4·8150	1·888	9·456
10 " " "	1·0744	9·2910	3·114	7·799
15 " " "	1·1107	13·480	4·276	7·139
20 " " "	1·1467	17·410	5·345	6·693

A solution containing 10^{gm} of the tartrate and 5^{gm} of thallium sulphate in 100^{cc} gave $[a] = 5°·841$; a solution containing 10^{gm} of the tartrate and 5^{gm} of lithium sulphate gave $[a] = 10°·104$, while a mixture of equal volumes of the two solutions gave $[a] = 8°·089$.

Here, as in the case of the thallium sodium compound, addition of more thallium produces a great decrease in the specific rotation, while addition of a lithium salt increases it. The result obtained from the mixture is greater than the mean of the other two, and probably because the number of molecules of lithium sulphate present is greater than the number of molecules of thallium sulphate.

Thallium Antimony Tartrate, $Tl(SbO)C_4H_4O_6 . H_2O$.

This salt was prepared by boiling thallium bitartrate with pure precipitated antimonious oxide in a large excess of water. On cooling, the salt separates out in small crystals which resemble the corresponding potassium compound. I found the above formula by analysis. The salt is but slightly soluble in water. For a solution containing 2^{gm} in 100^{cc} I obtained

$$[a]_{20} = 100°·443$$
$$[a]_{28} = 99°·644$$

It was shown above that a reduction of the specific rotation by increase of temperature takes place in solutions of potassium antimony tartrate. It would seem from these two experiments that this change must be due to the presence of the antimony, as in all other thallium solutions examined I find the temperature coefficient positive. The effect of addition of inactive salts is shown in the following table, 2^{gm} of the thallium antimony tartrate being used in each case except the last, where 4^{gm} were dissolved.

Formula and amount of inactive salt.		Observed rotation. a	Specific rotation. $[a]$	Deviation from normal.
Na_2SO_4	2 gm.	7°·912	99°·060	— 1°·383
Na_2SO_4	4 "	7 ·875	98 ·596	— 1 ·847
$NaC_2H_3O_1.3H_2O$	2 "	7 ·092	88 ·799	—11 ·644
$KC_2H_3O_2$	2 "	6 ·928	86 ·748	—13 ·695
KNO_3	2 "	7 ·858	98 ·385	— 2 ·058
K_2SO_4	2 "	7 ·850	98 ·295	— 2 ·148
NH_4NO_3	2 "	7 ·854	98 ·341	— 2 ·102
NH_4NO_3	4 "	7 ·715	96 ·590	— 3 ·853
NH_4NO_3 (4gm. TlSbOT)	2 "	15 ·663	98 ·059	— 2 ·384
$(NH_4)_2SO_4$	2 "	7 .830	98 ·040	— 2 ·403
$(NH_4)_2SO_4$	4 "	7 ·747	97 ·002	— 3 ·441

Especially noticeable in the above table is the fact that along with a general reduction in the specific rotation, because of the presence of inactive salts, there is a very marked reduction in the two solutions containing acetates. These two solutions had to be prepared without application of heat, as the slightest elevation of temperature produced precipitation. It will be remembered that an analogous reduction was noticed in the solutions containing potassium antimony tartrate, when the conditions of preparation were the same.

This behavior suggests a most interesting field of inquiry, viz: What in general is the behavior on polarization of solutions in an unstable condition of equilibrium? For example, a solution of potassium antimony tartrate, with a chloride may be called stable, as there is no precipitation at any temperature, but with iodides and many oxygen salts only dilute solutions can be made clear, and these remain so but a short time and at low temperatures.

The solutions prepared with acetates decompose, if heated, precipitating antimonious oxide or a basic salt, and leaving a simple tartrate in solution, which would now, of course, show a diminished rotation. The diminished rotation without precipitation suggests that even with solutions prepared in the cold some change has already taken place.

It is likewise worthy of note in the above table that the solutions with ammonium nitrate, ammonium sulphate and sodium sulphate show a further reduction by increase in the amount of inactive salt added.

Thallium Potassium Tartrate, $TlKC_4H_4O_6$.

The solutions used were prepared by weighing out equivalent portions of thallium bitartrate and potassium carbonate, sufficient to furnish 5, 10, 15 and 20 grams of the anhydrous salt in 100 c. c. The crystallized salt is not made as readily as the corresponding sodium compound. Mixed salts with variable amounts of water of crystallization are usually obtained, and to avoid any uncertainty as to the composition of the crystals I prepared the solutions as just described. Four solutions were tested, the results of which are found below. A curve showing the rate of change in the specific rotation is shown at B in the figure.

gm. in 100 cc.	D^{20}_{4}	P	a	$[a]$
			°	°
5 gm. $TlKC_4H_4O_6$ ----------	1·0377	4·810	2·008	10·057
10 " " " ----------	1·0764	9·274	3·530	8·840
15 " " " ----------	1·1143	13·437	5·010	8·365
20 " " " ----------	1·1530	17·316	6·527	8·173

Attention may be called to the influence of temperature here. For a solution containing 10 gm. of the salt in 100 c. c. I find

$$[a]_{20} = 8°·840$$
$$[a]_{30} = 10·092$$

The increase for 1°C. here is 0°·125 in sp. rotation, while for the sodium compound corresponding I found 0°·112.

As indicating the effect of addition of inactive salts, I found for a solution containing in 100 c. c. 10 gm. of the tartrate and

5 gm. of ammonium nitrate $[a] = 11°·355$, with 5 gm. of sodium sulphate $[a] = 11°·418$, with 5 gm. of potassium nitrate $[a] = 11°·155$, while with the 10 gm. of tartrate and 5 gm. of thallium sulphate I found $[a] = 6°·793$.

Thallium Ammonium Tartrate, $TlNH_4C_4H_4O_6$.

The crystals not appearing to be uniform in composition, I prepared solutions as desired by mixing calculated amounts of thallium bitartrate and ammonium hydrate. The results obtained by testing four solutions are given here.

gm. in 100 cc.	D^{20}_4	P	a	$[a]$
			°	°
5 gm. $TlNH_4C_4H_4O_6$ ------	1·0354	4·821	2·003	10·032
10 " " " ------	1·0726	9·306	3·520	8·815
15 " " " ------	1·1092	13·499	4·740	7·914
20 " " " ------	1·1459	17·423	6·040	7·563

The rate of decrease in the specific rotation with increase in concentration is very nearly the same as with the preceding compounds and is illustrated in the curve A. For $t = 31°$ the 10 gm. solution gives $a = 4°·142$, which is a more rapid rate of increase than with the potassium thallium salt.

The results obtained by adding inactive salts are quite analogous to those found in other cases; thallium sulphate decreases the rotation, while the sulphates of potassium, sodium and ammonium increase it.

Potassium Boro-Tartrate, $KBOC_4H_4O_6$.

This salt was prepared in the usual manner by heating a mixture of 3 parts of potassium bitartrate, $1\frac{1}{4}$ parts of boric acid and 10 parts of water to complete solution. The liquid was then brought to the boiling point and evaporated to dryness. The residue was powdered and washed thoroughly with alcohol to remove excess of boric acid. It was afterwards dried in the air and then over sulphuric acid. Four solutions of this preparation, gave at 20°:

$$C = 5, [a] = 53°·070, \qquad C = 15, [a] = 61°·703$$
$$C = 10, [a] = 59°·055, \qquad C = 20, [a] = 62°·621$$

For the 10 gm. solution I found, after determination of the density,

$$[a]_{29} = 57°·286$$

showing a decrease in the specific rotation by increase of temperature.

The increase with greater concentration is very marked, and the reverse of what was shown to be the case with the thallium solutions. Further experiments were tried with some of the boro-tartrate dried at 100°, it being evident that a small amount of water was held by the product dried over sulphuric acid. With the salt thoroughly dried I obtained higher results, as are shown in the following table.

gm. in 100 cc.	D^{20}_{4}	P	a	$[a]$
			°	°
5 gm. $KBOC_4H_4O_6$	1·0266	4·862	11·600	58·101
10 " " "	1·0533	9·416	25·388	63·581
15 " " "	1·0803	13·861	40·036	66·843
20 " " "	1·1068	18·038	54·534	68·287

The values are seen to be larger than with the other preparations. For the concentration $C=5·488$ at $t=20°$, Landolt found $[a]=58°·35$. The variation of the specific rotation with increased strength of solution is shown by the curve E. In order to represent this with the others, the values of $[a]$ were divided by 10, and the quotients so obtained diminished by 3. That is, the axis of abscissas is assumed to be 3° below.

The effect of addition of inactive salts is shown in the following table, 10 gm. of $KBOC_4H_4O_6$ being used:

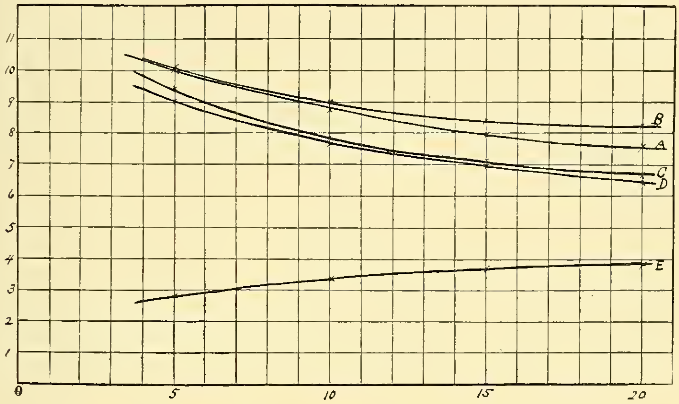
Formula and amount of inactive salt.		Observed rotation a.	Specific rotation $[a.]$	Deviation from normal.
		°	°	°
KCl	5 gm.	25·503	63·865	+0·284
NaCl	5 "	25·893	64·841	+1·260
NaBr	5 "	27·090	67·840	+4·259
Na_2SO_4 (dry)	5 "	27·600	69·117	+5·536
KNO_3	5 "	25·996	65·105	+1·524
$KC_2H_3O_2$	5 "	29·160	73·024	+9·443
NH_4Cl	5 "	26·726	66·928	+3·347
H_3BO_3	2 "	27·260	68·265	+4·684
H_3BO_3	4 "	27·788	69·587	+6·006

In this table the behavior with the acetate is again characteristic, but it must be said that in any case the increased rotation appears singular. Bearing in mind that the specific rotations of potassium tartrate and sodium tartrate are about half as great as that of the potassium boro-tartrate we should naturally expect a reduction by addition of either potassium or sodium compounds to the latter just as has been shown to take place in the case of potassium antimony tartrate or thallium antimony tartrate.

The specific rotations of the neutral tartrates of potassium, thallium, sodium and ammonium are known, as are also the rotations of the various double tartrates of these metals. I have shown in my former paper that the rotation of potassium sodium tartrate may be modified; that is, made to approach that of potassium tartrate or sodium tartrate by adding on the one hand a potassium salt, or on the other hand a sodium salt, and this apparently without exception.

The experiments in this paper on the double tartrates of thallium, potassium, sodium, ammonium and lithium seem to point to a law which may be stated in this way: the rotation of a double tartrate may be made to approach that of a neutral tartrate of either of the metals present by addition of a salt of that metal. In the case of Rochelle salts I tried to explain

1.



this by assuming that a substitution took place in the solution; that is, for instance, that by adding potassium chloride to a solution of sodium potassium tartrate the latter was converted more or less perfectly into neutral potassium tartrate. The same explanation would evidently hold for the other solutions.

But when we come to a consideration of the compounds containing antimony and boron we find several difficulties. Taking up the antimony potassium tartrate first, we notice that the slight decrease observed in several cases can be explained by assuming the displacement of the potassium, but this will not account for the decrease in the rotation in the cases where potassium salts were the inactive bodies added, nor for the very great decrease in the solutions containing acetates.

I am inclined to think that we must assume here a replacement of the antimony radical; but how? In what form can we suppose it to exist if withdrawn from the tartrate group? Most of the antimony compounds which could be formed in this way are usually considered insoluble, but unfortunately we have no very full data on the subject. A few experiments of my own may give a little light here. I mentioned above that the solution containing acetates had to be prepared in the cold to avoid precipitation of the antimony. I observed also that several solutions containing bromides could be made clear by boiling the tartrate and bromide together, while with others precipitation of the antimony took place even on slight warming. In these cases clear solutions could be prepared by mixing in the cold.

In seeking for an explanation of this curious behavior I found that the several samples of bromides employed in these last tests were not absolutely pure, but contained traces of carbonates, which would account for the precipitation of the antimony by heat. This suggested the use of a pure carbonate with the potassium antimony tartrate, and after a time I succeeded in making, at a low temperature, a clear solution containing in 100 cc. 5 gm. of the tartrate and 1 gm. of dried sodium carbonate ($Na_2CO_3+1\frac{1}{2}H_2O$). This, on polarization in the 400 mm. tube, gave a most remarkable result:

$$a=11°\cdot140 \qquad t=18°\cdot5$$

or $$[a]=55°\cdot795 \text{ (cor.)},$$

instead of $$141°\cdot273.$$

Here we have a loss of over 60 per cent and without apparent decomposition. However a very slight elevation of temperature was sufficient to produce a precipitation of the antimony, and it was also found that on standing in the cold a similar precipitation took place.

It was found that with care solutions containing the potassium antimony tartrate with phosphates and borates could be prepared at low temperatures. With a solution of 5 gm. of the tartrate and 1 gm. of ordinary sodium phosphate I observed

$$a=25°\cdot244 \qquad t=18°\cdot5$$
$$[a]=126°\cdot334 \text{ (cor).}$$

Slight warming decomposed this solution.

Now, what is the condition of the antimony just before precipitation here? In view of all the facts I believe it must be looked upon as an unstable oxycarbonate or phosphate, held in solution by the tartrate, and ready to precipitate by change of temperature or on standing. It has probably already left the tartrate group and its place has been taken by something else giving a lower rotation. On this hypothesis the phenomena observed with the thallium antimony tartrate can also be explained, but until such an investigation as I suggested above, in presenting the experimental data, is carried out, a fuller confirmation cannot be given. In such an investigation the behavior of many solutions, in what I have called a condition of unstable equilibrium, should be studied, and the polarizations should be made not only at low temperatures but at the highest temperature possible before precipitation actually takes place. Freshly prepared solutions and those which have stood should also be tried. Such an investigation I plan for the near future.

Accepting the hypothesis just brought forward the behavior of the tartrates of the alkalies and of antimony and thallium with inactive salts can readily be explained as cases of substitution. The phenomena of substitution are so characteristic in many instances that in my last paper I was led to suggest an application of these principles as offering a means of analyzing certain salt mixtures, and before the matter appeared in print the able article of Schütt (*Berichte*, 1888, p. 2586) came to hand, in which the quantitative analysis of mixtures of potassium and sodium chlorides by means of their action on neutral potassium tartrate was worked out. The principle can undoubtedly be extended to the analysis of many other substances.

All these cases, however, appear simple when compared with that of the potassium boro-tartrate. Here we have a compound with large specific rotation which increases rapidly with the concentration and also on addition of inactive substances. Any substitution for the boron radical which we can imagine would leave a molecule with decreased rotation, but it is possible that there may be both addition and substitution and in a manner which may account for the observed increase. A solution of neutral potassium tartrate containing 10 gm. in 100 cc. gives the rotation in the 400 mm. tube

$$a = 10°{\cdot}788, \qquad t = 22°{\cdot}4$$

A solution of 10 gm. of the same tartrate plus 10 gm. of KCl gives under the same conditions

$$a = 11°{\cdot}238$$

It is possible that the two substances have united in some way here to form a complex group with increased rotation, and it may be that with the boro-tartrate a similar group is formed.

The other supposition possible is that the boro-tartrate is wholly or in part decomposed, and if so it must be according to this reaction, or a similar one,

$$KBOC_4H_4O_6 + NaCl + 2H_2O = KNaC_4H_4O_6 + H_3BO_3 + HCl.$$

One of the experiments given above shows that free boric acid greatly increases the rotation of the boro-tartrate, and in view of this I thought it well to test the probability of the above equation. If a decomposition takes place in this manner the same rotation should be found by using the equivalent amount of Rochelle salt, boric acid and hydrochloric acid as indicated. I dissolved in 100 cc.

14·1 gm.	$KNaC_4H_4O_6 . 4H_2O$
3·1 gm.	H_3BO_3
1·82 gm.	HCl,

or one-twentieth of the molecular weights expressed in grams. This would correspond to a solution of 10·7 gm. of $KBOC_4H_4O_6$ in 100cc. that is an amount near what was taken for one of the tests described some time back.

I found for $t=20°$

$$a=28°·14$$

Considered as a solution of potassium sodium tartrate this gives

$$[a]=49°·89+$$

which is over twice the normal specific rotation of that salt. But considered as a solution of 10·7 gm. of potassium boro-tartrate it gives

$$[a]=65°·74+$$

which agrees very well with the other experiment. The value is a little greater than was found for the pure boro-tartrate.

That a decomposition of this sort takes place is shown also by the taste and reaction of a solution of potassium boro-tartrate and sodium chloride.

It seems, therefore, that we can look upon this as a case of very interesting substitution with liberation of boric acid, whose behavior with tartrates was long ago pointed out by Biot and others, and more recently by Landolt (Berichte, 1888, p. 191, and Fres. Zeitschr., 1889, p. 233).

While these experiments do not by any means explain the matter, they show that what, on first view, might be considered as something apart, is in reality but a special case of a well known phenomenon. Gernez has succeeded in isolating several complex bodies from solutions showing a greatly increased specific rotation, made by mixing tartaric acid with molybdates (Berichte, 1888, Ref. p. 251 and 773). It is possible that boric acid and tartrates form in solution some such complex compounds whose rotation is greatly in excess of that of the simple tartrate alone.

Considering the peculiar behavior of the antimony compounds with carbonates, phosphates and acetates and of the boro-tartrates with various inactive substances it is plain that we have what may prove a fruitful method for the study of changes in chemical equilibrium. The experiments given above indicate the direction in which further work should be prosecuted on this topic. In another communication I expect to give especial attention to the question of unstable solutions, and also to that suggested by the experiments of my first paper, a study of the action of varying amounts of a few salts on some one tartrate.

Chicago, June 1, 1889.

ART. XXXIX—*On the Gustatory Organs of the American Hare, Lepus Americanus;* by FREDERICK TUCKERMAN.

General description of the tongue.

THE tongue of this rodent shows two well-marked divisions, a more or less flattened and expanded anterior portion, and a raised posterior part. The posterior division is the longer of the two by about one-fifth, the total length of the organ being 48^{mm}.

The anterior division is $13{\cdot}5^{mm}$ in breadth, 5 to 8^{mm} in thickness, and is free from the floor of the mouth for 15^{mm}. The upper surface and lateral borders of this division are covered with small, closely set, cone-shaped papillæ, the apices of which are directed backward. The epithelium covering the papillæ is dense and imbricated, and in their upper half either partly or wholly cornified. They measure about $0{\cdot}20^{mm}$ in height, and terminate in one or more minute spines. There is only the faintest trace of a mesial furrow on the papillate surface, but the organ is impressed transversely, corresponding to the palatal grooves. The apex is short, broad and obtuse. The under surface is smooth, and marked by a longitudinal median ridge extending from the tip of the tongue to the frænum. Papillæ of the fungiform type are not especially numerous. They are rather thinly distributed over the anterior dorsal surface, and the posterior division of the organ appears to be nearly devoid of them. They are however quite thickly set about the tip, particularly its inferior part, and they are also collected into a single line on each side of the tongue, from the apex to the anterior limits of the foliate organs.

The posterior division, which rises somewhat abruptly above the level of the preceding, is $11{\cdot}5^{mm}$ in breadth and 8 to 12^{mm} in thickness. Anteriorly, the lateral margins of this division are stained a rusty-brown color. In some specimens this pigmentation of the epithelium involves nearly the whole of the anterior surface of the division. The upper surface is slightly convex, and, in front of the circumvallate area, is covered with closely-set mechanical papillæ, the points of which are directed backward. The extreme posterior region is traversed by a few inconspicuous ridges, in the furrows between which may be seen (with the aid of a lens) the minute orifices of the mucous ducts which open on the free surface in this region. The circumvallate papillæ are usually two in number. They are placed one on either side of the median line, $3{\cdot}6^{mm}$ apart, and 10^{mm} from the base of the organ. Very rarely there are three papillæ of this type present. When this is the case, they are arranged in a triangle, the apex of the triangle being directed backward toward the epiglottis. The foliate papillæ are situated obliquely on each side of the back of the organ, anterior to the glosso-palatine arch, their anterior extremity being directed downward and inward. Each papilla is about 5^{mm} long and $2{\cdot}7^{mm}$ broad. As seen from above, they are small, oval-shaped elevations, and are marked transversely by a number of ridges or lamellæ with intervening furrows.

Gustatory Structures.

The circumvallate papillæ.—The general surface in front of these papillæ is covered, as already mentioned, with small conical papillæ. The immediate area around them, however, is nearly free from papillary elevations. When well developed the circumvallate papillæ measure $0{\cdot}60^{mm}$ in diameter. Their summits are circular or slightly oval, and are more or less marked by verrucose elevations. Occasionally I have seen a fungiform papilla superposed upon one of this type. Each papilla is encircled by a narrow and rather shallow trench. Serous glands are abundant within the papillæ, and beneath and around them. Their ducts, which are numerous, open into the trench at its lower part. Mucous glands are also very plentiful in this region of the tongue, and their ducts have a greater diameter than those of the serous glands. They pass through the mucous membrane and open, somewhat obliquely, on the free lingual surface. In a horizontal section, two and a half millimeters square, I counted eighty ducts. The mucosa composing the body of the circumvallate papilla is cleft into three main portions, the central portion or lamella being much the largest, and overtopping the other two. In this particular the papilla bears a structural resemblance to the fold of the lateral organ, in which the mucosa is similarly arranged. The depressions between the lamellæ not infrequently extend to the base of the papilla, forming a deep and narrow furrow; usually, however, they are partially filled with epithelium. Covering the mucosa is a thin layer ($0{\cdot}03^{mm}$ in thickness) of stratified pavement epithelium. This layer is thicker above than at the sides, but the difference is only slight.

The taste-bulbs of this gustatory area occupy a somewhat exposed position. They are confined to the upper three fifths of the papillary wall instead of filling its lower and consequently more protected portion, as is the case in other Rodentia which I have investigated. They are also present in the corresponding region of the outer wall of the trench. The bulbs, to all appearance, are in contact by their edges and, in the papilla, are disposed in a zone of four to six tiers. Those embedded in the epithelium at the upper part of the outer wall of the trench are arranged in a girdle of four or five tiers. From horizontal sections I estimated the average number of bulbs in a tier of the papilla at sixty. If we allow for five tiers, we shall have three hundred bulbs for each papilla. The average number of bulbs present in a tier of the outer wall of the trench appears to be about seventy-five, which, allowing for four tiers, would give three hundred bulbs for this region. The bulbs, as usual, vary in size and shape. The mean length is $0{\cdot}051^{mm}$ and the mean breadth $0{\cdot}033^{mm}$. Most of the bulbs have a fairly well-developed neck, and in many of them the peripheral ends of the sensory cells project for some distance beyond the gustatory pore. The peripheral or supporting cells are elongated, slightly flattened structures, with an oval nucleus, containing several nucleoli, situated usually in their lower half. The outer end of the cells is more or less pointed, while their basal pole is generally slightly rounded, though it may be notched or even branched.* The sensory or taste-cells are fusiform, highly refractive elements, and consist of an elliptical-shaped nucleated enlargement, usually placed near the middle of the cell, and two processes. The peripheral process, broader than the central and quite straight, passes to the apex of the bulb, where it frequently terminates in a delicate hairlike projection. In other cells the apex of the peripheral process is truncated, but bears no cilium. The central process, more slender than the peripheral, and occasionally slightly varicose, sometimes divides below the nucleus into two or more branches, but more commonly it ends in a somewhat pointed extremity.

The circumvallate papilla is well supplied with nerves. Medullated and non-medullated fibers of the glosso-pharyngeus enter the papilla at its base, and ramify in all directions. In the mucosa directly beneath the bulb region, the finer branches form a delicate network. In chloride of gold preparations this subepithelial network is beautifully shown, the fibers of Remak and small ganglia, which are scattered through the membranous stroma, being stained deep violet or black. A portion of the terminal fibrils of the plexus enter the bulbs at their base, probably more than are represented by the sum of the taste-cells, while others pass between them and end freely in the epithelium or form an intra-epithelial network.

The papillæ foliatæ.—These papillæ measure 5^{mm} in length and $2{\cdot}7^{mm}$ in breadth. Each papilla consists of thirteen or fourteen folds, most of which bear bulbs on their lateral area. The folds are separated by narrow furrows, slightly dilated at

* Hermann describes three kinds of supporting cells in the taste-bulb of the rabbit. First, the outer or "pillar cells," which constitute the true supporting element of the bulb. Second, the inner supporting cells, which resemble the "staff cells" of Schwalbe and heretofore supposed to be sensory in function; and, third, "basal cells" which he regards as compensating cells for the bulbs.

their base, and having an average depth of 0·30^{mm}. The furrows are often partly filled with epithelium. The mucosa composing the body of each fold is divided into three quite symmetrical secondary folds or lamellæ. The primary or central lamella is taller and slightly broader than the two lateral, and at its upper part is frequently forked. The two secondary or lateral lamellæ contain the taste-bulbs. A thin stratum of stratified pavement epithelium is spread over the lamellæ, but is not sufficient to completely fill the depressions between them. Serous glands are abundant in this region, and their ducts, which are very numerous and occasionally of great length, usually open at the bottom of the furrows.

The taste-bulbs of this gustatory area are limited to the sides of the folds and, in the main, are restricted to their upper half. They traverse the epithelium more or less obliquely, and are so close as to be in actual contact. They are disposed four to seven tiers deep, the uppermost tier being on a level with the top of the lateral wall, while the lowest is about opposite the middle of the furrow. Each tier contains about thirty bulbs in its entire length. If we allow for five tiers, we shall have three hundred bulbs for each fold of the papilla. The bulbs have a clearly-defined neck, and, when well developed, are 0·056^{mm} in length and 0·035^{mm} in breadth.

The arrangement and distribution of the nerve-fibers in the folds of the foliate organ is very similar to that which exists in the circumvallate papilla. According to Drasch, who made the lateral gustatory organ of the rabbit and European hare a special study, there is beneath the basal membrane of the lateral lamella a plexus formed of medullated nerve-fibers. From this plexus, fibers, corresponding in number to the sum of the sensory cells, go directly to the bulbs. Other fibers, more numerous, pass between the bulbs to the epithelium situated above them. Many fibers, however, terminate in the membranous stroma. Below the bulb region, in the entire width of the lamella, is a connected stratum of ganglion cells which contribute to the multiplication of the fibers.

Other regions in which taste-bulbs occur, but which are not, strictly speaking, exclusively taste areas, are the fungiform papillæ and parts of the epiglottis. In the fungiform papillæ of *L. americanus* bulbs are but sparingly present, and only isolated ones were found in the epiglottis.

ART. XL.—*On the Output of the Non-condensing Steam Engine, as a Function of Speed and Pressure;** by FRANCIS E. NIPHER.

IN the discussion which follows, the engine is supposed to be running at a fixed cut-off, and without change in the throttle. The pressure changes required to produce a change of speed are supposed to be effected by a change in boiler pressure. The effect of the throttle or the governor with automatic cut-off will be pointed out as we proceed.

The difference between the two belt-pulls, or the load on the brake, is represented by w, r being the brake-arm, or radius of the driving-wheel. If the belt-pulls are F' and F'', then $F'-F''=w$. It is supposed also that the mean effective pressure required to drive the engine when $w=0$ is constant for all speeds. In an engine with balanced valves and where the amount of lubrication used increases with the speed, this assumption may be tolerated for a general treatment of the case, although the peculiarities of engines will doubtless cause them to depart from this assumption in a more or less irregular way. Engines are usually built for definite speeds, and often behave poorly when run at widely different speeds from those for which they were designed.

For these reasons, some portions of this treatment cannot lay claim to very great precision. It will serve mainly to present the general conditions of the problem, and may serve as a basis for investigating the peculiarities of individual engines.

Let $P_0 =$ mean effective pressure when $w=0$,
$P_0' =$ boiler pressure above atmospheric pressure when $w=0$.
$P =$ mean effective pressure with load w.
$R =$ piston radius.
$l =$ stroke. $n =$ revolutions per minute.

Then, during one stroke of the engine at uniform speed,

$$\pi R^2(P-P_0)l=\pi rw.$$

or

$$P=P_0+\frac{rw}{R^2l} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Multiplying this equation by $\frac{2\pi R^2 ln}{33000}$

$$I\text{HP} = \frac{2\pi R^2 lnP_0}{33000} + \frac{2\pi rnw}{33000} \quad . \quad . \quad . \quad (2)$$

The indicated horse-power is equal to the brake horse-power plus the power required to drive the engine alone.

In the equation leading to (1) the second member should strictly contain a term $=f(F'+F'')$ the exact form of which

* Read before the St. Louis Academy of Science, May 20th, 1889.

would depend upon how the belt is applied. It is so small that it cannot usually be measured on an indicator card, and is here omitted. It may be inserted, however, without changing the form of any of the succeeding equations.

The equation for brake horse-power is

$$B\text{HP} = \frac{2\pi rnw}{33000} \quad . \quad . \quad . \quad . \quad (3)$$

$$B\text{HP} = \frac{2\pi R^2 ln}{33000}(P - P_0) \quad . \quad . \quad . \quad (4)$$

and

$$I\text{HP} = \frac{2\pi R^2 lnP}{33000} \quad . \quad . \quad . \quad . \quad (5)$$

Taking $I\text{HP}$, as a function of n and P, and (5) is the equation of an hyperbolic paraboloid, the constant for which is entirely independent of the condition of the engine or the steam with which it is supplied. It depends solely on the geometry of the engine (the unit of power being fixed). It involves only the volume swept through by the piston-face during one stroke. The performance of all engines in which this volume is the same would always be represented by points on a common surface. These points may be made to move about in any arbitrary manner by variations in boiler pressure and load.

If the boiler pressure is held constant, then n becomes some definite function of w, and the point representing the performance of any engine would traverse some definite line upon the surface.

Equation (4) which represents brake horse-power, is also the equation of an hyperbolic paraboloid, having the same constant as the one represented by (5). The two surfaces have a common pressure axis, and the coördinate planes of HP, n for the two surfaces are separated by the distance P_0. On each of these surfaces, a condition of constant load, w, would be represented by some definite line, and (3) which is the ordinary formula for $B\text{HP}$ is a projection of that line upon the coördinate plane of HP, n.

For any definite values of n and P, a vertical ordinate drawn through the surfaces of $B\text{HP}$ and $I\text{HP}$ would determine simultaneous values of brake and indicated horse-power. The distance between the surfaces measured on this ordinate would represent the power consumed in the engine itself. Passing a plane through these surfaces at right-angles to the speed axis, the intersections with the two surfaces would be parallel lines. The distance between these lines measured parallel to the HP axis is constant, and represents as stated the power consumed in the friction. It is constant for all loads, as experiment shows it to be, and increases uniformly with the speed at constant pressure, or by (4) and (5),

$$\left(\frac{d(I\text{HP})}{dP}\right)_n = \left(\frac{d(B\text{HP})}{dP}\right)_n = \frac{2\pi R^2 ln}{33000}$$

$$\left(\frac{d(I\text{HP})}{dn}\right)_P = \frac{2\pi R^2 lP}{33000}$$

$$\left(\frac{d(B\text{HP})}{dn}\right)_P = \frac{2\pi R^2 l(P-P_0)}{33000} = \frac{2\pi rw}{33000}$$

In fig. 1, oP' and oA'' are the axes of pressure, HP, AA'' is the line of atmospheric pressure, and VV'' is the vacuum line. The lines op'' and P_0p' are rectilinear elements in the surfaces of IHP and BHP at constant speed, the ordinates Pp'' and Pp' representing simultaneous values. If the mean effective pressure were reduced to zero, the engine being driven at the same speed by means of the belt, the power required is represented by *od*. Line VB represents BHP as function of boiler pressures, OP and OP' being simultaneous values of mean effective and boiler pressure, measured from the atmospheric line. $V'V$ represents the belt-power required to drive the engine if boiler and mean effective pressure were zero.

Calling $h =$ the atmospheric pressure, and $P' =$ boiler pressure measured from atmospheric pressure, we have

$$\frac{h+P_0}{h+P'_0} = \frac{h+P}{h+P'}$$

or

$$P' = -h + \frac{h+P}{h+P_0}(h+P'_0) \quad . \quad . \quad . \quad (6)$$

In this equation the value of P is known from (1). P_0 is determined by means of the indicator. It remains to determine P'_0, the boiler pressure required to drive the engine at the fixed speed represented in fig. 1, when $w = o$.

If the engine were driven at a very slow speed, the cylinder pressure would be identical with boiler pressure until the point of cut-off. The mean effective pressure would be less, and the back pressure would be h. Increasing the boiler pressure, the back pressure increases by a quantity which is proportional to the speed.

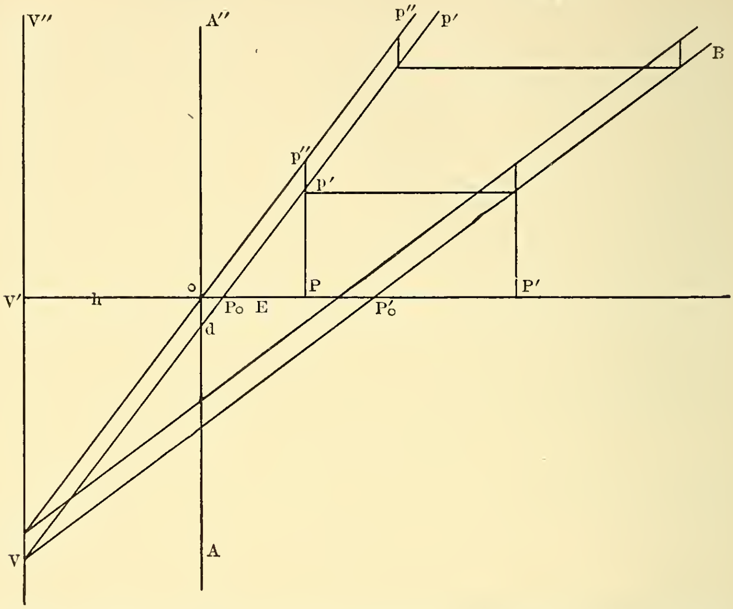
Measuring P'_0 from the atmospheric line,

$$P'_0 = cn + P_0 + E + bn \quad . \quad . \quad . \quad (7)$$

where cn is the mean back pressure, P_0 the mean effective pressure, E a function of the inverse expansion ratio, and bn is a term applying to the entry port which is entirely analogous to cn. The constants c and b depend upon the size of the ports, b also depending to a less extent upon the pipes connecting the steam-chest and boiler. In a throttle governor, the value of b is changed in order to change mean effective pressure. In a governor which varies the cut-off, both E and b are changed by the action of the governor.

The action of any governor changes the inclination of the line VB, in fig. 1. For a constant boiler pressure P', if the

Fig. 1.



cut-off comes earlier, or, if the steam is throttled, the line VB' becomes less steep, and the points p' and p'' sink to represent a smaller output.* In fig. 2, the action of the governor changes the position of the line $w = o$, and in fact the entire surface of HP as function of P'.

Making the indicated substitutions in (6)

$$P' = -h + \frac{h+P_0+\frac{rw}{R^2 l}}{h+P_0}(h+Po+E+(b+c)n) \quad . \quad (8)$$

Solving this equation for w,

$$w = \frac{R^2 l}{r}\left[\frac{(h+P_0)\ (h+P')}{h+P_0+E+(b+c)n} - (h+P_0)\right] \quad . \quad (9)$$

Multiplying (9) by $\frac{2\pi nr}{33000}$

* In an experimental engine the head of the screw which controls the steam should be provided with a divided scale like a micrometer.

$$B_{HP} = \frac{2\pi R^2 l}{33000}\left[\frac{(h+P_0)\,(h+P')n}{(h+P_0+E+(b+c)n} - (h+P_0)\,n\right] \quad . \quad . \quad (10)$$

For any constant boiler pressure there will be some definite speed which will make B_{HP} a maximum. The condition is

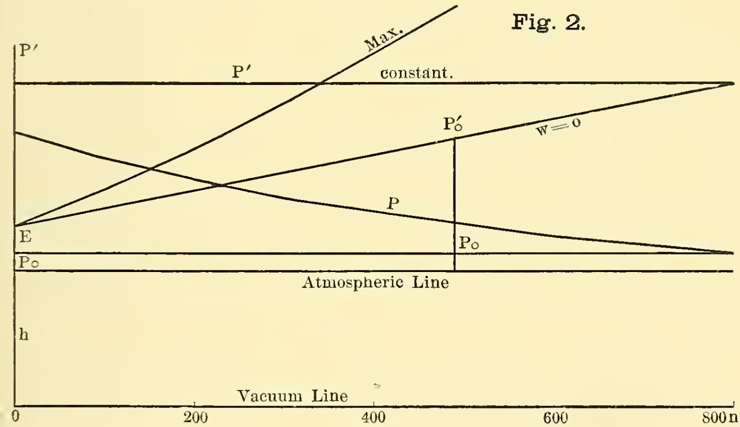
$$\left(\frac{dB_{HP}}{dn}\right)_{P'} = o.$$

Imposing this condition we have

$$(h+P')(h+Po+E) = [h+Po+E+(b+c)n]^2 \quad . \quad (11)$$

The speed must be such that the boiler pressure required to drive the unloaded engine at that speed, is a mean proportional between the constant boiler pressure under consideration, and the boiler pressure required to start the unloaded engine, [see (7),] all pressures being measured from vacuum. The load corresponding to this maximum is of course found by imposing this condition in (9) by the elimination of n.

Fig. 2.



Equation (11) gives the relation between n and P' for a maximum output at any boiler pressure P'. It is the equation of a parabola, which crosses the pressure axis at its intersection with the line of zero load (7). The slope of this parabola is

$$\frac{dP'}{dn} = 2(b+c) + 2\,\frac{(b+c)^2}{h+P_0+E}\,n \quad . \quad . \quad (12)$$

When $n = o$ the slope is therefore twice that of the line of zero load.

The value of n in (11) is

$$n = -\frac{h+P_0+E}{b+c} \pm \frac{1}{b+c}\sqrt{(h+P_0+E)\,(b+P')} \quad . \quad (13)$$

Hence the vertex of this parabola is at the intersection of the line of zero load (7) with the vacuum line. Its position is

$$P' = -h$$
$$n'' = -\frac{h+P_0+E}{b+c}$$

This value of n'' is rather large and therefore the part of the parabola which corresponds to a possible range of engine speed will be very nearly a straight line. The axis of the parabola is of course parallel to the pressure axis. It will be observed that all lines of constant load represented by (8) intersect the vertical line (parallel to the HP axis) which contains the vertex of the parabola of maximum effort. In (8) the condition $P' = -h$ at once gives the condition

$$n = -\frac{h+P_0+E}{b+c}$$

and this entirely independent of w.

The observations made regarding the parabola of maximum output justify the presentation of another formula which was deduced empirically from a large number of brake determina tions. The discovery of that formula was in fact the occasion for the present investigation.

The experiments were made by taking constant loads on a fixed brake arm varying the speed of the engine from 200 to 800 revolutions, for each load, by means of a throttle. The pressure of the supply steam was measured by means of a gauge between the throttle and the steam-chest, the cut-off remaining fixed.

The observations for constant load all satisfied equations of the form

$$P' = a + b'n \quad . \quad . \quad . \quad . \quad (14)$$

This equation is identical with (8). Computing from each equation the value of n for a given pressure, these values of n were plotted with their respective values of w, and gave a line which could not be distinguished from a right line. Its equation was of the form

$$w = k - k'n \quad . \quad . \quad . \quad . \quad (15)$$

This equation corresponds to (9) with P' constant, which is however the equation of an equilateral hyperbola, the asymptotes of which are

$$w = \infty \quad \text{if } n = -\frac{h+P_0+E}{b+c}$$
$$n = \infty \quad \text{if } w = -\frac{R^2 l}{r}(b+P_0)$$

It is manifest therefore that the part of the parabola examined would differ so little from a right line that (15) would satisfy any observations made upon an engine.

Multiplying (15) through by $\frac{2\pi rn}{33000}$ we have

$$B\text{HP}=\frac{2\pi r\, kn}{33000}-\frac{2\pi r\, kn^2}{33000} \quad . \quad . \quad (16)$$

This is the equation of a parabola and corresponds to (10), which is likewise a parabola when P' is constant.

Differentiating (16), the condition of maximum output is found to be

$$n'=\tfrac{1}{2}\frac{k}{k'} \quad . \quad . \quad . \quad . \quad (17)$$

or the speed must be one-half that which the engine should have at the same boiler pressure if $w=o$.

The condition for maximum, according to this, would be

$$P'=a_0+2b'_0n \quad . \quad . \quad . \quad . \quad (18)$$

It will be observed that this is a right-line, tangent to the parabola (11) where $n=o$. According to (11), these values of n represented by (17) would be somewhat too large.

Solving (15) for n and multiplying by $\frac{2\pi rw}{33000}$

$$\text{HP} = \frac{2\pi rk}{k'}w-\frac{2\pi r}{k'}w^2 \quad . \quad . \quad . \quad (19)$$

The condition for maximum obtained from this equation is

$$w'=\tfrac{1}{2}k \quad . \quad . \quad . \quad . \quad (20)$$

where w' is one-half the load which will bring the engine to rest at that pressure.

This value of w is somewhat too small to satisfy (11), although as stated the error is probably alway too small to have any importance. Substituting these two values of n' and w' in (3) and we undoubtedly have a very close approximation to the maximum output at any pressure P',

$$B\,\text{HP}=\tfrac{1}{2}\frac{\pi}{33000}\cdot\frac{k}{k'}\cdot kr$$

where $\frac{k}{k'}$ is the speed at that pressure when $w=o$ as computed from (7) and kr = the turning moment which for that pressure must be applied to the shaft in order to bring the engine to rest. This can be computed from (9). It is wr when $n=o$.

In a similar manner we may represent indicated horse-power as a function of boiler pressure. Solving (6) for P and substituting, as before,

$$P=-h+\frac{(h+P_0)\,(h+P')}{h+P_0+E+(b+c)n} \quad . \quad . \quad (21)$$

It may be remarked in passing that, for a constant value of P', this is an hyperbola which represents the relation between mean effective pressure and speed, with varying load. The asymptotes of the curve are the vacuum line and the axis of the parabola of maximum output, where

$$n = -\frac{h+P_0+E}{b+c}$$

The only part of this curve which has any practical significance is that included between the pressure axis and the line where $P=P_0$. This part of the curve is marked P on fig. 2, P' being the line representing the corresponding fixed boiler pressure. During the operation here considered, the point representing the performance of the engine would travel through a definite path on the surface represented by (4). The hyperbola marked P on fig. 2 would be a projection of that path on the plane P, n, while the parabola (10) with P' constant would be a projection of that path on the plane HP, n.

The engine might indeed be driven by a belt at a greater speed than that given it by the steam when $w = o$, and the mean effective pressure would continually fall as represented by the hyperbola. The part of the curve corresponding to negative values of n has no physical significance. The engine when brought to rest with any fixed load w, by a decrease of boiler pressure, would not reverse if the boiler pressure were still more reduced, until it became less than the atmospheric pressure.

Multiplying (21) by $\frac{2\pi R^2 ln}{33000}$

$$I\text{HP} = \frac{2\pi R^2 l}{33000}\left(-hn + \frac{(h+P_0)(h+P')n}{h+P_0+E(b+c)n}\right) \quad . \quad . \quad (22)$$

This equation corresponds to (10).

The condition of maximum IHP for constant P' is

$$\frac{(h+P_0+E)(h+Po)(h+P')}{h} = \left(h+P_0+E+(b+c)n\right)^2 \quad (23)$$

This like (11) is the equation of a parabola. The value of n is

$$n = -\frac{h+P_0+E}{b+c} \pm \frac{1}{b+c}\sqrt{\frac{(h+P_0+E)(h+P_0)(h+P)}{h}} \quad (24)$$

The slope of this parabola is

$$\frac{dP'}{dn} = 2\frac{h}{h+P_0}(b+c) + 2\frac{h}{h+P_0}\frac{(b+c)^2}{h+P_0+E}n^2 \quad . \quad (25)$$

which when $n = o$ is

$$\left(\frac{dP'}{dn}\right)_{n=o} = 2(b+c)\frac{h}{h+P_0} \quad . \quad . \quad (26)$$

while the line of zero load has the equation

$$h+P'=\frac{h}{h+P_0}\left(h+P_0+E+(b+c)n\right) \quad . \quad . \quad (27)$$

as is readily determined from (22).

The writer has examined engines in which the friction pressure increases with the pressure of the supply steam at constant load. The value of P_0 then becomes P_0+en, and the surface of brake horse-power as a function of mean effective pressure is then represented by equations similar to that which in this paper represent brake horse-power as a function of boiler pressure. The discussion then becomes more complex, although it can be made on the lines here laid down. It is better to avoid this discussion by refraining from building such engines.

The experience of the writer with condensing-engines has been very limited, but it would appear that the equations here given will apply also to them.

The four surfaces here discussed may all be constructed by means of threads to represent the two sets of rectilinear elements in each. These are constant speed, and constant load. Such models represent the working conditions of an engine in a most interesting way.

Art. XLI.—*On the Ratio of the Electromagnetic to the Electrostatic Unit of Electricity;* by Henry A. Rowland, with the assistance of E. H. Hall and L. B. Fletcher.

The determination described below was made in the laboratory of the Johns Hopkins University about ten years ago, and was laid aside for further experiment before publication. The time never arrived to complete it, and I now seize the opportunity of the publication of a determination of the ratio by Mr. Rosa in which the same standard condenser was used, to publish it. Mr. Rosa has used the method of getting the ratio in terms of a resistance. Ten years ago the absolute resistance of a wire was a very uncertain quantity and, therefore, I adopted the method of measuring a quantity of electricity electrostatically and then, by passing it through a galvanometer, measuring it electromagnetically.

The method consisted, then, in charging a standard condenser, whose geometrical form was accurately known, to a given potential as measured by a very accurate absolute electrometer, and then passing it through a galvanometer whose constant was accurately known, and measuring the swing of the needle.

Description of Instruments.

Electrometer.—This was a very fine instrument made partly according to my design by Edelmann, of Munich. As first made, it had many faults which were, however, corrected here. It is on Thomson's guard ring principle with the movable plate attached to the arm of a balance and capable of accurate adjustment. The disc is 10·18 cm. diameter in an opening of 10·38 cm. and the guard plates about 33·0 cm. diameter. All the surfaces are nickel plated and ground and polished to optical surfaces and capable of accurate adjustment so that the distance between the plates can be very accurately determined. The balance is sensitive to a mg. or less and the exact position of the beam is read by a hair moving before a scale and observed by a lens in the manner of Sir Wm. Thomson. The instrument has been tested throughout its entire range by varying the distances and weights to give the constant potential of a standard gauge, and found to give relative readings to about 1 in 400 at least. It is constructed throughout in the most elaborate and careful manner and the working parts are enclosed in sheet brass to prevent exterior action.

As the balance cannot be in equilibrium by combined weights and electrostatic forces, it was found best to limit its swing to a $\frac{1}{10}$ mm. on each side of its normal position. The mean of two readings of the distance, one to make the hair jump up and the other down, constituted one reading of the instrument.

The adjustments of the plates parallel to each other and of the movable plate in the plane of the guard ring could be made to almost $\frac{1}{40}$ mm.

The formula for the difference of potential of the two plates is

$$V^2 = \frac{8\pi d^2 wg}{A}$$

where d is the distance of the plates, wg the absolute force on the movable plate and A its corrected area. According to Maxwell

$$A = \tfrac{1}{2}\pi \left\{ R^2 + R'^2 - (R'^2 - R^2)\frac{\alpha}{d+\alpha} \right\}$$

where R and R′ are the radii of the disc and the opening for it and $\alpha = \cdot 221(R'-R)$. The last correction is only about 1 in 500, and hence we have, finally,

$$V = 17\cdot 221\sqrt{w}\, d\left\{ 1 + \frac{\cdot 0002}{d} \right\}$$

Standard Condenser.—This very accurate instrument was made from my designs by Mr. Grunow, then of New York, and consisted of one hollow ball, very accurately turned and nickel plated, in which two balls of different sizes could be hung by a silk cord. The balls could be very accurately adjusted in the center of the hollow one. Contact was made by two wires about $\frac{1}{100}$ inch diameter, one of which was protruded through the outer ball until it touched the inner one; by a suitable mechanism it was then withdrawn and the second one introduced at another place to effect the discharge. This could be effected five times every second. The diameters of the balls have been accurately determined by weighing in water, and the electrostatic capacities found to be

50·069 and 29·556 c.g.s. units.

A further description is given in Mr. Rosa's paper.

Galvanometer for Electrical Discharges.—This was very carefully insulated by paper and then put in hot wax in a vacuum to extract the moisture and fill the spaces with wax. It had two coils, each of about 70 layers of 80 turns each of No. 36 silk covered copper wire. They were half again as large as the ordinary coils of a Thomson galvanometer. The two coils were fixed on the two sides of a piece of vulcanite and the needle was surrounded on all sides by a metal box to protect it from the electrostatic action of the coils. A metal cone was attached to view the mirror through. The insulation was perfect with the quickest discharge.

The constant was determined by comparison with the galvanometer described in this Journal, vol. xv, p. 334. The constant then given has recently been slightly altered. The values of its constant are

By measurement of its coils	1832·24
By comparison with coils of electrodynamometer	1833·67
By comparison with single circle	1832·56

Giving these all equal weights, we have

1832·82

instead of 1833·19 as used before.

The ratio of the new galvanometer constant to this old one was found by two comparisons to be

10·4167
10·4115

Mean, 10·4141

Hence we have

$$G = 19087.$$

Electrodynamometer.—This was almost an exact copy of the instrument described in Maxwell's treatise on electricity except on a smaller scale. It was made very accurately of brass and was able to give very good results when carefully used. The strength of current is given by the formula

$$S=\frac{C\sqrt{K}}{t}\sqrt{\sin\alpha}$$

where K is the moment of inertia of the suspended coil, t its time of vibration, α the reading of the head, and C a constant depending on the number of coils and their form.

Large coils.

Total number of windings	240	
Depth of groove	·84	cm.
Width of groove	·76	cm.
Mean radius of coils	13·741	cm.
Mean distance apart of coils	13·786	cm.

Suspended coils.

Total number of windings	126	
Depth of groove	·41	cm.
Width of groove	·38	cm.
Mean radius	2·760	cm.
Mean distance apart	2·707	cm.

These data give, by Maxwell's formulæ,

$$C = 0·006457.$$

In order to be sure of this constant, I constructed a large tangent galvanometer with a circle 80^{cm} diameter and the earth's magnetism was determined many times by passing the current from the electrodynamometer through this instrument and also by means of the ordinary method with magnets. In this way the following values were found.

	Magnetic method.	Electrical method.
Dec. 16th, 1879	·19921	·19934
Jan. 3rd, "	·19940	·19942
Feb. 25th, "	·19887	·19948
" 28th, "	·19903	·19910
March 1st, "	·19912	·19928
Mean	·19912	.19933

which differ only about 1 in 1000 from each other. Hence we have for C:

From calculation from coils	·006457
From tangent galvanometer	·006451
Mean	.006454 c.g.s. units.

The suspension was bifilar and no correction was found necessary for the torsion of the wire at the small angles used.

The method adopted for determining the moment of inertia of the suspended coil was that of passing a tube through its center and placing weights at different distances along it. In this way was found

$$K = 826 \cdot 6 \text{ c.g.s. units.}$$

The use of the electrodynamometer in the experiment was to determine the horizontal intensity of the earth's magnetism at any instant in the position of the ballistic galvanometer. This method was necessary on account of the rapid changes of this quantity in an ordinary building* and also because a damping magnet, reducing the earth's field to about $\frac{1}{3}$ its normal value, was used. For this purpose the ballistic galvanometer was set up inside the large circle of 80^{cm} diameter with one turn of wire and simultaneous readings of the electrodynamometer and needle of ballistic galvanometer were made.

Theory of Experiment.

We have for the potential

$$V = \frac{8\pi g}{A} d\sqrt{w} = ed\sqrt{w}\left[1 + \frac{\cdot 0002}{d}\right]$$

For the magnetic intensity acting on the needle

$$H = \frac{2\pi np^2 c\sqrt{K \sin\alpha}}{t(p^2+b^2)^{\frac{3}{2}}\tan\varphi}$$

For the condenser charge

$$Q = 2\,\frac{HT}{\pi G}\,\sin\frac{\theta}{2}\,(1+\tfrac{1}{2}\lambda) = N\,\frac{VC}{v}$$

Whence

$$v = \frac{eGC(p^2+b^2)^{\frac{3}{2}}}{2nc\sqrt{K}p^2}\;\frac{Nt\sqrt{w}\,d}{T\sqrt{\sin\alpha}}\;\frac{\tan\varphi}{2\sin\frac{1}{2}\theta}\left[1 - \frac{\lambda}{2} + \text{etc.}\right]$$

but $$\tan\varphi = \frac{1}{2}\,\frac{\beta}{D}\left[1-\frac{1}{4}\left(\frac{\beta}{D}\right)^2+\frac{1}{8}\left(\frac{\beta}{D}\right)^4\right]$$

and $$2\sin\frac{1}{2}\theta = \frac{1}{2}\,\frac{\delta}{D}\left[1-\frac{1}{3}\left(\frac{\delta}{D}\right)^2\right] \text{ nearly.}$$

So that finally

$$v = \frac{eGC(p^2+b^2)^{\frac{3}{2}}}{2nc\sqrt{K}p^2}\;\frac{Nt\beta\sqrt{w}\,d}{T\sqrt{\sin\alpha}\;\delta}\left[1-A-B-C+D+E-F+I\right]$$

$A = 0$; $\cdot 0011$; $\cdot 0030$; $\cdot 0056$; $\cdot 0090$ for 1, 2, 3, 4, 5 discharges as investigated below.

$$B = \frac{1}{4}\left(\frac{\beta}{D}\right)^2 - \frac{1}{8}\left(\frac{\beta}{D}\right)^4$$

$$C = \frac{\lambda}{2}$$

$$D = \frac{\cdot 0002}{d}$$

* This experiment was completed before the new physical laboratory was finished.

$E = \frac{1}{3}\left(\frac{\delta}{D}\right)^2$

F = ·0013 for first ball of condenser and ·0008 for other, as investigated below.
I = correction for torsion of fibre = 0 as it is eliminated.
e = constant of electrometer = 17·221.
G = " " ballistic galvanometer = 19087.
p = radius of large circle = 42·105 cm.
n = number of coils on circle = 1.
c = constant of electrodynamometer = ·006454.
K = moment of inertia of coil of electrodynamometer = 826·6.
b = distance of plane of large circle from needle = 1·27.
C = capacity of condenser = 50·069 or 29·556.
D = distance of mirror from scale = 170·18 cm.
w = weight in pan of balance.
t = time of vibration of suspended coil.
T = " " " of needle of balistic galvanometer.
β = deflection of needle on scale when constant current is passed.
α = reading of head of electrodynamometer when constant current is passed.
δ = swing caused by discharge of condenser.
d = distance of plates of electrometer.
N = number of discharges from condenser.
λ = logarithmic decrement of needle.
A = correction due to discharges not taking place in an instant.

The principal correction, requiring investigation is A. Let the position and velocity of the needle be represented by

$$x = a_0 \sin bt \text{ and } v = a_0 b \cos bt, \text{ where } b = \frac{\pi}{T}.$$

At equal periods of time $t_{,}$, $2t_{,}$, $3t_{,}$, etc., let new impulses be given to the needle so that the velocity is increased by v_0 at each of these times. The equations which will represent the position and velocity of the needle at any time are, then,

between 0 and $t_{,}$	$x = a_0 \sin bt$	$v = a_0 b \cos bt$
" $t_{,}$ and $2t_{,}$	$x = a' \sin b(t+t')$	$v = a'b \cos b(t+t')$
" $2t_{,}$ and $3t_{,}$	$x = a'' \sin b(t+t'')$	$v = a''b \cos b(t+t'')$

At the times 0, $t_{,}$, $2t_{,}$ etc. we must have

$x = 0$	$v_0 = a_0 b$
$a_0 \sin bt_{,} = a' \sin b(t_{,}+t')$	$v_0 + a_0 b \cos bt_{,} = a'b \cos b(t_{,}+t')$
$a' \sin b(2t_{,}+t') = a'' \sin b(2t_{,}+t'')$	$v_0 a'b \cos b(2t_{,}+t'')$
etc.	$= a''b \cos b(2t_{,}+t'')$
	etc.

Whence we have the following series of equations to determine a', a'', etc., and t', t'' etc.

$a_0^2 b^2 = v_0^2$

$a'^2 b^2 = a_0^2 b^2 + v_0^2 + 2 v_0 a_0 b \cos bt_{,}$; $\quad \sin b(t_{,}+t') = \frac{a_0}{a'} \sin bt_{,}$

$$a''^2b^2 = a'^2b^2 + v_0^2 + 2v_0a'b\cos b(2t_, - t')\,;\quad \sin b(2t_, + t'') = \frac{a_{,0}}{a''}\sin b(2t_, + t')$$

$$a'''^2b^2 = a''^2b^2 + v_0^2 + 2v_0a''b\cos b(3t_, + t'')\,;\quad \sin b(3t_, + t''') = \frac{a''_0}{a''}\sin b(3t_, = t''')$$

etc. etc.

When $t_,$ is small compared with the time of vibration of the magnet, we have very nearly $t' = -\frac{1}{2}\,t_,$; $t'' = -t_,$, $t''' = -\frac{3}{2}t_,$ etc.

$$a'^2 = 2a_0^2(1 + \cos bt_,) = 4a_0^2(1 - \tfrac{1}{4}(bt_,)^2)$$
$$a''^2 = 9a_0^2(1 - \tfrac{2}{3}(bt_,)^4)$$
$$a'''^2 = 16a_0^2(1 - \tfrac{5}{4}(bt_,)^2)$$
$$a''''^2 = 25a_0^2(1 - 2(bt_,)^2)$$
$$a'''''^2 =$$

Whence

$$a' = 2a_0(1 - \tfrac{1}{8})bt_,)^2)$$
$$a'' = 3a_0(1 - \tfrac{1}{3}(bt_,)^2)$$
$$a''' = 4a_0(1 - \tfrac{5}{8}(bt_,)^2)$$
$$a'''' = 5a_0(1 - \quad (bt_,)^2)$$

Now a_0, a', a'', a''' and a'''' are the values of δ with 1, 2, 3, 4 and 5 discharges and a_0, $2a_0$, $3a_0$, $4a_0$ and $5a_0$ are the values provided the discharges were simultaneous.

This correction is quite uncertain as the time, $t_,$, is uncertain.

In assuming that the impulses were equal we have not taken account of the angle at which the needle stands at the second and subsequent discharges, nor the magnetism induced in the needle under the same circumstances. One would diminish and the other would increase the effect. I satisfied myself by suitable experiments that the error from this cause might be neglected.

The method of experiment was as follows: The store of electricity was contained in a large battery of Leyden jars. This was attached to the electrometer. The reading of the potential was taken, the handle of the discharger was turned and the momentary swing observed and the potential again measured. The mean of the potentials observed, with a slight correction, was taken as the potential during the time of discharge. This correction came from the fact that the first reading was taken before the connection with the condenser was made. The first reading is thus too high by the ratio of the capacities of the condenser and battery and the mean reading by half as much. Hence we must multiply d by $1 - \mathrm{F}$ where $\mathrm{F} = {\cdot}0013$ for first ball of condenser and ·0008 for other. This will be the same for 1 or 5 discharges. From 10 to 20 observations of this sort constituted a set, and the mean value of $\frac{d}{\delta}$, which was calculated for each observation separately, was taken as the result of the series.

Before and after each series the times of vibration, t and T, and the readings, β and α, were taken. The logarithmic decrement was observed almost daily.

Results.

The table on the opposite page gives the results of all the observations.

These results can be separated according to the number of discharges as follows:

1.	2.	3.	4.	5.
300·59	298·37	295·73	296·43	296·50
300·17	298·61	296·40	297·24	296·37
296·72	297·43	298·75	301·82	297·38
297·84	297·78	298·66	295·02	296·87
298·90	300·19	296·75	295·22	296·31
298·57				
299·05				
300·80				
296·56				
298·80	298·48	297·26	297·15	296·69

In taking the mean, I have ignored the difference in the weights due to the number of observations, as other errors are so much greater than those due to estimating the swing of the needle incorrectly.

It will be seen that the series with one discharge is somewhat greater than with a larger number. This may arise from the uncertainty of the correction for the greater number of discharges, and I think it is best to weight them inversely as this number. As the first series has, also, nearly twice the number of any other, I have weighted them as follows:

Wt.	$v \times 10^{-8}$
8	298·80
4	298·48
3	297·26
2	297·15
1	296·69
Mean	298·15

Or $v = 29815000000$ cm. per second.

It is impossible to estimate the weight of this determination. It is slightly smaller than the velocity of light, but still so near to it that the difference may well be due to errors of experiment. Indeed the difference amounts to a little more than half of one per cent. It is seen that there is a systematic falling off in the value of the ratio. This is the reason of my delaying the publication for ten years.

	Jan. 15, 1889.			Jan. 17.				Jan. 20.		Jan. 22.		Jan. 24.		Jan. 27.	Feb. 3.
	10	10	18	10	10	10	16	18	18	18	18	18	18	18	20
C	50·069	50·069	50·069	50·069	50·069	50·069	50·069	50·069	50·069	50·069	50·069	50 069	50·069	50 069	29·556
w	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3
t	2·436	2·436	2·436	2·436	2·436	2·436	2·436	2·436	2·435	2·437	2·437	2·436	2·436	2·437	2·435
β	34·03	34·08	33·82	33·10	33·10	32·99	32·99	33·43	33·18	33·60	33·60	34·30	34·53	33·64	33·79
$\frac{d}{\bar{\delta}}$	·4839	·2400	·4851	·4880	·1624	0981	·4900	·4871	·09759	·15954	·48065	·19588	·39279	·09777	·17145
N	1	2	1	1	3	5	1	1	5	3	1	2	1	4	4
λ	·03583	·03583	·03583	·03424	·03424	·03424	·03424	·0350	·0350	·03578	·03578	·03507	·03507	·03507	·03500
T	6·7505	6·7505	6·7467	6·636	6·636	6·631	6·631	6 693	6·689	6·792	6 783	6·796	6·788	6·7944	6·8471
a	14° 56′ 17″	14° 56′ 17″	14° 53′ 5″	15° 18′ 50″	15° 18′ 50″	15° 14′ 48″	15° 14′ 48″	15° 2′ 35″	14° 57′ 45″	14° 25′ 30″	14° 25′ 52″	15° 6′ 25″	14° 59′ 40″	14° 25′ 22″	15° 14′ 10″
δ*	4·2	7·2	4·2	4·3	11·5	18 3	3 7	4·1	16·8	10·8	3·7	7·7	4·0	13 3	8·0
$v \times 10^{-8}$	300·59	298·37	300·17	296·72	295·73	296·50	297·84	298·90	296·37	296.40	298·57	298·61	299·05	296·43	297 24

	Feb. 4.		Feb. 6.		Feb. 7.		Feb. 11.		Feb. 12.		Feb. 14.		Feb. 17.	
	20	20	18	18	19	19	18	18	18	18	18	18	18	18
C	29·556	29·556	29·556	29·556	29·556	29·556	29·556	29·556	29·556	29·556	29·556	29·556	29·556	29·556
w	3	3	4	4	4	4	2	2	2	2	1	1	1	1
t	2·436	2·436	2·436	2 436	2·436	2·436	2·436	2·436	2·436	2·436	2·435	2·435	2·436	2·436
β	33 08	32·72	33·19	33·18	32·27	32·44	32 89	32·75	32·82	32·42	32·72	32·39	31·77	31·39
$\frac{d}{\bar{\delta}}$	·17450	·69525	·29572	·58823	·11986	·19938	·41758	·16744	·16767	·42264	·39752	·29647	·40215	·30109
N	4	1	2	1	5	3	2	5	5	2	3	4	3	4
λ	·03500	·03500	·03500	·03500	·0352	·0352	·0356	·0356	·0354	·0354	·0361	·0361	·0348	·0348
T	6·822	6·825	6·811	6·828	6·809	6·808	6·8734	6·8557	6·860	6·854	6·890	6·890	6·788	6·788
a	14° 47′ 25″	14° 35′ 45″	14° 51′ 0″	14° 43′ 40″	14° 11′ 20″	14° 20′ 20″	14° 13′ 35″	14° 7′ 15″	14° 16′ 10″	14° 1′ 10″	14° 8′ 0″	13° 59′ 0″	14° 17′ 30″	14° 1′ 0″
δ*	7·5	2·0	3·3	1·8	7·3	4·7	4·3	9·3	10·3	4·3	6·2	9·5	8 6	9·5
$v \times 10^{-8}$	301·82	300·80	297·43	296·56	297·38	298·75	297·78	296·87	296·31	300·19	298·66	296·02	295·75	295·22

* Approximate value for correction only.

Had the correction, A, for the number of discharges been omitted, this difference would have vanished: but the correction seems perfectly certain, and I see no cause for omitting it. Indeed I have failed to find any sufficient cause for this peculiarity which may, after all, be accidental.

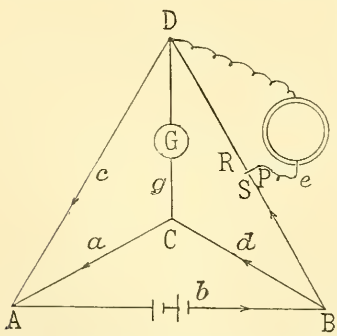
As one of the most accurate determinations by the direct method and made with very elaborate apparatus, I think, however, it may possess some interest for the scientific world.

ART. XLII.—*Determination of v, the ratio of the Electromagnetic to the Electrostatic Unit;* by EDWARD B. ROSA, Student in Physics in the Johns Hopkins University.

THIS investigation was conducted in the physical laboratory of Johns Hopkins University during the months of March to June, 1889, under the direction of Associate Professor A. L. Kimball. The writer takes great pleasure in acknowledging his obligation to Dr. Kimball for valuable advice and encouragement throughout the progress of the work.

The method employed is essentially that given by Maxwell, vol. ii, § 776. It was used by J. J. Thomson in his determination of v, published in the Phil. Trans. for 1883. The following is substantially his description of the method. In a Wheatstone bridge ABCD (fig. 1), the circuit BD is not closed but the points B and D are joined to two poles S and R of a commutator, between which vibrates the armature P, which is connected with the inner shell of a spherical condenser. When P touches S the condenser will be charged, and there will be a momentary current through the various arms of the bridge, through the galvanometer from D to C. When P touches R the two surfaces of the condenser are connected and the latter discharges itself through DR. If now the armature be made to vibrate continuously there will be a series of momentary currents through the galvanometer, and by adjusting the resistance a (c and d being large, fixed resistances), these interrupted currents may be exactly counterbalanced by the steady current from C to D, and the resultant deflection of the galvanometer is zero. When this is the case there is a relation between the capacity

1.



of the condenser, the number of times the latter is charged and discharged per second and the resistances in the various arms of the bridge. Maxwell gives an approximate value of this relation. Thomson's more complete investigation gives the following equation:

$$nC = \frac{a\left\{1 - \frac{a^2}{(a+c+g)(a+b+d)}\right\}}{cd\left\{1 + \frac{ab}{c(a+b+d)}\right\}\left\{1 + \frac{ag}{d(a+c+g)}\right\}}$$

where n is the number of complete oscillations of the armature P per second; C is the capacity of the condenser in electromagnetic measure; and the other letters are the resistances of the various arms of the bridge, as shown in the figure. In the present case the values of these resistances were about as follows:

$a =$ 40 to 1900 ohms.	$d =$ 100,000 ohms.
$b =$ 0 nearly.	$g =$ 6,000 "
$c =$ 1,570,000 to 2,450,000 ohms.	

Owing to the very high values of c and d as compared with a, b and g the above equation may be replaced by the approximate one $C = \frac{a}{ncd}$, which is true to within a hundredth of one per cent. The electrostatic capacity, C′, is determined by calculation from the geometrical constants of the condenser. The ratio of these values of the capacity $\frac{C'}{C}$ is v^2, the square root of which, v, is the quantity sought.

Advantages of the method.

Thus appears at once an important advantage of the method of determining the ratio of the units from the values of a capacity, namely, that v is the square root of the ratio of the capacities, and any error in the latter enters into v by only half its amount.

There are several important advantages of this method of measuring the electromagnetic capacity. In the first place, a knowledge of the exact electromotive force and resistance of the battery is not required, and their constancy is not essential. In the second place, since it is a null method, such uncertain quantities as logarithmic decrement, torsion of the suspending fibre and period of the needle are not required; the galvanometer can readily be made more sensitive than a ballistic galvanometer; its "constant" need not be known; and the field of force may be variable both in intensity and direction without prejudice to the experiment. On the other hand, the quantities which are required are the period of the vibrator and the values of three resistances, quantities which are capable of determination to a very high degree of accuracy. In the present case the vibrator was either a tuning fork or else it was driven by a tuning fork, and by the arrangement adopted the uncertainty in its period was reduced to an extremely small quantity. The difficulties and limits of the method will appear under the head of Sources of Error.

Instruments.

1. *Condenser.*—This was made from designs by Prof. Rowland. It consists of a hollow sphere whose radius is 12·7 cm. and within which may be hung either of two balls of 10·1 and 8·9 cm. radius, respectively. The condenser has a capacity of about 50 absolute electrostatic units with the larger ball and 30 with the smaller. The spherical surfaces are accurately ground, nickel plated and polished to a mirror surface. The ball is suspended by a silk cord C, fig. 3, passing through a hole, 7 mm. in diameter, in the outer shell, and attached to the insulated end of a pivoted beam and counterpoised. By means of a rack and pinion movement and vernier the ball may be accurately set in any desired position. Maxwell* objects to this form of a condenser on account of the difficulty of working the surfaces accurately spherical, making them truly concentric and determining with sufficient accuracy their dimensions. That these difficulties have in the present case been entirely surmounted will, I think, appear from the discussion under the heads of Displacement of the Ball (p. 305), and Electrostatic Capacity (p. 305).

2. *Galvanometer.*—This was one of Elliott Bros.' Thomson, high resistance, astatic galvanometers, made very sensitive.

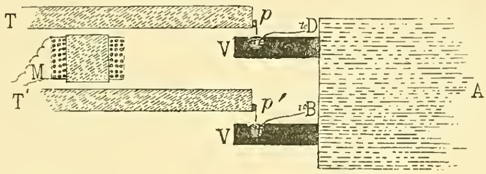
3. *Tuning forks.*—Two of König's forks were used, whose frequencies were approximately 32 and 130 per second. They were driven by three or four Bunsen cells, the same current in the case of the slower fork operating the vibrator P (fig. 1). Their exact periods were determined by Michelson's method.†

4 *Vibrators.*—The oscillating piece P in the case of the slower fork was a commutator, such as that used by Thomson.‡ The action of this form of a vibrator was regular and satisfactory in the case of the slower fork; but with the higher fork great difficulty was experienced in obtaining sufficient uniformity, and finally it was abandoned and the following plan devised as a substitute. T, T′ (figs. 2 and 3), are two prongs of the tuning fork, driven by the electromagnet M; the interrupter, attached to the end of one of the prongs, not being

* Vol. i, p. 321. † This Journal, Jan., 1883.
‡ Thomson, Phil. Trans., 1883, or Glazebrook, Phil. Mag., vol. xviii, p. 98.

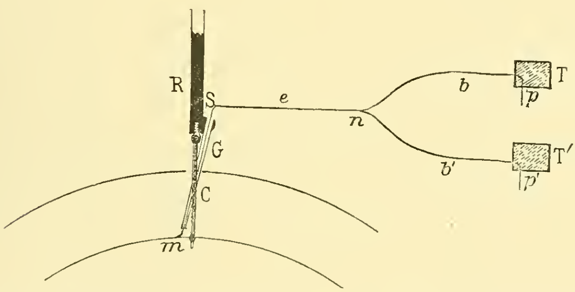
shown. b, b' (fig. 3), are two fine brass wires, uniting at n, and tipped with platinum at p, p', where they are bent at right

2.



angles and fastened to the fork with an insulating cement. V, V' are two small blocks of vulcanite attached to a firm support A. Below the platinum points are two cavities in the vulcanite which are filled with mercury, and as the fork vibrates, first one and then the other of the points dips into the mercury. Thus the mercury cups, which are joined to B and D, respectively (fig. 1), answer to the posts S and R, while the wires b, b' unite and run to the ball of the condenser. When

3.



the prongs separate p' dips into the lower cup and the condenser is charged; when they approach p dips into the other cup and the condenser is discharged. The points must be at least half a millimeter above the surfaces of the mercury when the fork is at rest, in order to avoid both dipping at once and short circuiting the condenser. With an amplitude of about three millimeters perfect contact is made at each vibration, and the regularity of action, as shown by the steadiness of the spot of light on the scale, is extremely satisfactory. The deflection of the needle when the steady current is not balanced by the intermittent current amounts in the case of the high fork to 125 scale divisions, using the one-tenth shunt; i. e., without the shunt as it was used in practice to 1250 scale divisions. With the fork's best action the resistances were adjusted until closing the key would cause a deflection of less than half a scale division, corresponding to less than $\frac{1}{2500}$th part of the whole current. To obtain a regularity of action which permitted such accurate observations required a very delicate adjustment of the distance between the surfaces of the mercury and the points above, as well as clean surfaces and a steady current.

5. *Battery.*—About forty cells of a storage battery with a total electromotive force of about eighty volts were used. A higher electromotive force, at first proposed, was thought to be unnecessary.

6 *Resistances.*—The resistance *a* was taken from a box of Elliott Bros., whose total resistance was about 12,000 ohms; the resistance *d* was a 100,000 box from the same firm. The first of these, box A, was carefully calibrated by comparing the several coils on a Fleming bridge with three standard coils of 10, 100 and 1000 B. A. units respectively. The first was a Warden Muirhead No. 292, 10 B. A. Units. Its value, determined by Glazebrook, Oct., 1887, is 9·99416 at 16°·5 C. The other two had been previously carefully compared with this. The values of the resistances of box A adopted were the means of three different and closely agreeing determinations, made at different temperatures. The several coils of box B were carefully compared with the known resistances of A. The temperature-coefficients of both boxes were also carefully determined.

The resistance *c* was of graphite. Plate glass was ground with fine emery and lines ruled upon it. Under a magnifying power of several hundred diameters the layer of graphite appears as made up of patches which run together at numerous points. The resistance of a strip of graphite of given length and breadth depends upon how well these patches are joined together. The glass and graphite are given a heavy coat of shellac and thoroughly dried. A series of ten such resistances was prepared and mounted, connection being made at the ends by tin foil, held firmly in contact with the graphite by rubber packing, wires passing out from the tin foil. The resistances were placed in cylindrical boxes with vulcanite tops, in which were set binding screws, joined to the wire terminals. The boxes can be surrounded by water or other material to lessen the temperature fluctuations. These resistances proved quite constant and reliable. Two were used in this experiment, R_2 and R_5, whose resistances were approximately 1,570,000 and 2,440,000 ohms. During the six weeks preceding May 9 their alteration, aside from temperature fluctuations, was inappreciable. But between May 9 and May 13, when not in use, from some as yet unknown cause, both increased about one-half of one per cent, and up to June 8, when last used, remained nearly constant at the new value. Inasmuch as glass and shellac are poor conductors, the temperature of the graphite resistances cannot safely be assumed to be the same as that of the air within the box, unless the latter has been kept constant for some time. In order, therefore, to avoid all uncertainty as to their values these resistances were determined anew whenever used, and, if their temperature changed materially, both just before and just after using. They were compared with the resistances of boxes A and B, two arms of a Wheatstone bridge, with a ratio of 99·89, being taken from A. Here is a specimen observation and calculation.

May 22. Bridge reading 24,430. Temperatures $\begin{cases} \text{Graphite } 19^\circ\!\cdot\!8 \\ \text{A} = 20^\circ\!\cdot\!3 \\ \text{B} = 20^\circ\!\cdot\!6 \end{cases}$

$$24{,}430 = \begin{cases} 20000 \text{ from B} = 20{,}012 \text{ at } 20^\circ = 20{,}015 \text{ at } 20^\circ\!\cdot\!6 \\ 4430 \quad \text{“} \quad \text{A} \qquad 4443 \quad \text{“} \qquad\qquad 4444 \text{ “ } 20\ \cdot 3 \end{cases}$$

$24{,}459 \times 99{\cdot}89 = 2{,}443{,}200$ ohms at $19^\circ\!\cdot\!8$ = temp. at which used. This value is reliable to within one part in five thousand.

It is proper to add that if these graphite resistances are put into a circuit where there is a large difference of potential between their terminals, their resistance is immediately diminished by heating. With three Bunsen cells used in measuring their resistance no heating was perceptible. In the determination of capacity there was a difference of potential between the terminals always less than two volts and usually less than one. When the temperatures were maintained constant the resistance after use was always precisely the same as before. While, therefore, the use of high graphite resistance is somewhat restricted where great accuracy is desired, they still may serve a very useful purpose in many cases, and are the most convenient and reliable of any high resistance, aside from metal wires, that I know anything about.

Arrangement of the apparatus.

The vibrators were fixed as near as possible to the condenser to reduce the capacity of the charging wires to a minimum. The condenser, galvanometer and other parts of the apparatus were insulated with great care; and yet in spite of all precautions leakage made its appearance on rainy days, and a slight trace of leakage could usually be detected. Observations were consequently confined to fair weather. The apparatus for determining the frequency of the forks was kept always ready for use.

Sources of Error.

1. *Resistances.*—The constant errors in the resistances must have been very small, and corrections for temperature fluctuations were made with great care.

2. *Tuning forks.*—Michelson's method furnishes a very exact determination of the period of an electric tuning fork, but unfortunately the period does not remain constant. This is especially the case with the higher fork, the charging wires and spring contact having a varying effect upon the rate in different adjustments. But the slower fork with mercury contact was not, even after making proper temperature-corrections, perfectly constant. To avoid all uncertainty and obviate the necessity of applying a temperature-correction the rates of the fork were determined each time anew, usually before and after, or in the midst of a series of observations on capacity. As stated, the apparatus for the purpose was always ready for use, and without stopping the fork or changing its circumstances in any way whatever, by simply closing the clock circuit and the primary circuit of the induction coil, I could in three to five minutes count a sufficient number of flashes to give me the period of the fork true to within less than one part in ten thousand. Occasionally a slight change in the sound emitted by the fork, due to variation in contact or current, suggested a possible change in the period; a moment's glance in the microscope would answer the question. This method of dealing with the rates of the forks avoids the introduction of small constant and large accidental errors, which may happen when the rates are determined once for all.

3. *Charging wires.*—The vibrating armature P (fig. 1), the wires b, b' (fig. 3) as well as the joining wire e have a certain capacity which adds itself to that of the condenser when they are connected, but which may be determined separately by disconnecting the charging wire at m. Thus, on April 15, with R_5 and fast fork, the resistance a was 1874·5 and 153·0 respectively in the two cases mentioned, which gives 1721·5 ohms as the resistance corresponding to the condenser alone. This assumes that the capacity of the charging wire is the same when joined to the ball as when separated. The capacity of the 2·5 cm. of fine brass wire between the ball and the shell, (fig. 3) is nearly one per cent of the capacity of the condenser, determined experimentally. It would seem that this capacity might be slightly greater when the wire was disconnected from the ball and at a different potential; but being lifted one or two millimeters in disconnecting its capacity would be thereby reduced. The effects of these two modifying circumstances were separately very carefully studied. With the rapid fork running very smoothly a change of half an ohm could be easily detected; this would be equal to a change of 1–3500th of the capacity of the condenser. No difference could, however, be observed, although the trial was several times repeated. The two effects have opposite signs, and if each is inappreciable

much more would their sum be so. I therefore conclude that the difference of the observed capacities of condenser and charging system together and of charging system alone is a true measure of the capacity of the condenser.

4. *Displacement of the ball.*—The upper half of the spherical shell was lifted and the lower half adjusted upon its supports until the distance of the ball from the shell was the same at all points on the equatorial circumference. The upper half of the shell was then replaced, and by means of the rack and pinion the ball was first lowered and then raised until it touched the shell, the exact moment of touching being indicated by an electrical contact, and several readings taken on the vernier in each position. The mean of the readings in the two positions gave the central position. In this manner the ball was adjusted vertically to within 0·1 mm. and equatorially within 0·2 mm. Thus the ball is centered to within less than one per cent of the distance between the ball and shell, which is 25 mm. Thomson has investigated a formula for the capacity of eccentric cylinders. The formula shows that for a displacement of one per cent the capacity is increased $\frac{1}{200}$th of one per cent. Evidently the capacity of spherical shells is less affected by slight eccentricity than cylinders. Therefore we may safely conclude that no error is due to eccentricity. This conclusion was verified experimentally, a displacement of four per cent causing an inappreciable change.

5. *Adjusting resistances.*—The accidental errors occurring in adjusting the resistances a so as to produce zero deflection will be eliminated by a large number of observations. Their magnitude depends on the strength of the current, delicacy of the galvanometer, regularity of the vibrator, etc., and are larger with the slow fork than with the fast. The stronger the current and more sensitive the galvanometer the greater the deflection due to a certain error in a, but on the other hand the greater the unsteadiness of the spot, so there is a practical limit in that direction. That these accidental errors are small is, I think, attested by the uniformity of the results obtained.

Electrostatic capacity.

The electrostatic capacity of the condenser was calculated from the formula $C = \frac{rr'}{r-r'}$, where r, r' are the radii of the shell and ball respectively. The radii are determined by finding the volume of water which fills the shell and which is displaced by the ball. These results are confirmed by direct measurement upon the dividing engine.

Ball A.

May 1. Weight in air 2903·83 g. Temperature 18°·9 ; Bar. 76 cm. Volume of ball 4339· cc. Correction for displaced air is consequently +4·83 g. ∴ Weight of ball in vacuo = 2908·66 g. A second determination gave 2908·64 g. I therefore take for the true weight in vacuo 2908·65. The ball being lighter than water a sinker was attached and the following weighings made :

May 3. W't in distilled water, ball and sinker, 210·62 g. at 17°·05 C.
" " " sinker alone, 1635·59 " at 17·10 C.

difference,	1424·97	"
Correction for $\frac{1425}{8\cdot4}$ cc. air displaced by weights	·21	"
	1424·76	"
Weight of ball in vacuo,	2908·65	"
Loss of weight in water at 17°·05 C. =	4333·41	"
" " " 4°· "	4338·68	" =

volume in cubic centimeters. Another determination gave 4338·87. I take as a mean 4338·8, which makes the mean radius $r_A' =$ 10·1180 cm. An error of 0·1 in the number 4338·8 would cause an error of less than a thousandth of a millimeter in r_A'.

Ball B.

May 1. Weight in air, 2321·40 g.
Correction for displaced air, 3·20 " = 2324·60 g. in vacuo.
May 3. W't in distilled water, ball and sinker, 208.96 g. at 16°·45 C.
" " " sinker alone, 807·86 g. " 16°·70 C.

difference,	598·90	"
Correction for air displaced by weights	·09	"
	598·81	"
Weight of ball in vacuo,	2324·60	"
Loss of weight in water at 16°·45 C. =	2923·41	"
" " " 4°· "	2926·65	" =

volume in cubic centimeters; this gives $r_B' = 8\cdot8735$. A second determination gave a closely agreeing result.

In these weighings the bodies were lifted completely out of water, replaced and air bubbles carefully removed at least three times in each weighing. The mean of the several values, which differed in the centigrams, was each time taken. These differences were usually due to slight changes in the temperature of the water, the balances being far more sensitive than the thermometer. As, however, the temperature was read to $\frac{1}{20}$th of a degree several times during a weighing and the mean taken, it is thought the temperature is true to within 0°·1 and this corresponds in the case of the larger ball to about ·07 g. I think the values of the radii given above are true to within two or three thousandths of a millimeter.

Shell.

The weighings of water contained by the shell were made by replacement. The shell was sealed about the junction of its two halves with white paint, filled with distilled water and allowed to stand to absorb any air bubbles which might have escaped the brushing with a wire which was given the inner surface after filling. The condenser was placed on the platform of the scales, approximately counterpoised and then accurately balanced by adding weights to the platform ; about 100 cc. of water was then withdrawn, temperature taken, shell refilled, (the space around the opening being thoroughly raked with a wire to prevent error from small air bubbles which tended to lodge there), and weights again added to balance. The following weighings were thus made:

130·7 g.	130·5	131·2	131·3	
132·0	132·0	131·7	131·4	Mean=131·4 g.
		131·6	131·4	Mean temp. 18°·4

The condenser being emptied and carefully dried required the following weights to balance the counterpoise.

8650·3, 8650·8, 8650·9, 8650·9; mean 8650·7

8650·7 − 131·4 = 8519·3 = W't of water at 18°·4 in air.

8531·8 = " " 4°·0 "

Correction for displaced air 9·1

8540·9 g. = " " " in vacuo

=volume of the shell in cubic centimeters. This makes the radius $r = 12{\cdot}6805$ cm. It seems reasonable to suppose that the number 8540·9 is true to within less than a gram. This would make the error in r less than ·0005 cm.

These values of the radii are confirmed by the following direct measurements made on a dividing engine, using calipers and a standard meter bar by Bartels and Diederichs, Göttingen, whose length is accurately known. Three mutually perpendicular diameters of the shell were found to be 25·357, 25·360, 25·358 cm. Mean = 25·358, giving $r = 12{\cdot}679$, a very close agreement in view of the difficulty of setting the calipers. More accurate measurements on the balls were obtained.

Ball A. Following are twelve diameters.

20·2399	20·2372	20·2170
20·2358	20·2336	20·2348
20·2350	20·2382	20·2250
20·2250	20·2315	20·2401

Mean = 20·2328 + correction for the bar, ·0038 = 20·2366 ∴ r'_A = 10·1183 cm.

Ball B. Following are six diameters.

17·7468	17·7408	17.7429
17·7465	17·7452	17·7407

Mean = 17·7438 + correction for the bar, ·0034 = 17·7472 ∴ r'_B = 8·8736.

It is perhaps somewhat accidental that these values coincide so closely with the values of the radii found by the first method. Their importance is not insisted upon further than as furnishing satisfactory confirmation of the results of the other and more accurate method.

It will be seen that in ball A no diameter differs from the mean by as much as a tenth of a millimeter, and in B the variation is still smaller. This deviation from perfect sphericity has no appreciable effect upon the value of the capacity calculated from the ordinary formula. We now have:

$$C'_A = \frac{12{\cdot}6805 \times 10{\cdot}1180}{12{\cdot}6805 - 10{\cdot}1180} = 50{\cdot}069.$$

$$C'_B = \frac{12{\cdot}6805 \times 8{\cdot}8735}{12{\cdot}6805 - 8{\cdot}8735} = 29{\cdot}556.$$

The radius of the hole in the shell through which the suspending cord passes is 0·35 cm. and its area $\frac{1}{5200}$th part of the area of the shell. The capacity is diminished in a less ratio than the area; therefore the capacity is diminished probably not more than a hundredth of one per cent, a quantity wholly negligible.

Electromagnetic capacity.

A series of observations on the electromagnetic capacity by the method described was made, extending from March 28 to June 8, under a variety of circumstances as to weather and external surroundings. The two graphite resistances, the two tuning forks, and different resistances from box A were variously combined, and at temperatures ranging from 17° to 25° C. The shell and ball were occasionally re-adjusted, and between April 16 and May 4 the condenser was taken apart and its electrostatic capacity determined. Further, in order to measure the graphite resistances the apparatus, as shown in fig. 1, was each time disconnected and put together again. All these variations must have had the effect of eliminating to a large degree constant errors, while of course the single observations do not agree as well among themselves as they otherwise would. Following is the last observation made, given as a specimen:

Resistances a:	1930·0 — 194·9 =	1736·0	Temperature:	
	1932·0 — 195·5	1736·5	A =	22°·3
	1932·0 — 197·0	1735·0	B	23°·0
	1932·5 — 196·5	1736·0	Graphite	23°·0

The wire was first in contact at m (fig. 3), and the resistance a corresponding to joint capacity of condenser and charging system was 1930·0 ohms. The wire e (which slides with some friction in the small glass tube G, the latter being fastened at S to the ebonite R) was now lifted very slightly, and 194·0 ohms found to give no deflection on closing the key in the galvanometer circuit. The wire was then again lowered to contact and the subsequent observations made in a similar manner. Any leakage increases the numbers alike in the first two columns, and if constant does not affect the differences, which give the capacity of the condenser. But the leakages are not constant, so that small differences are thereby introduced; this accounts in part for the differences above, though of course small differences are inevitable if there be no leakage. As illustrating how a large leak if constant eliminates itself the following item from my notes of June 6 is of interest. The wooden base of the condenser was thoroughly wet with a cloth, and the leakage thereby introduced changed the readings from 1924–186 to 1933–195, the difference, 1738, remaining unaltered.

The mean of the above differences is 1735·9
Correction: excess at 20° C. = 5·4; temp. corr. 1·3; = 6·7

$\therefore a = 1742·6$

Box B = 100, 120 at 23°·0 = d
R_5 (calculated as already explained) 2,435,800 = c
Frequency of the fork 130·075 = n
1 B. A. unit = ·98664 ohm.

$$C = \frac{a}{ncd} \times \frac{1}{·98664 \times 10^9},$$ C being the capacity of the condenser in absolute electromagnetic units.

log c =	2,435,800 =	6·386642
" d	100,120	5·000521
" n	130·075	2·114194
"	$·98664 \times 10^9$	8·994159
		22·495516
" a =	1742·6	3·241198
" C		20·745682 n.
" C'_A =	50·069	1·699568
" v^2		20·953886
" v		10·476943
$\therefore v$		$2·9988 \times 10^{10}$ cm. per sec.

Table of Results.

[The numbers in the columns headed v when multiplied by 10^{10} give the values of v in centimeters per second.]

Group.	Date.	No.	v, slow fork	Weight.	Weighted mean of group.	v, fast fork.	Weight.	Weighted mean of group.
	March 28.	1	3·0040	2				
	April 2.	2	3·0031	3				
		3	2·9993	3				
	4.	4	2·9980	3				
		5	3·0009	3				
	5.	6	3·0010	2				
		7	3·0036	2				
Group I.	10.	8			3·0012	2·9994	4	
	12.	9			(24)	2·9990	2	
	13.	10				2·9975	2	
		11				2·9953	2	
		12				2·9977	3	2·9987
	15.	13	2·9993	3				(25)
		14	3·0031	3				
	16.	15				2·9998	4	
		16				2·9986	4	
		17				2·9996	4	
	May 4.	18				3·0048	3	
		19				3·0041	4	
	6.	20				3·0053	4	
		21				3·0063	2	
		22				3·0029	4	3·0029
		23				3·0024	4	(33)
Group II.	7.	24				3·0006	4	
		25				3·0011	4	
		26				3·0009	4	
	8.	27	3·0058	3				
		28	3·0007	3				
		29	3·0039	2	3·0045			
		30	3·0069	2	(16)			
	9.	31	3·0033	3				
		32	3·0073	3				
	13.	33	3·0012	3				
		34	3·0105	1				
Group III.	14.	35	3·0090	3				
		36	3·0059	3	3·0043			
	15.	37	3·0021	2	(16)			
		38	3·0036	2				
		39	2·9990	2				
	21.	40				2·9947	1	
	22.	41				2·9950	2	
		42				2·9966	2	
		43	2·9996	4				
	23.	44	3·0025	4	3·0017			
Group IV.		45	3·0022	4	(15)			2·9977
		46	3·0028	3				(25)
		47				2·9988	4	
	June 6.	48				2·9978	4	
		49				2·9980	4	
	8.	50				2·9980	4	
		51				2·9988	4	

The results exhibited in the preceding table have been divided into four groups. The first group consists of seventeen values found before the condenser was taken apart to measure its electrostatic capacity. During this time the upper half of the shell was lifted and the ball adjusted two or three times. The values found by the fast fork are more uniform than the others and average somewhat lower. The second group extends from May 4 to 9, inclusive, when the condenser had been set up again. There were two small glass tubes about 5 mm in diameter and drawn out to about 2 mm, where they projected (between 1 cm and 2 cm) through the shell into the space within. They had once been used to pass charging wires through. The wires had been withdrawn, and it was supposed that the glass tubes had no appreciable effect. The holes were together only $\frac{1}{5000}$th of the area of the shell, and the tendency of the glass to slightly increase the capacity would tend to counterbalance the decreasing effect of the holes. When the condenser was set up the second time the tubes were intentionally left out, and the values of group II were noticed to be larger than those of group I. No cause could be discovered for this increase (which indicates a *less* electromagnetic capacity), but the tubes were replaced and group III taken. The mean of this group is as large as that of the preceding group. The tubes were now again withdrawn and the holes covered with gold foil, making the inner surface of the shell continuous. Group IV gave values averaging almost exactly the same as group I. The circumstances were alike in other respects so far as is known; the usual variations in the conditions of the observations, as already explained, occurring in all the groups. I do not think the presence or absence of the tubes could affect the capacity appreciably; they were altogether too small, probably not filling over a thirty-thousandth of the space between the ball and shell. But that there was a difference in the actual capacity of the condenser when groups I and IV were taken from its value when II and III were obtained seems almost certain. As yet I have not become satisfied as to the cause of this difference, but it seems probable that in putting the condenser together some obstruction lodged between the two halves of the shell and prevented them from coming completely together. Had they been separated a few hundredths of a millimeter only, the difference in question would be fully accounted for. The surfaces of contact are very accurately ground and polished, and loosening the screws does not cause them to separate, as proved by the capacity remaining constant. That the low fork should give higher values for v than the high one (which means a *lower* value for the capacity), is rather unexpected and not fully understood. The low fork gave only a quarter the current given by the high one, and was less steady in its action in proportion to the current; consequently the single observations were less reliable, but this alone does not account for the nearly uniform difference.

In view of the uncertainty as to the cause of the variations it is difficult to determine how best to combine the results. The weight of each single value of v in the table is determined by considering the number of observations from which it is calculated, the uniformity of the separate observations, the steadiness of the spot, etc. If we give to groups II and III one-half the weight of I and IV in proportion to the sum of the weights of the separate values we have as the mean for the fast fork 2·9994, and for the slow fork 3·0023. Giving now double weight to the results of the fast fork on account of their greater accuracy and uniformity, we have as a mean of all *$v=3{\cdot}0004\times10^{10}$ cm. per sec.*

Again, if it be found that the cause suggested is the true cause of the excess of groups II and III then those groups should be thrown out and we should have 2·9982 and 3·0014 as the means, which combined as before would give for the mean of all *$v=2{\cdot}9993\times10^{10}$ cm. per sec.* These values are based upon the value ·98664 for the British Association Unit.

It is proposed to resume this investigation next winter, when more perfect insulation can be obtained, and several improvements in the details of the apparatus will be made. The smaller ball of the condenser will then be used also, and the cause of the difference in the values given by the two forks will be studied. Although we cannot yet say whether v is greater or less than 300,000,000 meters per second, it seems certain that it is within a tenth per cent of this number, and it is hoped in the continuation of this investigation to narrow considerably further the range of uncertainty.

For convenience of reference the following values of v and of the velocity of light as found by different observers are added, the values of v being corrected to the value ·98664 for the B. A. Unit:

v, ratio of the units.		Velocity of light.	
[1] 1856. Weber & Kohlrausch	$3{\cdot}107\times10^{10}$	1879. Michelson	$2{\cdot}9991\times10^{10}$
[2] 1869. W. Thomson & King	2·808 "	1882. Michelson	2·9985 "
[3] 1868. Maxwell	2·842 "	1882. Newcomb	2·9986 "
[4] 1872. M'Kichan	2·896 "	and	2·9981 "
[5] 1879. Ayrton & Perry	2·960 "	1874. Cornu	2·9850 "
[6] 1880. Shida	2·955 "	1878. Cornu	3·0040 "
[7] 1883. J. J. Thomson	2·963 "	1880–81. Young & Forbes	3·0138 "
[8] 1884. Klemencic	3·019 "		
[9] 1888. Himstedt	3·009 "		
1889. W. Thomson	3·004 "		

Johns Hopkins University, Baltimore, June 15, 1889.

[1] Weber & Kohlrausch, Electrodyn. Maasbestim., Abh. der Königl. Sächs. Gesellschaft der Wissensch., vol. v, p. 219, 1856.
[2] King, Report of the Committee on Electrical Standards. 1869.
[3] Maxwell, Phil. Trans., 1868, p. 643. [4] Dugald M'Kichan, Phil. Trans., 1879.
[5] Ayrton & Perry, Jour. Soc. Tel. Engineers, 1879, p. 126.
[6] Shida, Phil. Mag., V, x, p. 431. [7] J. J. Thomson, Phil. Trans., 1883, p. 707.
[8] Klemencic, Wien. Ber. lxxxiii, 88. [9] Himstedt, Wied. Ann., No. 9, 1888.

Art. XLIII.—*Some suggestions upon the method of grouping the formations of the middle Cretaceous and the employment of an additional term in its nomenclature;* by Geo. H. Eldridge.

In recent studies in Colorado, in earlier work in many parts of Montana, and in a general examination of the results obtained by the leading workers in the Cretaceous geology of the West, it has several times occurred to the writer that there existed a demand for a reconsideration and revision of the methods of grouping the formations comprising the middle portions of the Cretaceous,—that is, the Fort Benton, the Niobrara, the Fort Pierre, and the Fox Hills.

Granting the desirability of such revision, there arises with it a parallel necessity for the reconsideration of the nomenclature of this part of the Cretaceous, and for the suggestion of a group name for one of the two more general divisions into which it is still proposed to cast the formations mentioned.

The object to be attained by the revision here advocated is: first, the creation out of the formations of the middle Cretaceous of two divisions, each of such stratigraphical and paleontological weight as shall rank it with either the Dakota below or the Laramie above; secondly, the assignment to these divisions of appropriate names, of a taxonomic value equal to that of the ones already given to the formations with which they are to rank.

The plan of grouping, suggested here, includes in the lower of the two more general divisions the formations of the Fort Benton and Niobrara; in the upper, the Fort Pierre and Fox Hills: for the former no better name can be found than that already in use—Colorado; for the latter the name—Montana—is now, for the first time, proposed.

To take up the foregoing points at somewhat greater length: first, a brief exposition of the leading characteristics of the formations involved is quite in order.

The Fort Benton.—This is essentially a formation of black, argillaceous shales, passing by transitional beds into the formations both above and below, though into the latter always in a manner more or less abrupt. Its thickness, like that of the other marine Cretaceous formations in the West, varies considerably from point to point, but is generally between four and eight hundred feet, approximating the smaller figure oftener than the larger. In addition to its leading characteristics—its black or leaden-hue color, argillaceous composition, and shaly nature—it is marked by the occurrence, here and there, of a few narrow and intermittent bands of fossiliferous limestone, more or less bituminous; by the frequent presence at certain horizons of concretionary, clay ironstones; and by the occasional appearance of a few narrow bands of impure, argillaceous sandstone. As the summit of the formation is approached, the clays become more calcareous, and the limestones more prominently developed, the latter, at times, bearing a distinct resemblance to the lower layers of the important bed at the base of the Niobrara, though rarely attaining a thickness of over four or five feet.

Among the characteristic fossils of this formation the species *Ostrea congesta* and *Inoceramus problematicus* are especially well represented, and by their abundance, often impart to the limestones in which they occur a texture most peculiar and distinctive; in addition to these, *Selachian* teeth are also frequently met with, especially in the more bituminous layers.

The Niobrara.—In thickness this formation varies from a mere trace to approximately four hundred feet. Where well developed, as along the foot-hills in Colorado, its sedimentation is sufficiently differentiated to readily permit its divisions into three distinct members: the lowest a bed of limestone, of an average thickness of fifty feet; the middle, a succession of gray, marly clays, one hundred and ten feet; the uppermost, a series of calcareo arenaceous clays, of various shades of yellow or buff, two hundred and forty feet in thickness, remarkable for the presence of "alkali salts," and containing several bands of impure, yellow, saccharoidal, fossiliferous limestone.

The basal member of limestone, from its general persistency and the prominence of its characteristics, forms an admirable datum level for reference in the study of Cretaceous stratigraphical geology. Its leading characteristics are its bluish-gray, light-gray, or clouded-white color; its superior hardness and consequent great resistence to atmospheric influences; its even, fine-grained texture; the general purity of its composition; its conchoidal fracture; the uniform thickness of its component beds, from one to three feet; and its fossil contents. Where well developed, as in Colorado, these characteristics are more especially applicable to the lower twenty-five or thirty feet of the limestone series, which is the portion of particular economic value and is extensively worked; the upper half is usually much thinner bedded, and passes by transitional shaly beds into the overlying group of marls. For two or three feet upward from the base of the series, also, the strata often show a transition character, linking this formation with the Fort Benton below.

The life of the Niobrara included three especially prominent molluscan forms, the *Ostrea congesta*, the *Inoceramus problematicus*, and the *Inoceramus deformis*, the last, a very characteristic species, but the first two being equally abundant in the formation below. Fish integuments also are equally plentiful in either series of beds. Both the Fort Benton and Niobrara are, however, largely dependent for their paleontological distinction upon species of much more unusual occurrence than those which are everywhere met with.

The Fort Pierre.—In marked contrast with both of the above formations is that of the Fort Pierre. The latter is, in the main, a great body of leaden-gray clays, carrying from bottom to top lenticular bodies of impure limestone and, in several localities midway in the series of beds, a zone of yellowish, quartzose, and more or less calcareous sandstone, of a thickness varying between one and two hundred feet. Though the formation attains the exceptional thickness of over seven thousand feet in the vicinity of Denver, Colorado, it generally falls far below this figure, rarely attaining fifteen hundred feet, and frequently only seven or eight hundred.

The clays are of a remarkably uniform texture; often show a tendency to concretionary structure, though always clearly and evenly stratified; are plastic in a noticeable degree; and have a general distribution of lime, gypsum, and alkali salts throughont. Their capacity for moisture is such, that, upon its evaporation under the rays of the hot western sun and the dry atmosphere of the prairies, the formation—especially if in an approximately horizontal position—becomes most characteristically reticulated with deep and gaping contraction cracks, a condition which renders the country both scant of vegetation and unattractive to the eye.

Equally characteristic with the above are the lenticular bodies of gray limestone, which occur promiscuously through the formation and carry the bulk of its fossils. The dimensions of these bodies very between two and six feet in the direction parallel to the bedding planes of the clays, and between six inches and two feet in the direction normal to these planes. Their composition lies between that of a clay with very little carbonate of lime and a very pure limestone, generally inclining to the more calcareous variety; they are frequently reticulated with narrow calcite seams, which, under a blow from the hammer, cause the bodies to break into sharp, angular fragments; in many of the limestone bodies fine particles of carbonized vegetable tissues also abound.

The sandy zone of the Fort Pierre derives special interest from its frequent, close resemblance to the heavy beds of sandstone at the base of the Laramie, from which, however, it is deadily distinguishable both by its fossils and its stratigraphical rosition.

The life of the formation is abundant, but its especially prominent forms are mainly included in the genera *Inoceramus*. *Cucullæa*, *Nautilus*, *Placenticeras*, *Baculites* and *Scaphites*.

At the summit of the Fort Pierre, between it and the Fox Hills, occurs the second marked zone of transition in the great Cretaceous series of formations. In passing upward, it is first recognized only in a very slight change in the character of the sediments laid down, their composition passing from that of a pure clay to one in which there is a minute but distinguishable amount of fine arenaceous material. In the overlying strata the arenaceous constituents are found to further increase until, finally, the opposite condition is reached, in which we have a large predominance of sandy material with but a comparatively small proportion of purely argillaceous matter,—a condition which shortly afterwards becomes normal for the main mass of the Fox Hills shales. Limestones, similar to those occurring below, are present throughout this zone and extend even well up into the formation above. Fossils also occur, but the special mark in the life of the zone, is the sudden increase in the members of the genus *Mactra*, a genus which has only occasionally been met with below, but which, from this upward, is present in innumerable quantities.

The Fox Hills.—This formation, the closing member of the marine Cretaceous, embraces a thickness of strata varying between two or three hundred and one thousand feet, according to locality. It is essentially a formation of arenaceous shales, of fine material, soft and friable, but still having in an important degree an admixture of argillaceous matter, which occurs both disseminated amidst the fine sand and in occasional bands interstratified with those more purely arenaceous. Limestone concretions, similar to those described for the Fort Pierre, occur here and there through the shales, though perhaps in somewhat fewer numbers. At the summit of the series lies a prominent and most important bed of sandstone, of universal occurrence, having a uniform thickness of about fifty feet. The entire formation has a decidedly yellowish cast, the capping sandstone especially so, though frequently modified by a slight tinge of green.

The sandstone referred to derives its importance from the position it holds as capping the great series of marine Cretaceous sediments; from the decided differentiation from its material, of that of the basal sandstone of the Laramie which immediately succeeds; and from the value of its upper stratum as a line of demarkation between the two formations. The last feature may be ascribed to the abundance and the distinct character of the fossil forms that occur at its very line of union with the overlying Laramie, none of which forms are ever found above, and but few of which are met with, in numbers, below.

This fact cannot be regarded of mere local importance, for it has, for a long time, been recognized over the entire West, wherever the summit of the formation lies exposed. Among these forms are *Mytilus subarcuatus*, *Crenella elegantula*, *Nucula cancellata*, *Cardium* [*Ethmocardium*] *speciosum*,* *Solemya subplicata*, *Sphæriola cordata*, *Veniella humilis*,* *Callista Deweyi*, *Callista* [*Dosinopsis*] *Owenana*, *Mactra alta*,* *Tellina scitula*, *Tancredia Americana*,* *Liopistha* [*Cymella*] *undata*, *Fasciolaria Cheyennensis*, *Pyrula Bairdi*, *Fusus sp.?* *Pseudobuccinum Nebrascense*, *Anchura Americana*, *Turritella sp.?* *Dentalium sp.?** *Cylichna sp.?**, etc., etc. According to Dr. C. A. White, such of the above as are starred especially characterize this horizon; the others may range from this, lower. In plant life *Halymenites major* is generally met with on all sides.

From the foregoing details, the following relations of the several formations to each other may be clearly and legitimately deduced: first, the component strata of the Fort Benton and Niobrara frequently, and the life generally, shade into each other; second, this is again, even more forcibly, paralleled in the sedimentation and life of the Fort Pierre, and Fox Hills; third,—and on the contrary,—between the Niobrara and Fort Pierre, or, which is the same thing, between the Colorado and Montana groups (as was suggested they should be designated early in this paper), there is a differentiation of both sediments and life, greatly in excess of any similarities in these respects that may be noticed from time to time in any particular locality. These facts—especially the ones in regard to life—are considered by Dr. White, the eminent authority upon the North American Cretaceous, as furnishing a most satisfactory basis for the grouping of the several formations as here adopted; and, indeed, it is on account of the paleontological relations of the formations to each other, that he himself was led, as early as in 1876 and '77, to employ a precisely similar system of grouping to that here suggested, though under a partially different nomenclature.

The above distinctions were also remarked upon by Professor Meek in his work—"Invertebrate Palæontology," vol. ix, U. S. Geological Survey of the Territories, 1876, pp. xxxii and xxxiii, —where he says: "In passing from this formation [the Niobrara] to the next above, we cross the most strongly-marked paleontological break in the whole series, unless that between the Dakota group and Fort Benton group may be equally so. As far as yet known, none of the Dakota group species occur in the beds above, but then the number of species yet found in that division and the Fort Benton group is hardly sufficient to warrant the conclusion that some forms may not be common to the two horizons, as seems to be the case in Texas and New Mexico. In passing from the Niobrara group, however, into the succeeding rocks above, in which great numbers of fossils occur, not a single species, as far as known to the writer, has yet been found identical with any form known from either of the three divisions below. In addition to this, the upper surface of the Niobrara beds is, at several places on the Missouri, seen to have been eroded into irregularities, or depressions, previous to the deposition of the succeeding Fort Pierre group, thus giving additional evidence that some kind of a physical change (perhaps slight) occurred between the deposition of the latest portion of the Niobrara division and the first of the Fort Pierre beds."

Finally, the views of Dr. George M. Dawson of the Canadian Geological Survey are also interesting in this connection. In a personal letter to the writer he remarks: "I agree fully with your main proposition as to the grouping together of the Fort Pierre and Fox Hills. It has proved impossible in our western region—from the 49th parallel to the Peace River—to make a satisfactory paleontological division, and in the northern part of Alberta sandy zones containing an essentially Fox Hills assemblage of fossils have been found even toward the base of the Pierre shales as locally developed."

With regard, however, to the lower portion of the series of formations under discussion, Dr. Dawson remarks: "Nothing which can really be said to represent the Niobrara has been found north of the 49th parallel to the west of Manitoba region. While the Belly River series may in part represent the Niobrara, this cannot yet be proved;"—and referring to the rank of the Dakota and Laramie: "The Belly River series for identical reasons, must be allowed to hold a similar independent position, representing, as it does, entirely different conditions of deposition from the formations above and below it." Again, however: "As an exception to the above, I may mention that in the Manitoba region, from the existence of blending between the Niobrara and Fort Pierre formations, it has so far been found impossible to there establish a dividing line between them."

Dr. Dawson, in concluding, remarks that, so far as his knowledge goes at the present time, he does "not consider the restricted Colorado group a useful division of the Cretaceous over the western portion of the country of the plains north of the 49th parallel."

Reflection upon the above facts presented by Dr. Dawson leads to the following observations: first,—in regard to that portion of them which relates to the Belly River series or its possible equivalent the Niobrara,—although the present state of knowledge of this formation and the Fort Benton below, in the Northwest Territory, does not seem to justify the grouping together, in that region, of two such apparently widely different series of beds, yet, with the exception noted for Manitoba, it serves well the purposes of the geologists of the United States, in supporting the argument for a division of the middle Cretaceous at the line suggested in the present article, namely, that of the Niobrara and Fort Pierre; secondly, that portion of Dr. Dawson's remarks which has reference to the relations between the Fort Pierre and Fox Hills formations is thoroughly consistent with the facts as developed within the area of the United States in regard to these two formations, and at once becomes available in support of so much of the argument of this paper, as bears upon the establishing of a comprehensive group to include these formations.

If, now, a group is constructed out of the upper two formations of the middle Cretaceous (a step which is undoubtedly warranted by the foregoing facts), an important point will be gained in the direction of simple geological classification,—there will be for the entire North American continent a single, comprehensive term for two most closely related members of the Cretaceous system. With reference to the first of the observations in the last paragraph, admitting the undesirability of such a grouping for the geology of Canada, it is, nevertheless, strongly advocated for that of the United States, in which the circumstances of deposition and life seem to be entirely different.

The methods of classification hitherto employed by the more prominent authorities in western geology are partly at variance, and partly in harmony, with the one here suggested.

That of the Fortieth Parallel Survey, which includes under the one group, Colorado, the Fort Benton, Niobrara, and Fort Pierre formations—the great clay series, in fact, of the middle Cretaceous—and which retains distinct the Fox Hills, making it of equal rank with the Dakota, Colorado, and Laramie, appears to have been adopted by them on petrological rather than paleontological grounds,—the available fossil evidence at that time being necessarily very imperfect as compared with the present day,—and because they did not always distinguish the individual formations over the area covered by their explorations.

Powell, on the other hand, who uses only local names, and does not attempt correlation with the Meek and Hayden groups of the Upper Missouri, divides this clayey series into two subdivisions, the Salt Wells and Sulphur Creek, and probably leaves the upper portion of the Fox Hills in his Point of Rocks group, which should correspond with King's Laramie.

Finally, the practice of the Hayden Survey, in spite of the earlier agreement made by Dr. Hayden with Mr. King at the time of the publication of the Fortieth Parallel maps, gradually inclined to the classification and nomenclature ascribed to Dr. White on a preceding page, so that in the "Geological Atlas of Colorado," the middle Cretaceous groups are distinguished as Colorado and Fox Hills, the former including the Fort Benton and Niobrara, the latter the Fort Pierre and original Fox Hills.

Turning now to the consideration of the names already in use for the systems of grouping as adopted by former geologists, and, of those proposed in the present article for the general division here advocated, a brief discussion as to their several merits will be the best means of bringing out the relative advantages or disadvantages in their use.

First, then, in regard to the terms employed by Mr. King in the survey of the 40th Parallel, it is evident that, inasmuch as the method of grouping there adopted cannot longer be accepted in the light of all the facts developed, the significance of the names as there employed must likewise fall to the ground; and while it is found inadvisable to discard the names used in the reports of this Survey, it is to be understood that they will henceforth have a significance entirely different from that which they have gained in the usage of Mr. King.

Dr. White, recognizing the undesirability of changing the nomenclature of groups upon what might be considered too slight a provocation, retained the names of King—"Colorado" and "Fox Hills"—but restricted the former to the two formations, Fort Benton and Niobrara, and designated the general group embracing the Fort Pierre and Fox Hills, by the term Fox Hills, discarding entirely the old established name of Fort Pierre. This practice Dr. White himself has since suggested, in a personal interview, is for obvious reasons liable to lead to confusion, so well known have become all the terms of the old nomenclature of Messrs. Meek and Hayden.

The objections to the nomenclature of Powell as given above are at once obvious from the inapplicability of such local, indefinite, and obscure names as "Sulphur Creek" and "Salt Wells" as designations for groups so widely distributed, so extremely characteristic, and now so well known.

The facts in Canadian geology relative to the lower members of the middle Cretaceous series, which preclude for the present the grouping together of the formations in Canadian Territory that in a general way may be found to correspond to the Fort Benton and Niobrara in that of the United States, naturally also preclude the use of the term, Colorado, within the same area: for this portion of the Cretaceous, therefore, their formation names already in use, "Fort Benton" and

"Belly River," will best be adhered to in all discussions regarding the geology of this region. In respect to the upper portion of the middle Cretaceous, the tendency of the Canadian Survey has, for some time, been in accord with the suggestions urged for acceptance in the preceding pages,—that is, toward the grouping together of the Fort Pierre and Fox Hills formations, but under the designation "Pierre (including Fox Hills)" rather than under a new term, employing the name, Fox Hills, to denote only the upper sandstones of the series, lithologically considered: this system of nomenclature is obviously open to the same criticism as that employed by Dr. White, namely, a confusion of ideas, necessarily resulting from the use of terms already long applied in an entirely different manner.

To briefly compare, now, with the foregoing the merits of the group names suggested in the present paper.

1st, That of "Colorado": this is retained on account of its long established usage and the impossibility of finding a term more suitable to the demands made upon it by the principles upon which it is to be employed; it has, indeed, had a signification different from that now assigned it, but this is by no means universally accepted, and hence cannot be considered an obstacle to its employment when really found desirable from every other point of view.

2d, The term, "Montana": In the first place, as a name, it is of equal rank with those of the other general divisions of the Cretaceous as proposed in the present paper, that is, with the Dakota, the Colorado, and the Laramie, though of rather greater geographical value than the last; in the second place, it is an especially appropriate term from the facts, (*a*) that in the territory of Montana a large part of the surface area is occupied by one or the other of its sub-divisions, between which, here, as elsewhere, it is impossible to draw a definite line of separation, either lithologically or paleontologically, and (*b*) that Montana contains a relatively greater proportion of the outcrops of this formation than any other region of the Northwest, with the possible exception of the British Northwest Territory; finally, there is the argument from its early discovery and study in this very area, an argument upon the principles of which, geological nomenclature has often, from the earliest times, been based.

In the foregoing facts, therefore, there exist the strongest grounds for the adoption within the United States of the method of grouping the middle Cretaceous formations advocated in this paper, and for the admission into geological literature of North America, of the name—Montana—as a designation of one of the more comprehensive divisions of the Cretaceous system.

ART. XLIV.—*Some Florida Miocene;* by DANIEL W. LANGDON, JR.

JUDGE LAWRENCE JOHNSON, of the United States Geological Survey, has pointed out the existence of Miocene deposits occupying depressions in the Eocene White Limestone in the vicinity of Tallahassee, Florida, but so far as the writer is informed the formation has not as yet been noted as occurring farther westward.

In November, 1887, while making a section of the Cretaceous and Tertiary rocks exposed along the course of the Chattahoochee river, the writer had the good fortune to discover at Alum Bluff some twenty-five miles below Chattahoochee or River Junction, Florida, the following section:

Alum Bluff, Fla.

1. White sand, evidently marine but of recent formation, 30 feet.
2. Black lignitic sand, very pyritous, and from the efflorescence of ferrous sulphate arises the name *Alum* Bluff. Variable in thickness, and unfossiliferous, . . 10–15 feet.
3. Gray calcareous sand, highly fossiliferous, the principal shell being *Mactra similis* Con. Varies in thickness with preceding stratum, ... 10–15 feet.
4. Gray sand, slightly calcareous, no fossils, . . 5 feet.
5. Light yellow sand, containing pockets of fossils. Where there are no shells the sand is very calcareous. To water's edge and probably slightly thicker than . . 35 feet.

Owing to the high stage of water it was not possible to collect many fossils from the lowest stratum, and only a partial series from the upper fossiliferous stratum is given.

Stratum 3 contains:

Echora quadricostata Say
Buccinum porcinum Say.
Conus adversarius Con.
Cancellaria depressa T. & H.
Typhis acuticostata Con.
Trochus philantrophus Con.
Fusus cinereus Say.
Dentalium attenuatum Say.
Oliva litterata Say.
Ranella (Eupleura) caudata Say.
Cadulus thallus Con.
Scalpellum, nov. sp.
Hipponix Bullii T. & H.
Crepidula plana Say.
Crepidula fornicata Say.
Trochita centralis ?
Crucibulum ramosum Con.
Pyrula pyriformis Con.
Drillia lunata Lea.
Natica heros Say.
Natica duplicata Say.
Turritella Purdenii ? T. & H.
Voluta sp. ?

Lucina contracta Say. (*Chama congregata*)
Lucina crenulata Con.
Lucina cribraria Say.
Lucina sp. ?
Crassatella Marylandica Con.
Venus concentrica Gmelin.
Venus cancellata Lin.
Dione cribraria Con.
Mercenaria Rileyi Con.
Circe metastriata Con.
Cardita granulata
Mactra similis Say.
Nucula (*Yoldia*) *acuta* Con.
Nucula dallabella H. C. Lea.
Nucula limatula Say.
Corbula cuneata ? Say.
Ensis ensiformis Lin.
Pecten eboreus Con.
Tellina, 2 *sp. ?*
Arca incongrua Say.
Arca lienosa Say.
Pectunculus subovatus Con.
Ostrea disparilis Con.
Panopea reflexa
Carcharodon megalodon Ag. (tooth).
Balanus sp.

Stratum 5, from which only a few of the species were collected, contains among other fossils:

Marginella limatula Con.
Solarium perspectivum Lin.
Cerithium sp. ?
Strombus sp. ?

Cytherea reposta Con.
Mercenaria tridachnoides Lam.
Cardita arata Con.
Cardium muricatum Lin.
Hemicardium hemicardium Lin.
Lucina Pennsylvanica Lin.
Lucina divaricata Lam.
**Tellina alternata* ——.

A comparison of the foregoing list with Meek's Check List† and the valuable compilation of Prof. Heilprin‡ shows that of the 63 species enumerated above, 44 or 70 per cent are found in South Carolina; 40 or 64 per cent are found in North Carolina; 26 or 41 per cent in Virginia; and 24 or 38 per cent among the newer beds in Maryland. A very fair inference then is that these Alum Bluff deposits are members of Dana's Sumpter Epoch or Heilprin's Carolinian, only one of the species enumerated, *Crucibulum ramosum* Con., being found in Heilprin's Marylandian, though a closer study of the fossils made possible by further collections may point to a faunal relationship to an older epoch.

These Miocene strata dip toward the south about twenty-five feet to the mile, and are soon covered by the sands of the Drift and the cypress swamps so common along this coast.

Immediately underlying these Miocene sands is a limestone of uncertain age, but which the writer is inclined to class with the Miocene beds.

Southward from Rock Island, nine miles by water, above Chattahoochee or River Junction, Florida, the white orbitoidal limestone disappears, and in lieu thereof there is a rock more argillaceous and siliceous in character resembling some phases of the Eocene Buhrstone. This limestone is very well developed in a railroad cut about half a mile east of the Chatta-

* The above determinations were made by and with the assistance of Mr. Truman H. Aldrich, of Blocton, Ala.

† Smithsonian Miscell. Col., vol. vii. 1867.

‡ U. S. Tertiary Geology, Angelo Heilprin, 1884.

hoochee river, Ocheesee, fifteen miles below the railroad bridge, and again at Rock Bluff, two miles below Ocheesee.

Section at Ocheesee, Fla.

1. Argillaceous limestone, greenish yellow in color, no fossils seen, ... 10 feet.
2. A purer, more granular limestone, creamy white and soft, resembling the "chimney rock" phase of the Vicksburg group. Contains a few obscure corals to water edge, 5 feet.

Rock Bluff, about thirty feet high, is made up of strata of limestone varying in purity as at Ocheesee.

For this older member of the Miocene or newest member of the Eocene White Limestone the writer suggests the provisional name, Chattahoochee Group. The only fossils found were a large *Pecten* about $3'' \times 3\frac{1}{2}''$ and an oyster resembling very closely our living *Ostrea Virginica.* This group, estimated to be 250 feet in thickness, differs materially in its lithologic characteristics from any phase of the White Limestone yet observed in Alabama or Mississippi. On the rich black loam, derived from the disintegration of these slightly phosphatic limestones, the unique *Torreia taxifolia* or "Stinking Cedar" is found growing.

These outcrops at Chattahoochee, Ocheesee, Rock Bluff, and Alum Bluff appear to be the western terminations of ridges that extend eastward parallel to each other like gigantic ribs, and between these ridges are found some of the richest "hummock" lands in West Florida.

On subsequent canoe trips down Conecuh and Pea rivers, the writer failed to discover any Miocene deposits or any traces of the Chattahoochee Group, so that it is believed that the Chattahoochee river marks the western limit of undoubted Miocene or at any rate Dana's Sumpter Epoch.

University Ala., May 20, 1889.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Heat of Combustion of Carbon.*—Berthelot and Petit have determined with great care the heat of combustion of carbon in the three forms of charcoal, graphite and diamond. Finely powdered wood charcoal was purified for the purpose by treating it successively with boiling hydrochloric and hydrofluoric acids, then igniting it in a current of chlorine gas and finally heating it to a high temperature in a Perrot furnace. On analysis it was found to contain 99·34 per cent carbon and 0·66 per cent of ash. The graphite was obtained by purifying the

crystallized variety by treating it several times with hydrochloric acid, washing and drying it, and heating it to redness in the open air for a short time. The diamonds used were those known as Cape diamonds and contained 0·12 per cent of ash; though essentially the same results were obtained with bort. The charcoal was burned with oxygen in a calorimetrical bomb under a pressure of 25 atmospheres. The graphite was mixed with from one-third to one-fifth its weight of naphthalene, the heat of combustion of which is accurately known, in order to burn it in the bomb. The diamonds finely pulverized were mixed with 11 to 16 per cent of naphthalene. Six determinations were made with charcoal, five with graphite, four with Cape diamonds and two with bort. The heat of combustion of one gram was found to be for charcoal 8137·4 water-gram-degrees, for graphite 7901·2 water-gram-degrees and for diamonds 7859·0 water-gram-degrees. Thus

$$C \text{ (diamond)} + O_2 = CO_2 \text{ develops } +94{\cdot}31 \text{ cal.}$$
$$C \text{ (graphite)} + O_2 = CO_2 \quad \text{"} \quad +94{\cdot}81 \text{ "}$$
$$C \text{ (charcoal)} + O_2 = CO_2 \quad \text{"} \quad +97{\cdot}63 \text{ "}$$

— *C. R.*, cviii, 1144–1148. G. F. B.

2. *On the Molecular Mass of Dissolved Substances.*—WILL and BREDIG have devised a modification of the methods of Tamman and Walker for estimating the vapor-pressure of a solution in order to measure the influence of the substance in solution on the vapor-pressure of the solvent, and so, from the results obtained, to determine the molecular mass of the dissolved substance. The solution is contained in a specially constructed Liebig apparatus having a number of bulbs, and the pure solvent itself is contained in a second and similar bulb. These two bulbs are weighed, joined in series, and air is passed through them for twenty four hours at the rate of about a liter per hour, both bulbs being immersed in a bath of constant temperature. At the end of the operation the bulbs are again weighed. The loss in weight of the first is proportional to the vapor-pressure of the solution, that of the second to the difference of the vapor-pressures of the pure solvent and of the solution. From these figures the molecular mass of the dissolved substance may be calculated by Raoult's formula

$$M = m \cdot \frac{p}{100} \cdot \frac{f'}{f - f'},$$

in which M is the molecular mass of the dissolved substance, m is the molecular mass of the solvent (for alcohol 46), p is the number of grams of substance dissolved in 100 grams of the solvent, f is the vapor-pressure of the solvent and f' that of the solution both at the same temperature. If s' be the loss in weight of the bulbs containing the solution, and s'' that of the bulbs containing the solvent, then $\frac{f'}{f-f'} = \frac{s'}{s''}$ and the above formula becomes

$$M = m \cdot \frac{p}{100} \cdot \frac{s'}{s''}.$$

From the variety of solvents experimented with by the authors, they have given the preference to alcohol; whence substituting its molecular mass for *m*, we have

$$M = \frac{46 . p . s'}{100\ s''}.$$

From the results obtained with this method, the authors give the following values, the numbers in brackets being the true molecular mass: nitrobenzene (123) 122, 127; acetamide (59) 58; ethyl benzoate (150) 137 and 143; benzoic acid (122) 107, 108; picric acid (229) 264; diphenylamine (169) 153, 146; atropine (289) 275, 250; hyoscyamine (289) 263; formamide (45) 49, 50; ethyl salicylate (166) 187, 189; urethane (89) 87, 91; carbamide (60) 60, 61; vanillin (152) 130, 135; acetovanillon (a new body not yet described OH . C_6H_3 (OMe) . COMe) (166) 144, 165, 157, 156. Since the new method requires three weighings only and is independent of delicate thermometric readings, it is obviously a very convenient method in practice.—*Ber. Berl. Chem. Ges.*, xxii, 1084–1092; *J. Chem. Soc.*, lvi, 820, Sept. 1889. G. F. B.

3. *On the Boiling point of Ozone and the Solidifying point of Ethylene.*—The experiments of Hautefeuille and Chappuis have proved that ozonized oxygen condenses to a dark blue liquid under a pressure of 125 atmospheres and at the temperature at which ethylene evaporates under the atmospheric pressure, namely −102·5°. Since the ozone remains in a liquid state after the pressure has been reduced to that of the atmosphere, it follows that the boiling point of ozone cannot be very much lower than that of ethylene. Consequently OLZEWSKI attempted to obtain liquid ozone by cooling ozonized oxygen to −150° at the ordinary atmospheric pressure. But though the receiver was cooled to −157° by liquid ethylene, no liquefied ozone was obtained, the result being due evidently to the large quantity of oxygen with which it mixed. But by using liquid oxygen at atmospheric pressure in place of ethylene, the temperature being now −181·4° the ozone was easily obtained in the form of a dark blue liquid. If by injecting the ozonized oxygen into a tube thus surrounded with liquid oxygen at this temperature, a drop of liquid ozone was formed, the author observed that on allowing the oxygen to evaporate, the influx of gas being stopped, the ozone remained liquid until the whole of the oxygen had evaporated. When this point was reached the temperature would be about −150°. At the boiling point of oxygen, the ozone remained a liquid, which was transparent in thin layers but almost opaque in a layer 2^{mm} thick. To determine the boiling point of the ozone, the tube containing it was placed in liquid ethylene at −140°. The ozone remained liquid until the ethylene had nearly reached its boiling point, when the temperature of its evaporation was noted on a sulphurous oxide thermometer and found to be −109° corresponding to −106° on the hydrogen thermometer. Hence this temperature −106° may be taken as the boiling point of liquid ozone. On

evaporation the ozone became a bluish gas which readily recondensed in liquid ethylene.

The author has succeeded in solidifying liquefied ethylene by enclosing it in a tube surrounded by liquid oxygen, this tube being itself surrounded with liquid ethylene. It was found to solidify at about the boiling point of oxygen —181·4°, to a white crystalline semi-transparent mass. On allowing the pressure and temperature to increase gradually by closing the stopcock which allowed the oxygen to escape, the solid ethylene became liquid at a pressure of 3·4 atmospheres, at which, as the author has shown, the temperature of the liquid oxygen would be −169°. This may therefore be taken as the melting point of solid ethylene.—*Ann. Phys. Chem.*, II, xxxvii, 337–340; *J. Chem.*, *Soc.* lvi, 821, Sept., 1889. G. F. B.

4. *On the Constitution of the Thionic acids.*—BERTHELOT has made a thermochemical study of the action of alkali hydrate upon the thionic acids. Treated with excess of the hydrate the pentathionates evolve heat and give thiosulphate. Since the heat observed was only +44 cal., while complete decomposition requires +48 cal., the change is incomplete. If the change of pentathionic into thiosulphuric acid be effected by the assimilation of water according to the reaction $(H_2S_5O_6)_2+(H_2O)_3=(H_2S_2O_3)_5$ the heat absorbed would be −34·6 cal. But this conversion increases the saturating power and corresponds to an increase of the heat of neutralization of +82·8 cal.; leaving a balance of +48·2 cal. in favor of the reaction. When tetrathionates are treated with alkali hydrate they are slowly converted into thiosulphate and sulphite $(Na_2S_4O_6)_2+(Na_2O)_3=(Na_2S_2O_3)_3+(Na_2SO_3)_2$. This reaction when complete gives rise to an evolution of heat corresponding to +72·6 cal., and the conversion of tetrathionic acid into thiosulphuric and sulphurous acids would absorb −18·6 cal. The exothermic character of this reaction, like that of the preceding one, depends on an increase in the saturating power of the acids. The trithionates are more stable and their reaction with alkali hydrate cannot be detected at ordinary temperatures until after a considerable time. On heating, however, the trithionate is converted into thiosulphate and sulphite $(K_2S_3O_6)_2+(K_2O)_3=K_2S_2O_3+(K_2SO_3)_4$; a change corresponding when complete to the evolution of +35·8 cal. The heat absorbed by the conversion is −36·2 cal., but that corresponding to the increase in the heat of neutralization is +72·0 cal. On the dithionates in the cold, sodium hydrate has no action. From these results Berthelot regards the thionic acids as derivatives of condensed, simple or mixed anhydrides, themselves derived from thiosulphuric and sulphurous acids. If thiosulphuric acid be regarded as $S_2O_2 . H_2O$, it is capable of giving rise to a series of condensed anhydrides having the general formula $nS_2O_2 . n-mH_2O$, the basicity of the resulting acids being proportional to m. Hence according to this view pentathionic acid would be $(S_2O_2)_5(H_2O)_2$, n and m being in this case 5 and 3 respectively. If sulphurous

acid $SO_2 . H_2O$ be present also it may act similarly and the following mixed condensed anhydrides would be obtained; $(S_2O_2)_3 . (SO_2)_2 . (H_2O)_2$ which is tetrathionic acid; $S_2O_2 . (SO_2)_4 . (H_2O)_2$ which is trithionic acid; $(S_2O_2)_4 . SO_2 . (H_2O)_2$ which is the acid obtained when preparing pentathionic acid by the method of Debus, in the first crystallizations; and $(S_2O_2)_3 . (SO_2)_3 . (H_2O)_2$, an acid not yet isolated. Since the conversion of the thionic acids into thiosulphuric acid alone or into this acid and sulphurous acid would involve an absorption of heat, the change does not occur in acid solutions.—*C. R.*, cviii, 925–930; *J. Chem. Soc.*, lvi, 823, Sept., 1889. G. F. B.

II. Geology and Mineralogy.

1. *Geological Society of America.*—Sessions of the Geological Society were held at Toronto on Wednesday, August 28th, after the General session of the American Association, and also on Thursday, August 29th. Professor James Hall was the president of the meeting. Besides the address of the president and the transaction of business connected with the organization of the Society, papers were read as follows: J. D. Dana on the Areas of Continental Progress in North America, and the influence of these areas on the work carried on within them; James Hall, on the subdivision and grouping of species usually included under the generic term Orthis, in accordance with external and internal characters and microscopic shell structure, and on new genera and species of the Family Dictyospongidæ; G. K. Gilbert, on the strength of the Earth's Crust; Joseph LeConte, on the origin of normal faults and of the structure of the Basin region; T. C. Chamberlin, on Bowlder belts as distinguished from Bowlder trains, their origin and significance; C. D. Walcott, study of a line of displacement in the Grand Cañon of the Colorado, Arizona; J. F. Kemp, on Trap dikes near Kennebunkport, Maine. Although the number of members enrolled exceeds one hundred and fifty, and many of them were present, the sessions for reading papers were restricted to Thursday in order not to interfere with the American Association. The Society adjourned to meet in the city of New York on the 26th of December.

2. *North American Geology and Palæontology.*—This is the title of a work, now in press, by S. A. Miller of Cincinnati. The book will be in royal octavo and contain about 800 pages of two columns each in brevier type. The first hundred pages is devoted to Geology and the laws of nomenclature, then follows a Catalogue of the American Paleozoic Fossils arranged in classes with the genera in alphabetical order. Every genus is defined and nearly all of them are illustrated and to a great extent by a figure of the type species. Synonyms, preoccupied names and those too poorly defined to warrant recognition are in italics. Special attention has been paid to Classification so as to present to view, at once, the existing state of our knowledge of the zool-

ogy of the Paleozoic era. The book will contain a glossary and also an index of the genera, and is expected to be ready for delivery by November. It is to be published by the author.

3. *Note on the composition of Uraninite;* by W. F. HILLEBRAND (Communicated).—In the course of an examination of uraninite which began with a specimen from Glastonbury, Conn., and which has since been extended to specimens from every available locality in this country and Europe, it was noticed that on treatment of uraninite with an acid—sulphuric, hydrofluoric, or hydrochloric,—a gas was invariably liberated in rather considerable quantity so long as any of the mineral was yet undecomposed, the time required varying very greatly with specimens from different localities. The quantity of this gas given off has been found to be from one to two per cent of the weight of the mineral, and careful spectroscopic as well as eudiometric tests indicate that it is nothing else than *nitrogen.* As to the reaction by which this gas is given off or the manner in which it is combined in the mineral, no clue has yet been discovered. It is only in part driven off by ignition in air, and the portion retained seems to bear a direct relation to the amount of NO_2 still in the ignited product. Pending further investigation looking to the clearing up of these interesting points and to the settlement of the composition of uraninite in general, regarding which in other respects as well as the above, my results are widely at variance with those of Comstock, Blomstrand, and Lorenzen, this preliminary notice is now made public. It may be added that no uraninite from any American or European locality from which specimens were obtainable except Bohemia has failed to show a considerable percentage of thoria or (in one case) zirconia.

Laboratory of the U. S. Geol. Survey Washington, D. C., Sept. 11th, 1889.

4. *Minerals from Franklin, N. J.*—Dr. G. A. KOENIG has recently described the occurrence of chloanthite at the Trotter mine, Franklin, N. J.; it is chiefly massive, but crystals of octahedral habit have also been observed. An amorphous mineral of a green color occurring as a crust or filling cavities in fluorite has proved to be a hydrous silicate of nickel and zinc (ZnO 4·00 p. c.) allied to garnierite, giving the formula (Ni, Zn, Fe) $SiO_3 + 1\frac{1}{2}H_2O$. This is named DE SAULESITE after Major A. B. de Saules, manager of the Trotter mine. An analysis is also given of a manganesian variety of willemite, (ZnO 60·61, MnO 10·04), to which the name of TEPHROWILLEMITE is attached.—*Proc. Acad. Sci. Philad.*, p. 184, 1889.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Parallaxes of the fixed Stars.*—In the *Astronomische Nachrichten* Nos. 2915–6 Dr. Oudemans gives the results of the determinations of stellar parallax by astronomers during the last 60 years, being a Jubilee memoir on the 50th anniversary of the

Pulkova Observatory. The following tables give the parallaxes arranged in the order of magnitude of the proper motions of the stars.

Star.	Mag.	Proper Motion.	Ann. Parallax.	Dist. in Light—yrs.
Groombr. 1830	6·5	7″·05	0″·07	47
Lal. 9352	7·5	6·96	0·28	12
61 Cygni	5·1	5·16	0·40	8
Lal. 21185	6·9	4·75	0·50	6·5
ε Indi	5·2	4·60	0·20	16
Lal. 21258	8·5	4·40	0·26	12.5
o^2 Eridani	4·5	4·05	0·19	17
μ Cass. (OΣ)	5·2	3·75	0·34	10
" (Pritch.)	5·2	3·75	0·04	82
α Centauri	0·7	3·67	0·75	4
Mean of group		4·93	0·32	10

Star.	Mag.	Proper Motion.	Ann. Parallax.	Dist. in Light—yrs.
AOe. 11677	9·0	3″·04	0″·26	12·5
e Eridani	4·4	3·03	0·14	24
Groomber. 34	7·9	2·80	0·29	11
Σ 2398	8·2	2·40	0·35	9
Arcturus	0·0	2·28	0·02	16·3
B. A. C. 8083	5·5	2·09	0·07	47
ζ Tucani	4·1	2·05	0·06	54
δ Draconis	4·7	1·84	0·25	13
Groombr. 1618	6·5	1·43	0·32	10
Mean of group		2·33	0·20	16

Star.	Mag.	Proper Motion.	Ann. Parallax.	Dist. in Light—yrs.
Sirius	—1·4	1″·31	0″·39	8
85 Pegasi	5·8	1·29	0·05	65
AOe. 17415–6	9·	1·27	0·25	13
Procyon	0·5	1·25	0·27	12
η Cassiopejae	3·6	1·20	0·15	22
70 (p) Ophiuchi	4·1	1·13	0·15	22
α Aquilae	1·0	0·65	0·20	16
6 Cygni (Ball)	6·6	0·64	0·48	7
" " (Hall)	6·6	0·64	—0·02	—
β Geminorum	1·1	0·64	0·07	47
Mean of group		1·00	0·20	16

Star.	Mag.	Proper Motion.	Ann. Parallax.	Dist. in Light—yrs.
β Cassiopejae	2·4	0″·55	0″·16	20
10 Ursae Maj.	4·2	0·51	0·20	16
ι Ursae Maj.	3·2	0·50	0·13:	25
α Aurigae	0·2	0·43	0·11	30
Σ 1516	7	0·42	0·28	11
α Lyrae	0·2	0·36	0·16	20
α Leonis	1·4	0·27	0·09	36
α Geminorum	1·6	0·21	0·20	16
α Tauri (OΣ)	1·0	0·19	0·52	6
" (Elkin)	1·0	0·19	0·12	27
Mean of group		0·38	0·18	18

Star.	Mag.	Proper Motion.	Ann. Parallax.	Dist. in Light—yrs.
ν^1 Draconis	4·9	0″·16	0″·32	10
ν^2 "	4·8	0·16	0·28	11
η Herculis	3·7	0·08	0·40	8
α Cassiopejae	2·25	0·05	0·07	47
α Ursae minoris	1·15	0·045	0·07	47
π Herculis	3·4	0·04	0·00	—
α Herculis	3·2	0·04	0·06	54
γ Draconis	2·35	0·03	0·09	36
γ Cassiopejae	2·3	0·02	0·01	326
α Argûs	0·4	0·00	0·03	109
Mean of group		0·05	0·16	20

2. *American Association for the Advancement of Science.*—The thirty-eighth meeting of the American Association was held in Toronto, in the University building, during the week commencing with the 28th of August, under the presidency of Prof. T. C. Mendenhall, Superintendent of the Coast and Geodetic Survey.

The address of the retiring president, Major Powell, who was absent, was delivered Wednesday evening by Prof. G. K. Gilbert—the subject, the Evolution of Music. Opening addresses were made to the sections on the afternoon of Wednesday by the vice-presidents: Mr. R. S. Woodward, on the Mathematical Theories of the Earth; Prof. H. S. Carhart, on Theories of Electrical Action; W. L. Dudley, on Amalgams; Dr. C. A. White on Mesozoic divisions of the Geological record as exhibited on this Continent; Prof. G. L. Goodale, on Protoplasm or Living Matter; Col. G. Mallery, on the Israelite and Indian parallel in planes of culture; Col. Charles S. Hill, on the economic and sociologic relations of the United States and Canada, prospectively considered. Friday evening Prof. Gilbert gave a lecture on the Geological History of the Niagara River. On Monday evening a lecture was delivered by Prof. H. Carrington Bolton on "four weeks in the Deserts of Sinai."

Indianapolis was selected as the place for the next meeting, and appointments of officers were made as follows: for *President*, Prof. George L. Goodale, of Cambridge, Mass. For *Vice-Presidents*, S. C. Chandler, of Cambridge, in the section of Mathematics and Astronomy; Cleveland Abbe, of Washington, in that of Physics; R. B. Warden, of Washington, in that of Chemistry; James E. Denton, of Hoboken, N. J., in that of Mechanical Science and Engineering; John C. Branner, of Arkansas, in that of Geology and Geography; C. S. Minot, of Boston, in that of Biology; Frank Baker, of Washington, in that of Anthropology, and J. R. Dodge, of Washington, in that of Economic Science and Statistics. For *Permanent Secretary*, F. W. Putnam, of Cambridge, as heretofore; *General Secretary*, H. C. Bolton, of New York; *Secretary of the Council*, James Loudon, of Toronto.

The citizens of Toronto made in many ways very liberal provisions for the entertainment of the members of the Association. On Saturday there was an excursion for the day to Niagara Falls, and another to the Muskoka Lake region, over a hundred miles north of Toronto. There was also a geological excursion, starting Tuesday night, after the close of the meeting, to the Huronian region.

The following is a list of the papers read at the sessions:

Section of Mathematics and Astronomy.

G. W. Hough: The New Dearborn Observatory.

E. S. Holden: Astronomical Observations made with the Great Telescope of the Lick Observatory since June, 1888.

C. H. Chandler: A Desideratum in the presentation of mathematical truth.

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OBITUARY.

GIUSEPPE MENEGHINI.—An announcement of the death of Professor Meneghini in January last appeared in the last volume of this Journal. Born in Padua in July, 1811, he died at Pisa where he had passed forty years of his life "the admiration," says Professor Capellini, "of scholars, of friends, and of the city;" and by the decree of the city, he was buried in the monumental Campo Santo, by the side of Paolo Savi.

Professor Meneghini's first scientific investigations were botanical. Their publication commenced in 1834; and until 1849 his work was chiefly in that department. Soon after this date appeared his first paper on the Geology and Paleontology of Tuscany, and subsequently his work was almost exclusively paleontological; and in his many memoirs he covered nearly all departments of zoology. In 1857 was published his report on the Paléontology of Sardinia, in the "Voyage en Sardaigne" of General A. De la Marmora, and from 1867 to 1881, monographs on fossils, in the "Paleontologic Lombarde" of Stoppani. The last of his numerous publications was a memoir, in 1888, on the Cambrian Fauna of Iglesiente in Sardinia, in which he describes the Cambrian Trilobites and illustrates them with seven plates of figures.

In 1849, Meneghini was made Professor of Mineralogy and Geology in the University of Pisa, his connection with the University of Padua having been cancelled in 1848, for political reasons. In 1874, the chair was divided, the department of mineralogy being given to Professor D'Achiardi, leaving to him that of geology. He was President of the "Societa Toscana di Scienze Naturali" from its foundation until 1874; also of the "Societa Malacologica Italiana," of the Geological Society of Italy, and of the Comitato Geologico.

In 1884, the fiftieth anniversary of the commencement of his career as instructor, a gold medal was struck in commemoration, at the expense of contributors all over the scientific world. In 1886 he was made Senator—an honor well-merited, says Professor Seguenza, in view of the positions he held, his academic honors and his scientific labors.

GEORGE H. COOK, the able Geologist of the State of New Jersey, and Professor in Rutgers College, died on the 22d of September at the age of seventy-two.

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[THIRD SERIES.]

ART. XLV.—*The Mathematical Theories of the Earth*; by R. S. WOODWARD, as Vice-president of Section A, of the American Association for the Advancement of Science, Toronto meeting, Aug. 27 to Sept. 3, 1889.

THE name of this section, which, by your courtesy, it is my duty to address to-day, implies a community of interest among astronomers and mathematicians. This community of interest is not difficult to explain. We can of course imagine a considerable body of astronomical facts quite independent of mathematics. We can also imagine a much larger body of mathematical facts quite independent of and isolated from astronomy. But we never think of astronomy in the large sense without recognizing its dependence on mathematics, and we never think of mathematics as a whole without considering its capital applications in astronomy.

Of all the subjects and objects of common interest to us, the earth will easily rank first. The earth furnishes us with a stable foundation for instrumental work and a fixed line of reference, whereby it is possible to make out the orderly arrangement and procession of our solar system and to gain some inkling of other systems which lie within telescopic range. The earth furnishes us with a most attractive store of real problems; its shape, its size, its mass, its precession and nutation, its internal heat, its earthquakes and volcanoes, and its origin and destiny, are to be classed with the leading questions for astronomical and mathematical research. We must of course recognize the claims of our friends the geologists to that indefinable something called the earth's crust, but, considered in its entirety and in its relations to similar bodies of the universe, the earth has long been the special province of astronomers and mathematicians. Since the times of Galileo and Kepler and Copernicus it has supplied a perennial stimulus to observation and investigation, and it promises to tax the resources of the ablest observers and analysts for some centuries to come. The mere mention of the names of Newton, Bradley, d'Alembert, Laplace, Fourier, Gauss, and Bessel, calls to mind not only a long list of inventions and discoveries but the most important parts of mathematical literature. In its dynamical and physical aspects the earth was to them the principal object of research, and the thoroughness and completeness of their contributions toward an explanation of the "system of the world" are still a source of wonder and admiration to all who take the trouble to examine their works.

A detailed discussion of the known properties of the earth and of the hypotheses concerning the unknown properties, is no fit task for a summer afternoon; the intricacies and delicacies of the subject are suitable only for another season and a special audience. But it has seemed that a somewhat popular review of the state of our mathematical knowledge of the earth might not be without interest to those already familiar with the complex details, and might also help to increase that general interest in science, the promotion of which is one of the most important functions of this association.

As we look back through the light of modern analysis, it seems strange that the successors of Newton, who took up the problem of the shape of the earth, should have divided into hostile camps over the question whether our planet is elongated or flattened at the poles. They agreed in the opinion that the earth is a spheroid, but they debated, investigated, and observed for nearly a half century before deciding that the spheroid is oblate rather than oblong. This was a critical question and its decision marks perhaps the most important epoch in the history of the figure of the earth. The Newtonian view of the oblate form found its ablest supporters in Huyghens, Maupertuis, and Clairaut, while the erroneous view was maintained with great vigor by the justly distinguished Cassinian school of astronomers. Unfortunately for the Cassinians, defective measures of a meridional arc in France gave color to the false theory and furnished one of the most conspicuous instances of the deterring effect of an incorrect observation. As you well know the point was definitely settled by Maupertuis' measurement of the Lapland arc. For this achievement his name has become famous in literature as well as in science, for his friend Voltaire congratulated him on having "flattened the poles and the Cassinis" and Carlyle has honored him with the title of "Earth-flattener."*

Since the settlement of the question of the form, progress toward a knowledge of the size of the earth has been consistent and steady, until now it may be said that there are few objects with which we have to deal whose dimensions are so well known as the dimensions of the earth. But this is a popular statement, and like most such, needs to be explained in order not to be misunderstood. Both the size and shape of the earth are defined by the lengths of its equatorial and polar axes; and, knowing the fact of the oblate spheroidal form, the lengths of the axes may be found within narrow limits from simple measurements conducted on the surface, quite independently of any knowledge of the interior constitution of the earth. It is evident in fact, without recourse to mathematical details, that the length of any arc, as a degree of latitude or longitude, on the earth's surface, must depend on the lengths of those axes. Conversely, it is plain that the measurement of such an arc on the surface and the determination of its geographical position constitute an indirect measurement of the axes Hence it has happened that scientific as distinguished from practical geodesy has been concerned chiefly with such linear and astronomical measurements, and the zeal with which this work has been pursued is attested by triangulations on every continent. Passing over the earlier determinations as of historical interest only, all of the really trustworthy approximations to the lengths of the axes have been made within the half century just passed. The first to appear of these approximations were the well founded values of Airy, published in 1830.† These, however, were almost wholly overshadowed and supplanted eleven years later by the values of Bessell ‡ whose spheroid came to occupy a most conspicuous place in geodesy for more than a quarter of a century. Knowing as we now do that Bessel's values were considerably in error, it seems not a little remarkable that they should have been so long accepted without serious question. One obvious reason is found in the fact that a considerable lapse of time was essential for the accumulation of new data, but two other possible reasons of a different character are worthy of notice because they are interesting and instruc-

* Todhunter, History of the Theories of Attraction and the Figure of the Earth, London, 1873, Vol. 1, Art. 195.

† Encyclopedia Metropolitana.

‡ Astronomische Nachrichten, No. 438, 1841.

tive whether specially applicable to this particular case or not. It seems not improbable that the close agreement of the values of Airy and Bessel, computed independently and by different methods—the greatest discrepancy being about one hundred and fifty feet,—may have been incautiously interpreted as a confirmation of Bessel's dimensions, and hence led to their too ready adoption. It seems also not improbable that the weight of Bessel's great name may have been too closely associated in the minds of his followers with the weights of his observations and results. The sanction of eminent authority, especially if there is added to it the stamp of an official seal, is sometimes a serious obstacle to real progress. We cannot do less than accord to Bessel the first place among the astronomers and geodesists of his day, but this is no adequate justification for the exaggerated estimate long entertained of the precision of the elements of his spheroid.

The next step in the approximation was the important one of Clarke in 1866.* His new values showed an increase over Bessel's of about half a mile in the equatorial semi-axis and about three-tenths of a mile in the polar semi-axis. Since 1866, General Clarke has kept pace with the accumulating data and given us so many different elements for our spheroid that it is necessary to affix a date to any of his values we may use. The later values, however, differ but slightly from the earlier ones, so that the spheroid of 1866, which has come to be pretty generally adopted, seems likely to enjoy a justly greater celebrity than that of its immediate predecessor. The probable error of the axes of this spheroid is not much greater than the hundred thousandth part,† and it is not likely that new data will change their lengths by more than a few hundred feet.

In the present state of science, therefore, it may be said that the first order of approximation to the form and dimensions of the earth has been successfully attained. The question which follows naturally and immediately is, how much further can the approximation be carried? The answer to this question is not yet written, and the indications are not favorable for its speedy announcement. The first approximation, as we have seen, requires no knowledge of the interior density and arrangement of the earth's mass; it proceeds on the simple assumption that the sea surface is closely spheroidal. The second approximation, if it be more than a mere interpolation formula, requires a knowledge of both the density and arrangement of the constituents of the earth's mass, and especially of that part called the crust. "All astronomy," says Laplace, "rests on the

* Comparisons of Standards of Length, Made at the Ordinance Office, Southampton, England, by Capt. A. R. Clarke, R. E. Published by order of the Secretary of State for War, 1866.

† Clarke, Col. A. R., Geodesy, Oxford, 1880, p. 319.

stability of the earth's axis of rotation."* In a similar sense we may say all geodesy rests on the direction of the plumb-line. The simple hypothesis of a spheroidal form, assumes that the plumb-line is everywhere coincident with the normal to the spheroid, or that the surface of the spheroid coincides with the level of the sea. But this is not quite correct. The plumb-line is not in general coincident with the normal, and the actual sea-level or geoid must be imagined to be an irregular surface lying partly above and partly below the ideal spheroidal surface. The deviations, it is true, are relatively small, but they are in general much greater than the unavoidable errors of observation and they are the exact numerical expression of our ignorance in this branch of geodesy. It is well known, of course, that deflections of the plumb-line can sometimes be accounted for by visible masses, but on the whole it must be admitted that we possess only the vaguest notions of their cause and a most inadequate knowledge of their distribution and extent.

What is true of plumb-line deflections is about equally true of the deviations of the intensity of gravity from what may be called the spheroidal type. Given a closely spheroidal form of the sea level and it follows from the law of gravitation, as a first approximation, without any knowledge of the distribution of the earth's mass, that the increase of gravity varies as the square of the sine of the latitude in passing from the equator to the poles. This is the remarkable theorem of Stokes,† and it enables us to determine the form, or ellipticity of the earth, by means of pendulum observations alone. It must be admitted, however, that the values for the ellipticity recently obtained in this way by the highest authorities, Clarke‡ and Helmert,§ are far from satisfactory whether we regard them in the light of their discrepany or in the light of the different methods of computing them. In general terms we may say that the difficulty in the way of the use of pendulum observations still hinges on the treatment of local anomalies and on the question of reduction to sea level. At present, the case is one concerning which the doctors agree neither in their diagnosis nor in their remedies.

Turning attention now from the surface toward the interior, what can be said of the earth's mass as a whole, of its laws of

* Toute l'Astronomie repose sur l'invariabilité de l'axe de rotation de la Terre à la surface du sphéroïde terrestre et sur l'uniformité de cette rotation. Mécanique Céleste, Paris, 1882, tome 5, p. 22.

† Stokes, G. G., Mathematical and Physical Papers, Cambridge University Press, 1880, vol. ii.

‡ Geodesy, Chapter XIV.

§ Helmert, Dr. F. R., Die mathematischen und physikalischen Theorien der höheren Geodäsie, Leipzig, 1880, 1884, II Teil.

distribution, and of the pressures that exist at great depths? Two facts, namely, the mean density and the surface density are roughly known; and a third fact, namely, the precession constant, or the ratio of the difference of the two principal moments of inertia to the greater of them, is known with something like precision. These facts lie within the domain of observation and require only the law of gravitation for their verification. Certain inferences also from these facts and others have long been and still are held to be hardly less cogent and trustworthy, but before stating them it will be well to recall briefly the progress of opinion concerning this general subject during the past century and a half.

The conception of the earth as having been primitively fluid was the prevailing one among mathematicians before Clairaut published his Théorie de la Figure de la Terre in 1743. By the aid of this conception Clairaut proved the celebrated theorem which bears his name, and probably no idea in the mechanics of the earth has been more suggestive and fruitful. It was the central idea in the elaborate investigations of Laplace and received at his hands a development which his successors have found it about equally difficult to displace or to improve. From the idea of fluidity spring naturally the hydrostatical notions of pressure and level surfaces, or the arrangement of fluid masses in strata of uniform density. Hence follows, also, the notion of continuity of increase in density from the surface toward the center of the earth. All of the principal mechanical properties and effects of the earth's mass, viz: the ellipticity, the surface density, the mean density, the precession constant, and the lunar inequalities, were correlated by Laplace in a single hypothesis, involving only one assumption in addition to that of original fluidity and the law of gravitation.* This assumption relates to the compressibility of matter and asserts that the ratio of the increment of pressure to the increment of density is proportional to the density. Many interesting and striking conclusions follow readily from this hypothesis, but the most interesting and important are those relative to density and pressure, especially the latter, whose dominance as a factor in the mechanics of celestial masses seems destined to survive whether the hypothesis stands or falls. The hypothesis requires that while the density increases slowly from something less than 3 at the surface to about 11 at the center of the earth, the pressure within the mass increases rapidly below the surface, reaching a value surpassing the crushing strength of steel at the depth of a few miles and amounting at the center to no less than three million atmospheres. The inferences, then, as distinguished from the

* Mécanique Céleste, Tome 5, Libre xi.

facts, are that the mass of the earth is very nearly symmetrically disposed about its center of gravity, that pressure and density except near the surface are mutually dependent, and that the earth in reaching this stage has passed through the fluid or quasi fluid state.

Later writers have suggested other hypotheses for a continuous distribution of the earth's mass, but none of them can be said to rival the hypothesis of Laplace. Their defects lie either in not postulating a direct connection between density and pressure or in postulating a connection which implies extreme or impossible values for these and other mechanical properties of the mass.

It is clear, from the positiveness of his language in frequent allusions to this conception of the earth, that Laplace was deeply impressed with its essential correctness. "Observations," he says, "prove incontestably that the densities of the strata (couches) of the terrestrial spheroid increase from the surface to the center";* and "the regularity with which the observed variation of a second's pendulum follows the law of the squares of the sines of the latitudes, proves that the strata are arranged symmetrically about the center of gravity of the earth."† The more recent investigations of Stokes, to which allusion has already been made, forbid our entertaining anything like so confident an opinion of the earth's primitive fluidity or of a symmetrical and continuous arrangement of its strata. But, though it must be said that the sufficiency of Laplace's arguments has been seriously impugned, we can hardly think the probability of the correctness of his conclusions has been proportionately diminished.

Suppose, however, that we reject the idea of original fluidity. Would not a rotating mass of the size of the earth assume finally the same aspects and properties presented by our planet? Would not pressure and centrifugal force suffice to bring about a central condensation and a symmetrical arrangement of strata similar at least to that required by the Laplacian hypothesis? Categorical answers to these questions cannot be given at present. But whatever may have been the antecedent condition of the earth's mass the conclusion seems unavoidable that at no great depth the pressure is sufficient to break down the structural characteristics of all known substances, and hence to produce

* Enfin il (Newton) regarde la Terre comme homogène, ce qui est contraire aux observations, que prouvent incontestablement que les densités des couches du sphéroïde terrestre croissent de la surface au centre. Mécanique Céleste, Tome 5, p. 9.

† La régularité avec laquelle la variation observée des longueurs du pendule à secondes suit la loi du carré du sinus de la latitude prouve que ces couches sont disposees régulièrement autour du centre de gravité de la Terre et que leur forme est à peu pres elliptique et de révolution. Ibid, p. 17.

viscous flow whenever and wherever the stress difference exceeds a certain limit, which cannot be large in comparison with the pressure. Purely observational evidence, also, of a highly affirmative kind in support of this conclusion, is afforded by the remarkable results of Tresca's experiments on the flow of solids and by the abundant proofs in geology of the plastic movements and viscous flow of rocks. With such views and facts in mind the fluid stage, considered indispensable by Laplace, does not appear necessary to the evolution of a planet, even if it reach the extreme refinement of a close fulfilment of some such mathematical law as that of his hypotheses. If, as is here assumed, pressure be the dominant factor in such large masses, the attainment of a stable distribution would be simply a question of time. The fluid mass might take on its normal form in a few days or a few months, whereas the viscous mass might require a few thousand or a few million years.

Some physicists and mathematicians, on the other hand, reject both the idea of the existence of great pressure within the earth's mass and the notion of an approach to continuity in the distribution of density. As representing this side of the question the views of the late M. Roche, who wrote much on the constitution of the earth, are worthy of consideration. He tells us that the very magnitude of the central pressure computed on the hypothesis of fluidity is itself a peremptory objection to that hypothesis.* According to his conception, the strata of the earth from the center outward are substantially self-supporting and unyielding. It does not appear, however, that he had submitted this conception to the test of numbers, for a simple calculation will show that no materials of which we have any knowledge would sustain the stress in such shells or domes. If the crust of the earth were self-supporting its crushing strength would have to be about thirty times that of the best cast steel, or five hundred to one thousand times that of granite. The views of Roche on the distribution of terrestrial densities appear equally extreme†. He prefers to consider the mass as made up of two distinct parts, an outer shell or crust whose thickness is about one-sixth of the earth's radius, and a solid nucleus having little or no central condensation. The nucleus is conceived to be purely metallic and to have about the same density as iron. To account for geological phenomena, he postulates a zone of fusion separating the crust from the nucleus. The whole hypothesis is consistently worked out in conformity with the requirements of the ellipticity, the superficial density, the mean

* Mémoire sur l'Etat Intérieur du Globe Terrestre, par M. Edouard Roche. Mémoires de la section des Sciences de l'Académie des Sciences et Lettres de Montpellier. Montpellier, 1880–1884. Tome x. † Ibid.

density and precession; so that to one who can divest his mind of the notion that pressure and continuity are important factors in the mechanics of such masses, the picture which Roche draws of the constitution of our planet will present nothing incongruous.

In a field so little explored and so inaccessible, though hedged about as we have seen by certain sharply limiting conditions, there is room for a wide range of opinion and for great freedom in the play of hypothesis; and although the preponderance of evidence appears to be in favor of a terrestrial mass in which the reign of pressure is well nigh absolute, we should not be surprised a few decades or centuries hence to find many of our notions on this subject radically defective.

If the problem of the constitution and distribution of the earth's mass is yet an obscure and difficult one after two centuries of observation and investigation can we report any greater degree of success in the treatment of that still older problem of the earth's internal heat, of its origin and effects? Concerning phenomena always so impressive and often so terribly destructive as those intimately connected with the terrestrial store of heat, it is natural that there should be a considerable variety of opinion. The consensus of such opinion, however, has long been in favor of the hypothesis that heat is the active cause of many, and a potent factor in most of the grander phenomena which geologists assign to the earth's crust; and the prevailing interpretation of these phenomena is based on the assumption that our planet is a cooling sphere whose outer shell or crust is constantly cracked and crumpled in adjusting itself to the shrinking nucleus.

The conception that the earth was originally an intensely heated and molten mass appears to have first taken something like definite form in the minds of Leibnitz and Descartes.* But neither of these philosophers was armed with the necessary mathematical equipment to subject this conception to the test of numerical calculation. Indeed, it was not fashionable in their day, any more than it is with some philosophers in ours, to undertake the drudgery of applying the machinery of analysis to the details of an hypothesis. Nearly a century elapsed before an order of intellects capable of dealing with this class of questions appeared. It was reserved for Joseph Fourier to lay the foundation and build a great part of the superstructure of our modern theory of heat diffusion, his avowed desire being to solve the great problem of terrestrial heat. "The question of terrestrial temperatures," he says, "has always

* Protogée, ou De la Formation et des Révolutions du Globe, par Leibnitz, Ouvrage traduite . . . . avec une introduction et des notes par le Dr. Bertrand de Saint Germain, Paris, 1859.

appeared to us one of the grandest objects of cosmological studies, and we have had it constantly in view in establishing the mathematical theory of heat."* This ambition, however, was only partly realized. Probably Fourier underestimated the difficulties of his problem for his most ingenious and industrious successors in the same field have made little progress beyond the limits he attained. But the work he left is a perennial index to his genius. Though quite inadequately appreciated by his contemporaries, the Analytical Theory of Heat which appeared in 1820 is now conceded to be one of the epoch-making books. Indeed, to one who has caught the spirit of the extraordinary analysis which Fourier developed and illustrated by numerous applications in this treatise, it is evident that he opened a field whose resources are still far from being exhausted. A little later Poisson took up the same class of questions and published another great work on the mathematical theory of heat.† Poisson narrowly missed being the foremost mathematician of his day. In originality, in wealth of mathematical resources, and in breadth of grasp of physical principles he was the peer of the ablest of his contemporaries. In lucidity of exposition it would be enough to say that he was a Frenchman, but he seems to have excelled in this peculiarly national trait. His contributions to the theory of heat have been somewhat overshadowed in recent times by the earlier and perhaps more brilliant researches of Fourier, but no student can afford to take up that enticing though difficult theory without the aid of Poisson as well as Fourier.

It is natural, therefore, that we should enquire what opinion these great masters in the mathematics of heat diffusion held concerning the earth's store of heat. I say opinions, for, unhappily, this whole subject is still so largely a matter of opinion that in discussing it one may not inappropriately adopt the famous caution of Marcus Aurelius: "Remember that all is opinion." It does not appear that Fourier reached any definite conclusion on this question, though he seems to have favored the view that the earth in cooling from an earlier state of incandescence reached finally through convection, a condition in which there was a uniform distribution of heat throughout its mass. This is the *consistentior status* of Leibnitz, and it begins with the formation of the earth's crust, if not with the consolidation of the entire mass. It thus affords an initial distribution of heat and an epoch from which analysis may start, and the problem for the mathematician is to assign the

* La question des températures terrestres nous a toujours paru un des plus grands objects des études cosmologiques, et nous l'avions principalement en vue en établissant la théorie mathématique de la chaleur. Annales de Chimie et de Physique, 1824. Tome 27, p. 159.

† Théorie Mathématique de la Chaleur. Paris, 1835.

subsequent distribution of heat and the resulting mechanical effects. But no great amount of reflection is necessary to convince one that the analysis cannot proceed without making a few more assumptions. The assumptions which involve the least difficulty, and which for this reason, partly, have met with most favor, are that the conductivity and thermal capacity of the entire mass remain constant, and that the heat conducted to the surface of the earth passes off by the combined process of radiation, convection, and conduction, without producing any sensible effect on surrounding space These or similar assumptions must be made before the application of theory can begin. In addition, two data are essential to numerical calculations; namely, the diffusivity, or the ratio of the conductivity of the mass to its thermal capacity, and the initial uniform temperature. The first of these can be observed, approximately, at least; the second can only be estimated at present. With respect to these important points, which must be considered after the adoption of the *consistentior status*, the writings of Fourier afford little light. He was content, perhaps, to invent and develop the exquisite analysis requisite to the treatment of such problems.

Poisson wrote much on the whole subject of terrestrial temperatures and carefully considered most of the troublesome details which lay between his theory and its application. While he admitted the nebular hypothesis and an initial fluid state of the earth, he rejected the notion that the observed increase of underground temperature is due to a primitive store of heat. If the earth was originally fluid by reason of its heat, a supposition which Poisson regarded quite gratuitous, he conceived that it must cool and consolidate from the center outward;* so that according to this view the crust of our planet arrived at a condition of stability only after the supply of heat had been exhausted. But Poisson was not at a loss to account for the observed temperature gradient in the earth's crust. Always fertile in hypotheses, he advanced the idea that there exist by reason of interstellar radiations, great variations in the temperature of space, some vast regions being comparatively cool and others intensely hot, and that the present store of terrestrial heat was acquired by a journey of the solar system through one of the hotter regions. "Such is," he says, "in my opinion, the true cause of the augmentation of temperature which occurs as we descend below the surface of the globe."† This hypothesis was the result of Poisson's mature reflection, and as such is well worthy of attention. The no-

* Théorie Mathématique de la Chaleur, Supplement de, Paris, 1837.

† "Telle est, dous mon opinion, la cause véritable de l'augmentation de température qui a lieu sur chaque verticale à mesure que l'on s'abaisse au dessous de la surface du globe."—Ibid., p. 15.

tion that there exist hot foci in space was advanced also in another form in 1852 by Rankine, in his interesting speculation on the reconcentration of energy. But whatever we may think of the hypothesis as a whole it does not appear to be adequate to the case of the earth unless we suppose the epoch of transit through the hot region exceedingly remote, and the temperature of that region exceedingly high. The continuity of geological and paleontological phenomena is much better satisfied by the Leibnitzian view of an earth long subject to comparatively constant surface conditions but still active with the energy of its primitive heat.

Notwithstanding the indefatigable and admirable labors of Fourier and Poisson in this field, it must be admitted that they accomplished little more than the preparation of the machinery with which their successors have sought and are still seeking to reap the harvest. The difficulties which lay in their way were not mathematical but physical. Had they been able to make out the true conditions of the earth's store of heat they would undoubtedly have reached a high grade of perfection in the treatment of the problem. The theory as they left it was much in advance of observation, and the labors of their successors have therefore necessarily been directed largely toward the determination of the thermal properties of the earth's crust and mass.

Of those who in the present generation have contributed to our knowledge and stimulated the investigation of this subject it is hardly necessary to say that we owe most to Sir William Thomson. He has made the question of terrestrial temperatures highly attractive and instructive to astronomers and mathematicians, and not less warmly interesting to geologists and paleontologists. Whether we are prepared to accept his conclusions or not, we must all acknowledge our indebtedness to the contributions of his master hand in this field, as well as in most other fields of terrestrial physics. The contribution of special interest to us in this connection is his remarkable memoir on the secular cooling of the earth.* In this memoir he adopts the simple hypothesis of a solid sphere whose thermal properties remain invariable while it cools by conduction from an initial state of uniform temperature, and draws therefrom certain striking limitations on geologic time. Many geologists were startled by these limitations and geologic thought and opinion have since been widely influenced by them. It will be of interest, therefore, to state a little more fully and clearly the grounds from which his arguments proceed. Conceive a sphere having a uniform temperature initially, to cool in a

* Transactions of the Royal Society of Edinburgh, 1862. Thomson and Tait's Natural Philosophy, vol. i, Part II, Appendix D.

medium which instantly dissipates all heat brought by conduction to its surface, thus keeping the surface at a constant temperature. Suppose we have given the initial excess of the sphere's temperature over that of the medium. Suppose also that the capacity of the mass of the sphere for the diffusion of heat is known and known to remain invariable during the process of cooling. This capacity is called diffusivity and is a constant which can be observed. Then from these data the distribution of temperature at any future time can be assigned, and hence also the rate of temperature increase, or the temperature gradient, from the surface toward the center of the sphere can be computed. It is tolerably certain that the heat conducted from the interior to the surface of the earth does not set up any reaction which in any sensible degree retards the process of cooling. It escapes so freely that, for practical purposes, we may say it is instantly dissipated. Hence, if we can assume that the earth had a specified uniform temperature at the initial epoch, and can assume its diffusivity to remain constant, the whole history of cooling is known as soon as we determine the diffusivity and the temperature gradient at any point. Now Sir William Thomson determined a value for the diffusivity from measurements of the seasonal variations of underground temperatures, and numerous observations of the increase of temperature with depth below the earth's surface gave an average value for the temperature gradient. From these elements and from an assumed initial temperature of 7000° Fahr., he infers that geologic time is limited to something between 20,000,000 and 400,000,000 years. He says: "We must allow very wide limits in such an estimate as I have attempted to make, but I think we may with much probability say that the consolidation cannot have taken place less than 20,000,000 years ago, or we should have more underground heat than we actually have, nor more than 400,000,000 years ago, or we should not have so much as the least observed underground increment of temperature. That is to say, I conclude that Leibnitz's epoch of emergence of the *consistentior status* was probably between those dates." These conclusions were announced twenty-seven years ago and were republished without modification in 1883. Recently, also, Professor Tait, reasoning from the same basis, has insisted with equal confidence on cutting down the upper limit of geologic time to some such figures as 10,000,000 or 15,000,000 years.* As mathematicians and astronomers we must all confess to a deep interest in these conclusions and the hypothesis from which they flow. They are very important if true. But what are the probabilities? Having been at some pains to look into

* Recent Advances in Physical Science, London, 1876.

this matter, I feel bound to state that, although the hypothesis appears to be the best which can be formulated at present, the odds are against its correctness. Its weak links are the unverified assumptions of an initial uniform temperature and a constant diffusivity. Very likely these are approximations, but of what order we cannot decide. Furthermore, if we accept the hypothesis, the odds appear to be against the present attainment of trustworthy numerical results, since the data for calculation, obtained mostly from observations on continental areas, are far too meager to give satisfactory average values for the entire mass of the earth. In short, this phase of the case seems to stand about where it did twenty years ago, when Huxley warned us that the perfection of our mathematical mill is no guaranty of the quality of the grist, adding that "as the grandest mill will not extract wheat flour from peas-pods, so pages of formulæ will not get a definite result out of loose data."*

When we pass from the restricted domain of quantitative results concerning geologic time to the freer domain of qualitative results of a general character, the contractional theory of the earth may be said to still lead all others, though it seems destined to require more or less modification, if not to be relegated to a place of secondary importance. Old, however as is the notion that the great surface irregularities of the earth are but the outward evidence of a crumpling crust, it is only recently that this notion has been subjected to mathematical analysis on anything like a rational basis About three years ago Mr. T. Mellard Reade announced the doctrine that the earth's crust from the joint effect of its heat and gravitation should behave in a way somewhat analogous to a bent beam and should possess at a certain depth a "level of no strain," corresponding to the neutral surface in a beam.† Above the level of no strain, according to this doctrine, the strata will be subjected to compression and will undergo crumpling, while below that level the tendency of the strata to crack and part is overcome by pressure which produces what Reade calls "compressive extension," thus keeping the nucleus compact and continuous. A little later the same idea was worked out independently by Mr. Chas. Davison,‡ and it has since received elaborate mathematical treatment at the hands of Darwin,§ Fisher,‖ and

* Geological Reform (The Anniversary Address to the Geological Society for 1869), Lay Sermons, Addresses and Reviews. D. Appleton & Co. New York, 1871.

† Reade, T. Mellard, Origin of Mountain Ranges, London, 1886.

‡ On the Distribution of Strain in the Earth's Crust Resulting from Secular Cooling; with special reference to the growth of continents and the formation of mountain chains. By Charles Davison, with a Note by G. H. Darwin, Philosophical Transactions, vol. clxxviii (1887), A, pp. 231–249.

§ Ibid.

‖ Fisher, Rev. Osmond, Physics of the Earth's Crust, second edition, London, 1889, Chapter VIII.

others. The doctrine requires for its application a competent theory of cooling and hence cannot be depended on at present to give anything better than a general idea of the mechanics of crumpling and a rough estimate of the magnitudes of the resulting effects. Using Thomson's hypothesis, it appears that the stratum of no strain moves downward from the surface of the earth at a nearly constant rate during the earlier stages of cooling, but more slowly during the later stages; its depth is independent of the initial temperature of the earth; and if we adopt Thomson's value of the diffusivity it will be about two and a third miles below the surface in a hundred million years from the beginning of cooling, and a little more than fourteen miles below the surface in 700,000,000 years. The most important inference from this theory is that the geological effects of secular cooling will be confined for a very long time to a comparatively thin crust. Thus, if the earth is a hundred million years old crumpling should not extend much deeper than two miles. A test to which the theory has been subjected, and one which some* consider crucial against it, is the volumetric amount of crumpling shown by the earth at the present time. This is a difficult quantity to estimate, but it appears to be much greater than the theory can account for.

The opponents of the contractional theory of the earth, believing it quantitatively insufficient, have recently revived and elaborated an idea first suggested by Babbage and Herschel† in explanation of the greater folds and movements of the crust. This idea figures the crust as being in a state bordering on hydrostatic equilibrium which cannot be greatly disturbed without a readjustment and consequent movement of the masses involved. According to this view, the transfer of any considerable load from one area to another is followed sooner or later by a depression over the loaded area and a corresponding elevation over the unloaded one; and in a general way it is inferred that the elevation of continental areas tends to keep pace with erosion. The process by which this balance is maintained has been called isostasy, and the crust is said to be in an isostatic state.‡ The dynamics of the superficial strata with the attendant phenomena of folding and faulting are thus referred to gravitation alone, or to gravitation and whatever opposing force the rigidity of the strata may offer. In a mathematical sense, however, the theory of isostacy is in a less

* Notably Rev. Osmond Fisher. See his Physics of the Earth's Crust, Chapter VIII.

† Appendix to the Ninth Bridgewater Treatise (by C. Babbage), second edition, London, 1838.

‡ Dutton, Capt. C. E., On some of the Greater Problems of Physical Geology, Bulletin Philosophical Society of Washington, vol. xi, pp. 51–64.

satisfactory state than the theory of contraction. As yet we can see only that isostasy is an efficient cause if once set in action; but how it is started and to what extent it is adequate remain to be determined. Moreover, isostasy does not seem to meet the requirements of geological continuity, for it tends rapidly towards stable equilibrium, and the crust ought therefore to reach a state of repose early in geologic time. But there is no evidence that such a state has been attained, and but little if any evidence of diminished activity in crustal movements during recent geologic time. Hence we infer that isostasy is competent only on the supposition that it is kept in action by some other cause tending constantly to disturb the equilibrium which would otherwise result. Such a cause is found in secular contraction, and it is not improbable that these two seemingly divergent theories are really supplementary.

Closely related to the questions of secular contraction and the mechanics of crust movements are those vexed questions of earthquakes, volcanism, the liquidity or solidity of the interior, and the rigidity of the earth's mass as a whole—all questions of the greatest interest, but still lingering on the battle fields of scientific opinion. Many of the "thrice slain" combatants in these contests would fain risk being slain again; and whether our foundation be liquid or solid, or to speak more precisely, whether the earth may not be at once highly plastic under the action of long continued forces and highly rigid under the action of periodic forces of short period, it is pretty certain that some years must elapse before the arguments will be convincing to all concerned. The difficulties appear to be due principally to our profound ignorance of the properties of matter subject to the joint action of great pressure and great heat. The conditions which exist a few miles beneath the surface of the earth are quite beyond the reach of laboratory tests as hitherto developed, but it is not clear how our knowledge is to be improved without resort to experiments of a scale in some degree comparable with the facts to be explained. In the meantime, therefore, we may expect to go on theorizing, adding to the long list of dead theories which mark the progress of scientific thought, with the hope of attaining the truth not so much by direct discovery as by the laborious process of eliminating error.

When we take a more comprehensive view of the problems presented by the earth, and look for light on their solution in theories of cosmogony, the difficulties which beset us are no less numerous and formidable than those encountered along special lines of attack. Much progress has recently been made, however, in the elaboration of such theories. Roche,* Darwin† and others have done much to remove the nebulosity of Laplace's nebular hypothesis. Poincaré‡ and Darwin§ have gone far toward bridging the gaps which have long rendered the theory of rotating fluid masses incomplete. Poincaré has in fact shown us how a homogeneous rotating mass might, through loss of heat and consequent contraction, pass from the spheroidal form to the Jacobian ellipsoidal form, and thence, by reason of its increasing speed of rotation, separate into two unequal masses. Darwin, starting with a swarm of meteorites and gravitation as a basis, has reached many interesting and instructive results in the endeavor to trace out the laws of evolution of a planetary system.‖ But notwithstanding the splendid researches of these and other investigators in this field, it must be said that the real case of the solar system, or of the earth and the moon, still defies analysis; and that the mechanics of the segregation of a planet from the sun, or of a satellite from a planet, if such an event has ever happened, or the mechanics of the evolution of a solar system from a swarm of meteorites, are still far from being clearly made out.

Time does not permit me to make anything but the briefest allusion to the comparatively new science of mathematical meteorology, with its already considerable list of well defined theories pressing for acceptance or rejection. Nor need I say more with reference to those older mathematical questions of the tides and terrestrial magnetism, than that they are still unsettled. These and many other questions, old and new, might serve equally well to illustrate the principal fact this address has been designed to emphasize, namely, that the mathematical theories of the earth already advanced and elaborated are by no means complete, and that no mathematical Alexander need yet pine for other worlds to conquer.

Speculations concerning the course and progress of science are usually untrustworthy if not altogether fallacious. But, being delegated for the hour to speak to and for mathematicians and astronomers, it may be permissible to offer, in closing,

* Essai sur la Constitution et L'Origine du Système Solaire, par M. Édouard Roche. Mémoires de L'Académie des Sciences et Lettres de Montpellier, tome viii, 1873.

† On the Precession of a Viscous Spheroid and on the remote History of the Earth, Phil. Trans., Part II. 1879; On the secular changes in the Elements of the Orbit of a Satellite revolving about a tidally distorted Planet, Phil. Trans., Part II, 1880; On the Tidal Friction of a Planet attended by several Satellites, and on the Evolution of the Solar System, Phil. Trans., Part II, 1881.

‡ Sur L'Équilibre d'une Masse Fluid animé d'un mouvement de rotation, Acta Mathematica, vol vii, 1885.

§ On Figures of Equilibrium of Rotating Masses of Fluid, Phil. Trans., vol. 187, 1887.

‖ On the Mechanical Conditions of a Swarm of Meteorites and on Theories of Cosmogony, Phil. Trans., vol. 180, 1889.

a single suggestion, which will perhaps help us to orient ourselves aright in our various fields of research. If the curve of scientific progress in any domain of thought could be drawn, there is every reason to believe that it would exhibit considerable irregularities. There would be marked maxima and minima in its general tendency toward the limit of perfect knowledge; and it seems not improbable that the curve would show throughout some portions of its length a more or less definitely periodic succession of maxima and minima. Races and communities as well as individuals, the armies in pursuit of truth as well as those in pursuit of plunder, have their periods of culminating activity and their periods of placid repose. It is a curious fact that the history of the mathematical theories of the earth presents some such periodicity. We have the marked maximum of the epoch of Newton near the end of the 17th century, with the equally marked maximum of the epoch of Laplace near the end of the 18th century; and, judging from the recent revival of geodesy and astronomy in Europe, and from the well nigh general activity in mathematical and geological research, we may hope if not expect that the end of the present century will signalize a similar epoch of productive activity. The minima periods which followed the epochs of Newton and Laplace are less definitely marked but not less noteworthy and instructive. They were not the periods of placid repose; to find such one must go back into the night of the middle ages; but they were periods of greatly diminished energy, periods during which those who kept alive the spirit of investigation were almost as conspicuous for their isolation as for their distinguished abilities. Many causes, of course, contributed to produce these minima periods, and it would be an interesting study in philosophic history to trace out the tendency and effect of each cause. It is desired here, however, to call attention to only one cause which contributed to the somewhat general apathy of the periods mentioned, and which always threatens to dampen the ardor of research immediately after the attainment of any marked success or advance. I refer to the impression of contentment with and acquiescence in the results of science, which seems to find easy access to trained as well as untrained minds before an investigation is half completed or even fairly begun. That some such tacit persuasion of the completeness of the knowledge of the earth has at times pervaded scientific thought, there can be no doubt. This was notably the case during the period which followed the remarkable epoch of Laplace. The profound impression of the sufficiency of the brilliant discoveries and advances of that epoch is aptly described by Carlyle in the half humorous, half sarcastic language of Sartor Resartus. "Our Theory of Gravitation," he says, "is as good as perfect: Lagrange, it is well known, has proved that the Planetary System, on this scheme, will endure forever; Laplace, still more cunningly, even guesses that it could not have been made on any other scheme. Whereby, at least, our nautical logbooks can be better kept; and water transport of all kinds has grown more commodious. Of geology and geognosy we know enough; what with the labors of our Werners and Huttons, what with the ardent genius of their disciples, it has come about that now, to many a royal society, the creation of a world is little more mysterious than the cooking of a dumpling, concerning which last, indeed, there have been minds to whom the question *How the apples were got in?* presented difficulties." This was written nearly sixty years ago, about the time the sage of Ecclefechan abandoned his mathematics and astronomy for literature to become the seer of Chelsea; but the force of its irony is still applicable, for we have yet to learn, essentially, "*How the apples were got in*," and what kind they are.

As to the future we can only guess, less or more vaguely, from our experience in the past and from our knowledge of present needs. Though the dawn of that future is certainly not heralded by rosy tints of over-confidence amongst those acquainted with the difficulties to be overcome, the prospect on the whole has never been more promising. The converging lights of many lines of investigation are now brought to bear on the problems presented by our planet. There is ample reason to suppose that our day will witness a fair average of those happy accidents in science which lead to the discovery of new principles and new methods. We have much to expect from the elaborate machinery and perfected methods of the older and more exact sciences of measuring and weighing—astronomy, geodesy, physics and chemistry. We have more to expect, perhaps, from geology and meteorology with their vast accumulations of facts not yet fully correlated. Much, also, may be anticipated from that new astronomy which looks for the secrets of the earth's origin and history in nebulous masses or in swarms of meteorites. We have the encouraging stimulus of a very general and rapidly growing popular concern in the objects of our enquiries, and the freest avenues for the dissemination of new information; so that we may easily gain the advantage of a concentration of energy without centralization of personal interests. To those, therefore, who can bring the prerequisites of endless patience and unflagging industry, who can bear alike the remorseless discipline of repeated failure and the prosperity of partial success, the field is as wide and as inviting as it ever was to a Newton or a Laplace.

Art. XLVI.—*Darkened Silver Chloride not an Oxychloride;* by M. Carey Lea.

About two years ago, I published a series of papers in this Journal, the main object of which may be briefly stated as follows:—to prove that the substances which I described as "photosalts" and obtained by purely chemical means were identical with those produced by light, with both the visibly darkened substances, and the material of the latent image. Further, that all these substances consisted of a silver haloid (normal chloride, bromide or iodide) combined with the corresponding subsalt, not in equivalent proportions, but after the manner of a "lake" The subsalts, being unstable substances when isolated, acquiring much greater stability by the union.

The only objections I have seen to these views were based on investigations made in England by Dr. Hodgkinson: his conclusions were that an oxysalt and not a subsalt was formed. Although several years have elapsed since these conclusions were made public, the means by which they were reached and the necessary experimental proof, do not seem to have been published. Mr. Meldola in his interesting "Chemistry of Photography," in treating of this part of the subject seems disposed to accept Dr. Hodgkinson's theory and his formula Ag_4OCl_2 for darkened silver chloride. Mr. Meldola adopts my views that the photosalts which I described and which were obtained by purely chemical means are identical with the products resulting from the action of light on the silver haloids, but expresses the opinion that I have not proved my theory of their constitution.

It has always seemed to me that the whole mass of observation on the action of light on silver chloride tended so thoroughly to indicate the formation of subchloride, that we might reasonably accept that view, at least until something in the way of proof were offered for the oxychloride theory. But, waiving this objection, I will endeavor to show that subchloride and not oxychloride is the product of the action of light on silver chloride.

The question as to the presence or absence of oxygen in colored silver chloride is one that cannot be determined satisfactorily by quantitative analysis. Taking for example the formula just mentioned, Ag_4OCl_2, it would involve the presence of about 3 per cent of oxygen, if the entire mass of silver chloride were converted into this substance. But we know that even by the longest exposure, the proportion of AgCl acted upon is very small. It would probably be a liberal estimate if we were to fix 5 per cent of the whole mass as the proportion changed by light. So that the amount of oxygen that would, according to the oxychloride theory, be introduced into a given quantity of chloride by prolonged exposure would not exceed three twentieths or 0·15 of one per cent, of the material under examination, a dangerously small quantity on which to attempt to decide an important question, especially where the estimation is indirect. If even a very careful determination of the silver and the chlorine present should bring the sum of these to a quantity represented by figures amounting to from 99·80 to 99·90, would it be allowable to assume that the difference between this and 100 consisted of oxygen and so to take the presence of an oxychloride as proved? Such reasoning could not be accepted; the errors incident to the most careful analysis would too largely affect the point vitally at issue, not to speak of the entire absence of proof that the deficient quantity was oxygen.

These considerations convinced me that it was not in that direction that one should seek for proof of the presence or absence of oxygen in the the substance in question. I therefore looked for what may be called *proof by exclusion*.

Coal naphtha (refined petroleum) is a substance absolutely free from suspicion of containing oxygen or moisture as impurities, so much so as to be universally used for the preservation of sodium. I have sodium that has been preserved in this way for over thirty years. Silver chloride was precipitated with excess of hydrochloric acid, was washed in a darkened room and dried in a dessicator. From this it was transferred to a porcelain crucible, covered and fused over a lamp. When thoroughly fused (in this condition it is as fluid as water) it was poured directly into naphtha. This naphtha had been placed to the depth of an inch or more in a dry porcelain vessel, which was first well wiped out with naphtha to remove the film of atmospheric moisture which condenses on surfaces.

The chloride congealed into a pale gray lump which, whilst it remained under the petroleum, was absolutely free from all possibility of contact with oxygen, free or combined. Without removing it, the vessel was moved into the sunshine. When touched by sunlight, the chloride instantly became as black as ink.

This experiment seems decisive as to the oxychloride theory.

It seemed desirable not to stop here, but to find a means of applying an equally decisive proof by exclusion to the converse case. In the above instance, a photosalt was formed by reduction starting with normal chloride. The converse case would be the formation of a photosalt by chlorination, starting with metallic silver, and excluding oxygen, free or combined, thus demonstrating that that element is not needed and plays no necessary part in the formation of silver photochloride.

Anhydrous cupric chloride, which I at first thought of employing, proved to be insoluble in naphtha. In rendering ferric chloride anhydrous there is a possibility of forming oxychloride; it could therefore not be employed. As it is not in the least important which halogen is used, I concluded to take iodine which proved to be slightly soluble in naphtha with a beautiful violet coloration. The mode of operation was as follows. Pure silver reduced by cadmium from the chloride was heated nearly to redness in a porcelain capsule, and at the instant of removal from the flame, was dropped into naphtha. Some fragments of iodine were added. Owing to the very small amount of iodine soluble in naphtha, the action was slow, but continuous and regular. As fast as the iodine dissolved, it was taken up by the silver. At the end of some hours the iodine had disappeared wholly, and the naphtha was colorless. Fresh naphtha replacing it failed to dissolve any iodine. The whole of it had combined with the silver to a black compound. This experiment may be varied by using a piece of clean silver foil or even a silver coin that has been boiled a few moments with nitric acid, washed and heated by a blast lamp. Immersed in the naphtha with iodine its surface soon becomes perfectly black.

This reaction forms the complement of the other and the two show that whether we start from silver chloride and proceed by reduction or from metallic silver and proceed by iodization, in either case we can obtain a photosalt under conditions which rigorously exclude all possibility of the presence of moisture or of oxygen in any shape.

Therefore the photosalt is not an oxysalt, but, as I endeavored to prove two years ago, a compound of normal salt with subsalt.

The action of light upon silver chloride appears to take place in the following manner.

If any substance is present with which chlorine can combine, either directly or by substitution,* the AgCl is decomposed with

* As to the action of light on silver chloride perfectly isolated, i. e. in a perfect vacuum would appear from an interesting experiment of Abney's that no decomposition takes place. It was found that AgCl in vacuo did not darken even by prolonged exposure.

This experiment does not indicate that the presence of moisture is essential for decomposition, it simply proves that some substance (by no means necessarily water) must be present upon which chlorine can act Accordingly, when the vacuum tube contained mercury, the AgCl was decomposed by exposure to light. —It may be remarked that this last mentioned fact, properly considered, would have been found to be fatal to the oxychloride theory, inasmuch as darkened chloride was formed in the total absence of oxygen.

formation of subchloride. As the product is subchloride and not oxychloride it is not necessary that the substances present should contain oxygen, as has just been shown. The subchloride thus formed instantly combines with a portion of the silver chloride as yet unacted upon by light, forming a photochloride of great stability, capable for a time of resisting the action of nitric acid (I have shown that the photochloride made by purely chemical means also shows this stability.)

This combination is not by equivalents but it is of the nature of a lake, and the affinity of silver chloride for the subsalt is of a progressively diminishing character. Small quantities of subchloride are held with great tenacity; as the proportion of subchloride increases the affinity diminishes. This is no assumption, it is easy to form chemical photochloride containing a large proportion of subchloride. Much of this latter is instantly decomposed by cold nitric acid; with heat, an additional quantity disappears and so on until the last portions may require hours of boiling with strong acid, for decomposition.

This stable combination of the chloride and subchloride constitutes alike the material of darkened chloride, of the latent image, and of the photochloride.

An excellent mode of testing the value of a chemical theory is to observe its ability to explain not only the general result of a reaction, but also the secondary facts observable. In the present matter, the action of light on silver chloride, there are two such secondary facts of a quite remarkable nature, for which, though long familiarly known, no explanation has hitherto been found, but which, I think, will be found to be readily and satisfactorily explained by the photochloride theory.

1. When silver chloride is exposed to light, there is a certain pause, an interval during which very little action takes place. After this, the darkening sets in rapidly. This fact is so conspicuous as to attract the attention of everyone who exposes chloride paper.

The explanation is: light pink or violet photochloride is vastly more sensitive to light than white chloride, a fact easily proved by preparing light colored photochloride by any of the chemical means I have elsewhere described, brushing it and white chloride, each in a pasty condition, over respective strips of paper and exposing side by side; the difference in the darkening is very striking.—Now the first action of light on white chloride is to form this light-colored photochloride, and whilst that is going on but little visible effect is produced. As soon as the photochloride is once formed, the darkening becomes rapid. The time required for the first formation of the photochloride gives rise to the pause which is observable.

2. When pure moist silver chloride is exposed to light, the darkening goes on steadily to a certain point and then virtually ceases. Although the mass may be constantly agitated so as to expose fresh portions whilst it is kept moist, or better, kept under water, the action of light after a few days exposure, ends almost wholly, and though the chloride now seems perfectly black, analysis shows that the amount of chloride altered has been very small, perhaps a twentieth. For this well known and most remarkable fact I believe no explanation has ever been offered.

It is to be explained I think as follows: When light acts on moist silver chloride, acid products are formed, the nature of which has not been fully made out, but whose presence is certain. (If the exposure is made under water, the water reddens litmus, it does not bleach it.) These acid products would instantly destroy silver subchloride isolated. As long as the quantity of subchloride present and combined with normal chloride is small, the protecting power of the normal chloride saves the subchloride from decomposition. The ability of normal chloride to protect the subsalt rapidly diminishes as already mentioned as the proportion of the latter increases; these forces in time find an equilibrium (as in the case of many other chemical reactions), in which the quantity of subchloride becomes constant, and any excess that is formed by light beyond the quantity which the chloride can protect is instantly destroyed. Consequently even the most protracted exposure fails to increase the proportion of subchloride beyond its limit.

The complete cessation of the reducing action of light after a certain very small fraction of the chloride present has been attacked cannot be explained by the oxysalt theory. For, if a small portion of the chloride has been converted into Ag_4OCl_2 there is no conceivable reason why a continuance of the same agencies at work should not affect the residue and so go on until the whole of the silver chloride passes into the new condition.—No theory deserves serious consideration that does not offer a satisfactory explanation of these two conspicuous facts: the pause at the outset, and the cessation of action as soon as a certain small proportion of chloride is reduced.

A confirmation of the explanation here offered is to be found in the fact that black forms of photochloride chemically formed are almost wholly unacted upon by light. By treating metallic silver in a state of fine division* with sodium hypochlorite, black photochloride is easily formed which, after two

* For such purposes, metallic silver is best obtained by precipitating the nitrate with sodium hydroxide in excess, and without washing, adding a solution of milk sugar. In a few hours the reaction is complete (Levol's method.) If the presence of any undecomposed oxide is feared the product may be washed with ammonia.

or three treatments with hypochlorite solution, gives up nothing to cold nitric acid. It is almost wholly insensitive to light; because as fast as normal chloride is decomposed by light it is reconstituted by the conversion of a corresponding quantity of subchloride present, to normal chloride. The chloride and subchloride are in an equilibrium which the action of light does not alter.

August, 1889.

ART. XLVII.—*Observations on some of the Trap Ridges of the East Haven-Branford Region*,* *with a map* (Plate IX); by EDMUND OTIS HOVEY, Ph.D.

Contents.—The topography of the region—its trap belts and sandstone ridges—general position and forms of the trap belts—particular description of Pond Rock and the ridges east of it. Kinds of trap rock in different parts of the region—the amygdaloidal trap and its relation to that which is non-vesicular. The relation of the sandstone to the trap—contact phenomena. Main theories which have been advanced to account for the occurrence of the trap—special discussion of the theory of "contemporaneous overflow." The age of the trap. Conclusions.

THE character and age of the ridges of trap which occur so numerously in the Triassic sandstone of Massachusetts, Connecticut and New Jersey are questions that have been discussed with more or less vigor for the last seventy years. In the Bulletin of the Museum of Comparative Zoology, 1883, Prof. W. M. Davis has given a valuable list of papers bearing upon the subject. In this Bulletin, in this Journal, III, xxiv, 1882, and III, xxxii, 1886, and in the Seventh Annual Report, U. S. G. S., 1885–86, just issued, he has detailed his own observations, illustrating them by figures and sections, and has elaborated his conclusions as to the trap. The investigations, the results of which are given in the present communication, were undertaken by the writer in the hope of throwing additional light upon the perplexing question.

The region most carefully studied in this connection lies to the east and southeast of the city of New Haven, Conn., in the towns of New Haven, East Haven, Branford and North Branford, and though small, being about eight miles in greatest length, from southwest to northeast, by four miles in width, it is full of interest topographically as well as geologically. The general monoclinal eastward dip of the sandstone, with numerous faults, gives long ridges whose general trend is that of the strike of the strata; i. e., N. 10° or 15° E. Most of these

* Presented in June, 1889, as a thesis for the degree of Ph.D. from Yale University. Read in part before the American Association for the Advancement of Science at its Toronto meeting, 1889.

ridges present bluffs or very steep faces to the west, while their eastern sides are gradual in slope. These ridges are all low, none of them rising to a height of more than 140 feet above the sea, though in Branford the sandstone rises gradually to the height of 226 feet.*

The most striking feature of the topography, however, is that of the outcrops of trap. These arrange themselves in about six lines of ridges, as is well shown on Percival's elaborate and excellent map of the State,† and also on the map accompanying this article. The most important range comprises Pond Rock (Percival's E. I.), and Totoket Mountain (E. II.), which seem to belong to different systems; while the five subordinate ranges are made up of many small exposures of trap, and lie two to the east and three to the west of Pond Rock. With the exception of the easternmost, these ranges show a general convexity toward the west, while Pond Rock and Totoket are almost semicircles. The eastern of the six ranges is very short, and is remarkable for being convex toward the east—the only well-marked example of the kind in the Connecticut Triassic area.

The map accompanying this article has been prepared with considerable care. Most of it was taken from the charts of the New Haven Region by the U. S. Coast and Geodetic Survey; but the region east of the road crossing Pond Rock, northeast of Lake Saltonstall, and the southern hook of Totoket Mountain were mapped by myself, using a compass and measuring the distances by pacing. The town maps of the district as given in an atlas of New Haven County were found to be almost entirely valueless, even for the roads. The outlines of the exposures of trap were all laid down from my own observations. I have endeavored to represent with approximate accuracy the position and shape of every exposure of trap in the region mapped; the task required the location of about 270 exposures.‡ See further, the closing note on page 383.

Pond Rock.—Pond Rock, with the eastern ridges, is considered by Prof. Davis to contain the key to the whole problem of the origin of the trap ridges of the valley, hence a detailed description of this and the other ranges will not be out of place. The main range, Pond Rock, begins $1\frac{1}{8}$ miles S. 10° E. of the railroad embankment across Lake Saltonstall, and extends northerly and easterly for six miles. For rather more

* Map of the New Haven region by the U. S. Coast Survey.

† Report on the Geology of Connecticut, 1842; J. G. Percival.

‡ The degree of excellence attained by Percival in his map is something marvelous. Working alone and without any of the modern appliances, he produced a map which to-day stands very fairly the test of field work in a region of exceptional intricacy. The scale of his map is small, being but one inch to five and one-half miles.

than three miles the eastern slope of the ridge is washed by the lake, which is noted for the purity and depth of its waters. Three-quarters of a mile from the northern end of the lake and 300 feet from the western shore the Coast Survey found a depth of 107 feet, and other depths nearly as great are recorded. The surface of the lake is less than 15 feet above tide-level, a height which is largely due to a dam. There are three main curves in the range, with the convexity to the west and northwest. The first extends from the southern end of the ridge to the middle of the lake; the second, from the latter point to the crossing of the Branford-Foxon road; the third, from that point to the eastern extremity of the ridge. The whole ridge forms a grand curve, convex toward the northwest, with its chord, 4¾ miles long, extending nearly northeast and southwest. From its southern point to the railroad the ridge trends N. 10° W.; north of the head of the lake the trend for two miles is nearly east and west, while the eastern extremity bends around to the south.

This range consists of three distinct parts. The southern portion has a general course of about N. 15° W., is rather more than three-fourths of a mile long, and its highest points are 140 feet above mean tide-level. At its southern end the trap rises close to a ledge of granite from which it is separated by low marshy land. Toward the north the trap tapers out and the ridge decreases in height so that where it crosses the New Haven-Branford turnpike the width of its horizontal section is less than fifty feet, and it rises but thirty feet above the sea. Here the rock is broken into small angular fragments clinging loosely together, and is much decomposed. This is what Prof. Davis calls trap "breccia" or a "brecciated structure," but the term seems to be misapplied; for the rock evidently is not sedimentary in origin, and its structure is due to lines of fracture in the mass which have been made prominent by decomposition. This portion of the ridge ends a few feet north of the turnpike and is now separated from the second part by the extremity of the lake, the waters of which conceal the junction of the two parts. The second part begins about ten feet north of the turnpike, at the dam, and extends somewhat more than a quarter of a mile west of north to a point fifty or sixty feet north of the railroad (the Shore Line Division of the N. Y., N. H. & H. road), which makes a cut thirty feet deep through the ridge. The hill rises to the height of 140 feet, and is surmounted by the stand-pipe of the New Haven Water Co.'s works. This part, like the first, is precipitous toward the west, and slopes more gradually toward the east.

The third part of Pond Rock joins the second by a narrow neck of trap, and, beginning forty or fifty feet north of the railroad, extends in a bold curve to the northward and eastward for nearly five miles. At the southern end the ridge rises very rapidly to a height of 175 feet, then more gradually until it reaches 240 feet, at a mile and a quarter from the railroad. This height is maintained very uniformly for about three miles, though several points are twenty to thirty feet higher and lower, and two points attain 280 feet of elevation—one at the head of the lake and the other a mile farther east. The eastern extremity of the ridge is a bluff rising 160 feet (aneroid measurement), above a small lake at its base, which is perhaps fifty feet above the sea. The slope of the eastern side of the ridge along Saltonstall lake is usually 25° or 30°, while that of the western side varies from 40° and more at the southern extremity, and at the bend near the head of the lake to 10° or less, in the curve opposite the middle of the lake; east of the head of the lake the southern side is usually steeper than the northern. The *bluffs*, however, are on the convex side. In many places the convex side of the ridge is covered with a heavy talus of trap, while the concave side has comparatively few fragments on it.

It is hard to determine how much of the ridge is trap and how much sandstone. The eastern and southern slopes of the third part of the ridge seem to be composed entirely of trap, except at one point within a mile of the eastern extremity, where sandstone is exposed high up on the slope. Along the lake most of the rock is solid and hard, but much of it is amygdaloidal in structure, indicating that the present may be nearly the same as the original surface. Shale is exposed on the eastern slope of the second part of the ridge, but neither sandstone nor shale has been observed on the same slope along the first part except at the foot of the lake. The western faces of the first and second parts show well the contact of the trap and underlying sandstone, but the dip of the strata is hard to obtain satisfactorily. On the western and northern slopes of the third part of the ridge no contact has been found. Near the railroad the sandstone rises on the ridge to perhaps eighty feet above sea-level. Measuring in the direction of the dip to the same level on the other side of the ridge, as given on the chart of the Coast Survey (an unsatisfactory method), and taking 40° as the dip of the sandstone at this place, we get 225 feet as the thickness of the sheet of trap. Southeast of Lyman Granniss's house (C, on the map), and a mile and a half from the railroad, a trench about 250 feet long was dug into the side of the hill about thirty years ago in a fruitless search for silver. The trench passes through fine, soft shale and ends against fine-grained drab sandstone, which looks as if it had been subjected to the action of heat, and is probably very near the contact. This sandstone occurs 180 feet above tide-water, aneroid measurement. The locality is marked A on the map. The strike and dip of the sandstone were not obtained here, but taking the dip as 25°, which is probably not too low for this region, and applying the method of calculation just given, the thickness of the trap sheet at this point is about 317 feet. On the same basis the second part of the ridge at the stand-pipe would have the trap 260 feet thick, and the trap of the first part would be about as thick.

In the village of North Branford, about a mile northeast from the eastern extremity of the Pond ridge, Toket (or Totoket) mountain begins. This trap sheet has the same general outlines as Pond Rock, but it is broader and longer and rises to greater elevations. Its chord trends nearly north-northeast, and is about eight miles in length. The ends of this ridge, like those of the other, rise close to the crystalline rocks which form the eastern boundary of the Triassic region. Only the southern portion of Toket will be especially referred to in the course of the present discussion. This part extends west-northwest for about a mile, being nearly parallel to the eastern extension of Pond Rock. It is higher than the latter and presents a bold, partly precipitous front to the south, while it slopes away very gradually to the north. Percival's map shows such a remarkable "hook" at the southern end of Toket, that especial care was taken in tracing out the shape of the trap, with the result given on my map, which is confirmatory of Percival's outline

The eastern subordinate ranges.—Percival's map and description* of his "first posterior" range (the one next east of Pond Rock and marked E 1, on my map), would indicate that it was almost as continuous as the main ridge, but inspection of the field shows that it is composed of a good many more or less distinct parts. The range begins about a third of a mile east-northeast from the southern end of the Pond ridge, and is remarkable for the close parallelism between it and the main range, not only in the principal curve but also in the subordinate ones. At its southern end two small ridges extend northeasterly. The second eastern range of trap (E. 2), begins about 600 feet north of the railroad in that part of Branford known as Plantsville, and extends N. 30° E. for rather more than a mile, and, as has been already stated, is remarkable for its convexity toward the east. The range consists of seven or eight ridges, three of which are more than 100 feet high, and with E 1 makes an almost complete oval. It is separated from the crystalline rocks by a narrow swampy valley.

* Geology of Connecticut, p. 324.

The western subordinate ranges.—Of the three ranges of trap ridges mentioned as lying west of Pond Rock, the one nearest to the main ridge is the most continuous. Beginning at the railroad, a third of a mile west of the Pond ridge, this range (W 1, on the map), extends to the north and northeast for rather more than four miles. The convexity toward the west is marked, though not as noticeable as that of the main ridge; like that of the Pond ridge at the southern end, it is caused by the exposures of trap being arranged in what Percival calls the advancing order; i. e., the southern end of the northern member overlaps on the west the northern end of the southern member. The northern end of the range consists of a very complex set of short ridges which may, perhaps, be joined into two or three strongly curved ranges. Each of the other two ranges (W 2, and W 3), is composed of many small exposures, but the most western has several large ridges, the largest of which are Hemingway mountain, 260 feet high, and Eaton Hill, 200 feet high, north of the borough of Fair Haven East, and two nameless hills, each 240 feet in height, north of and in line with Hemingway mountain. Besides these ranges of ridges there are many small exposures of trap in this part of the district which do not seem to belong to any range.

Kinds of trap rock in different parts of the region.—Dr. G. W. Hawes* and Prof. E. S. Dana† made a somewhat extended chemical and microscopic study of the trap rocks of the Connecticut valley some years ago. The results, though incomplete, show that the trap is of very uniform mineral composition, and that the main differences are due to the alteration consequent upon hydration. These observers concluded that the hydration increased from west to east, the trap of the western border of the Triassic being almost non-hydrous. While the increase is not a regular one, it is true that the ridges of the eastern part of the valley generally show more alteration than those of the western. The trap is a true diabase, the augite of which has suffered the most from alteration. The alteration products, according to my study of slices, are usually chlorite and magnetite, the latter sometimes arranging itself in beautiful arborescent groups of crystals, while the former frequently exhibits a fibrous structure. The ridge which shows the most complete alteration of any in the region is a part of the most western of the six ranges (W 3). Where exposed by Farren avenue and Center street the rock has been deeply decomposed, while other ridges in its vicinity and Hemingway mountain, a mile and a half north in the same range, are composed of hard dense trap, not very lustrous but still showing some of the augite unaltered. The trap of the

* This Journal, III, ix, 192, 1875. † This Journal, III, viii, 390, 1874.

range next west of the main range contains many amygdules and pipestems of calcite at its southern end and the rock is a dull black; toward the north some of the ridges consist of hard and somewhat lustrous trap, and others of that which is much decomposed and soft; some are amygdaloidal while others are not. These ranges are composed of many isolated members, and some variation might be expected.

The main ridge is composed for the most part of a continuous sheet of trap, but the external appearance and texture of the rock vary somewhat in different parts of it. By far the largest part of the sheet is composed of hard, dense, tough trap which is almost as lustrous as that from East Rock, but its color is a lighter green and planes of alteration penetrate its mass. At the railroad cut the rock is somewhat amygdaloidal, and much of it is decomposed, some even into coarse dark-brown earth The solid rock at this place is green or black, is almost lusterless, and rarely if ever shows its crystalline structure macroscopically.

Along the lake, as has been remarked already, much amygdaloid occurs; it alternates with the dense and the decomposed rock. The amygdules are mostly of calcite, which easily weathers out leaving the rock very vesicular. Fragments of this vesicular trap cover large areas of the southern slope near the eastern extremity of the ridge.

In Prof. E. S. Dana's collection of. thin sections there are two from Pond Rock, one from the railroad cut and one from the head of the lake; in mine there are three: one from the lower contact with the sandstone in the railroad cut, one from near the middle of the sheet on the northern side, a mile and a half from the lake, the third from the southern slope within half a mile from the eastern extremity of the ridge, showing the contact with the overlying sandstone. Prof. Dana's sections and the first and third of mine (Nos. 21*a* and 18 of the collection), show very much the same thing, viz: an altered diabase with the augite constituent almost entirely gone, and with the plagioclase somewhat affected. The section (No. 23), from the northern slope is very different from these. Considerable chlorite appears, but much of the augite is apparently but little altered, giving the usual brownish color in ordinary light and bright colors between crossed Nicols. The structure is rather coarsely crystalline and the individuals of the plagioclase twins are much larger than have been observed in other sections. In this section the feldspar constituent seems to be the one that has suffered most from hydration.

No thin sections have been made of the trap of the first range east of Pond Rock, but I have two (Nos. 15 and 25 in my collection), from the second range; the former is from the contact with the eastern sandstone, and the latter is from near the middle of the ridge, and both are from the cut made by the wagon road from Branford to Cherry Hill (at B on the map). No. 25 is of a very finely crystalline rock, hard and lustrous, and breaking with conchoidal fracture. Under the microscope the rock shows less alteration than No. 23. The augite has suffered the most from hydration, though many crystals show their characteristic colors and cleavage lines, and very little chlorite has been formed. The feldspar shows very little alteration; it occurs in its usual form—thin lath-shaped twin crystals, each of which is made up of but two individuals. Much magnetite appears, some of which is arborescent in form, the octahedral crystals being connected along their cubic axes. The trap of No. 15 from the contact shows more alteration than the section just described, the augite being entirely decomposed and more chlorite appearing, the feldspar also has suffered from alteration. Of the other members of this range some show the effects of much decomposition, while most are composed principally of dense, sub-lustrous trap.

The amygdaloidal trap and its relation to that which is non-vesicular.—Much amygdaloidal trap occurs in the East Haven Branford region, and while most of what is exposed is on the upper or concave side of Pond Rock, it is by no means confined to that position. The first and second members of the Pond ridge show a band of amygdaloidal trap six inches wide at the lower contact wherever this is exposed. The amygdules are of calcite. Amygdules of prehnite and calcite have been observed in the first range east of this. Prof. Davis says that no dikes are amygdaloidal in character,* defining a dike as trap crossing the strata of sandstone or shale more or less obliquely. In the second railroad cut east of Center street, Fair Haven East (G, on the map), there is a typical dike twenty-three feet wide. Four feet from the southeastern wall of this dike a band nine inches wide, containing amygdules of calcite and amethystine quartz extends in a line parallel with the wall of the dike. The band does not appear to be a vein. Section No. 19 is from this band of amygdaloid. The trap shows much more alteration than appears in Prof. Dana's section from the compact trap of the same dike. No augite is perceptible and much chlorite has been formed. A great deal of magnetite is present and most, if not all, of it is crystalline. The chlorite occurs disseminated through the rock and in the amygdules. The amygdules are various; some are all chlorite, others calcite with a border of chlorite, or vice versa; some are of quartz inclosing chlorite, or of calcite fringed with some zeolite, while others have quartz

* This Journal, III, xxiv, 346, 1882.

and calcite in the same cell. With the exception of this band of amygdaloid the rock of this dike is compact and almost lustrous. This dike is a member of the third range west of Pond Rock. The southern member of the first western range is remarkable for the number of amygdules and "pipestems" of calcite which it contains throughout its mass. A mile and a half north of the railroad there is a similar occurrence of amygdaloid. In both instances the trap is dull black in color without apparent crystalline structure. Three miles from the railroad the northern end of one of the members of this range appears as a dike intersecting the layers of sandstone (D, on the map).

The relation of the sandstone to the trap.—If the sandstone were oftener exposed in close proximity to the eastern slopes of the ridges of trap, there would have been less opportunity for discussion as to the relative age of the igneous rocks and the sandstone. The southern members of the third western range in and near the hill crowned by the New Haven Water Co.'s reservoir in the southern part of the borough of Fair Haven East are clearly seen to cut obliquely across the layers of sandstone. The walls of these dikes are very regular, much more so than those of the dikes in Wallingford and some other parts of Connecticut. The southern end of the member of this range next north of Hemingway mountain is exposed within 200 feet of the end of that ridge. The exposure is in the face of a bluff on the northern side of the road from New Haven to North Branford, and shows an irregular mass of trap lying between strata of sandstone. The latter is hard, mostly compact, and bright red. Heat from the trap, probably through the aid of moisture, has penetrated the joints of the overlying rock, vesiculating the sandstone. Tongues of trap also have pushed their way into crevices of the overlying sandstone. The dip of the sandstone is eastward and high, but was not satisfactorily determined.

The ridges of the second western range cut somewhat obliquely across the strike of the sandstone, but turn to the north a mile and a half north of the railroad just before they would otherwise have joined the first western range. No contact, or sandstone near a contact, is visible except at one place, where one small mass of trap shows itself in the road a third of a mile west of Lyman Granniss's house (C, on the map), as a distinct dike. Sandstone covers the top of the dike and shows that it has been pushed up by the trap. The sandstone beneath the trap of the first western range is exposed at many places on the western slopes of the ridges; but the overlying sandstone has been almost completely denuded from the ridges, its first occurrence being three miles from the railroad, where it is in contact with the trap. At this place (D), which has been mentioned already, the strike and dip of the strata could not be satisfactorily determined, but it is evident that the trap intersects the layers obliquely and is a dike.

The underlying rock of Pond Rock is well exposed in the precipitous western faces of the first and second divisions, where the contact in many places is sixty feet above tide, and on the southern ends of the second and third. The sandstone is hard and compact at and near the contact, but farther down there are some loose and shaly layers At the foot of the lake the strike of the sandstone is N. 10° E., its dip 50° E. A good cross-section of the contact is shown on the southern side of the railroad cut just east of the abutment of the wagon bridge over the cut; on the northern side the abutment hides the contact. At and near the contact the sandstone is much indurated, and the trap and sandstone are so firmly united that hand specimens of the contact can be trimmed with the hammer without loosening the joint. The trap seems to lie conformably upon the sandstone, which strikes N. 16° E., and dips 40° E. Most of the sandstone exposed in the western part of this cut is shaly and irregular in texture, but there are a few layers of compact rock. North of the railroad the underlying rock has been observed at only three places; everywhere else it is covered with the talus of the trap bluff or with earth, and no contact has yet been found. The first exposure is in the silver seekers' trench, a mile and a half from the railroad, and is of fine soft shale and hard drab sandstone, the latter being the nearer to the trap. The next exposure is nearly two miles from this, in a ravine, on the northern slope of the rock, five-eighths of a mile east of the crossing of the Branford-Foxon road (R). The rock is a rather soft red shale some distance below the trap, with its strike S. 87° E., and its dip 25° S. Three-eighths of a mile farther east the third and most extensive exposure occurs. Near the probable location of the contact a rather soft, fine-grained, well laminated, brownish red shale is exposed. Its strike is S. 70° E., and its dip 23° S. Going down the ravine the edges of the strata are crossed, which are of coarse, hard red and brownish red sandstone interlaminated with shale which varies much in texture. The exposure extends for some 300 feet down the gentle slope.

The rock beneath the southern hook of Toket mountain is exposed at several places on the New Haven-North Branford road as a loose sandy shale with strike S. 65°–70° E., and dip about 18° N. This should be noted in connection with the strike and dip of the shale on the other side of the transverse valley beneath the northern hook of Pond Rock. No exposure near the contact was found.

Though many bowlders lie scattered over the eastern slope of the first member of the Pond ridge, none of the overlying sandstone has been observed *in situ* near the trap, except at the foot of the lake where a soft reddish brown micaceous shale forms the bank for some distance east of the trap. The contact of the two rocks, however, is not exposed. The shale dips steeply to the south of east. Prof. Davis, in speaking of the railroad through the ridge, says: "No overlying sandstone could be found."* It is there, however The exposure begins 135 feet east of the south abutment of the wagon bridge, and extends for about 150 feet along the track and southeastward for 500 feet to a point south of the ice-houses on the bank of the lake. Soil and underbrush prevent a determination of the exact extent of the occurrence up the slope, and grass hides the outcrop by the railroad. The rock is soft, sandy shale like that at the foot of the lake; for the most part dark red or reddish brown in color but dark green near the contact with the trap. The strike and dip of the shale were obtained at three places by digging and were: strike, N. 16° E., dip, 75° E. The dip of the eastern face of the trap at the contact is 80° or more toward the *north* of east. Fig. 3 is a plan showing the relation of the sandstone and trap at the two places just described, as well as the mode of union between the first and second, and second and third parts of Pond Rock. Fig. 4 represents the section exposed by the railroad.

North of the railroad the overlying sandstone is exposed at but two places near the trap of this ridge: these are on the southern side of the eastern prolongation of the rock. Half a mile east of the Branford-Foxon road a deep ravine (P) cuts into the southern slope of the trap and extends nearly to the top of the ridge. Into this ravine from the south a steep promontory of sandstone forty feet high projects, forming a triple ravine. The rock of this projection is a rather hard, very coarse sandstone containing some shaly layers; its strike is N. 60° E., and its dip 45° eastward. The contact is not exposed, but the sandstone is seen within fifteen feet of the trap. Half a mile farther eastward and well up on the slope is the last exposure of the overlying rock (H, on the map), and the contact is shown. The exposure is in a shallow ravine worn by a small stream. The trap is of dark reddish brown color, and, though filled with amygdules of calcite, is very firm where decomposition has not set in The sandstone is coarse and is very hard especially at the contact where it is firmly joined to the trap. Twenty-five feet down the hill from the contact and a few feet above the trap, the strike of the sandstone is S. 70° E., and its dip 42° S.

* Bull. Mus. Comp. Zool., 1883, p. 268.

South of the north end of Pond Rock and east of the Branford-Foxon road, between the main ridge and the first eastern range, much coarse, hard, yellowish-brown to red sandstone occurs together with some layers of shaly and soft stone. Overlying this and at least a third of a mile from the rock, we come upon a peculiar conglomerate containing bowlders and fragments of trap, which will be described later. It is briefly noticed by Percival,* who does not seem to have attached much significance to it. I have not found any bowlders or fragments of trap in the sandstone immediately overlying the trap of the main ridge or in the area just referred to between the coarse conglomerate and the main ridge.

Sandstone and sandy shale are exposed at several places, and to a considerable extent on the east side of Lake Saltonstall. For a third of a mile, beginning just east of the lake, the railroad cuts through two low hills which are composed of shale with an occasional stratum of sandstone. There is some variation of strike and dip in these cuts, but most of the strata of the western cut strike N. 10° E., while in the eastern the general strike is N. 20° E. The dip decreases from 61° E. near the lake, to 42° E. in the eastern part of the eastern cut. This shale is the continuation of that at the northern end of the second member of the main range which dips 75° E. Half way up the lake the eastern bank for several hundred yards is formed by a low bluff of sandy shale having its strike N. 52° E. and its dip 30° E. The lake is a fourth of a mile wide at this point. Within a quarter of a mile of the head of the lake coarse, rather hard sandstone is exposed at the water's edge under overhanging trees. The strike of the rock is N. 12° E., its dip 27° E. The trap is an eighth of a mile distant. Reference to the map will show that the strikes of these exposures of sandstone are nearly parallel to the trend of the heavy trap ridge across the lake from them.

Overlying sandstone is exposed at but few places near the first eastern range, and actual contact is shown at but one place: it is where the Branford-Foxon road crosses the ridge (near I, on the map). At this place a thin layer of very hard sandstone is firmly welded to the trap, which is vesicular. The strike of the strata is generally parallel with the trend of the range and the dip is high and away from the trap.

One contact of the trap of the second eastern range with the sandstone on its eastern side has been observed; this is at and near where the road from Branford village to "Cherry Hill" crosses the ridge. The locality is marked B on the map. Fig. 5 was made from a photograph of the contact exposed by the west side of the road. The strike of the sandstone is

* Geol. Conn., p. 324.

N. 45° E., its dip 60° E. Thirty feet southwest of this point the trap lies upon the edges of the upturned strata of sandstone, forming the contact-breccia from which thin section No. 15 was made. In the old quarry east of the road the eastern sandstone has a *westward* dip. The line of contact showing the gradual overthrow of the dip may be traced from the road into the quarry. North-northeast of this old quarry and nearly half a mile distant on another road much coarse, hard, dark-red sandstone is exposed, having its strike N. 45° E. and its dip 40° E. This exposure is just west of the southern end of the last member of the second eastern range of trap ridges.

Contact phenomena.—Contact with the underlying sandstone. The thin sections already mentioned as from contacts between the trap and the sandstone, when examined under the microscope, show no peculiar character that can surely be assigned to the heated state of the trap at the time of its rising. In No. 21*a*, which is from the contact with the underlying sandstone in the railroad cut through Pond Rock, the line of contact is strongly marked by an almost black band of iron-stained trap. The trap and sandstone seem to be cemented by the Fe_2O_3 rather than by calcite, which appears as amygdules in the trap.—*Contact with the overlying sandstone.* No. 18, from the southern slope of the northern hook of the same ridge, shows this contact. The trap is rather uniformly stained with Fe_2O_3, but there is no band characteristic of the contact, as in the slide just described. In the thin section some small inclusions of trap appear in the sandstone near the contact, but they are irregular in outline and show no signs of having been at all water-worn before they were surrounded by the sandstone. On the other hand particles of quartz, orthoclase and mica are isolated in the trap near the contact. No. 15, from the contact-breccia already described as occurring on the east side of the second eastern trap range, shows small angular masses of trap which appear to have been rolled up in a soft sandy shale and consolidated by Fe_2O_3. There are isolated inclusions of the shale in the trap. Hand specimens from the same locality show fragments of sandstone intimately mixed with the fragments of trap. This slide and No. 18 show a peculiar arrangement of the feldspar crystals in feathery aggregates. These tufts are most noticeable at the contact, but they are not confined to this position, and the ordinary lath-shaped crystals alternate with these aggregates at the contact, while some of the fragments in No. 15 do not show the structure at all. The tufts show only aggregate polarization. That they are composed of altered feldspar seems to be true from the fact that they are seen occasionally to grade off into the common lath-shaped crystals of plagioclase. They do not seem to be sphærocrystals or the result of rapid cooling. No glass has been observed in these specimens, but the trap appears to be holocrystalline, except as alteration has taken place.

The macroscopical contact phenomena are well known, and have been described many times. They are, the induration or "baking" of the sandstone, the change of its color, and the production of chlorite and zeolites in its seams and cavities by the action of steam ; while, in a thick sheet, the trap from the middle is much more coarsely crystalline than that from the sides. Prof. Davis states that the indurating or metamorphic effect of true dikes upon adjacent rocks is slight, and may be taken as extending from the dike to a distance equal to one-tenth of its thickness.* My own observations lead to the conclusion that no rule even approximately correct can be laid down. The most accessible of the pronounced dikes of the third western range are on the road from New Haven to East Haven half a mile east of Tomlinson's drawbridge (at F, on the map), and in the second and third railroad cuts east of Center street, Fair Haven East. The walls of some of these dikes show great variation in the amount of baking done to the different strata composing them. A layer of rock which has been compacted and indurated to a distance of from one to six feet from the trap will be overlain by shaly sandstone or coarse sand which has been affected in this manner but a few inches from the contact, and this in turn will be overlain by indurated rock. A nine foot dike on the East Haven road stands between walls of hard sandstone about 18 inches thick, but the same dike is exposed under a barn 450 to the north with its western wall composed of purplish black sandstone which has been indurated to a high degree for more than eight feet from the trap. The eastern wall has been removed, either naturally or artificially. This variation in the relative amount of baking of the different layers through which a dike has passed may be explained by supposing that some strata contained more water than others which were comparatively dry at the time of the eruption of the trap. Wet sand or other rock material being a better conductor than dry, the heat of the dike would penetrate farther into the wet layers than into the dry ones; furthermore the hot water and steam thus produced would dissolve silica, which, on being deposited again, would cement the particles of sand together. Dry heat not greater than that which the trap probably had at the time of its eruption would have no consolidating effect upon sand composed, as the Connecticut Triassic is, of quartz, orthoclase (and microcline) and mica.

* This Journal, III, xxiv, 346, 1882.

Sandstone containing trap.—This rock may be separated into two classes: (*a*) the contact breccia, which is the result of the rubbing of the trap against the sandstone on its upward or onward passage, (*b*) trap conglomerate, which is, probably, the effect of the action of aqueous forces. The contact breccia occurs on the east side of the range E. 2, (B), on the southern slope of the northern hook of the main ridge (H), and on the northern slope of the southern hook of Toket Mt. The trap-and-sandstone rock lying upon parts of the range E. 2, may possibly belong to this class. The trap conglomerate lies on both sides of the northeastern extension of E. 2, and east of its end, and, as has already been stated, the northern limit of the area is about a third of a mile from Pond Rock where nearest to it.

The region containing the most interesting part of the conglomerate, i. e. the ridges, is about three-fourths of a mile long from S.W. to N.E. and perhaps half a mile wide. There are several of these ridges each of which is from 300 to 400 yards long; and their general trend is N. 25° E. They are narrow, begin and end abruptly, have almost precipitous sides, and rise about 125 feet (aneroid measurement) above the brook and meadow bounding their region on the east and south. The valleys between them are narrow and from 40 to 60 feet deep. The outlines of the bowlder ridges are indicated on the map by dotted lines.

The rock of the ridges is exceedingly coarse. Well rounded bowlders a foot in diameter are very numerous, while others two, three and even four feet long are by no means rare. Much trap is present in the rock. In some of the western ridges the conglomerate is mainly composed of trap fragments with a small amount of coarse sandstone cement; the middle ridges contain many bowlders of quartzite, mica- and hornblende-schist, gneiss and granite; while the eastern ridges seem to have rather more of the latter constituents than of trap. Bowlders of coarse sandstone also occur in this rock, and many of the fragments of trap have coarse sandstone adhering firmly to them and forming a part of the bowlders imbedded in the conglomerate. The pieces of trap are either angular, subangular, or well rounded, compact or amygdaloidal, and quite fresh or much decomposed. Many of them contain long, vermiform cavities, either empty or filled with calcite, like the trap of the southern end of the ridge next west of Pond Rock. But few trap bowlders and those widely scattered occur in the western and southern part of the conglomerate area.

Main theories as to the origin of the trap.—Prof. Davis, in connection with his bibliography of the subject,* has given

* Bull. Mus. Comp. Zool., vii, 1883.

an abstract of the views of most of the writers who have dealt with the Triasssic trap; those, therefore, who desire to investigate in detail the history of the discussion are referred to his article. In 1833, Pres. E. Hitchcock supposed that the trap ridges were overflow sheets contemporaneous with the deposition of the sandstone;* but afterwards he modified his views so far as to hold that some of the sheets were intrusions.† H. D. Rogers claimed that the trap of the New Jersey Triassic region was erupted "through a series of nearly parallel fissures in the strata, and after their consolidation and subsequent disturbance."‡ Prof. J. D. Dana adopts this theory to account for the trap of the Connecticut valley Triassic.§ Most writers on the subject agree to the latter view, but Prof. Davis sustains the former, taking the ground that, while some of the ridges are intrusions, most of them are overflows, and that all were ejected before the tilting of the strata took place;‖ and further, that the present tilted position of the trap is due to monoclinal faulting of a sandstone-and-trap formation.

In the New Haven region the West Rock range, Pine and Mill Rocks, and the East Rock series of ridges are regarded by Prof. Davis as intrusive sheets and dikes.¶ The trap ridges in the eastern part of the town of New Haven, already described as the southern members of the third western range, would be recognized as dikes by any observer. In Connecticut it is only with regard to the great ridges which lie in the middle and eastern part of the Triassic area, and extend northward into Massachusetts that there is doubt as to the intrusive or extrusive origin of the trap. Pond Rock is one of these ridges; and this ridge, together, with its associated ranges, has been taken by Prof. Davis to be typical of the whole Connecticut system.** He says that Pond Rock is an overflow sheet on account of "its small metamorphic effect at the base, its decided amygdaloidal texture on its back or upper surface, its irregular and brecciated structure, and its alteration and hydration."†† The following facts bear on these arguments.

At the section exposed in the railroad cut the underlying sandstone was indurated for four or five feet from the trap. The thickness of the trap sheet here is about 84 feet. The extent of the induration is not proportionally much different from what is shown at undoubted intrusions, but I have already

* Rep. on Geol., Min., etc., of Mass., 1833, p. 243.

† Final Rep. on Geol. etc, of Mass., 1841, p. 653, but cf. p. 526.

‡ Rep. on the Geology of New Jersey, 1836, p. 160.

§ Manual of Geology, 1880, p. 423.

‖ This Journal, III, xxxii, 344, 1886.

¶ Seventh Ann. Rep't U. S. G. S., p. 463.

** Ibid. p. 346. See also 7th Ann. Rep. U. S. G. S., p. 478, where special stress is laid upon Pond Rock.

†† Bull. Mus Comp. Zool., vii, 269. Cf. this Journal, III, xxxii, 347, 1886.

shown that the absence of extensive baking of the contiguous strata would not alone prove much regarding the heat of the trap. Furthermore, as heat is propagated more readily in the direction of the strata than perpendicularly to them, the consolidating effect of a mass of trap lying conformably upon the sandstone would not be apparent as far from the contact as it would from trap intersecting the strata.

The amygdaloidal or, rather, the vesicular structure of eruptive rocks is supposed to have been produced wherever diminution of pressure allowed the highly heated water contained in their mass to expand into steam. The most favorable place for the production of vesicular lava is the upper part of a subaerial flow; but that the formation of vesicular lava, or trap, has not been confined to subaerial or subaqueous flows has been proven by the amygaloidal character of some of the dikes in the first and third ranges west of Pond Rock. The six inch band of amygdaloid at the botom of the main trap sheet can not be used as an argument either way, for it can be explained easily whether the trap be intrusive or extrusive.

The "irregular and brecciated" structure of the ridge is best shown at the junctions between the first and second and the second and third parts of it, and is not well developed anywhere else. Such a structure would be produced by the sudden cooling of liquid rock, and is frequently found near the walls of anhydrous as well as of hydrous dikes and intrusive sheets. Decomposition has been more extensive in the hydrous trap than in the other, which brings out the structure more plainly. A low dike about 130 feet wide is exposed on Farren Avenue, Fair Haven, the rock of which is as much broken and decomposed as that at the lake. This is distinctly a dike, the strata across which it cuts being exposed on each side of it. This "brecciated structure," therefore, being produced by local conditions, proves nothing with regard to the intrusive or extrusive character of a trap sheet.

The "alteration and hydration" of the Pond Rock trap is Prof. Davis's fourth argument for the extrusive, or overflow, character of the sheet. The alteration of the rock of this ridge varies greatly in degree, in different places. At the foot of the lake and at the railroad cut, decomposition has gone so far as even to destroy the crystalline texture of the rock, but the trap of most of the ridge is dense, tough and sublustrous and shows its crystalline structure plainly, though much chlorite is present. Slide No. 23 is from the middle of the sheet on the northern hook of the ridge. The Farren Avenue dike is thicker than the Pond Rock sheet at either the wagon-road or the railway crossing and is much decomposed throughout its mass; and many of the dikes and intrusive sheets which form the range next west of Pond Rock show as much hydration as any part of the great ridge itself, so far as macroscopical examination goes. The lavas of Kilauea show no hydration of their constituents, and other modern lavas are like them in this respect. Daubrée has shown experimentally that liquid rock under great pressure will absorb into its mass vapors from surrounding material, and hence that the vapors formed by liquid rock ascending through wet porous rocks may find readier means of egress with the moving mass than back through the interstices of the porous rock against hydrostatic pressure. The present hydrated or non-hydrated character of the trap, therefore, is not dependent upon its being an overflow sheet: it may be due to the nature of the strata through which it passed.

Better than all this negative evidence as to the character of Pond Rock is the positive testimony of the overlying sandstone and shale. Wherever these are exposed near or against the trap their dip is much higher than that of the rock underneath the sheet (vid. pp. 28, 29 supra); the difference of dip between the underlying and the overlying strata in the railroad cut being 35°, and on the northern hook of the ridge 17°. The *overlying* sandstone on the northern hook is hard baked, and at the contact is mixed with the trap in such a way as to show that it must have been laid down before the advent of the trap (vid slide No. 18), and also that the difference of dip cannot be ascribed entirely to lateral shoving since the eruption of the trap. These facts appear to sustain fully the conclusion that Pond Rock is an intrusive sheet.

The breaks in the southern part of the ridge, near the railroad cut and at the foot of the lake, seem to be due to irregularities in the original fissure rather than to faulting after the trap was in place.* The thickness of the trap sheet diminishes greatly and rapidly at each place, leaving a narrow isthmus to connect the larger portions. The sheet thins from 225 feet, a short distance north of the railroad, to 84 feet in the cut and thickens again to 250 feet or more in the second part of the ridge; while at the foot of the lake the trap is apparently less than 40 feet in thickness. The isthmus at the cut is very short, but from the end of the lake the narrow portion extends more than 200 feet southward. If these were faults we should expect to find approximately the same thickness of the trap sheet on both sides of the fault-plane, unless the trap on one side had suffered more from erosion than the other. That the narrowing in Pond Rock is due to the original fissure and not to erosion, glacial or other, is proven by the presence of

* Prof. Davis says that these notches are "oblique faults" in the trap. Vid this Journal, III, xxxii, 346, 1882.

the overlying shale on the thin part. Again, there should be close similarity between the rocks on each side of such small dislocations as these are, if they were faults; but the trap rock in the necks is much more fractured in structure, than it is either just north or south of them, which is a result of its being thinner at the time of eruption and therefore more rapidly cooled.

The crescentic form of many of the outcrops of the trap has called out much speculation as to its origin. The best examples of these "crescents" are Pond Rock and Toket Mt. Prof. Davis advances the idea that the form is due to "a combination of faults and faint dish-like folds,"* and would make the ranges east of Pond Rock confirm the theory, saying that the second range is but the eastward outcrop of the first, brought up by the saucer-like synclinal. The facts do not appear to me to support this conclusion. His scheme demands that the sandstone near the second eastern range should dip to the west, while that below and above the southern portions of the main sheet and the first eastern should dip northward. But the sandstone on both sides of the main sheet in the railroad cut dip 16° south of east; at the foot of the lake the direction of dip is about the same, and there is no reason to suppose that there is any change throughout the remainder of the ridge, which is short and nearly straight. No outcrop of the sandstone has been observed near the southern end of the first eastern range, but the shales in the railroad cuttings just east of the lake, and on the Branford turnpike very near the crystalline rocks, dip high to the south of east. At two places half a mile apart, near E 2, the sandstone is exposed with its strike N. 45 E., and its dip at one place 60° and at the other 40° toward the southeast, while the only westward dip observed in connection with this range is in the old quarry east of the road from Branford to "Cherry Hill," and this is probably due to an overthrow by the trap. Fig. 1 was prepared from data obtained in the field. Near the northern part of the main sheet and the first eastern range most of the sandstone is conformable with the trap.

Concerning Pond Rock and Toket Mt., which he considers parts of one great sheet, Prof. Davis says: "Toket Mountain is not separated from Pond Mountain by a fault, but by erosion on a transverse flat-arched anticlinal, clearly defined by the dip of the adjacent conformable sandstones." † A faintly developed transverse anticlinal is called in to explain a slight indentation in Toket Mt. north of its middle, and a large one

*This Journal, III, xxxii. 347, 1882. In the 7th Ann. Rep't U. S. G. S., just issued, this theory is more fully worked out.

† This Journal, III, xxxii, 347, 1882.

to account for the wide separation of the Mt. Holyoke and Deerfield ranges in Massachusetts, besides others of greater or less extent for other parts of the valley. The cause assigned for the production of these "transverse anticlinals," is that they would be a result of the general movement which caused the usual eastward dip of the sandstone, acting in connection with an uneven foundation of gneisses and schists. Horizontal compression produces folds the axes of which are at right angles or nearly so to the direction in which the force acts. Prof. Davis's theory, however, demands the frequent repetition on large and small scales of very peculiar conditions in the crystalline rocks, which as yet have no proof in observation and do not seem to be probable; and it seems to necessitate a homogeneity and a tenacity in the sandstone which that rock does not possess. Further evidence against his "faint, dish-like folds" is found in the broken character of the subordinate ranges, and in the high southeastward dip of the sandstone near the range E2 and the whole southern part of the Pond Rock region. The strike of the sandstone in the southern part of the Connecticut Triassic region, except in some places near the trap, may be taken as averaging N. 15° E., therefore the tilting force must have acted from S. 75° E. with considerable constancy: such a force could not have produced an anticlinal like that between Pond Rock and Toket Mt. The underlying shale on the northern hook of the former has its strike S. 69° E., and its dip 23° S., while the sandy shale three quarters of a mile away beneath the latter strikes S. 65°–70° E., and dips 18° N. There are some irregularities of strike and dip in the valley between the mountains but the axis of the arch may be taken as being W.N.W.–E.S.E., or nearly parallel to the direction of the general force tilting the strata of the Connecticut valley Triassic. Since the transverse anticlinal cannot owe its existence to the general tilting force, it may be assigned to another one, viz: dikes having a general W.N.W. course, most of which have not yet been exposed. A ridge which may be the southeastern of such a line of dikes is exposed northeast of the end of Pond Rock on the Branford–Northford road. The exposure is some 500 feet long on this road and the crossroad to North Branford village, and is about 100 feet wide. No sandstone is exposed near it to prove or disprove the theory. It may be of interest to note, in passing, that this little ridge is curved with convexity to the west. The range of trap ridges next west of Toket Mt. ends at the entrance to this transverse valley (K, on the map); if extended, it would join the trap ridge just described and satisfy the theory. The observations necessary to establish this theory for other localities have not been made.

H. D. Rogers proposed a theory to account for the crescentic form of the ridges in New Jersey, which will hold very well for those in Connecticut, especially if the theory just proposed to account for the dip of the underlying sandstone be correct. He said: "The sandstone being disrupted in a plane parallel to the dip, the beds on the upper side of the sloping dyke will be lifted off from those upon which they reposed, and in this tilting of the beds, there will arise towards the extremities of the fissure seams or transverse cracks extending in the direction of the dip."* This theory readily accounts for the conformability of the overlying sandstone in the "hooks," for the trap flowing into these transverse cracks would modify the dip of the upper sandstone so as to make its direction more or less nearly the same as the slope of the upper surface of the intrusive rock. That the fissures were sometimes originally curved is shown by curved dikes and lines of dikes in the region west of Pond Rock, while the curved outline of many of the ranges in the whole valley is produced by what Percival calls the "advancing or retreating order" of position of nearly straight fissures. It has been shown experimentally that when one set of fissures is produced in strata, another subordinate set transverse to them may be produced at the same time; this fact would explain the network of dikes east of Foxon in the northern part of East Haven.

Hemingway mountain is another of the trap ridges in the region which Professor Davis has claimed to be overflow sheets. Its intrusive character is shown at its northern end where the extremity of the trap sheet stands between walls of sandstone, both of which have been much indurated and otherwise affected by the heat of the trap; and is also indicated by the trap of the ridge next west, which is exposed almost horizontally between strata of sandstone, the upper of which it has penetrated and scorified as well as hardened. North and northwest of Hemingway mountain, within a mile, there are several high ridges which seem to be dikes; they begin and end abruptly and both sides are precipitous, while the outliers of some of them are seen squeezed in between layers of sandstone. The sandstone has been indurated to such an extent and degree that it stands in ridges as high as those of the trap with sides almost as steep.

The heavy trap conglomerate south of the north end of Pond Rock is a puzzling factor in the problem, not only on account of the trap in it and its relation to the trap ridges near which

* This Journal, xlv, 334, 1843. Report of meeting of the Association of American Geologists and Naturalists. At this meeting a committee, consisting of Professor Silliman, J. D. Whelpley and H. D. Rogers, was appointed to determine, if possible, the correctness of this theory. I have not found any report of the results of their investigations.

it occurs, but also on account of the great size of the bowlders composing it. In the southern part of the Connecticut valley this heavy conglomerate occurs only in connection with the ranges of trap southeast of Toket Mt. and those east of Pond Rock, all of which are very near the eastern crystalline rocks. The most probable sources of the trap in the conglomerate are the heavy sheets near by, though the bowlders do not much resemble the trap of the great ridges. But the conglomerate does not affect the question of the intrusive or extrusive origin of Pond Rock and Toket, for in each case much comparatively fine sandstone containing no trap except such as forms a contact breccia lies between it and the main ridge. The formation is older than the ranges east of Pond and Toket; for the trap of the range east of the latter lies on top of it, and that of the ranges east of the former intersects it.

The age of the trap.—Professor Davis concludes that all the trap was ejected before the tilting of the sandstone took place. This does not appear to be true in the region I have examined. The sandstone of the western part of the region was much faulted and broken in the process of upheaval; but the true dikes do not appear to have been faulted, and therefore must have been formed since the tilting of the strata. The fissures through which the trap came up may have been made in connection with the tilting. Pond Rock is an intrusive sheet, but the evidence regarding its age seems to be incomplete. It is certainly more recent than the youngest strata now exposed in this part of the valley (except the trap conglomerate), for it is intruded between them. The crescentic form, if we accept Rogers's theory of its origin, might be taken as an indication of intrusion after the tilting. If Pond Rock be of more recent date than the upheaval of the sandstone, then the first eastern range is still more recent, for its northern members separate the strata of the conglomerate which was probably derived in part from Pond Rock. If we make Pond Rock intrusive after the tilting, we must suppose the heavy trap conglomerate to have been made later than the Triassic era; which may be a rather violent hypothesis, as unconformability between the conglomerate and the sandstone has not been proven. The second eastern range consists of dikes, as is shown by the dip of the adjacent sandstone and the position of the trap with reference to it; and, on the same evidence as is presented by the western dikes, these are more recent than the tilting of the sandstone.

Conclusions.—My observations, then, lead me to agree with Professor Davis in so far as to make some of the trap older than the very last of the sandstone formation. Probably Pond Rock is this older trap; and the southern part of the range

W. 1 also may antedate the tilting of the sandstone. I differ from him, however, in making all the trap of the East Haven-Branford region intrusive, and the western dikes, at least, of later origin than the tilting of the sandstone.

NOTE.—On the accompanying map the exposures of trap are represented by solid black areas, except that the trap of Pond and Toket Mts. is cross-lined. Separate ridges that are supposed to be connected near the surface of the earth are joined by a light line. Where sandstone has been observed between the ridges of trap, the fact has been indicated by thickly-set dots. Some strikes and dips of the sandstone have been recorded by using T's and placing the number of degrees from the horizontal near the stem and the declination from north or south near the cross line. The small circles in E. 2 represent the trap-and-sandstone rock there. In the figures trap is indicated by crossed lines; and sandstone and shale by parallel lines, the former by those which are the farther apart.

A—Silver-seeker's trench, west side of Pond Rock, sandstone.
B—Contact of trap of E. 2 with sandstone where the road from Branford to "Cherry Hill" crosses the ridge.
C—Lyman Granniss's house.
D—Exposure showing dike-like character of some members of W. 1.
F—Dikes on the road from New Haven to East Haven.
G—Dike in second railroad cut east of Center st., Fair Haven.
H—Exposure of overlying sandstone, northern hook of Pond Rock.
I—Branford-Foxon road.
K—Southern end of trap range next west of Toket Mt.
L—Southeastern end of range from Peter's Rock.
M—Southern end of ridge next north of Hemingway Mt. where it lies between layers of sandstone.
O—Southern most exposure of trap conglomerate.
P—Triple ravine formed by ridge of sandstone jutting into a ravine in the trap of Pond Rock.
Q—Complex set of dikes northeast of Foxon. No sandstone is exposed between these ridges and there probably is more or less connection between most of them. They seem to occur along two or three lines.
R—Exposure of sandstone near northwest angle of Pond Rock. Strike S. 87° E., dip 23° S.

Yale University, June, 1889.

Art. XLVIII.—*A Theory of the Mica Group*; by F. W. Clarke.

Ever since its publication in 1878,* in spite of a few dissentient voices, Tschermak's theory of the mica group has been generally in vogue. Nevertheless, upon careful inspection, the theory seems open to serious objections. In brief, omitting details for the present, Tschermak regards the micas as made up of four fundamental molecules; to which the following formulæ are assigned:

1. $R'_6Al_6Si_6O_{24}$.
2. $Mg_{12}Si_6O_{24}$.
3. $H_8Si_{10}O_{24}$.
4. $F_{24}Si_{10}O_8$.

R' stands obviously for K, Na, Li, or H; Mg is equivalent to Fe'', and aluminum may be replaced by ferric iron. The first of these formulæ represents fairly well the composition of normal muscovite and paragonite; the only objection to it being that, as used by Tschermak, it assumes the double atom of quadrivalent aluminum. Since it has been proved by Nilson and Petterson, Combes, Quincke, and others, that aluminum is truly trivalent, the formula should become $R'_3Al_3Si_3O_{12}$; which, as I have shown in several previous papers, may be regarded as a substitution derivative of normal aluminum orthosilicate.

The second, third, and fourth of Tschermak's formulæ represent hypothetical compounds; the second being a polymer of chrysolite, to which, in nature, some varieties of talc offer the nearest approximation. The third and fourth formulæ are analogous to no known substances, and are, moreover, improbable chemically. No mica, by itself, resembles in composition either of the three. One formula, then, corresponds to an observed mineral, while the others are purely speculative; a state of affairs which is not altogether satisfactory. Furthermore, the four formulæ represent as many distinct chemical types, whereas it would seem as if all the true micas should be reducible to one general form, under which their isomorphism would be more readily intelligible.

There is still another objection to Tschermak's system of formulæ, which, if sustained by future investigation, will be fatal. Under his theory the ratio of oxygen to silicon in the micas can never exceed four to one; while the published analyses of micas often show values far higher, ranging in

* Ber. Wien. Akad., lxxviii, 5. Zeitschr. Kryst., iii, 122.

some cases nearly up to five. In certain instances, as Tschermak himself suggests, this excess of oxygen over the orthosilicate ratio may be due to water enclosed between micaceous laminæ; and in other cases it may indicate partial alteration. There are micas, however, in which neither of these explanations appears to be satisfactory, and the weight of evidence goes to show that the excess of oxygen is essential. If this be true, Tschermak's theory is so far inadequate; for to such micas it cannot apply without serious modification. The question can only be settled experimentally, but at present the objection raised by it cannot be ignored. Some of its details will be considered later.

Now, in order to conclusively replace Tschermak's theory by something better, two fundamental conditions must be satisfied. First, all micas, with the possible exception of the pseudomica, margarite, should be reducible to one general type of formula, which shall express all known relations equally well with the formulæ proposed by Tschermak. Secondly, hypothetical compounds must be so far as possible avoided, and admitted into consideration only when their assumption can be shown to be absolutely necessary. The chief difficulties to be overcome are the variations in the silicon-oxygen ratio, and the presence of fluorine in many common micas.

In a number of papers published during the past four years,* I have sought to show that all orthosilicates containing aluminum may be represented as substitution derivatives of the normal salt $Al_4(SiO_4)_3$. Muscovite can be so derived, theoretically, through the replacement of one aluminum atom by R'_3; and in many other cases we have equal simplicity of expression. The ferro-magnesian micas, the phlogopites, and the lepidolites, however, are less simply derived; and I have in certain cases suggested a linking together of two orthosilicate nuclei to the group $Al_2(SiO_4)_6$ in order to account for their formation. I am now inclined to believe, however, that all the true micas are referable to the same general type, and have discussed nearly one hundred published analyses from that point of view. If we take magnesium as a generic representative of the bivalent metals, and give univalent elements or groups the general symbol R, we can imagine the following derivatives of $Al_4(SiO_4)_3$ as easily possible.

$$\begin{array}{ccc} 1. & 2. & 3. \\ Al\begin{cases} SiO_4\equiv R_3 \\ SiO_4\equiv Al \\ SiO_4\equiv Al \end{cases} & Al\begin{cases} SiO_4\equiv R_3 \\ SiO_4\equiv R_3 \\ SiO_4\equiv Al \end{cases} & Al\begin{cases} SiO_4\equiv R_3 \\ SiO_4\equiv R_3 \\ SiO_4\equiv R_3 \end{cases} \end{array}$$

* See this Journal, Nov., 1886 and Aug., 1887. Also Amer. Chem. Journ., x, 120, March, 1888.

4.	5.	6.
$\diagup SiO_4\equiv MgR$	$\diagup SiO_4\equiv MgR$	$\diagup SiO_4\equiv MgR$
$Al-SiO_4\equiv Al$	$Al-SiO_4\equiv MgR$	$Al-SiO_4\equiv MgR$
$\diagdown SiO_4\equiv Al$	$\diagdown SiO_4\equiv Al$	$\diagdown SiO_4\equiv MgR$

To these we may add, as No. 7, the compound $Al_2(SiO_4)_6Mg_9$, the bivalent analogue of No. 3, and identical in type with it. Now, so long as we have only orthosilicate micas to consider, these seven formulæ cover all their variations in composition; provided that fluorine, when present, is represented either by $-Mg-F$ or $-Al=F_2$, univalent groups which are included under the general symbol R′. Most of the micas appear as intermediate mixtures of these presumably isomorphous types. No. 1 represents muscovite and paragonite, and No. 6 agrees tolerably with some phlogopites. No. 2 may be resolved into a mixture, in equal molecules, of No. 1 and 3; and similarly No. 5 may be regarded as composed of Nos. 4 and 6. Nos. 5 and 6, moreover, may be simplified into mixtures between 3 and 7, so that numbers 1, 3, 4 and 7, represent all the necessary relations. Even No. 4 is possibly superfluous.

So much for the normal orthosilicate micas. But in the lepidolites, phlogopites, and some muscovites, the oxygen-silicon ratio is low; and in the lepidolites especially it approximates more or less closely to the metasilicate type. This order of variation is clearly established, while variations in the opposite direction, that is toward excess of oxygen may be questionable. If, however, in any mica the oxygen, can be properly in excess of SiO_4, that excess may be fairly regarded as present in the group $-Al=O$, which is obviously equivalent to $-Al=F_2$, and takes place with the latter as a part of R′. Examples of this kind are given in one of my former papers.* In all such cases the system of formulæ proposed above applies perfectly, and needs no qualification. The variations in R′ always fall within its limits.

The lower values for the silicon-oxygen ratio are explicable as follows: The polysilicic acid $H_4Si_3O_8$, which, like H_4SiO_4 is tetrabasic, is represented in nature by orthoclase and albite. In anorthite we have an orthosilicate, and its mixture with albite gives, as is well known to all mineralogists, the intermediate triclinic feldspars in which pseudo-metasilicate ratios often appear $H_4Si_3O_8+H_4SiO_4=H_8Si_4O_{12}=4H_2SiO_3$. If we assume a similar state of affairs among the micas, and regard orthosilicates and polysilicates as isomorphously miscible, the lepidolites and other low-oxygen micas are completely accounted for. We have then the same system of general formulæ for all micas, the normal salts $Al_4(SiO_4)_3$ and $Al_4(Si_3O_8)_3$ being the theoretical starting points for derivation. In every

* This Journal, Aug. 1887, p. 131.

case the composition of a mica becomes reducible to the one general type, under the proposed theory of substitution. Representing the groups SiO_4 and Si_3O_8 by the common symbol X, the micas all fall within limits indicated by the formulæ $Al_3X_3R'_3$, and $AlX_3R'_9$. We may test this principle and the preceding formulæ by application to actual examples, taking the different micas group by group. In general, however, I must omit the details of the individual analyses discussed, as I hope to publish them more fully hereafter.

Muscovite.

This mica, the most typical and most abundant of all, is also the simplest chemically. It is best represented by formula No. 1, which, in its special application becomes ordinarily $Al_3(SiO_4)_3KH_2$, with some variation in the ratio of K to H. In most cases muscovite contains small amounts of magnesia and ferrous iron; and if these are deducted, as shown in formula No. 6, the residue agrees still better with formula No. 1. Fluorine is often present in small quantities, and appears to vary in relation to hydrogen, being lowest when the latter is high, and the reverse. Hence it is probable that the group AlF_2 replaces H rather than K. This is shown more clearly among the lepidolites, in which fluorine reaches a maximum, while the proportion of water is almost insignificant.

Some muscovites, however, vary from the normal compound in that they contain more silicon and less oxygen; thus approaching somewhat to lepidolite. These micas, which Tschermak has called "phengites," are represented by him as mixtures of $Al_6R'_6Si_6O_{24}$ with $H_8Si_{10}O_{24}$ in the ratio of three to one. It is simpler, however, to follow out the analogy offered by the feldspar group, and to assume the existence in muscovite of the isomorphous compound $Al_3(Si_3O_8)_3KH_2$. True, this compound has not been found by itself in nature, and so far its assumption is objectionable. But the compound $H_8Si_{10}O_{24}$ is also non-existent, is different in type from ordinary muscovite, and is not easily conceivable as a definite entity. The alternative which I offer for it is therefore, it seems to me, more philosophical and more satisfactory; and it accounts completely for all the oxygen variations in muscovite. For the sake of brevity, however, we may well retain the name of *phengite* in our vocabulary, and may speak of micas containing the Si_3O_8 groups as more or less *phengitic*.

Lepidolite.

In this species, the most phengitic of all the micas, we find little water, high fluorine, and a very notable proportion of lithia. It always occurs with muscovite, and commonly implanted upon the latter, in such a way as to clearly indicate its later formation. In composition it is regarded by Tschermak as a mixture of $Al_6K_6Si_6O_{24}$ with $F_{24}Si_{10}O_8$, the former being about half replaced by the corresponding $Al_6Li_6Si_6O_{24}$, and the latter in part by $H_8Si_{10}O_{24}$. The objections to this interpretation have already been pointed out.

Under the new mode of interpretation, lepidolite becomes much simpler. In every case, if we eliminate traces of magnesia and iron, as was done under muscovite, the residue corresponds sharply to a mixture of the two molecules $AlX_3R'_9$ with $Al_3X_3R'_3$, X representing Si_3O_8 and SiO_4 indiscriminately. In the purest lepidolites these molecules are in the ratio 1 : 1, corresponding to $Al_2X_3R'_6$; but in general the second molecule is slightly in excess, due to small admixtures of normal muscovite. In the discussion of fourteen published analyses of lepidolite the ratio $Si_3O_8 : SiO_4$ varies from 1 : 1 to 1 : 3; and the sum of $Li + AlF_2$ appears to be directly related to the proportion of Si_3O_8. In brief, expanding the general formulæ given above, typical lepidolite may be expressed by the two compounds $Al_3(SiO_4)_3KHLi$ and $Al(Si_3O_8)_3K_3Li_3(AlF_2)_3$ in equal molecules. All the variations may be accounted for by admixtures of muscovite.

Two other highly fluoriferous lithia micas, cryophyllite and zinnwaldite, may properly be considered here. For the former we have Riggs's analysis, and for the latter, analyses by Berwerth and Rammelsberg. From these analyses we get the following empirical formulæ: 1, Riggs, cryophyllite; 2 and 3, Berwerth and Rammelsberg, zinnwaldite.

1. $Al_{186}Fe''_{94}K_{266}Li_{324}H_{146}(AlF_2)_{178}(Si_3O_8)_{227}(SiO_4)_{186}$.
2. $Al_{239}Fe''_{186}K_{236}Li_{218}H_{102}(AlF_2)_{209}(Si_3O_8)_{161}(SiO_4)_{312}$.
3. $Al_{244}Fe''_{167}K_{242}Li_{224}H_{116}(AlF_2)_{200}(Si_3O_8)_{166}(SiO_4)_{306}$.

Condensing these formulæ they become:

1. $Al_{186}Fe_{94}R'_{904}X_{412}$.
2. $Al_{239}Fe_{186}R'_{766}X_{463}$.
3. $Al_{244}Fe_{167}R'_{782}X_{462}$.

Expanding again, these formulæ give:

1. $31(AlX_3Fe''_3R'_3) + 81(AlX_3R'_9) + 25(Al_3X_3R'_3)$.
2. 62 " + 49 " + 43 "
3. 56 " + 53 " + 45 "

The component molecules here correspond essentially to Nos. 6, 3, and 1 of the fundamental series, the last one in each expression being muscovite. The method of factoring here shown I have adopted throughout my investigation of the micas, and I have found very few trustworthy analyses to which it does not apply. Even the exceptions are apparent only, and can be met by a modification of the process which is somewhat more generalized. Whether the separate components of R′ and of X can be distributed with certainty among the several molecules is an outstanding question, but not, I believe, an unanswerable one.

Phlogopite.

In order to ascertain the composition of this mica I have discussed the four analyses cited by Tschermak, (*l. c.*), and three of Rammelsberg's.* All of these are fluoriferous, and all but one are phengitic, the exception in the latter case being the Edwards, N. Y., mineral, which Tschermak regards as somewhat altered. I have also considered the new phlogopite from Edwards, recently described by Penfield,† which is remarkable as being free from fluorine.

In general, phlogopite agrees quite closely with the formula $AlX_3Mg_3R'_3$, but there are often variations which are not easy to explain, and which are greater than can be accounted for by presumable errors of analysis. They may be due in part to impurities arising from the great alterability of the mineral; but I am inclined to trace the difficulties to other sources.

In order to satisfy the conditions of the formulæ proposed by me, it is necessary that the aluminum atoms, apart from AlF_2, shall be in number at least one-third of X. But in several phlogopites the alumina is too low to fulfil this requirement; and the difficulty is best obviated by assuming an MgF group in place of AlF_2. In Penfield's phlogopite, however, there is no fluorine, and yet the alumina is considerably—about two per cent—too low. If we suppose in his mineral, which came from a talc mine, a small admixture of talc, the residue agrees with the theoretical formula, X being wholly SiO_4. But if that impurity is absent we must assume that the mica differs from ordinary phlogopite by containing the group $-Mg-OH$ instead of the usual MgF. The composition of the mineral then reduces to the uniform type. I am now disposed to believe that phlogopite differs from the other micas in that it contains these special groups MgF and MgOH, both as part of R′; but the supposition is not yet fully justified. It is, however, I think, susceptible of experimental investigation, and a laboratory research upon the problem is now being carried out under my direction. Apart from that, the supposition is strengthened by the composition of certain vermiculites; some of which have certainly been formed by the alteration of phlogopite. Three of these interesting minerals are

* Wied. Annal., ix, 129.

† This Journal, III, xxxvi, 329.

represented fairly well by the subjoined formulæ, in which ferric iron, present in small quantities, has been reckoned with the alumina.

$$\begin{array}{l} \quad \diagup SiO_4 \equiv (MgOH)_3 \\ Al - SiO_4 \equiv Al \\ \quad \diagdown SiO_4 \equiv Al \\ \quad + 3H_2O. \end{array} \qquad \begin{array}{l} \quad \diagup SiO_4 \equiv \\ Al - SiO_4 \equiv \\ \quad \diagdown SiO_4 \equiv Al \\ \quad + 3H_2O. \end{array}\!\!\begin{array}{l} \left.\begin{array}{l} \\ \\ \end{array}\right\} Mg_3 \\ \\ \\ \end{array} \qquad \begin{array}{l} \quad \diagup SiO_4 \equiv MgH \\ Al - SiO_4 \equiv MgH \\ \quad \diagdown SiO_4 \equiv Al \\ \quad + 3H_2O. \end{array}$$

Dudleyite. Culsageeite. Jefferisite.

It is by no means certain that the vermiculites are so simple in composition or so definite as these symbols would seem to indicate; but the formulæ are decidedly suggestive, and they show how clearly the relations between the micas and their derivatives may be expressed.

The ferro-magnesian micas.

This group of micas, which includes biotite, lepidomelane, annite, haughtonite, siderophyllite, and other supposed species, is apparently quite complex. In place of magnesia, ferrous iron is often predominant; in the lepidomelanes, ferric iron replaces aluminum, and in forty-four out of the fifty-six analyses discussed, the oxygen was in excess of SiO_4. Only seven of these micas appeared to be phengitic; and only sixteen of the analyses reported fluorine in small quantities. In six instances AlO and AlF_2 were both absent.

For thirty-four of the micas in this group, formulæ could be easily computed upon the lines already followed. That is, in each case the composition was represented by a mixture of $AlX_3R''_3R'_3$ with $AlX_3R'_9$ and $Al_3X_3R'_3$, the second or third of these molecules being occasionally absent. Among the lepidomelanes there was an approximation to a distinctively muscovitic type; and in two cases formula No. 4, $Al_3X_3R''R$, seemed to apply. With each mica an attempt was made to determine the proportions of the several admixed molecules; but the results, although numerically conformable to the general theory, were not absolutely conclusive. The chief difficulty lay in the uncertainty attaching to the water determinations, upon which the question of oxygen excesses depends. Since water has a low molecular weight, a small error in its estimation becomes relatively large in the molecular ratios; and two sorts of errors are presumable. First, an excess of water may be enclosed mechanically in the material analyzed; and secondly, a determination by simple ignition is likely to be too low because of the oxidation of ferrous iron. If these errors occur together, they obviously tend to compensate each other; but either one alone seriously affects the coefficient of R′, and appears in the ratio between $Al_3X_8R'_3$ and $AlX_3R'_9$.

In twenty-two of the fifty-six analyses, however, the symbol $AlX_3R''_3R'_3$ failed to account for all the bivalent metals, iron and magnesium. In these cases R″ was in excess of R′, and it became necessary to make use of formula No. 7, $Al_2(SiO_4)_6R''_9$. With the aid of this expression, all the ferro-magnesian micas without a positive exception, including the phlogopites, were resolvable into mixtures of $Al_3X_3R'_3$, $AlX_3R'_9$, and $Al_2X_6R''_9$. Upon this basis formula No. 6 becomes useless, for $AlX_3Mg_3R'_3$ is evidently equivalent to a mixture, in equal molecules, of $AlX_3R'_9$ and $Al_2X_6Mg_9$. All micas, then, so far as the analyses are authentic, may be represented as mixtures of the molecules 1, 3, and 7, these being symbols of one and the same general type. The magnesium (or ferrous) salt thus assumed, moreover, is not absolutely hypothetical; for, with six molecules of water of crystallization added it approximates to certain individuals of the chlorite group. Some examples of penninite, for instance, approach rather closely to the composition $Al_2(SiO_4)_6Mg_9 . 6H_2O$, which requires 38·71 of silica, 10·97 alumina, 38·71 magnesia, and 11·61 water. We have thus a clue to the constitution of the chlorites, by means of which they may be brought into simple relations with the micas. This problem is now under investigation, and I can only state as a probability that most of the chlorites, if not all, may be represented as mixtures of three fundamental molecules, $Al_2X_6R''_9$, $6H_2O$; $AlX_3R''_3H_3$, $3H_2O$; and $Al_2X_3(MgOH)_6$. I hope to speak more positively upon this subject before long; at present I need only point out that two of these molecules are simple hydrates of Nos. 6 and 7, while the third is covered by the general symbol No. 3, in which R'_6 becomes $(MgOH)_6$. The easy alterability of garnet, $Al_2(SiO_4)_3R''_3$ into mica and chlorite, is a suggestive bit of evidence bearing upon these expressions.

Margarite.

Whether this species is to be considered as a true mica or not, is perhaps an open question. Its composition is relatively simple, and is represented by the empirical formula $H_2CaAl_4Si_2O_{12}$. Structurally, this may be written in two distinct ways, as follows:

$$Al\begin{cases} OH \\ SiO_4\equiv CaH \\ SiO_4\equiv (AlO)_3 \end{cases} \quad \text{or} \quad Ca\begin{cases} SiO_4\equiv (AlO)_2H. \\ SiO_4\equiv (AlO)_2H. \end{cases}$$

The first of these symbols derives the compound from the normal aluminum salt, and indicates a similarity of type with the micas proper. The second assumes a normal calcium salt as the point of derivation; and I am unable as yet to assign a distinct preference to either expression. A careful study of the genesis and associations of margarite may determine which of the two formulæ is the better. Possibly the occurrence of the mineral in such mixtures as euphyllite, and the probable existence of a similar barium salt in œllacherite points to the first of the two formulæ as the better. The common occurrence of margarite with diaspore also points in the same direction.

The Clintonite group.

These minerals, the so-called "brittle micas," have also been discussed by Tschermak,* who includes under this heading seybertite, brandisite, xanthophyllite, chloritoid, masonite, ottrelite, sismondine, and sapphirine. Physically, they are closely related to the micas proper, and to margarite in particular; but chemically they are much more basic. The first three species Tschermak regards as mixtures of the hypothetical compounds $H_2CaMg_4Si_3O_{12}$ and $H_2CaMgAl_6O_{12}$; to chloritoid he assigns the composition $H_2Si_2Fe''_2O_7 + H_2Al_4O_7$, and sapphirine he represents by the formula $Si_2Mg_2O_6 + Al_6Mg_2O_{11}$.

Using the analyses cited by Tschermak, I find that all these minerals, with the possible exception of sapphirine, may be represented by the general expression

$$Al\begin{cases} \begin{matrix} O \\ O \end{matrix} > R'' \\ SiO_4 \equiv R'_3, \end{cases}$$

which is clearly and directly related to the formulæ already assigned to the micas and to margarite, and in which the mode of union of R'' with Al, when $R''=Mg$, suggests the common association of members of this group with spinel. In seybertite we have a mixture of $AlO_2R''SiO_4(MgOH)_3$ with $AlO_2R''SiO_4(AlO)_3$, R'' being partly Ca and partly Mg. In brandisite we have a similar constitution, with about one fourth of R'' replaced by H_2. In chloritoid, $R''=Fe$ and $R'_3=H_3(AlO)$; and sismondine is similar, with R'_3 possibly replaced in part by Al. The compound $AlO_2MgSiO_4(AlO)_3$, found in seybertite, is a rough approximation to sapphirine, which mineral possibly has this composition plus some impurities as yet unidentified. A wider range of analyses is needed in order to establish these formulæ completely; but they seem to have distinct advantages over the formulæ proposed by Tschermak.

Conclusions.

All the micas, vermiculites, chlorites, margarite, and the clintonite group may be simply represented as isomorphous

* Zeitschr. Kryst. Min., iii, 496.

mixtures, every constituent being a substitution derivative of normal aluminum poly- or ortho-silicate. To the latter compound a structure may be assigned somewhat different in form from the one I have chosen, without affecting in any notable way the general system adopted. Upon this basis all the minerals named are reducible to the same general type, which accounts for observed isomorphisms, and for the relations of the micas to other species, with fewer assumptions of hypothetical compounds than are necessary under other known schemes of interpretation. In most cases the evidence is clear, direct and conclusive; in other cases, few in number, it is at present somewhat obscure. It may be claimed, without extravagance, that the formulæ have the merit of suggestiveness, and that they form a scientific basis for future research.

Washington, July 15, 1889.

Art. XLIX.—*The Probable Law of Densities of the Planetary Bodies;* by Robert Hooke.

As far as the writer is aware no inquiry has ever been made into the connection between the diameters and mean densities of the planetary bodies, or if such inquiry has been made we have no record of the result arrived at; yet it is an interesting subject of investigation, and in the light of modern science it is to be wondered at that the subject has not attracted the attention of some investigator long before this. Some three years ago the attention of the writer was accidentally directed to this subject through the reading of Professor Newcomb's Popular Astronomy, and the result of the investigation, which is now given publicity for the first time, was quickly arrived at, owing to its very simple character.

In the absence of knowledge respecting the law of compressibility of matter as it exists in the planets, it was impossible to formulate the law of relative density of planetary bodies, of different diameters, from theoretical considerations. It was therefore necessary to determine the law by experiment alone, and the experiments must, from necessity, be the great natural ones presented by the planets themselves. It was necessary at the very outset of the investigation to adopt the hypothesis—that the planets were formed of the same material, or to put it more accurately—that the material which forms the principal part of the masses of the planets and their satellites would, when subjected to the same conditions of temperature and pressure, have the same density. Under this hypothesis the difference between the mean and surface densities of the earth was due alone to the compression to which the matter in the interior of the earth is subjected, and the difference in the mean densities of the moon and the inner planets, to the different degrees of compression which has been produced by gravity in the interior of their masses. It was clear that, under this hypothesis, all of the bodies referred to would have the same surface density, provided they had reached the same physical condition, that is, the condition of solidification.

In the selection of the planetary bodies for the purpose of experiment, to determine the law of density, and also the bodies to which the law indicated may be applied as a test of its correctness, it was necessary to arrange the bodies of the solar system into two classes, the first to embrace those in which solidification had taken place, and which, under the adopted hypothesis, would have the same surface density; and the second, those bodies which had not reached the solid state, and in which there was an expansion of volume beyond that which they would have in the solid condition. It is clear that with the latter class the surface density would probably be different with each body. Therefore the bodies to be selected for the experiment, to determine the law connecting the density with the diameter, and also the bodies to which the law indicated must be applied as a test, must belong to the first class. Though the law in question, when determined, would not be applicable to the planetary bodies of the second class in their present condition, yet it could be applied to the computation of the ultimate diameters and mean densities of those bodies, that is, the diameters and mean densities they will have when they reach the condition of solidification.

The planetary bodies which were assumed to belong to the first class are the earth, the moon, and the planets Mars, Venus and Mercury, and probably also the satellites of the outer planets ; and those belonging to the second class are the outer planets, Jupiter, Saturn, Uranus and Neptune, and also the sun. The evidence to justify the foregoing classification will be referred to in the concluding remarks of this paper.

In seeking for the law connecting the mean density with the diameter it was clear that no attempt should be made to find the law connecting directly the diameter with the mean density as a whole, but simply with that part of the mean density which was due to compression, or, in other words, to find the law connecting directly the diameter with the difference between the mean and surface densities. This made it necessary to adopt some value for the surface density of the bodies selected for the investigation, which were those in which the greatest accuracy had been attained in the determination of their mean densities and diameters, namely, the earth and the moon. And the value adopted for the surface density of the two bodies, was the mean of the following values assigned to the earth's surface density by eminent authorities:

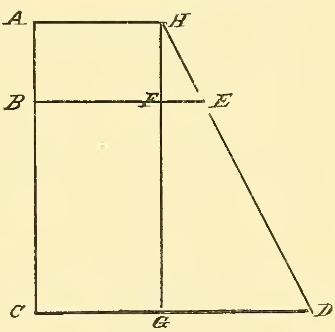
Laplace	2·50
Airy	2·56
Waltershausen	2·66
Mean of the above values	2·57

The values of the mean diameters and mean densities of the earth and moon used in the investigation, are as follows:

Mean diameter of the earth	7918 miles.
Mean diameter of the moon	2160 "
Mean density of the earth	5·66 that of water.
Mean density of the moon	3·42 " "

(All of the densities given in this article are relative to that of water, which is taken as 1.)

Let AB, on the diametral scale, represent the diameter of the moon, and AC the diameter of the earth; draw CD, on the scale of density, for the earth's mean density, BE for the moon's mean density, and AH for the density of a planetary body whose diameter is supposed to equal 0, and also for the surface density of the earth and moon; draw HG parallel to AC, and we have GD for the difference between the mean and surface density of the earth, and FE for the difference between the mean and surface density of the moon.



Adopting for AH, BE and CD, the values given above for the earth's surface density, the moon's mean density and the earth's mean density, respectively; and for AC and AB the values given for the respective diameters of the earth and moon, we perceive that the point E lies so nearly in a straight line connecting H and D, that it is highly probably that

$$FE : GD :: AB : AC.$$

From the above simple investigation we conclude that for planetary bodies of the same surface density, the *increase of the difference between the mean and surface density is proportional to the increase of diameter.* A test of the correctness of this conclusion will be made by applying the law to the computation of the mean densities of the inner planets from their assigned diameters.

To determine the value of the surface density of the earth and moon from their mean densities and diameters, we have, according to the indicated law of density, the following equations:

Make P the surface density of the earth and of the moon.
X the difference between the mean and surface density of the earth.
Y the difference between the mean and surface density of the moon.
$P+X$ the earth's mean density.
$P+Y$ the moon's mean density.
D the earth's diameter.
d the moon's diameter.
And k the difference between the mean and surface density of a planet of unit diameter, and we have

$$k=\frac{P+X-(P+Y)}{D-d} \qquad (1)$$

and
$$P=P+X-Dk=P+Y-dk. \qquad (2)$$

If we have another planet of the same class as the earth and moon, whose diameter is D', and whose mean density is $P+Z$, we have, according to the law of density,

$$P+Z=P+D'k. \qquad (3)$$

Substituting the proper numerical values in equations (1) and (2), and making the unit of diameter a mile, we get

$$k=\cdot 000389, \text{ and } P=2\cdot 58.$$

Dk and dk in equation (2) represent respectively that part of the earth's mean density, and that part of the moon's mean density, which is due to compression, and their numerical values are as follows:

$$Dk=3\cdot 08, \text{ and } dk=0\cdot 84.$$

The writer has tested the law of density by applying equation (3) to the planets Mars, Venus and Mercury. The following are the computed values of the mean densities of these planets, on the basis of the law in question, compared with the values which have been computed from the assigned values of their masses and diameters.

	Diameter in miles.	Value computed from law of density.	Value computed from assigned values of masses and diameters.	Mass (Sun=1.)
Mars	4211	4·22	4·17	$\frac{1}{3093500}$
Venus	7660	5·56	5·24 (?)	$\frac{1}{390000}$
Mercury	2992	3·74	4·56 (?)	$\frac{1}{7500000}$

The agreement of the computed and assigned values is very close in the case of Mars, but not so close in the cases of Venus and Mercury, yet the differences in the latter cases are probably not greater than the uncertainty of the assigned values; for the density of Venus as given in the Ninth Edition of the Encyclopædia Britannica (Art. Astronomy), is 1·03 that of the earth, which reduced to that of water, is 5·83. This value is based on a diameter of 7510 miles. Computing the mean density of Venus from this value of the planet's diameter, according to the law of density, comparing the result with the assigned value just given (5·83) and then taking the mean of the values given in the two comparisons, we have the following result:

	Values according to law of density.	Values computed from the assigned masses and diameters.
1st comparison	5·56	5·24
2d comparison................	5·50	5·83
Mean of the above values	5·530	5·535

From the results of the foregoing test of the law of density, as applied to the planets Mars and Venus, the law may be said to be verified. The apparent discrepancy in the case of Mercury does not prove the inapplicability of the law to that planet, as the assigned value of the mass is still somewhat in doubt, and the doubt of the mass taken in connection with the uncertainty in the assigned value of the planet's diameter, may be sufficient to eliminate the entire discrepancy.

The foregoing tests include all of the planets to which the law of density is directly applicable, but, as before stated, it is quite probable that the satellites of the outer planets belong to the same class of bodies as that to which the inner planets and the moon have been assigned. The test cannot, however, be applied to these bodies for the reason that nothing certain is known of their diameters. The masses of the satellites of Jupiter have probably been determined with sufficient accuracy to give approximate values of their densities, provided the diameters of the satellites were accurately determined. The observed values of the diameters of these satellites are probably very much in error, as their apparent size would be increased by irradiation. But if we suppose the principal error in the observed values to be that due to irradiation, we may get some evidence of the applicability of the law of density to these bodies in the following manner: thus, if the errors in the determination of a set of values for the diameters of these satellites were those due to irradiation alone, the value determined for each satellite would probably be affected by the same error of angular measure, and the error would be one of excess, so that, if we had the actual diameters of the satellites, and should subtract them from the observed diameters, the same difference would be obtained in the case of each satellite. The writer has computed the diameters of these satellites from the law of density, previously applied to the inner planets, and the most recent values of the masses of the satellites relative to that of Jupiter, and the following is a comparison of the computed with the observed values, the latter being those given in the ninth edition of the Encyclopædia Britannica:

	Observed diameter in miles.	Computed diameter in miles.	Difference in miles.
Satellite I	2352	1663	689
Satellite II	2099	1837	262
Satellite III	3436	2768	668
Satellite IV	2929	2214	715

It will be observed that the difference is about the same for each satellite except the second, the diameter of which computation makes larger than the first, but which observation makes smaller. With the single exception just noted, the result of the above test is confirmatory of the law of density and the theory that these satellites have solidified, and therefore, under the adopted hypothesis, have the same surface density as the inner planets and the moon. The apparent want of coincidence in the difference obtained for the second satellite does not disprove the law of density, or its applicability to these satellites, for the reason that several distinguished observers have observed this satellite to be larger than the first, as the value of its mass indicates it should be.* The values used for the masses of the satellites in the computation of the diameters above given are as follows:

	(Mass of Jupiter=1.)
Satellite I	0·000016877
Satellite II	0·000023227
Satellite III	0·000088437
Satellite IV	0·000042475

The mean densities of the satellites of Jupiter are, according to the above values of their masses and the computed diameters already given, as follows: satellite I, 3·22; satellite II, 3·29; satellite III, 3·66; satellite IV, 3·44.

* There is, in all probability, a serious error either in the observed value of the diameter, or in the assigned value of the mass of the second satellite of Jupiter, as it is very improbable that in the same system of satellites, a satellite of given volume should have a greater mass than one of larger volume.

An interesting application of the law of density, under the adopted hypothesis, is to determine, by computation, the ultimate diameters and mean densities of the sun and the outer planets, that is, the diameters and mean densities they will have when they have become solid like the earth and moon. That they will ultimately reach this condition, if they undergo no other change except that due to the radiation of heat, cannot be questioned. The application referred to will, first, be made to the sun.

Let d be the diameter of an hypothetical planet of the class to which the inner planets have been assumed to belong, and whose mean density is $2P$, P being its surface density, and let the diameter of this hypothetical planet, which is found by the law of density to be 6632 miles, be taken as the unit of diameter, and its mass as the unit of mass. Now if we make M the mass of another planetary body whose diameter is $1+x$, we have, by the law of density

$$M=(1+x)^3\frac{x+2}{2}$$

or $$2M=2+7x+9x^2+5x^3+x^4.$$

Making M the ratio of the mass of the sun to that of the hypothetical planet (610400) which is taken as the unit of mass, and finding the root of the equation, we have

$$1+x=1+31{\cdot}9928=32{\cdot}9928,$$

from which we get the following value for the ultimate diameter of the sun, in miles:

$$32{\cdot}9928\times 6632=218808;$$

and for the sun's mean density we have from equation (3)

$$218808\,k+P=87{\cdot}69.$$

The same application of the law of density has been made to the outer planets, and the following are the results obtained for their ultimate diameters and mean densities, the list being headed with the values for the sun for the purpose of comparison:

	Ultimate diameters.	Ultimate mean densities.
Sun	218,808 miles.	87·69
Jupiter	37,183	17·04
Saturn	27,128	13·13
Uranus	16,552	9·00
Neptune	17,220	9·28

The foregoing results are based on the following values of the masses of the sun and of the planets mentioned:—

Sun	326800 times that of the earth.			
Jupiter	$\frac{1}{1047.88}$	"	"	sun.
Saturn	$\frac{1}{3501.6}$	"	"	"
Uranus	$\frac{1}{22600}$	"	"	"
Neptune	$\frac{1}{19300}$	"	"	"

We may apply the foregoing values of the ultimate mean densities of the sun and outer planets to the computation of the present surface densities of these bodies; but the results must be based on the following supposition, namely, that in the contraction of the sun or planet from its present diameter to that assigned above for its ultimate diameter, the mean motion of the molecules at different distances from, and in the direction of the center of the mass, would be proportional to their distance from the center. According to this supposition the ratio of the mean to the surface density will remain constant during the contraction.

Let d be the present mean density of the sun;
D its ultimate mean density;
S its ultimate surface density,
and X its present surface density,

then $$X = \frac{dS}{D} = \frac{1 \cdot 444 \times 2 \cdot 58}{87 \cdot 69} = 0 \cdot 0424.$$

Applying the same method of computation to the outer planets we get the following values for their present surface densities:—

	Present surface density.	Ratio of mean to surface density.
Sun	0·0424	34·0
Jupiter	0·208	6·6
Saturn	0·147	5·1
Uranus	0·365	3·5
Neptune	0·321	3·6

These results show that the surface density of the sun is, as would naturally be expected, much less than that of either of the outer planets. They also show that the surface densities of Uranus and Neptune are greater than the corresponding values for Jupiter and Saturn; this is also what might have been expected, as the former planets being smaller than the latter have made greater progress in the process of condensation. The only anomaly in the above results is in the case of Saturn, which, being smaller than Jupiter, might have been expected to have a somewhat greater surface density, though the results show that the surface density of the former planet is less than that of the latter. But when it is considered that Saturn presents a most striking anomaly in another feature, that of being encircled by a system of rings, we may fairly conclude that the results given above probably represent truly the relative, if not the actual, surface densities of the outer planets and the sun.

The following interesting inquiry naturally presents itself in considering the law connecting the mean densities of the planets with their diameters: What, under the law connecting the mean density with the diameter, should be the law connecting the density with the pressure? The relation of density to pressure, as deduced by the writer from the law of the planets' densities, is, that *the increase of the square of the density minus the density, is proportional to the increase of pressure;* thus, if D is the density and P the pressure, the increase of D^2-D is proportional to the increase of P. The relation of density to pressure, according to Laplace's hypothetical law of density within the earth, is, that the *increase of the square of the density is proportional to the increase of pressure.* For very great condensations the two laws would give approximately the same results.

The writer believes that all eminent observers who have in late years directed their attention to the examination of the surfaces of Jupiter and Saturn, agree that these planets present features widely different from those presented by the inner planets, and that on account of the rapid changes taking place on their surfaces, the interior must be the seat of enormous activity, which can be ascribed to no other cause than to a very high temperature resembling that of the sun. Could the planets Uranus and Neptune be examined from a distance not greater than that which separates us from Jupiter, they would in all probability present features similar to those of the latter planet. We are therefore justified by observation in assigning the outer planets to a different class from that to which the inner planets belong. The adopted hypothesis and the law of density herein indicated, require that the planets Jupiter and Saturn be not only in a fluid condition, but that their present volumes are from 12 to 17 times greater, respectively, than that which they will have after solidification has taken place.

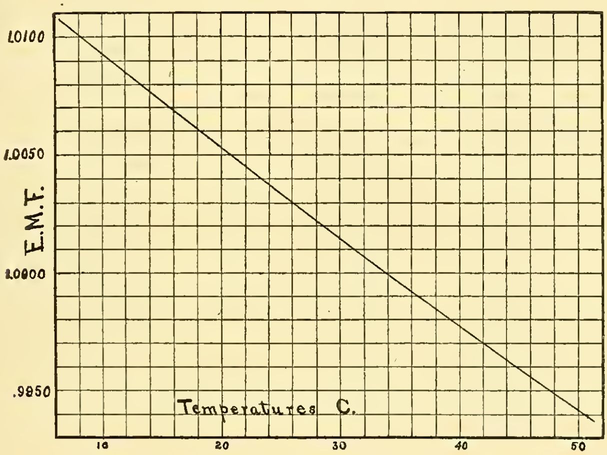
Of the improbability of the law of density, herein indicated for the inner planets, being true, the writer has not been able to obtain the slightest evidence, based on accurate knowledge (the greatest disagreement in the test to which the law has been subjected, being in the case where there was the greatest uncertainty in the values with which those derived from the law were compared); but on the other hand all of the evidence which has any bearing on the subject at all tends to the confirmation of the law. For instance the most recent changes in the assigned values of the masses of the planets Mars, Venus and Mercury, based presumably on more accurate data or improved methods of computation, have been in the direction of the values which the law in question would from their observed diameters have assigned to them. For the full confirmation of the law it may yet be considered necessary by the cautious investigator to have some additional proof of its correctness. In what direction it is best to seek for additional proof of a decisive character it is difficult to say. Could the law of increase of density within the earth which would result from the derived law of the planets' densities, be deduced, evidence of the correctness of the law might be found in the same way that Thomson and Tait have in their treatise on Natural Philosophy, Part II, section 828, sought for evidence of the correctness of Laplace's hypothesis. It is to be hoped that more accurate determinations may be made of the masses and diameters of the planets Venus and Mercury, and of the satellites of Jupiter. It is in this direction that the writer has most hope for the full confirmation of the law in question.

ART. L.—*An improved Standard Clark Cell with Low Temperature-Coefficient;* by H. S. CARHART.

THE best form of Clark cell hitherto made is that of Lord Rayleigh, described in the Philosophical Transactions for 1885. The objections to this form are that the temperature-coefficient is not the same for all cells, as is shown in Lord Rayleigh's paper, and it is so high as to introduce a very troublesome and uncertain error because of the difficulty of ascertaining the exact temperature of the cell; second, it is not so constructed mechanically as to prevent the mercury from coming into contact with the zinc when the cell is subjected to violent jars in transportation; thirdly, a great chemical defect is the facility with which local action takes place between the zinc and the mercury salt. I might add that the mercurous sulphate, purchased by Lord Rayleigh, evidently contained considerable salt in the mercuric form, as is shown by its turning yellow on mixing with the zinc sulphate solution.

All these difficulties I have, at least in large measure, overcome. Respecting the materials, the greatest care is required to secure and maintain cleanliness and purity in their preparation. The mercury must be distilled *in vacuo* after being cleaned by chemical means. The zinc sulphate should be free from iron as well as other impurities. The mercurous sulphate can be made almost or quite free from the mercuric form by using plenty of mercury; keeping the temperature down to the lowest point at which action will take place; and letting the mixture of salt, acid and metallic mercury stand for some time. I have made in this way a salt that remains white, not only when the free acid is all washed out, but when mixed with the standard zinc sulphate solution. Further, it remains white in the cell indefinitely if it is not exposed to a bright light.

Hitherto the importance of the local action going on in a Clark cell appears not to have been appreciated. It accounts for some of the differences in temperature-coefficient and leads to some more serious results in some cells. The zinc replaces mercury when in contact with the mercury salt. This amalgamates the zinc, producing a slight change in the E. M. F.;



and then the amalgam is liable to creep up to the top of the zinc where it attacks the solder. The copper wire is thus sometimes loosened. The zinc sulphate follows up and the cell may thus be short-circuited by the zinc and the copper wire. Upon taking down one cell, which was perhaps a year old, I found that the zinc had been removed from the rod at the surface of the liquid and had been deposited again upon the rod at the surface of the mercury salt, in a solid frill around the zinc. The copper wire in this cell became entirely detached, partly because of the expansion upward of the marine glue, which brought a severe strain upon the wire.

The local action then increases zinc sulphate in the cell at the expense of the mercury sulphate and amalgamates the zinc rod. I have become convinced by some experiments extending over several weeks that this substitution process goes on only when the zinc is in contact with the solid mercury salt. The mercurous sulphate is only slightly soluble in a saturated solution of zinc sulphate. I prevent local action, therefore, by keeping the zinc and the mercury salt out of contact. The same device operates to raise the E. M. F. about 0·4 per cent. The following table exhibits the observed and calculated values of the E. M. F. of cells No. 17, 112, 113 in terms of No. 1 [old style] at 20° C.:

No. 17.			No. 112.		
Temp. C.	Observed.	Calculated.	Temp. C.	Observed.	Calculated.
8°·3	1·0108	1·0106	5°·1	1·0124	1·0125
8·5	1·0103	1·0105	10·6	1·0106	1·0103
9·3	1·0104	1·0102	12·5	1·0098	1·0096
11·8	1·0093	1·0092	15·2	1·0087	1·0086
13·8	1·0084	1·0085	19·5	1·0069	1·0069
15·0	1·0080	1·0080	21·2	1·0062	1·0062
18·1	1·0069	1·0068	31·1	1·0024	1·0024
19·4	1·0064	1·0063			
19·9	1·0062	1·0061	No. 113.		
20·3	1·0060	1·0059			
20·8	1·0054	1·0057	5·1	1·0124	1·0125
21·1	1·0057	1·0056	10·6	1·0106	1·0104
21·6	1·0054	1·0055	12·5	1·0098	1·0097
22·4	1·0050	1·0052	15·2	1·0088	1·0087
23·3	1·0048	1·0048	19·5	1·0070	1·0070
25·1	1·0044	1·0041	21·2	1·0062	1·0063
26·4	1·0035	1·0036	31·1	1·0025	1·0025
30·2	1·0019	1·0022			
33·1	1·0014	1·0013			
39·1	0·9991	0·9989			
41·7	0·9980	0·9979			
50·4	0·9949	0·9947			
52·7	0·9939	0·9940			

Cell No. 1 was always very near 20° C., and the reduction to that temperature was made by means of Lord Rayleigh's reduction coefficient, ·00077 per degree C.

The equation for the E. M. F., derived from the observations on No. 17, is

$$E' = E[1 - \cdot 000387(t-15) + \cdot 0000005(t-15)^2].$$

The calculated values for the three cells were all obtained by this formula. The change for one degree C. is, then, the following linear function of the temperature :—

$$-\cdot 000386 + \cdot 000001(t-15).$$

The temperature-coefficient ranges from ·000361 at 0° C. to ·000376 at 25° C., and to ·000361 at 40°C. At the highest observed temperature in the preceding table it was only ·000348. The curve of E. M. F. with temperatures as abscissas is clearly concave upward, indicating a fall in the temperature-coefficient with rise of temperature. The change is, however, so small as to be quite negligible within the range of temperature to which a normal element is subjected in practice. Lord Rayleigh's cells show a change in the temperature-coefficient directly the reverse of the above; that is, the coefficient increases by a very appreciable quantity with rise of temperature. For his No. [36] the coefficient ranged from ·000556 at 0° C. to ·00101 at 25° C., if his equation holds true for the higher temperature.

In making comparisons of E. M. F. I have used Lord Rayleigh's method, slightly modified, by means of which a difference of one ten-thousandth part is observed directly and with the greatest ease. In fact a difference of half that amount is easily measured. A comparison of half a dozen cells can be made in as many minutes without difficulty.

As to polarization, these cells show none with external resistance greater than 30,000 ohms. At 30,000 ohms the polarization is just discernible; and with 10,000 ohms it amounts to only one ten-thousandth part in five minutes. This fall in E. M. F. is less than the accidental differences between different cells in general, and much smaller than the almost unavoidable errors due to ignorance of the real temperature of the cell. If the cell is not closed on less than 10,000 ohms resistance, and only for a few minutes, the polarization may be entirely neglected.

As indicating the uniformity attained, the following relative values of the E. M. F. of six cells, only four days old, may be given: 9048, 9049, 9049, 9048, 9046, 9043. The last one was still approaching the others when last observed. Six cells of later construction gave the following relative values when less than two days old: 9182, 9182, 9182·5, 9182, 9182, 9182·5. The two sets of numbers do not represent at all the relative values of one set as compared with the other.

It will be seen from the table that Nos. 112 and 113 never differ by more than one part in ten thousand at the same temperature.

Art. LI.—*Pseudomorphs of Native Copper after Azurite, from Grant County, New Mexico*; by W. S. Yeates.

During the month of April of this year, Mr. J. A. Lucas of Silver City, Grant County, New Mexico, sent to the U. S. National Museum a specimen with this brief note:—"From the 'Copper Glance' and 'Potosi' copper mines, Grant Co., New Mexico. This ore is found in all imaginable shapes and sizes from 1 oz. to 70 lbs." The specimen was referred to the writer, for identification. It had the appearance of copper; but it was very brittle, and its specific gravity was much too low for ordinary metallic copper, a fragment yielding only 4·15. The surface was, in part, made up of what appeared to be tabular crystals, reminding one, in general form, of the azurite crystals from the Copper Queen mine, in the adjoining county of Cochise, Arizona, though the surfaces of the planes were stippled, rendering only approximate measurements of the angles possible. The surface of the specimen was coated with a white clay-like substance, the most of which had been cleaned off with a knife. This substance was found to be kaolin. An examination of the fresh fracture with a lens showed that the kaolin not only coated the surface, but that it was intimately mixed with the copper-like particles, producing a granular fracture, and giving rise to the stippling on the crystal surfaces. A fragment under the pestle in an agate mortar was reduced to powder, the metallic grains, which had been proved, before the blowpipe, to be copper, segregating together, and marking the mortar and pestle with bright shining streaks. The copper being so finely divided, it was now clear why the specimen was brittle, and why it had so low specific gravity. If the copper was, as it appeared to be, a pseudomorph after azurite, the latter must have lost its carbonic acid and water in the presence of some reducing agent, probably volcanic gases thrown up from below, leaving the copper in a spongy state, upon which the kaolin was deposited, and forced by pressure, while in a soft, semi-liquid condition, into the pores of the sponge.

With a view to determining whether or not this was true, Mr. Lucas was requested to furnish additional specimens for study, which he kindly did. Among them, were several, which, he informed the writer, had been cleaned with brush and water and a knife; the others were in the condition in which they were taken from the mines. These last appeared, externally, to be flattened nodules of kaolin, sometimes colored reddish brown. On the two opposite flattened sides were slickensides—evidence of the pressure, which had forced the kaolin into the copper sponge. With dental instruments, the writer exposed a fine group of the crystals of one of the nodules, the most prominent crystal being almost perfect, and simulating in form those azurite crystals flattened parallel with the plane $-1\text{-}i$, so common at the Copper Queen mine. By measurement with a contact goniometer the angle between the broad plane and an adjacent plane, on the copper crystal, was found to be identical with that of $-1\text{-}i \wedge 2$ on a fine Copper Queen azurite crystal in the Museum collection.

Additional circumstantial evidence may be found in the fact that the azurite crystals from the "Anson S." mine in Grant county, a neighbor to the "Copper Glance" and "Potosi" mines, are generally covered with kaolin, when found; and this is true of many of those from the Copper Queen mine.

In a letter, Mr. Lucas says:—"At a depth of about 40 ft., the green and blue carbonates run out, and the brittle copper comes in, getting better and purer, and increasing in quantity."

In conclusion, the writer wishes to tender his acknowledgments to Mr. Lucas, for his generous courtesy and aid.

U. S. National Museum, July 2, 1889.

Art. LII.—*Note on the Relation of Volume, Pressure and Temperature in case of Liquids*;* by Carl Barus.

Many experiments made with alcohol, ether, para-toluidine, diphenylamine, paraffine, thymol, and less completely with naphthaline, vanilline, azo-benzol, α-naphtol, monobrom camphor, benzoic acid, caprinic acid, palmitic acid, and monochloracetic acid, show that if temperature and pressure vary linearly at a mean rate of about ·11° C. per atmosphere there will be no change of volume. My temperatures lie between 30° and 300°, and the pressure between 20 atm. and 500 atm. By judicious extrapolation (enclosure of the experimental data, volume, pressure, temperature, between two mathematical functions, one of which is necessarily above and the other below the observed values; whereas both of the said functions fall within the limits of error, within the interval of observation), the probable contours can be computed to 1000 atm., with results accentuating the above law. The linear relation was predicted from theoretical considerations by Dupré (1869) and by Lévy (1884)—considerations soon proved to be inadequate by Massieu, H. F. Weber, Boltzmann and Clausius. Ramsay and Young (1887) established the relation in question experimentally for vapors, but not, I think, very fully for liquids decidedly below their critical points. Reasoning from these data Fitzgerald (1887) investigated the consequences of the law, viz: (1) specific heat under constant volume is a temperature function only; (2) internal energy and entropy can be expressed as a sum of two terms one of which is a volume function only and the other a temperature function only. Thus Ramsay, Young and Fitzgerald arrive substantially at the same position from which Dupré and Lévy originally started.

* The present communication has the assent of Mr. Clarence King, at whose suggestion and under whose instruction the work was done.

My own results were developed quite independently of the earlier work, and they apply emphatically for liquids. Thymol and toluidine were even under cooled 25° and 15° below their respective melting points. My range of pressures is therefore 6 or 7 times as large as that of Ramsay and Young. Thus my work, supplementing the researches of the English chemists, is not superfluous. Water seems to be a notable exception.

I found furthermore, that the pressure necessary to solidify a substance is, cæt. par., decidedly in excess of the pressure (positive or negative, external) at which it again liquifies. Here therefore is an exceedingly simple, and hence a type lag phenomenon. Making extensive use of it, I am led to results bearing directly on all lag phenomena, and beyond this on the molecular structure of matter in general. Data are in hand for paraffine, naphthaline, palmitic and chloracetic acids.

Operating above 100° C., I observed that (liquid) water at a pressure of 20 atm. and a temperature of 185° attacks ordinary lead glass so rapidly that in very fine capillary tubes the contents become opaque and solid in about an hour. During this action the compressibility at 185° gradually and regularly increased to a final value (200×10^6), about 3 times the original value (77×10^6). At the same time the isothermal volume of the silicated water decreased fully 13 per cent of its original bulk. So large a contraction will probably not be unaccompanied by rise of temperature.

Finally, in case of mercury, the simultaneous decrements of electrical resistance, r, and volume, v, due to pressure (0 to 400 atm.), were found to be proportional to each other. Approximately $\delta r/r = 10\ \delta v/v$. This result initiates a new method of attacking the above thermo-dynamic problems, and it has already led ulteriorly, to results of electrical interest.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Colloidal Cellulose.*—By treating filter-paper, previously purified with hydrochloric and hydrofluoric acids, or the finest quality of carded cotton, carefully dried, with sulphuric acid of 50° B. in the cold, Guignet has obtained a colloidal form of cellulose which, when the acid has been completely removed by washing, is readily soluble in pure water. To ensure a complete removal of the acid the last washings are performed with alcohol and the product is dried at the lowest possible temperature. Before washing, the cellulose forms a transparent gelatinous mass which is not affected by contact with a large excess of

acid, but at 100° is rapidly converted into dextrin. The solution of colloidal cellulose in water is slightly milky, is readily filtered, deposits no precipitate even after several hours' standing and is not altered by boiling. It is slightly orange-yellow in color and rotates the polarized ray slightly to the right. Small quantities of sulphuric or of nitric acid, of sodium chloride or sulphate, of lead acetate, etc., precipitate it, as is the case with other colloids. Alcohol in large excess acts similarly. Colloidal cellulose does not reduce Fehling's solution, is not colored by iodine, and differs from the achrodextrins in being precipitated by salts added in small quantity. A solution poured on a marble surface previously rubbed with vaseline and well polished, forms brilliant semi-transparent pellicles which swell up in water and then dissolve. An immersion in sulphuric acid of 60° B. for a short time, or in acid of 55° B. for a longer time, causes the colloidal cellulose to become insoluble in water, a small quantity of dextrine being at the same time formed. Nitric acid converts it into nitrocellulose. Parchment paper, thin and prepared probably by means of a somewhat weak acid, yields colloidal cellulose to boiling water. But thick paper, presumably treated with a stronger acid is insoluble. Parchment paper therefore may be regarded as a cellular tissue, the pores of which have been filled up with colloidal cellulose.—*C. R.*, cviii, 1258–1259, August, 1889. G. F. B.

2. *Watts' Dictionary of Chemistry*, revised and entirely rewritten by H. Forster Morley and M. M. Pattison Muir; assisted by eminent contributors. In four volumes, vol. i, 752 pp. 1888, vol. ii, 760 pp. 1889. London and New York. (Longmans, Green & Co.).—The first edition of Watts's Dictionary of Chemistry, the publication of which was begun in 1863, will always rank as one of the monumental works of the science. The fifth volume was completed in 1868 and since then a series of supplementary volumes has been issued, the last (1881) being the ninth volume of the entire work. The immense growth in the subject of chemistry in all its branches, however, had already carried it well nigh beyond the possibilities of a single work.

Sometime before the death of Mr. Watts in 1884, he had undertaken to prepare a new edition of the Dictionary, but his too early death interrupted the work before more than a beginning had been made and the labor passed to the hands of the present editors. As this new edition is to be limited to four volumes of about 750 pages each, the subjects treated of have been restricted in the first place to those in chemistry proper, excluding the "allied branches of other sciences" which found place in the first edition, and also reserving technical chemistry for a companion volume to be published under the editorship of Professor Thorpe. Moreover it has been necessary to adopt a rigid system of abbreviation and condensation so as to compress the almost unmanageable mass of material into the smallest possible space. Half of the work is now in the hands of chemists and it is needless to say that the great labor has been performed in a faithful, accurate and masterly manner—in fact the names of the editors and of the special contributors are a sufficient guarantee of the excellence of the whole. The unavoidable brevity of treatment will sometimes be regretted and the amount of abbreviation may seem to an occasional reader a serious drawback; but this disappears upon frequent use. Subjects in general chemistry have not been neglected and we note, for example among the numerous excellent articles, one by Mr. Muir upon atomic and molecular weights (24 pages), others by Dr. W. Ostwald on affinity, by Prof. E. Ray Lankester on bacteria, by Prof. J. J. Thomson on states of aggregation, and chemical equilibrium, by Prof. T. E. Thorpe on the atmosphere, combustion and flame, by Prof. F. W. Clarke on elements and Prof. Ira Remsen on equivalency and formulæ. The completion of the entire work will be looked forward to with much interest, and the gratitude of chemists is due to those who have been willing to undertake so great a labor. It is a matter of regret that the author who projected the work and whose name it bears could not have lived to see its completion.

3. *A Treatise on the Principles of Chemistry;* by M. M. Pattison Muir. Second edition. 490 pp. 8vo. Cambridge, 1889, (University Press).—The second edition of this philosophical work will be warmly welcomed by all who have become acquainted with the excellence of the first edition published five years ago (see this Journal, vol. ix, 255). Rapid progress has been made during this period in the development of chemical principles, and this has necessitated the fundamental revision of much of Book I on Chemical Statics, and the entire rewriting of Book II on Chemical Kinetics, especially that part dealing with chemical affinity. The chemical student will find the modern ideas on both branches of the subject presented in a very satisfactory and instructive form.

4. *Definitions adopted by the International Congress of Electricians.*—Professor Mascart communicated to the French Academy the following definitions proposed by the late Congress of Electricians:—

Unit of Work, the Joule. Equal to 10^7 C.G.S. units. It is the energy equivalent to the heat produced by one ampere through one ohm in one second.

Unit of Power, the Watt. Equivalent to the power produced by one Joule in one second and is equal to 10^7 C.G.S. units.

The Quadrant is the unit for coefficient of induction. The quadrant is expressed as a length and is equal to 10^9 centimeters.

The frequence of an alternating current is the number of periods per second.

The actual strength of an alternating current is the square root of the mean square of the strengths.

The actual electromotive force is the square root of the mean square of the electromotive forces.

The apparent resistance of the current is the factor by which one must multiply the actual strength in order to obtain the actual electromotive force.

The practical unit of light is called the decimal light and is the one-twentieth of the absolute standard defined by the International Conference of 1884.

The *bougie décimale* is sensibly equal to the English candle—or to one-tenth of the Carcel burner.—*Comptes Rendus*, Sept. 2, 1889, p. 393. J. T.

5. *Lightning and the Eiffel Tower.*—The Eiffel tower was struck by lightning on the 19th of August, 1889, and Professor Mascart gives a short account of the occurrence in a note to the French Academy. The tower is protected by a central rod at its summit and by rods projecting from the balustrade of the third platform. The lightning discharge passed down the central lightning rod. Various subsidiary discharges were noticed at different parts of the tower by the four attendants who were on the tower at the time. The cloud which touched the top of the tower was vividly lighted. None of the four persons on the tower received the slightest shock although the iron work of the tower was wet by the shower. Professor Mascart remarks that security to life is absolute on a tower of this construction.—*Comptes Rendus*, Aug. 26, 1889, p. 355. J. T.

6. *Transmission of power by Electricity.*—M. Deprez states that power has been transmitted regularly for some months from a fall of water to the village of Bourganeuf, a distance of 14 kilometers. The line which transmits the current is of *bronze silicieux* (pure copper). The wire is 5mm. in diameter, uninsulated and is supported on wooden poles furnished with porcelain insulators. The generator and motor are ring-formed and furnish 100 nominal horse power. The electromotive force of the generator is 3000 volts.—*Comptes Rendus*, Sept. 2, 1889. J. T.

7. *Dissipation of negative electric charges by sunlight and daylight.*—J. Elster and H. Geitel show that the dissipation of negative charges can be caused not only by the ultra violet rays, but also by sunlight and diffuse daylight.—*Ann. der Physik und Chemie*, No. 9, 1889, p. 40. J. T.

8. *Photography of the invisible portions of the Solar Spectrum.*—M. Ch. V. Zenger states that one prism of rock salt combined with two rectangular prisms of *anéthole* gives between the lines A and D six times the dispersion of one prism of rock salt. The arrangement is called by Zenger a parallelopiped of dispersion.—*Comptes Rendus*, Sept. 9, 1889, p. 434. J. T.

9. *The Carbon Spectrum.*—H. Kayser and C. Runge have examined the band spectra of carbon given by the electric light between carbon terminals in order to see if these band spectra coincide with those of cyanogen. The results of their measurements force them to conclude that the identity of the cyanogen spectrum and the carbon spectrum has not been made out. They give an empirical formula for the arrangement of lines in the band spectra of carbon, and state their belief that the true law of the arrangement of lines in the band spectra can only be arrived at from a theoretical discussion of the law of molecular move-

ments. A table of wave-lengths of carbon bands and cyanogen bands is appended to their article.—*Ann. der Physik und Chemie*, No. 9, 1889, pp. 80–90. J. T.

II. Geology.

1. *Movement of the Upper ice of Glaciers over the Lower.*—Mr. Forel describes cases of the over-riding of the lower beds of ice by the upper in the glaciers of the Alps. (1) A cavern excavated in the spring for several years past, in the vertical wall in the left side of the Glacier des Bossons, at Chamouni, at the level of the lateral moraine (for the gratification of tourists) becomes raised, as the ice moves on, to a higher level during the summer, and in the following spring, it is some 25 to 30 meters above its former level, at the middle of the ice-wall; and during the following year the remains of the ice-cave reach the upper surface of the ice. (2) At the lower extremity of the Glaciers de Fée Inférieur, the Alallin, and the Rhone, in 1884 and of Zigiorenove in 1886, the slipping or over-riding of the upper beds has been observed to take place along planes of cleavage, which planes are those of the lamellar structure or of the blue bands. (3) A small frontal moraine, was formed in 1884 at the glacier of Hochbalm, by the slipping of a bed of white ice over an old bed of debris-covered ice. (4) Horizontal earthy bands of interior moraine are formed at the terminal extremity of certain glaciers as that of the Rhone in 1870, 1871, the Trient in 1882, and the Fée Supérieur in 1884. This movement takes place, says Mr. Forel, not by the deformation of the plastic mass, but by the slipping of one bed on another along planes of cleavage, which planes are those of the lamellar structure of the glacier. He observes that the facts serve to explain (*a*) the difference of velocity between the upper and lower beds; (*b*) the diminished rate of flow at the lower extremity of a glacier; (*c*) the re-appearance at the surface of bodies buried in the interior of the glacier; (*d*) the preservation of the thickness of the ice at the lower extremity, notwithstanding the annual loss from melting.

2. *The Ice Age in North America, and its bearings on the Antiquity of Man*, by G. Frederick Wright, D.D. 622 pp. 8vo, with many new maps and illustrations. New York, 1889. (D. Appleton & Co.)—Prof. Wright has for many years, as the readers of this Journal know, been an investigator of the Drift phenomena of North America. In 1886 he added to his knowledge of facts from the glaciated regions others from the study of existing glaciers in Alaska. Hence his right to speak with a degree of authority on the events of the Ice-age and formulate conclusions meriting consideration. He has made a work of great interest; and through the liberality of his publishers, one of special excellence in its illustrations and typography.

After general remarks on the structure of glaciers, the volume gives an account of the glaciers of the Pacific Coast from California to Alaska, dwelling at length on the Muir glacier which was the one the author investigated. It next treats of the Greenland ice, in whose features the condition of the Ice-age are most nearly exhibited, and then of glaciers in Europe and other lands. After this introduction, extending over more than a hundred pages, the evidences and events of the Ice-age in North America are discussed at length with some account also of the facts from Europe. The position of the southern limit of the ice is described in detail and partly from personal observations, especially in Pennsylvania, Ohio, Indiana and Dakota. Afterward, the effects produced by glacial erosion and transportation are reviewed, the former including, in the author's opinion, many lake basins as well as river channels, and the latter comprising accumulations of debris into drumlins and kames. Other chapters treat of the buried valleys and extensive changes in river courses as a result of glacial depositions,—changes that led to the production of many of the waterfalls of the country, even the largest; the geographical march of vegetable and animal life consequent on the advance and retreat of the glacier; the cause of the glacial climate, under which subject Croll's theory is considered and no theory is found to be satisfactory; the date of the Ice-age; the antiquity of man. It is shown pretty satisfactorily that according to evidence from the rate of erosion at Niagara Falls, the St. Croix Falls, and from other facts, that the Ice-age probably closed from 8,000 to 10,000 years back, and it is inferred, from less clear proof, that only 15,000 to 25,000 years have elapsed since it began. The chapter on human relics in America reaches the conclusion that the earliest of them occur in deposits of the Glacial era, some thousands of years before its close.

An Appendix contains the views of Mr. Upham on "the probable causes of glaciation."

With regard to the Glacial period there is on several points wide diversity of opinion among geologists, and much is yet to be learned, and some of the conclusions of the author will find opponents. But the work, nevertheless, is a valuable review of the marvelous events of the Ice-age.

3. *Annual Report of the Geological Survey of Arkansas for* 1888, John C. Branner, State Geologist. Vol. II. *The Neozoic Geology of Southwestern Arkansas,* by Robert T. Hill, Assistant Geologist.—The whole breadth of southern Arkansas and more than half of middle and northern are underlaid by Cretaceous and later deposits—a part of those of the great Mississippi bay of the Cretaceous and Eocene-Tertiary periods. The Report of Professor Hill treats of the distribution and stratigraphical features of the Cretaceous, Tertiary and Quaternary deposits in the southwestern portion of the State, the term Neozoic as used by him including the uppermost Jurassic, Cretaceous, Tertiary and Quaternary strata of the region. The Cretaceous formation has two divisions, as already explained by Mr. Hill* in this Journal,

* Vol. xxxiv, 287, 1887; xxxvii, 282, 1889.

the Lower or Comanche Series and the Upper or Exogyra costata series; and the lower of these has three divisions, the Trinity (or lowest), the Fredericksburg and the Washita. The author describes the several divisions, both of the Lower and Upper Cretaceous beds in detail, mentions the characteristics fossils and gives their distribution. Chalk, of varying purity, with and without flints, is described as constituting a large part of the Cretaceous of Arkansas as well as Texas, and especially of the Upper Cretaceous. In the middle portion of the latter in Arkansas, a bed of chalk is 500 feet thick. It is largely composed, according to the observations (for the Arkansas Survey) of Mr. J. S. Diller, of foraminifers, among which the genera Textularia and Globigerina predominate.

The Tertiary strata are chiefly those of the Lignitic series, the Eo-lignitic of Heilprin. The beds are treated of in the report under the local names of the Camden series, and the Cleveland County red-lands. The latter overlie the Camden series and contain Claiborne fossils. The Arkadelphia shales are at the base of the Camden. Professor Hill also describes the Quaternary beds. In later chapters he treats of the economical geology of the region—its iron ores, marls and chalk, its forests and its mineral springs.

The report contains also a chapter on the northern limit of the Mesozoic rocks in Arkansas by Dr. O. P. Hay, giving local details, and another on the manufacture of Portland cement, by J. C. Branner.

4. *Jurassic Plants from Kaga, Hida, and Echizen, (Japan);* by Matajiro Yokoyama. Journal of the College of Science, Imperial University of Japan, Vol. III, Part I, Tokyo, Japan, 1889.—This paper was announced three years ago in the Bulletin of the Geological Society of Japan (Part B, Vol I, No. 1, Tokyo, 1886), and a provisional list of the species given, of which the author then enumerated 54. Thorough study has reduced the number to 49, four of which had already been described by the late Dr. Geyler from collections made by Dr. J. Rein in the valley of the Tetorigawa, probably at Shinamura. This locality has since been thoroughly re-investigated together with six others. The flora shows a decided predominance of ferns, in which respect it differs from the Mesozoic floras of India and of Siberia and agrees better with that of the Yorkshire Oolite, but taking other elements into consideration it seems upon the whole to have the closest affinities with the Brown Jura of Siberia. The author refers the Japanese deposits to the Bathonian stage of the Lower Oolite. The paper is illustrated by fourteen litho-plates, in which the figures are as good as those of many European works. A second paper is promised on the Jurassic plants of the northern part of Shinano. L. F. W.

5. *The Rivers and Valleys of Pennsylvania*, by Wm. Morris Davis, Nat. Geogr. Mag. i, No. 3, p. 103.—Professor Davis describes in this elaborate paper, the general topography of Penn-

sylvania with reference to the courses and kinds of valleys, their methods of origin as determined by the stratigraphic and other conditions, and illustrates the subject with sections, diagrams, views and maps.

III. Botany and Zoology.

1. *Die natürlichen Pflanzenfamilien.*—A. Engler and K. Prantl. Part 2, six sections, in all 1024 pages, with 3537 figures. (Leipzig, W. Engelmann, 1889).—The early signatures of this work have been already noticed in this Journal. Following the current fashion of "Subscription Books," the different signatures are scattered about among the different subjects in such a way that a subscriber must get the whole work, in order to secure what he may chance to want. And so we have part, or volume, second, before volume first. But this cannot be said to be a real hardship when the whole work must be regarded as indispensable to any botanical library. The editors have had numerous and able collaborators;—Graf zu Solms, Ascheron, Drude, Buchenau, Gürke, Häckel, Petersen, Pax, Pfitzer, and others, but they have themselves done a large portion of the work.

The volume begins with the treatise on the Gymnosperms by the lamented Eichler, and the Monocotyledonous orders follow in succession, closing with Orchidaceæ. Drude has a very interesting chapter on palms, Engler has treated of the following orders among others, Araceæ, and Liliaceæ, while Orchidaceæ naturally fell to Pfitzer. In treatment the authors have followed one plan throughout, namely, that of giving with illustrations, everything of importance in regard to the structure and relations of the typical plants of the respective orders, presenting necessary details regarding the genera. There appears to be in all parts of the work a general desire to present the more important facts relative to the plants which possess economic interest, and most of the more striking figures have been prepared with reference to this. The typography and illustrations are worthy of the text.

G. L. G.

2. *Guide pratique pour les travaux de Micrographie,* par Beauregard et Gallippe. Paris, 1888, pp. 901.—This work is the second and much improved edition of a hand-book of general utility in laboratories where the microscope is used. It presents a wide range of subjects, and most of them are well treated, but there is great inequality in their presentation, and some of them have no interest from a botanical point of view. For instance more than eighty pages are devoted to the hair, considered in its medico-legal aspects. But Botany and general technique receive over three hundred and fifty pages. G. L. G.

3. *Contributions to the Physiology of Growth.*—J. Wortmann (Bot. Zeit., April and May, 1889), describes a method of studying the effects of different media upon the growth of root-hairs, with special reference to the increase or the diminution of turgescence.

Seeds of Lepidium were made to sprout in moist air, with the roots of the germs vertical. As soon as the root-hairs began to appear, the seedlings were placed under a cover glass on a slide and the given liquid added. Under such circumstances the root-hairs grow for several days and the process can be watched at short intervals. Janse has shown that by increasing the turgor in Algæ by means of plasmolytic media, growth can be made to recommence after an arrest. The method of Wortmann is substantially a modification of Janse's and leads to similar conclusions. As an outcome of his studies, Wortmann believes that he has strengthened the theories of Sachs and of de Vries regarding growth; in short, he holds that growth is the result of mechanical turgescence brought about by the interaction of the surroundings and the interior of the vegetable cell. Some of the distortions produced by varying the media, are very remarkable and indicate that the field should be much further explored. G. L. G.

4. *Atlas deutscher Meeresalgen.* Erstes Heft. In Verbindung mit Dr. F. Schütt und P. Kuckuck bearbeitet von Dr. J. Reinke. Berlin. Paul Parez, 1889. Folio, pp. 34, Pl. XXV.—In his recent work, *Algenflora der westlichen Ostsee deutschen Antheils*, Professor Reinke, to the surprise of most algologists who supposed that little new remained to be discovered on a coast which had been so long known to marine botanists, showed that a remarkable number of new species and even genera, especially of very interesting *Phæosporeæ*, had escaped the notice of previous explorers. In that work, he gave an interesting account of the new species found by him and critical notes on many others, illustrated, however, by only a few wood-cuts. The present work, prepared at the request of the commission for the scientific investigation of the German Marine Waters in the interest of the fisheries, has for its aim the scientific description and illustration of Algæ of which no adequate account exists in other works. The first part includes twenty-nine species and varieties, among them fourteen of the new species discovered by Reinke. The whole work is to be completed in four parts of the size of the present, but the second part will not be published as a whole but will be issued in fasciculi with five plates. Botanists will appreciate the enlightened spirit of the German commission in entrusting to Professor Reinke the preparation of a work, which is not only thoroughly scientific in its method, but also artistically beautiful in its presentation. The lithographic plates, in part colored, are excellently drawn by Schütt and Kuckuck and the accompanying text gives a clear and well condensed description of the species figured without entering into details of structure and nomenclature which were more appropriately given by Professor Reinke in his Algenflora, previously published. Illustrations of the new chlorosporic genera, *Pringsheimia*, *Epicladia* and *Blastophysa* are given, but twenty of the twenty-five plates are devoted to *Phæosporeæ.* Besides representatives of old genera such as *Ectocarpus*, *Scytosiphon*, etc., we have here for

the first time figures of the new genera *Symphoricoccus*, *Halothrix*, *Kjellmania*, *Microspongium* and *Leptonema*. The *Phæosporeæ* evidently are much more rich in generic types than was formerly supposed, and the complication of species in this order has become so great that, even with as excellent descriptions as those in the *Algenflora*, one would be glad to have also good plates as a supplement. Not the least interesting plates to American algologists are those of the much confused and much abused species, *Ralfsia verrucosa* and *R. clavata*, whose characteristics are here well given. We would add that the remarks on those species in the *Algenflora* are especially to be commended. We have only one suggestion to make. Although the full synonymy is given under the species described in the *Algenflora*, we think it would be well to repeat the main points of the synonymy briefly when the same species occur in the *Atlas*. We would congratulate Professor Reinke on the excellence of the part already published and hope that the work in his hands will progress without interruption. W. G. F.

5. *A Monograph of the Horney Sponges;* by ROBERT VON LENDENFELD. 936 pp. 4to, with 50 plates. Published, for the Royal Society, by Trübner & Co., London, 1889.—The author of this elaborate monograph has worked up the science of sponges, and especially that of the Horney Sponges, from its foundation. His studies on the subject began with the Mediterranean species. In 1881 he extended his researches to Australia and afterward continued them in New Zealand and again in eastern Australia; and in these regions, besides making large collections he had placed at his disposal all those gathered in the museums of scientific institutions. Finally, returning to Europe in 1886, the specimens of the British Museum were opened to him. Mr. Lendenfeld has thus been enabled to make a careful study of and re-describe all previously known species, to investigate the anatomy and physiology of the different types in the field, and obtain that comprehensive knowledge of the subject required for a true classification of the sponges.

The number of species described in the work is 348, of which 258 live in Australian seas and 179 or 69·3 per cent of these are confined to those seas. The European coast of the North Atlantic afforded 12 species, the American coast of the same, 56, and the Mediterranean, 44 species. The number of Australian species found in other regions and the percentage relation is given as follows, omitting the Asiatic and American coasts of the Pacific from all of which only 7 species are recorded.

	Total.	Also Australian.	Per cent Australian.
Mediterranean	44	21	47·7
European coast of North Atlantic	12	3	25·0
African coast of Atlantic	10	4	40·0
American coast of North Atlantic	56	29	51·8
American coast of South Atlantic	12	5	41·7
African coast of Indian Ocean	38	22	57·9
N. and E. parts of Indian Ocean	32	16	50·0

It is thus shown that, according to present knowledge, the Horney Sponges of the eastern and northern parts of the Indian Ocean are not so similar to the Australian as those from the remoter African coast of the Indian Ocean and those from the still more remote American coast of the North Atlantic. "The similarity of the Mediterranean and Australian faunas and the dissimilarity of the European Atlantic and Australian are very striking." The species, it is remarked, are typically shallow water forms. The greatest number occur at depths of 20 to 50 meters and only 17 are reported from depths over 100 meters; the greatest depth of any is 750 meters.

The figures of sponges are mostly photo-lithographs taken direct from the types, and are admirable. A large part of the plates are devoted to anatomical dissections, and all are remarkably fine. The bibliography occupies 68 pages. The author adds to his acknowledgments: "Throughout my labors I have had the constant assistance of my wife, and by her the greater number of my microscopic preparations were made."

6. *The Bermuda Islands; a Contribution to the Physical History and Zoology of the Somers Archipelago with an examination of the structure of Coral Reefs.* Researches undertaken under the auspices of the Academy of Natural Sciences of Philadelphia; by ANGELO HEILPRIN. 231 pp. 8vo, with 17 plates illustrating the zoology of the Bermudas, and others, its scenery and geology.—Professor Heilprin has made an attractive volume for the Bermuda traveler, by his vivid descriptions of the islands and of their scenery above the water and beneath it, illustrated by phototypes, and by his account of the coral reefs and discussion of their origin. The scientific reader will find that the subject of the reefs and that of Bermuda zoology is presented by one who fully understands the problems he deals with, and is familiar with much of the life of the seas. His conclusion on the question of the origin of Coral islands he expresses as follows: "If the theory of subsidence cannot, perhaps, be considered to be absolutely demonstrated, it accords best with the facts, and, indeed, may be said to be in substantial harmony with them.". The additions to the list of Bermuda species of invertebrates is quite large. The number of known marine mollusca living about the reefs is increased from about 80 to 170 species, all of them excepting less than a dozen, "members of the West Indian or Floridian faunas. Eleven are peculiar to the islands, and are here first described. So again the number of known species of terrestrial mollusks is increased from about 20 to 30; sixteen of all are West Indian, and three are species of East Atlantic islands. Similarly the lists for other departments of invertebrates are much increased, and made valuable by original notes.

To his own notes on the faunas, the author adds chapters on the Actinology of the Bermudas by Professor J. PLAYFAIR MCMURRICH, on the Insects by Dr. P. R. UHLER, on the Spider fauna, by

Dr. G. Marx, on the Myriapods, by Mr. C. H. Bollman, and on the Helicoid Land Mollusks, by Mr. H. A. Pilsbry.

An appendix contains notes on the recent literature of coral reefs, presenting fairly the general course of argument in the several papers or works mentioned.

IV. Miscellaneous Scientific Intelligence.

1. *British Association.*—The meeting of the British Association for the year was held at Newcastle, commencing on Wednesday, September 11. The address of Professor W. H. Flower, the president, was devoted mainly to the subject of the arrangement of museums, but it closes with a few words on evolution which end in the expression of his opinion, that the "principle of natural selection has played a most important part in the production of the present condition of the organic world; that it is a universally acting force continually tending toward the perfection of the individual, of the race, and of the whole living world." The address in the section of Mathematics and Physics was by Capt. W. de W. Abney, on the effect of light on matter; in that of Chemistry, by Sir Lowthian Bell, on progress in metallurgy through the aid of chemistry; in that of Geology, by Professor James Geikie, on progress in knowledge and theory with respect to the Ice-age; in that of Geography, by Sir F. de Winton; that of Economic science and Statistics, by Professor F. Y. Edgeworth, on mathematical reasoning in political economy; that of Mechanical science, by Wm. Anderson, on the molecular structure of matter, etc.; that of Biology, by Professor J. S. Burton Sanderson, on the mechanism of life in its simpler aspects; that of Anthropology, by Sir Wm. Turner, on the subject of heredity.

For the several addresses in full, the reports of committees, and abstracts of papers read, we refer readers to "Nature," commencing with the number for September 12.

2. *Scientific Papers of Asa Gray. Selected by* Charles Sprague Sargent. In 2 vols. 8vo. of 398 and 504 pp. (Houghton, Mifflin & Co.).—These handsome volumes contain a selection from the reviews, biographical sketches and shorter essays of Dr. Gray, and not from those issued by himself in volume form, nor any of his papers in descriptive botany. For fifty years he was personally identified with the botanical work of the world, and particularly with that of America; and, besides his special labors in the science, he was led by his interest in botany and in his fellow-workers to write reviews of botanical publications as they appeared, biographical sketches, and essays on various topics suggested by his own researches or those of others. These shorter papers, therefore, "furnish the best account of the development of botanical literature during those fifty years." Prof. Sargent states in his Preface that the amount of material he had for selection was overwhelming, the bibliographical notices and reviews

alone numbering eleven hundred. He has performed his duty well, having made a work that will be welcomed by all botanists, and friends of science--a memorial work, as the genial, judicious, truth-loving Dr. Gray is every where brought to mind; a historical work, historical of workers as well as work done; and a repository of views and discussions connected with structural and physiological subjects, the geographical distribution of species, nomenclature, heredity, variation and self-fertilization in plants, and various other topics, always instructive and often entertaining. Many of the papers are very much like talks from their author; and they present him in so many different moods, dependent on the subject in hand, that the volumes serve quite well in place of a biography.

3. *A popular Treatise on the Winds*, comprising the general motions of the atmosphere, monsoons, cyclones, tornadoes, water spouts, hailstorms, etc.; by WILLIAM FERREL, M.A., Ph.D. 505 pp. 8vo. New York, 1889 (John Wiley & Sons).—The great progress that has resulted from the recent systematic study of meteorology is well shown in this excellent volume. The eminent author has himself made important contributions to this advance. It could be safely assumed that a work from his pen would most satisfactorily represent the present state of the science, and this expectation is not disappointed.

The topics presented embrace the general constitution and circulation of the atmosphere, and further those disturbances in the general equilibrium which manifest themselves as cyclones, tornadoes, thunder storms, etc. These subjects are presented in simple, direct language, and with very little mathematical analysis, so as to appeal to a large class of readers who are not in a position to take up the study in accordance with the more profound scientific method.

4. *Sixth Annual Report of the Bureau of Ethnology to the Secretary of the Smithsonian Institution.* 1884–85, J. W. POWELL, Director. 675 pp. royal 8vo., with many illustrations. This richly illustrated report contains a paper by Mr. Wm. H. Holmes of 175 pages on the ancient art of the Province of Chiriqui, and another, of 50 pages, on a study of the textile art in its relation to the development of form and ornament; a paper by Dr. Franz Boas, 165 pages, on the Central Eskimo; one of over 100 pages, by Mr. Cyrus Thomas on the study of the Maya Codices, and one of 30 pages, by J. O. Dorsey, on Osage traditions.

5. *Elementary Algebra;* by ROBERT GRAHAM. Longmans, Green & Co.—This text-book develops the ordinary subject of Algebra including the Binominal Theorem but not logarithms.

6. *Numbers Universalised, an Advanced Algebra;* by DAVID M. LENSENIG. Part First. D. Appleton & Co.

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SCIENTIFIC INTELLIGENCE.

ERRATUM.

Pages 323, 324, for Sumpter, read Sumter.

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[THIRD SERIES.]

ART. LIII.—*The Temperature of the Moon.* From Studies at the Allegheny Observatory by S. P. LANGLEY, with the assistance of F. W. VERY.

(Memoir read to the National Academy of Sciences, November, 1887.)

THIS memoir may be regarded as the completion of the investigation commenced in 1883, and continued during the next four years, and of which previous portions have been published in the Memoirs of the National Academy of Sciences, in a paper read Oct. 17, 1884 (vol. iii), and in that read Nov 9, 1886, (vol. iv), the latter having been published in abstract in the American Journal of Science.*

The original memoir, of which the following is a very succinct abstract, can, from its special character, hardly claim the attention of the general reader; but the latter may, perhaps, be here reminded that the main questions at issue are the temperature of an airless planet at the earth's distance from the sun, the action of the atmosphere in modifying the temperature of such a planet, and, in general, the study of those conditions of radiation and absorption which have actually rendered life possible on our own. He may be reminded also that it has been generally assumed hitherto that the temperature of the sunlit surface of an airless planet at such a distance, *e. g.* of the

* For December, 1888. See also London, Edinburgh and Dublin Philosophical Magazine, December, 1888; also Ann. de Chemie et de Physique, July, 1889.

moon, would be excessively high. Thus Sir John Herschel, in his latest "Outlines of Astronomy," says: "The surface of the full moon exposed to us must necessarily be very much heated, *possibly* to a degree much exceeding that of boiling water." The only experimental evidence obtainable appeared to lend support to this view, for though Lord Rosse did not undertake to directly determine the lunar temperature (as he is often supposed to have done) any inference which can be drawn from his experiments appears to support the above views of Herschel, which he also cites.*

It has also been almost universally supposed that our atmosphere was nearly impervious to the lunar radiant heat, so that, if any existed, it could still not be perceived by us at the sea-level. Thus Sir John Herschel says of the moon that "its heat (conformably to what is observed of that of bodies heated below the point of luminosity) is much more readily absorbed in traversing transparent media than direct solar heat, and is extinguished in the upper regions of the atmosphere, never reaching the surface of the earth at all."

The reader may also be reminded that these statements have remained unchallenged on account of the hitherto insuperable difficulties of experimental investigation, arising from the all but infinitesimal amount of heat which the moon sends us, and the added fact that this heat, small as it is, is necessarily of two essentially different kinds, that which the moon, acting as a mirror, reflects from the sun, and that which directly emanates from the substance of her own sun-heated soil, while it is only by an analysis of each of these two kinds of heat, each in its totality non-existent to the most sensitive thermometer, that we can expect to give an experimental answer to the question.†

It was Melloni who, on Mt. Vesuvius, in 1846, by the employment of a polyzonal lens, one meter in diameter, and the

* See Proc. Royal Society, xvii, 1869, p. 443; xix, 1870, p. 12; Transactions, clxiii, pp. 622–4. Having elsewhere shown that the lunar radiation consists of a small quantity of reflected heat and a comparatively large quantity of heat emitted from its soil, Lord Rosse compares the total effect of this lunar radiation over that from the sky with that from two blackened vessels, one producing the same effect on his thermopile and galvanometer as the sky, the other as the moon, and finds that the observed galvanometer range is that due to a temperature of excess in the latter vessel to be computed at 197°·5 F. if Dulong and Petit's law of cooling is used, or at a still higher one if Newton's is employed. The effective sky temperature was about +20° F., so that if we suppose the result due wholly (instead of mainly) to the emitted heat, this would indicate a temperature of the lunar soil at any rate above that of boiling water. Lord Rosse, however, in view of the empirical character of the formula employed, and of other considerations, is careful to state as his conclusion "that the problem of the determination of the lunar temperature is nearly as far as ever removed from our grasp."

† In an appendix (No. 1) of the memoir referred to, will be found a historical account, believed to be fairly complete, of the labors of previous thinkers and workers in this subject.

newly invented thermopile and galvanometer, first succeeded in getting *any* certain indications of heat from the moon, though these were of the feeblest kind. It is Lord Rosse, employing the Parsonstown telescope with improved thermopiles and galvanometers, who has the credit of abundantly confirming Melloni's observation of the fact of the moon's radiant heat being perceptible, and further the great merit of making a preliminary investigation of its character, by showing by its imperfect passage through glass that it is chiefly non-reflected heat. Lord Rosse, however, as has been said, concludes that the problem of the moon's temperature is still indeterminate.

At this point the question is taken up by the writer who, with the aid of the bolometer, used directly in the lunar image, had already reached, in the first of the memoirs, mentioned above, the following inference among others of less importance, viz:—*that the sunlit surface of the moon is not far from the freezing temperature.*

This inference resulted both from observations in the direct beam and from a preliminary and partially successful attempt to form a heat-spectrum, for this gave indications of *two* maxima in the heat curve, the first corresponding to the heat from the solar reflected rays, the second (indefinitely lower down in the spectrum), corresponding to a greater amount of radiant heat emitted from a source at a far lower temperature, lower at any rate than that of boiling water, above which the temperature of the lunar soil has been hitherto supposed to not improbably be. This statement of the first memoir is put forward as inferential and probable merely, and not as conclusively proven.

The second memoir, on "The Solar and the Lunar Spectrum," is chiefly devoted to the invisible spectrum of the sun, but incidentally describes the progress of the improvement of the apparatus employed so as to better fit it for the delicate task

(1) of measuring the already feeble lunar heat when diffused by expansion into a lunar spectrum, and

(2) of determining the possible existence and the exact position of the two heat maxima already described in the first memoir.

We are now prepared to take up the present memoir, and give an abstract of its results. It contains researches pursued through several years with constantly improving instrumental means, and while the writer cannot feel that (owing to the extreme experimental difficulty of the subject) the results have obtained a certitude corresponding to the great labor bestowed upon them, he believes that this labor is justified by the fact that it has not been given to a question of merely abstract interest, but that the whole subjects of terrestrial radiation and the conditions of organic life upon our planet are intimately related to the present research.

Spectroscopy has hitherto dealt almost exclusively with light, but in this new field we consider chiefly that great invisible spectral region in which the *entire* radiation of the soil of our own planet is to be found, a region of which we have until quite recently known nothing. To see how the question of the lunar heat affects our knowledge on the whole subject of our planet's temperature, we must remember that until a few years past, it had been assumed by all writers of repute that the earth's atmosphere acted exactly like the glass cover of a hot-bed, and kept the planet warm in exactly the same way that the hot-bed is warmed, by admitting the light-heat of the sun, which was returned by the soil in the invisible radiation of greater wave-length to which the atmosphere was supposed to be impervious, and that thus the heat was stored, glass being till lately supposed to be practically athermanous to *all* infra-red heat. It was a necessary part of this assumption that all or very nearly all the infra-red was absorbed by our atmosphere, but in 1881, the observations of the Mount Whitney expedition, supplementing previous ones made at this observatory, showed that through the infra-red, *as far as it had then been explored*, the atmosphere transmitted the invisible rays with greater facility even than the luminous heat, so that the ordinarily received idea must be essentially modified, and, if the absorption of the telluric radiation did indeed take place as supposed, it must be in spectral regions then entirely unknown. It is in an examination of these, till now, quite unknown regions beyond the extreme boundaries of former researches on the infra-red, and in the study of the radiations of corresponding wave-length emitted from the lunar soil, that we find the principal subject-matter of the present memoir.*

It is, in introduction, again pointed out that the absorption of the earth's atmosphere for these radiations, as for all others, is not simple, but eminently complex, and that the old formulæ lead to gross errors in practice. Further, as the amount of radiation of a planet is like that of any other body, dependent on that of its surroundings, reasons are repeated for believing

* The reader is reminded that the words "infra-red" have obtained an extension of meaning since we have been able to show in previous memoirs, not only the vast amount of the energy in this region (which, in the case of the sun, is over 100 times that in the ultra-violet,) but that in this invisible infra-red there is every variety of condition, greater differences than there are *e. g.* between violet and orange light, and that Melloni's anticipatory comparison of varieties of radiant heat to varieties of color actually understates the truth.

that the so called temperature of space (a term due to Fourier and afterwards adopted by Pouillet who fixed its value at −142° Cent.) has no sensible existence, but may be here treated as that of the absolute zero.

There is next given a description of the apparatus, which consists essentially of a siderostat, carrying an 18-inch mirror, and capable of sending a lunar beam of corresponding capacity horizontally into an adjoining dark room and keeping it fixed there during the night's observations. In the path of the beam can be interposed a large double screen of blackened copper, ordinarily filled with water. The beam then falls on a condensing mirror, whose ordinary aperture of 8 inches does not, as may be seen, utilize the whole of the beam transmitted by the siderostat, but has been selected in reference to the capacity of the rock-salt train of lenses and prisms which forms the spectrum. This train is believed to consist of pieces of salt of hitherto unapproached perfection in workmanship, as at the time our investigation commenced, no salt prisms were procurable giving a single Fraunhofer line in the solar spectrum; while with the actual rock-salt train, D is divided in the spectrum of the moon. The general construction of the spectrobolometer, and of the special bolometer employed with it, will be found given in previous papers.*

There are three principal methods of investigation:

First; the measurement of the total heat of the moon with a concave mirror, admitting the interposition of a sheet of glass to rudely indicate the quality of lunar rays as compared with those of the sun. This method, which was that employed by Lord Rosse, has been very thoroughly practised here with results which have been partly given in the previous memoir.

Second; A method, practised here for the first time, and yielding quite peculiar results, has been to form, usually with this same mirror, an image of the moon, but to now let this fall upon the slit of a special spectroscope provided with the rock-salt train referred to; and after expanding this excessively minute heat in this way, it has been found possible, with late improvements in the apparatus, to measure by the bolometer the different degrees of heat in the different parts of this lunar heat-spectrum, both visible and invisible. The doing of this, with its results, forms the principal subject of the present memoir.

Third; since such a mirror as that just mentioned, owing to its short focus, forms an extremely small lunar image, in cer-

* See this Journal, xxv, March, 1883, and xxxi, January, 1886. For a description of the improved form of bolometer and galvanometer, see vol. xxxii, August, 1886.

tain observations (carried on, however, only during a limited time), we have taken advantage of the sensitiveness of our apparatus to directly explore a large lunar image with the bolometer, in spite of the diminished heat in such one. For this purpose a special mirror, 303^{mm} in diameter and 3137^{mm} focus, giving a lunar image of about 30^{mm} diameter, has been employed. On the occasion of a lunar eclipse the last named apparatus has also been used.

We have already alluded (see Memoirs of the National Academy, Vol. III, p. 20) to the especial importance of the action of the screen in these observations. This arises from the fact, as will be seen later, that we shall deal with lunar heat of a totally different quality from that of moonlight or sunlight. It is, in a large part, radiation emanating from the lunar soil, and of a quality, as we shall see, approximating that of the screen itself. It must be evident, then, that the radiations from this screen assume here a wholly abnormal importance.

An investigation of the theory of the screen accordingly occupies a chapter, for which the reader is referred to the original. We may remark here, in passing, that the investigation incidentally offers an explanation of the empirically known fact that the velocity of cooling of a hot body at various temperatures of excess varies with that of the enclosure itself. The discussion also indicates what appears to be an independent method of determining the absolute zero; but the method, although apparently correct in theory, would demand observations more accurate than our own casual ones to give it practical value. It may be, however, worth mentioning that the observations, such as they are, indicate by this novel method, the existence of an absolute zero at a point between $-250°$ and $-300°$ Cent.

A list of all the observations in the lunar spectrum extending from October, 1884, to February, 1887, is then given, together with some collateral ones upon the "great radiator." This latter instrument may be briefly described as analogous to an immense Leslie cube, presenting as it does a blackened radiating surface of the temperature of boiling water and of 1 square meter area. The object in giving it this extraordinary dimension, is to enable it to still angularly subtend the whole field of view of the bolometer, while it is at such a distance that the intervening column of air may be supposed to exercise a measurable absorptive effect. Its actual distance was 100 meters, and at this distance the absorption of the intervening air on the dark radiant heat, emanating from its surface at 100° Cent., was in fact manifest, and gave evidence, novel and interesting, both as to the actual absorption by our atmosphere for radiations from bodies of low temperature, and as to the spectral region where it chiefly occurred.

This list includes, besides the described heat observations on the moon at every obtainable lunation, the following others:

(1) On the heat during a lunar eclipse;

(2) On the quality of the heat in the lunar spectrum at different stages of the moon's age;

(3) On the direct heat observable from different regions of the moon's face in an enlarged lunar image, and of comparisons of the heat radiated by the dark and by the bright regions of the moon;

(4) A supplementary investigation showing that different percentages of the radiations from these dark and bright regions were transmitted by glass;

(5) Observations giving the means of comparing the atmospheric absorption of lunar radiations in summer with that in winter for equal altitudes;

(6) Very numerous observations of the spectrum of the midnight sky;

(These last are specially important here, where they are rendered necessary by the fact that this sky is the standard with which the lunar radiations are to be compared. These last observations give, for example, certain evidence of a great "hot band" in the negative sky spectrum, corresponding in position to the great cold band in the lunar spectrum, which is thus shown to be produced jointly by the absorption of the moon's rays and by the absorption of the radiation of the bolometer to the intervening air-column between it and the moon.)

(7) Observations supplementary to the last, by comparative measurements of the sky radiation from the zenith to the horizon;

(8) On further supplementary measurements made by comparing the energy in the spectrum of a lamp-black screen at 100° C. with that of the sky, showing the existence of several regions of atmospheric absorption, giving "hot bands" in the negative sky-spectrum.

(We only allude here, in passing, to the important inference to be drawn with regard to the nocturnal radiations from the soil of our own planet, to which these observations show that our atmosphere is partially diathermanous.)

(9) Of other measurements giving the means of estimating the total lunar radiation in terms of solar,

but for these and many more subsidiary ones, the reader must again be referred to the original memoir.

The only one of these subsidiary researches which needs further mention here is the measurement of the heat from different parts of the *eclipsed* moon, on the night of September 23, 1885.

The diameter of the lunar image was 28·3^{mm}, and of this only a limited portion (0·08 of the whole), fell upon the bolometer. As the penumbra came on, the diminution of heat was marked, being measured by the bolometer even before the eye had detected any appearance of shadow. The heat continued to diminish rapidly with the progress of the immersion in the penumbra, but at no time did the lunar radiation from the part in full shadow entirely vanish. At one hour before the middle of the total eclipse, the deflection in the umbra was 3·8 divisions. Fifty minutes after the middle of the eclipse it had diminished to approximately 1·3 divisions, less than one per cent of the heat from a similar portion of the uneclipsed moon, a deflection so small that its significance may be somewhat doubtful. It need hardly be stated that this heat from the eclipsed moon was almost absolutely cut off by the interposition of glass. The rise of the temperature after the passage of the umbra was apparently nearly as rapid as the previous fall. The vicissitudes of the lunar climate indicated by these observations in the short time of a few hours, must exceed the change from our torrid zone to the greatest cold of an arctic winter.

In this connection it should be stated that repeated observations on the dark side of the moon, have given only the same heat-spectrum as shown by the sky away from the moon, the conclusion being that, so far as our present observation carries us, the moon has no internal heat sensible at the surface, so that the radiations from the lunar soil, already spoken of, are to be understood to be due purely to solar heat which has been absorbed and almost immediately re-radiated.

The principal method employed in the present research for determining the temperature of the surface of the moon is founded on the fact, already experimentally established by the writer, that the position of the maximum in a curve, representing invisible radiant heat, furnishes a reliable criterion as to the temperature of the radiating (solid) body,* and on the further fact, established by Mr. F. W. Very and the writer, that two distinct heat maxima are observable in the lunar spectrum, one corresponding to the radiation reflected from the soil, the other to that emitted by it. It at first seemed, in accordance with what has just been said, that the accurate determination of the wave length of this latter maximum would give a correspondingly accurate determination of the temperature of the sunlit surface of the moon; and, accordingly, to this object the main portion of the observations were given. We may anticipate what follows by here saying that by this method, a per-

* Proc. Am. Assoc. for Adv. of Sci.. 1885; also this Journal, xxxi, Jan., 1886.

fectly correct one in theory, the writer believes that the temperature of the lunar soil could be determined with great exactness, were it not for the intervention of the earth's atmosphere, which exercises, in this part of the spectrum as in every other, a highly selective absorption, indicated here, however, not by fine lines like the Fraunhofer lines of the solar spectrum, but by enormously wide "cold bands," which vary in size and even in position from night to night,* rendering the exact position of this maximum in a corresponding degree indeterminate.

Another chapter is occupied by an example of a single night's work in detail, with a statement of some of the precautions and corrections employed in practice. It may be observed here in general as to the apparatus, that while the rock-salt train, as already mentioned, is of such perfection as to show the Fraunhofer lines very completely in the lunar luminous spectrum, the accompanying bolometer and galvanometer enable us to measure cold bands in the non-luminous lunar or air spectrum, whose heat is otherwise inappreciably so small that it corresponds to a radiation of $\frac{1}{100000000}$ of a small calorie per second, measured by the generation of a current of 0·000,000,001 ampère. This is the amount of heat and current implied in moving the galvanometer image over 1^{mm} of the scale. The image is quite steady enough under favorable conditions in fact to admit of the observation of less heat than this, giving deflections of fractional portions of a millimeter; but owing to fluctuations in the absorption of our atmosphere which transmits this radiation, rather than to any limitations of the instrument itself, it is generally found best not to note deflections of less than 1^{mm}. What has just been said refers particularly to measures of the diffused heat from the moon's soil in the invisible lunar spectrum and of the corresponding spectral analysis of the reflected heat. When, however, we place the bolometer directly in the lunar image formed by the 8-inch aperture, the deflection throws the needle at once off the scale, and is found on more careful measurement to correspond under favorable circumstances to a potential deflection of about $1{,}500^{mm}$ divisions. Melloni, it will be remembered, obtained four or five divisions on his galvanometer with the thermopile and the meter polyzonal lens on Vesuvius, and the immense difference just noted is some indication of the advance of experimental physics in this matter since his day.

* That an absorption band may vary in magnitude will excite no surprise, but that it should vary sensibly in position may appear to some in contradiction with our knowledge of the fixity of lines in the upper spectrum. An explanation of the anomaly will be found in this Journal for Dec., 1888.

Theory of observation; with typical example, showing method.

Every observation on the moon, whether on its total heat, as observed directly in the lunar image, or on its diffused heat in the spectrum, should consist in a comparison of its radiations with those of the adjacent sky on either side of it. If our thermometric apparatus had an absolute scale, and there were no intervening atmosphere, it appears, in accordance with what has already been said, that such apparatus, when directed not to the moon but to "space" more or less adjacent, should indicate the temperature of this space, which is sensibly that of the absolute zero; and then, when it is turned upon the moon, supposing it to receive only the emitted and not the reflected heat, it would give, also on the absolute scale, the temperature of the lunar soil. In fact, with such an absolute thermometer, the preliminary comparison with space would be unnecessary. In reality, we use not an absolute apparatus with a natural scale, but a differential apparatus with an arbitrary scale; and if we could work without an intervening atmosphere, we should, even in this case, require to let the bolometer radiate to space in order to determine the point on our arbitrary scale which corresponds to zero. We should then observe a second point corresponding to the temperature of the lunar surface, and having determined the value of the units of our arbitrary scale in terms of the natural one, we should evidently have the quantity sought.

The above conditions are still of ideal simplicity. The great, the almost insuperable difficulty of actual observation, lies less in the minuteness of the actual radiation, or even in its two-fold character, than in the fact that it is masked to us by the changes of an always intervening atmosphere. The case of observations on the sun is totally different from the present one, and would be so even if the sun were withdrawn till it emitted no more heat than the moon; for in this latter imaginary case, the greater proportion of the solar radiation would still lie in a spectral region totally distinct from that in which the radiations proper to the obscuring atmosphere are found, and it is the peculiar, unavoidable difficulty, at every stage of this long investigation, that since the moon and the air are both alike cold bodies, their invisible spectra are, in general, superposed in the same field. Let us add to this, that the (invisible) spectrum of the air is usually not fixed but fluctuating, and we shall see the desirability of having some separate standard with which to compare it from night to night. This we obtain most conveniently by filling a vessel of proper shape and size, either with water or with a freezing mixture at a temperature, constant for the series, and making this vessel itself the screen which is interposed between the bolometer and the lunar rays.

The bolometer must remain unmoved, and the direction of the heat-receiving apparatus to the east or west of the moon must always be understood to be obtained by a slight motion of the siderostat mirror.

That the minute change in the angle of presentation of the face of this mirror does not affect its own radiations appreciably, might well be anticipated, but is a fact which has not been left unproven by direct experiment. The bolometer, then, enclosed in a non-conducting case which cuts off radiations from every object but the mirror or prism immediately in front of it, practically feels only the radiations from the moon, or from the sky immediately on each side of it, except when the screen is interposed. Mirrors and prisms do indeed radiate heat to it from their own substance, but these radiations may be considered as absolutely constant, and as therefore absolutely negligible during the brief cycle of a single observation.

We confine ourselves here to the above general explanation, referring the reader who may be interested in the details of the observations to the original memoir, remarking, however, that the actual spectral position of a ray is given by a circle; reading to 10″ of arc, and that previous measures of our own* enable us to convert this arc into wave-length. This fixes the position of bands in the spectrum. The amount of heat in any portion of the spectrum is, within the narrow limits of errors of observation, strictly proportional to the deflection on the galvanometer scale (the conditions of the bolometer, battery current, galvanometer, etc. remaining constant). As these degrees are arbitrary, they are converted into thermometric degrees by a process fully detailed in the original memoir.

The preliminary record of the humidity, state of the sky, temperature, etc., is nearly self-explanatory. We need only explain that "Rock-salt lenses at 37^{cm}" refers to the fact that the focal length of these lenses increases from 35^{cm} in the visible spectrum to one indefinitely greater with heat of great wave-length, and that this focus accordingly needs to be adjusted for the particular part of the heat spectrum under study.

"Deflection per degree Centigrade" refers to the use of a constant determined for each evening, giving the actual deflection the galvanometer produces, for each degree of excess of temperature, in a certain standard Leslie cube at a certain standard distance from the bolometer.

The order of observation consists first, in noting the time. (We will suppose, in the example which follows, that the time is 9h. 08 M. T., on the evening of February 9, 1887); next, in noting the prismatic deviation corresponding to the actual position of the bolometer in the spectrum, which in this particular

* See this Journal, xxxii, August, 1886.

case is 41° 08′ 30″, or that of the D line in the visible spectrum. Previously to observation the bolometer has been radiating through the spectroscopic train and mirror to the special screen described, which, on this particular evening, is at the constant temperature of +18° Cent. Under these circumstances, the needle will take up some position representing radiation to the screen, which at this first exposure we will call (A), its position here on our arbitrary scale being at the 215th millimeter. During this time the siderostat mirror has been so placed as to be sending toward the bolometer radiations from the sky on the *east* of the moon.* Call the effect of these particular sky radiations (B). They have been intercepted by the screen, but now the screen is withdrawn and the bolometer radiating to this eastern adjacent sky receives less heat than the screen gave it (213·2). The siderostat mirror is moved to throw on the image of the moon. Let us call the resultant deflection (C). The moon appears in this example very slightly warmer than the sky for the image moves on to 213·4. Next by another adjustment of the siderostat mirror, the sky *west* of moon is thrown on. Call this result (D). The image on the galvanometer scale moves back to 211·9, indicating cold. Finally the screen is interposed the second time. Call this second interposition (E). In an ideally constant apparatus, the second interposition of the screen should give the same reading as the first. Actually 210· divisions is obtained, instead of 215· as before, owing to the so-called "drift" of the needle during observation. The mean of the two readings for sky-east and sky-west is now subtracted from that for the moon and gives, under the column $C - \frac{B+D}{2}$, the difference between the temperature of the moon and the sky in our arbitrary degrees. It will be seen from a comparison of all the numbers in this column that there are fairly accordant indications of a maximum near the prismatic deviation of 39° 30′ which corresponds with the wave-length of $2 \cdot^{\mu} 1$, and approximately with the maximum of the solar heat curve. There is another maximum of far greater magnitude near 37° 30′ (wave-length about $14 \cdot^{\mu}$), corresponding to the maximum known to exist in the radiations of bodies at a temperature of about 0° Cent., and due, it would seem almost beyond doubt, to radiations from the sun-heated lunar soil. It will be seen also that all numbers in this column have one sign, i. e. the positive, indicating that throughout this series, without exception, the moon has been found warmer than the adjacent sky. This, indeed, is to be expected, since, without the atmosphere, the temperature of this sky would be nearly that of the absolute zero, and at any rate lower than

* The area of sky observed is virtually the same as that of the moon.

that of the moon. The difference is so considerable that even the temperature fluctuations due to the interposition of the intervening atmosphere in no case this evening hide the fact.

In order to compare the fluctuating radiations of the atmosphere with a constant source, we take the mean of the sky observations and compare it with the mean of the readings on the screen. In this particular case, $\frac{B+D}{2} - \frac{A+E}{2}$ gives a difference of but 0·1 division; but this is, as we have already observed, when the bolometer is directed towards the orange in the luminous part of the spectrum, and our cold screen, it need hardly be said, is not emitting any rays of orange light. We conclude, then, that the apparent deflection of 0·1 div. here has no real significance; but, as we go down the spectrum towards the region of the radiations from cold bodies, we find, beyond deviation 39° ($\lambda=4{\cdot}^{\mu}3$), values which indicate a real excess of screen over sky radiations.

We have selected the first number in our second series of Feb. 9, 1887, as the example, because this follows the normal course without marked instrumental disturbance The nature of these fortuitous disturbances and the methods adopted for their correction are explained in the original memoir. In many cases, as will be seen, they may cause the sky on one side or the other of the moon to appear momentarily warmer, although the mean of the two is colder.

Comparisons of the sky and screen by directing the bolometer to the sky at the zenith and at the east and west horizons follow, and three double series at the most important points in the spectrum, made with the moon at a high, a low, and an intermediate altitude, give indications of the atmospheric absorption. These, however, are not given here, but only the double series (No. 2) of which a literal transcript from the book of original entry now follows:

Station, Allegheny.
Date, February 9, 1887.
Wetbulb at $7^h 30^m = +11°{\cdot}2$ C. } Internal
Dry bulb at $7^h 30^m = +16°{\cdot}0$ C. } Internal
Temperature apparatus at $9^h 45^m = +19°{\cdot}8$ C.
External temperature, near the freezing point.
State of sky at $8^h 30^m$ clear. Very good sky.
Aperture of slit $= 3^{mm} = 27'{\cdot}9$.
Prism used L_{II}: $A = 60° 00' 28''$.
Rock-salt lenses set at 37^{cm}.

Spectrum thrown west.
Galvanometer No. 3.
Time single vibration $= 12^s$.
Deflection per degree Centigrade $= 17{\cdot}8$.
Bolometer No. 1; aperture $= 3^{mm} = 27'{\cdot}9$.
Setting on $D_2 = 41° 08' 30''$.
Battery current $= 0{\cdot}036$ ampère.
Reader at circle, J. P.
Reader at galvanometer, F. W. V.

Time.	Deviation.	Screen A.	Sky B.	Moon C.	Sky D.	Screen E.	$C-\frac{B+D}{2}$.	$\frac{B+D}{2}-\frac{A+E}{2}$
Series II								
$9^h\ 08^m$	41 08 30	215	213·2	213·4	211·9	210	0·8	+0·1
	40 20	228	233	235·6	234·8	233·8	1·7	+3·0
	40	183·8	183	184·6	181	180	2·6	+0·1
	39 40	183·8	185	188·2	184·2	184	3·6	+0·7
	20	192	193·5	198·8	196	197	4·1	+0·2
	39	185	185·3	188·4	186	188	2·7	−0·8
$9^h\ 20^m$	38 40	197·7	196·2	198·3	197·5	197·8	1·5	−0·9
	30	214	213	214·5	212	212·8	2·0	−0·9
	20	182·5	183	183·6	182·4	184	0·9	−0·6
	10	185	184·6	186·7	186·7	189	1·0	−1·0
	38	191·6	184	189·2	182·8	186·2	5·8	−5·5
	37 50	175	170·8	180	167	170·2	11·1	−3·7
	40	167·4	161	177·2	159·4	168	17·0	−7·5
	30	171·4	165	181·8	161·2	172	18·7	−8·6
	20	171	166·7	182·8	164	171·7	17·4	−5·9
	10	173	169	182	168·8	176·2	13·1	−5·7
	37	173	166·5	176	166	174	9·7	−7·5
	36	178·2	174	184	172·8	178·2	10·6	−4·8
$9^h\ 42^m$	35	183·2	182	184·3	179·6	180·6	3·5	−1·1
				Temperature of Screen = 18°.				
$9^h\ 45^m$	35	190	185	186·2	178·2	181	4·6	−3·9
	36	191	190	201·3	191·8	197·6	10·4	−3·4
	37 00	199·5	193·8	205·5	192·2	200·9	12·5	−7·2
	10	198·2	190	203	186·8	195	14·6	−8·2
	20	189·5	181·5	197·2	178	187·1	17·5	−8·6
	30	188·2	182·4	200·2	180	189·5	19·0	−7·9
	40	189	183·5	200·5	178	182	19·4	−4·4
	50	181·4	176·3	188·8	175·4	176	12·8	−2·7
	38 00	173·6	172·8	180·6	175·9	181	6·3	−3·0
$10^h\ 00^m$	10	185	183·7	185·8	185	188	1·4	−2·1
	20	195	195·9	198	197·8	199·7	1·2	−0·6
	30	203	203·5	205	201	201	2·8	+0·2
	40	209·7	208	208·7	206	205·8	1·7	−0·7
	39 00	206	207	211·2	207·4	209	4·0	−0·3
	20	210	211·4	215	210·5	210·5	4·0	+0·7
	40	200·5	201·5	205	201	202·3	3·7	−0·1
	40 00	206·4	209·2	215	211·6	211·6	4·8	+1·2
	20	214·5	214·7	217	214	215	2·7	−0·4
$10^h\ 20^m$	41 08 30	221·4	222	224·1	223·2	223	1·5	+0·4

The observations of this night may serve as a type of a great many others. They all show *two* maxima (see column $C-\frac{B+D}{2}$) whose apparent position differs little from that already given in the example, and it may be added that in all cases the radically different character of the heat in these two maxima bears the proof of the independent test furnished by passing the rays through glass before measurement, the rays from the upper maximum passing freely, as rays belonging to the maximum of solar reflected heat should do—those in the lower maximum, on the contrary, being absolutely cut off by the glass, as rays of this wave-length from a source at a temperature below that of boiling water are known to be. This test of the glass, employed by Lord Rosse in the direct lunar beam, is here, it will be observed, applied at different parts of the lunar heat-spectrum and its result in the latter case, corroborating that already obtained by the respective wave-lengths of the maxima, brings evidence of a radiation of heat from the lunar soil at a temperature at any rate below that of boiling water.

Other observations furnish the means of computing the relative absorption of the earth's atmosphere as exhibited in extended cold bands in the region of the lower maximum. Then, from a combination of the two, we are enabled to reach a certain approximation to the position and magnitude of this maximum as it would appear if the atmosphere had not intervened. The existence of some of the principal atmospheric cold bands in this region, due to the absorption exercised by an atmospheric column 100 meters in length, has been quite independently determined by means of the great radiator already referred to. During moist summer weather two principal maxima have been found in its spectrum, the larger at deviation 37° 15′, nearly agreeing with the lunar curve in summer, a second smaller maximum at deviation 38° 45′, and between them a cold band with its minimum at deviation 38° 20′. Remembering that the unabsorbed spectrum from a radiating surface of lamp-black, at the temperature of boiling water, has its maximum at 38° 25′, or very near the deepest depression of the cold band, it will be recognized that we have evidence of a considerable absorption at this point.

To this must be added the fact, shown by our observations, that in the case of solids the greater part of the whole heat is always found *below* the maximum of the (unabsorbed) prismatic curve. If this law hold in the case of the sun, since little heat is found below its actual prismatic maximum (near deviation 39° 40′), the inference is that absorption in that region (i. e. the *extreme* infra-red), must have been great.

Arguments on these different lines, combined with another derived from a direct comparison of sun and electric arc radiation, which will be described farther on, enable us to present a curve (Plate X) showing with the degree of approximation compatible to the first attempt in such a field, the atmospheric absorption in all parts of the spectrum.

The final result of the measures, extending over the three years from 1884 to 1887, is given in Plate XI, in which abscissæ correspond to deviations of a rock salt prism of 60°, vertical ordinates to directly observed heat from radiations, while the dotted curve indicates what seems to be the most probable position and amount of the lower maximum, as it would be observed were there no intervening atmosphere.

The following remarks may serve to make the full meaning of this curve clearer.

The heat is a vanishing quantity at deviation 42° at the left of the scale (42° with a 60° prism at the temperature of +20° Cent., corresponding to a wave-length of $0 \cdot^{\mu} 48$, or that of "blue" radiant energy). Confining our attention to the solid curve, we observe that it reaches a maximum near 39° 40′=$1^{\mu} \cdot 5$, corresponding to rays of dark heat which are yet transmitted by glass, and which must be emitted from a source at a very high temperature. The maximum of the *solar* heat directly observed through the rock-salt train is found to be at the same point. There is no reason to doubt, then, that this maximum is due to the solar heat reflected from the lunar surface, and its actual effect is to produce a deviation of rather less than 20 degrees on the arbitrary scale of the galvanometer from the small part of the spectrum covered by the bolometer. Continuing to go down the spectrum in the direction of greater wave-lengths, and passing with casual notice a depression at 39° 15′ ($\lambda = 3^{\mu} \cdot 1$), which, it is probable, would be found in the direct lunar spectrum were there no intervening atmosphere, we come to a very large depression at 38° 30′ ($\lambda = 7^{\mu}$), due almost beyond doubt to the rays emitted from the lunar soil having been here absorbed by our atmosphere. The conclusive evidence that this is due to the atmosphere is derived, first, from the constant appearance of an analogous band in the heat spectrum of the sky away from the moon, and second, from the independent observation of the existence of this band in the invisible spectrum of a terrestrial object after absorption by 100 meters of air. In the latter case it is always found distinctly marked in moist weather and can even be observed under circumstances favorable to its development, in the few meters of air within the length of the observing room. It is important here to remark that the maximum of the *unabsorbed* radiation of a Leslie cube, at a temperature a little below that of boiling water, is found at the deviation of 38° 20′ ($\lambda = 8^{\mu}$), when observed by the same rock-salt train.

Following the solid curve down the spectrum, we find it rise into its principal maximum just below deviation 37° 30′ (λ, about 14^{μ}) where it attains a height of about 43 degrees of our arbitrary scale.* It is again most important to remark that this point, just below 37° 30′, corresponds to the maximum of the unabsorbed radiation of a lamp-blacked surface at a temperature of about −10° Cent. Were it not, then, for atmospheric absorption, we should assert with confidence that, so far as the radiations of a lamp-blacked surface and the

* It may be interesting to observe that we infer from our bolometric observations that the effect of the total and unconcentrated lunar radiation on a blackened thermometer would be something like $\frac{1}{6000}$° Cent.

lunar soil are comparable, the temperature did not exceed −10° Cent. Below this point, the curve falls off with interruptions by several cold bands, until evidence of heat disappears near deviation [illegible]3° of our rock-salt train; but of this latter portion of the solid curve, we will not pause here to speak. The dotted line is an attempted reconstruction of the original curve of lunar heat as it would appear before atmospheric absorption. It is made by allowing for the amount of absorption directly observed in the sky radiation, and in the radiation from terrestrial objects at a low temperature, already referred to, supplemented by an estimate of atmospheric absorption in this region inferred from a comparison of solar and electric arc radiation, to be presently described; and this constructive maximum occurs near deviation 38° 15′ which corresponds to the maximum of unabsorbed radiations from a terrestrial source at a temperature of a little over +50° Cent.

Direct observation, then, of the lunar heat curve, indicates that the probable temperature of the lunar soil is between 0° and −20° Cent. This is subject to the effect of our atmosphere which probably is to displace this maximum in some degree towards the position of greater cold; but the highest temperature we can assign by an allowance for this, is +50° Cent. Between these points, we believe it probable that the temperature of most of the lunar sunlit soil must lie. The temperature of the lunar poles has not been specifically determined, but direct observation indicates that it is still lower.

The relative amounts of the reflected solar and the emitted heat could evidently be obtained with satisfactory accuracy by measurements within the respective portions of the solid curve, were it not for the distorting action of the terrestrial atmosphere already mentioned. We must refer to the original memoir for reasons for estimating the total amount of the reflected radiation as little more than $\frac{1}{7}$ of that emitted.*

* Lord Rosse found that 87 per cent of all the solar rays were transmitted by a particular piece of glass which allowed 92 per cent of solar light to pass, and 12 per cent of the total lunar beam. He attempted from this to determine the relative amounts of the solar and lunar heat, but felt obliged, in the then state of knowledge, to make the assumption (which our subsequent researches have shown to be erroneous) that the glass absorbed *all* the invisible rays, or that the lunar radiation contains 12 per cent of luminous rays, instead of less than 5 per cent, which is more nearly the actual case; but when Lord Rosse's own observations are reduced with the aid of the facts determined by the writers, and representing the actually large transmissibility by glass of the invisible rays of shorter wave-length in the infra-red, his expression for the relative value (which we will call x) of the emitted part of the lunar radiation (whose transmission by glass is presumed from observations on a Leslie cube to be 1·6 per cent) becomes $\frac{0·87+0·016x}{1+x}=\frac{12}{100}$, from which $x=7·2$ times the reflected solar part; so that if Lord Rosse could have possessed, at the time his reductions were made, knowledge as to the diathermic properties of glass which has only been acquired since, his own observations would have given results for the relative amounts of reflected and radiated heat in somewhat remarkable accordance with our own.

The memoir, of which an abstract is here given, contains numerous subsidiary researches and observations for which we must refer the reader to the original, only here mentioning two:

First.—Temperature correction of a rock salt prism. This investigation of the change of refrangibility due to temperature was carried only far enough to give such approximate accuracy as served our immediate purpose, giving a value of $-13''$ of arc for each degree Centigrade, but subsequent measurements have materially modified this, and I give the value now adopted, which is $-9''\cdot5$ the formula being

$$d_{t^\circ}=d_{20^\circ}-(t-20)10''$$

where $d=$ deviation, and $t=$ temperature in Centigrade degrees.

Second.—Comparison of the intrinsic intensity of solar radiation with that of the electric arc in different parts of the spectrum. This observation of the comparative intensity of the sun and the electric light is given in the original memoir only so far as to show that it brings independent evidence of a large atmospheric absorption of the extreme infra-red rays and enables us to estimate approximately the amount of this absorption at each point in the spectrum. The observations were not repeated to obtain such a thorough comparison as would be desirable. As they have never been printed, however, and since, as far as we know, none other such exist, we will give them here under the caution that they are to be considered only first approximations. The light was that from the pit of the positive carbon of gas coke, one inch in diameter, with the current derived from a dynamo, actuated by an engine of ten horse power, and therefore certainly at least as intrinsically hot and bright as any smaller arc-light in more common use, and presumably much more so. The apparatus was that already described in the memoir "On Hitherto Unrecognized Wave-lengths."*

The following table gives the observed galvanometer deflections after applying a multiplying factor for the shunt, which had to be used for the larger readings:

1 Deviation Rock Salt 60° Prism.	2 Wave-Length.	3 Observed deflection *sun* after absorption.	4 Observed deflection *arc.*	5 Calculated deflection *sun* without absorption.	6 Observed ratio sun and arc.	7 Calculated ratio of unabsorbed sun and arc.
° ′	μ	div.	div.	div.		
43 53	0 373	7·5	1·3	34·	5·77	26·0
43 17	0.398	11·5	1·5	38·	7·67	21·8
41 54	0·489	33 5	5·3	60·	6 32	14·4
41 05	0·587	104·0	10·5	115·	9 90	11·1
40 45	0·663	204·0	22·0	204·	9 27	10·0
40 27	0 749	432·0	43·5	450·	9 93	9·1
40 05	0 96	1 073·0	215·0	1 763·	4·99	8·2
39 54	1·13	1 783·0	459·0	3 534·	3·88	7·7
39 20	2·87	1 905·0	882·0	5 645·	2·16	6·4
39 00	4·3	521·0	235·0	1 363·	2·22	5·8
38 45	5·6	75.0	157·0	832·	0·48	5·3
38 00	10·4	19·5	39·0	156·	0·50	4·0

* See this Journal, xxxii, August, 1886.

The result of the comparison of the (of course unabsorbed) electric arc with the radiation of the sun after absorption, as shown in the sixth column, is that this solar radiation in the orange and red is nearly ten times that of the arc, while towards the violet end of the spectrum, the relative superiority of the absorbed solar heat diminishes, evidently because of the progressive increase of the atmospheric absorption in that direction, which lessens the solar intensity without sensibly affecting that of the arc. The solar efficiency continues greater through all the infra-red spectrum known until very lately, while in the extreme portions recently investigated, it falls below that of the arc. This is partly due to the fact that radiation from a source at a lower temperature (the arc in this case) is relatively more powerful in the longer than in the shorter waves; yet it can hardly be doubted that here also (that is, in the *extreme* infra red) a very large atmospheric absorption has taken place.

There is reason to believe that a considerable part of this absorption takes place in the first few meters of air, while we conclude, from all the evidence in our possession, that the real telluric absorption, being a locally selective one, is much greater than the comparison of high and low altitude observations alone would indicate.

The import of this comparison will be still more evident from a consideration of the seventh column, where by means of the Allegheny tables of the solar absorption, we have calculated the ratio of the arc heat to that of the sun before absorption by the earth's atmosphere. Although a large absorption by the solar atmosphere has already taken place, we see that in the ultra-violet the solar radiation is from 20 to 30 times that of the arc, while that of the absorbed sun is only about 6 or 7 times. When we reach the region of the red and upper infra-red, we see that these ratios are nearly the same in the absorbed and unabsorbed solar radiation, showing that the terrestrial absorption in this region (which was once supposed to be its principal seat), is in fact very small, while in the regions of the extreme infra-red corresponding to temperatures not greatly exceeding that of the terrestrial soil (regions only revealed by quite recent investigation) the telluric absorption again becomes considerable.

The general result of this comparison is to enhance our ideas as to the rate of solar radiation, and as to the solar temperature. Comparisons of the total solar radiation with the total arc radiation have (it may be observed) been made before, but so far as I am aware, comparisons of the heat in different portions of their spectra are here presented for the first time.

Principal Conclusion.

Of the numerous conclusions to be drawn from this research, we here only direct the reader's attention to what we consider the most important one, namely: That the mean temperature of the sunlit lunar soil is much lower than has been supposed, and is most probably not greatly above Zero Centigrade.

Post Scriptum.

I would ask to be allowed here to state that the very considerable expense for the special means and reduction of the preceding series of lunar researches was borne by one of the most generous and disinterested friends that Science has had in this country, the late William Thaw, of Pittsburgh. By his own wish, no mention of his name was made in previous publications in connection with the results so greatly indebted to his aid. His recent death seems to remove the restriction imposed by such a rare disinterestedness.

ART. LIV.—*The Lower Cretaceous of the Southwest and its relation to the underlying and overlying formations*; by CHARLES A. WHITE.

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THE Cretaceous strata which constitute what has become known as the Texas section are referable to two natural divisions which, in North American geology, may be properly designated as Upper and Lower Cretaceous respectively, although not implying thereby that they are respectively the equivalents of the Upper and Lower Cretaceous of Europe.* The fossil contents of each division indicates that each represents an unbroken portion of Cretaceous time; and the paleontological contrast between the two divisions indicates that there is a time hiatus between them.

The Upper Missouri river section of Meek & Hayden, from, and including, the Dakota Group upward, may be taken as representing the upper division, while the lower division, which I have heretofore designated as the Comanche series, has been often omitted by geologists from their sections of the North American Cretaceous, or its relation to other formations has been imperfectly understood, or stated. Strata of the lower division have not been discovered to the eastward of the 95th meridian, and, with the probable exception of a locality in

*In my future writings upon the North American Cretaceous I propose to make its division into Upper and Lower Cretaceous still more general.

central Kansas, none have been discovered farther north than the southern part of Indian Territory and the southwestern part of Arkansas.

The results of observations made by myself during the past season indicate that they do not extend so far northward in New Mexico as the central part of that territory, although they are known to exist in the extreme southern part. Several years ago M. Remond obtained a collection of fossils containing characteristic species of the Lower Cretaceous from "the Sierra de las Conchas, near Arivechi, Sonora," which were described and figured by Mr. Gabb in volume ii, Paleontology of California. This is the most westerly locality at which the Lower Cretaceous strata discussed in this article are known to exist, the Lower Cretaceous of California, which contains a totally different fauna, not being now referred to. Important exposures of the Lower Cretaceous strata which are discussed herein are known in the Mexican states of Chihuahua and Coahuila, and I have obtained some indirect indication of their presence in the States of Nuevo Leon and Zacatecas also. They are believed to extend still farther southward in the Republic of Mexico, but I have yet no definite information of it.

The greatest known development of these Lower Cretaceous strata, as regards thickness, is reached in northern Mexico, but more abundant collections of the fossil fauna which characterizes them have been obtained within the limits of the State of Texas than elsewhere. This latter fact is probably due not more to the originally greater prevalence of the fauna there than to the greater consolidation which the strata have undergone in their westward extension and the consequent obscuration and inaccessibility of most of the fossils which the rocks there really contain.

The contrast between the Lower Cretaceous of the Southwest and the Upper Cretaceous which overlies it there, and which also prevails in the Atlantic, Gulf and Interior regions, is very great. The former. wherever it has been found, is shown by its fossils to have been an open sea deposit. The strata are either limestones or strongly calcareous rocks, sandstones and argillaceous shales having never been found to enter largely into their composition; and, except locally, it has not yet been found practicable to divide them into separate formations upon paleontological grounds. On the contrary the Upper Cretaceous is largely composed of sand and other detrital material, plant remains are frequently found in its strata and, in the great interior region, portions of all the formations are coal-bearing. Furthermore, it is divisible into several separate formations which are recognizable over large geographical areas.

The paleontological contrast between the Upper and Lower Cretaceous is also great, as has just been intimated. With the exception of the Laramie formation at the top of the Upper Cretaceous series, and the Dakota at its base, all the formations of that series are characterized by marine fossils, and the southern equivalent of the Dakota formation is also of marine origin, as is shown by the character of its fossils. But while the marine faunas of the respective formations which compose the Upper Cretaceous are so related to one another by identity of a portion of their specific and generic forms as to indicate that no complete chronological break occurred between any of them, such faunal relationship between the Upper and Lower Cretaceous, so far as is now known, does not exist. That is, not only are no known species common to both divisions, but many of the genera and some of the families of mollusks found in the lower, are not known in the upper, division. Besides the lithological and paleontological contrast between the two divisions, which has just been noticed as indicating their separateness, they have been found in some places to be plainly unconformable.

The extent of the chronological hiatus between the Upper and Lower Cretaceous we have at present no satisfactory means of determining, because the Cretaceous record for our continent, so far as it is now known, is much broken below the horizon of the Dakota Group; because most of the known subdivisions below that horizon are geographically widely separated from one another and all of them have not yet been thoroughly studied; and also because the European record is not an adequate standard in this case. For the latter cause, we cannot say with confidence that the Comanche series really represents any one of the divisions of the European Cretaceous from the Gault to the Lower Neocomian inclusive. Furthermore, while it is not at present improbable that this series is equivalent with the Queen Charlotte Island and Kootanie formations, as has been suggested by Dr. G. M. Dawson,* we have yet no direct evidence of it; that is, there is no known stratigraphical continuity between those northwestern formations and the Comanche series, and no fossils have been found common to both. The presumptive evidence of their equivalency is therefore apparently confined to the position which each is known to hold beneath acknowledged Upper Cretaceous strata and to certain probably contemporaneous displacements of the lower series which have occurred in both regions.

The unconformity between the Lower and Upper Cretaceous of the Southwest, together with the faunal break between them, which have already been mentioned, make it evident

* This Journal, vol. xxxviii, p. 122.

that the latest strata of the Comanche series are considerably older than the earliest ones of the Dakota Group, but we yet know of no formation, either upon this continent or elsewhere, which can be confidently assigned to a place between them. Between the Lower Cretaceous of the Southwest and the underlying formations there is a distinct hiatus which will presently be further mentioned.

In Texas, east of the Pecos river, and in Arkansas and the Indian Territory, the Comanche or Lower Cretaceous strata, while they are frequently in the condition of ordinary firm limestones, often consist of friable, more or less concretionary calcareous layers, the prevailing color of the whole being light gray. All the strata are usually fossiliferous, often abundantly so, and it is from the less compacted layers that most of the collections of fossils have been made. Even where these eastern Comanche strata are most displaced, they rarely consist of densely compacted layers.

East of Pecos river they are found on the east, south and west sides of the Texas Paleozoic area, where the series ranges in thickness from one hundred to eight hundred feet, with a considerable thickening above this in the neighborhood of Austin. Upon the western side of that area the whole series disappears from view by a westerly dip; and when it is brought up again west of the Pecos in Texas, and south of the Rio Grande in Mexico, by the mountain uplifts which are presently to be further mentioned, it is found to have become greatly thickened and its strata all changed to compact bluish limestone closely resembling those of Paleozoic age, especially those of the Carboniferous of the great interior region. In these respects they are in strong contrast with all other known strata of the North American Cretaceous.

Within the region that includes the portion of Western Texas which lies west of Pecos river, together with the adjacent parts of the Mexican states of Chihuahua and Coahuila, there are numerous clusters and short ranges of mountains, a part of which are composed of erupted rocks, but many of which are true orogenic uplifts of stratified formations. It is the latter that have just been briefly referred to. These uplifts have brought to view strata of various ages including Lower Cretaceous, Carboniferous, Silurian and apparently still older strata. The Upper Cretaceous, including the Laramie, was also involved in the same displacements. Besides these stratified rocks, a crystalline granitic rock is sometimes observable beneath them, in the mountain ranges, which has sometimes the appearance of having been intruded, but it is not thought to have any relation to the erupted rocks which have been mentioned as composing a part of the mountain ranges of this region.

One of these short ranges lying in the Mexican state of Chihuahua, 75 miles southeastward from Presidio del Norte, and known as the Sierra San Carlos, was observed by Dr. Newberry several years ago, and lately by myself, to consist mainly of the hard bluish limestones which, from bottom to top carry fossil forms which are characteristic of the Comanche series. These strata which are there strongly upturned and flexed, have a thickness of fully 4,000 feet, to which should probably be added 500 feet of similar and conformable strata at the base of the former, the only doubt as to their being a part of the Lower Cretaceous series there arising from the obliteration or obscuration of the contained fossils. These latter strata which, it may be incidently mentioned, contain deposits of argentiferous galena, rest with apparent conformity upon others which are mostly siliceous, highly metamorphosed, and probably of pre-Silurian age. The latter in turn rest upon the crystalline granitic rock which has already been referred to, and which seems to form the core of the mountain range.

At the eastern base of the range about 700 feet in thickness of strata occur which bear *Inoceramus problematicus* and other Upper Cretaceous fossils. The lowermost of these Upper Cretaceous strata are there almost vertical, and they are apparently conformable with the almost vertical Lower Cretaceous strata with which they are in contact; so that it is evident that both the Upper and Lower Cretaceous were involved in one and the same displacement. Because of this apparent conformity the stratigraphical hiatus which is understood to exist between the Upper and Lower Cretaceous is not distinctly shown here.

There is no apparent reason for supposing that the much altered strata which underlie the Lower Cretaceous in the San Carlos Mountains are of Mesozoic age, and therefore it is assumed that both the Jura and Trias, perhaps also the Carboniferous, Devonian and Silurain are absent there. It is such evidence as this of a great hiatus beneath the Lower Cretaceous that has been referred to.

The only other uplift of Lower Cretaceous strata that will be specially mentioned in this article occurs in the Chinate Mountains, in Texas, about 25 miles north of Presidio del Norte. At the eastern end of this range, near the Shafter silver mines, the Lower Cretaceous* strata are found resting directly and conformably upon the Carboniferous limestones; both formations being composed of limestones which are so similar in color and lithological character that their difference in age would hardly be suspected by casual observation, and is only demonstrable by the discovery of characteristic fossils in

* These Cretaceous strata also bear silver ores.

each. Omitting mention of the Permian, or uppermost portion of the Carboniferous system, which seems to be absent here, the hiatus between the Lower Cretaceous, and the Carboniferous strata of the Chinate Mountains amounts to at least the whole of the Jura and Trias.

This hiatus is no greater than is exhibited in others of the mountain uplifts in the region under discussion, and not so great as it is in some cases. Indeed, so far as I am now aware, the hiatus between the Lower Cretaceous and the next underlying rocks is nowhere in all that region less than it is at the locality in the Chinate Mountains just mentioned. That is, both the Jura and Trias are believed to be absent there. That neither the Jura, Trias, or Lower Cretaceous occur between the Upper Cretaceous and Carboniferous in central New Mexico, accords with observations that I made there during the past season. So far as both the Jura and Trias are concerned, I have not yet been able to obtain any satisfactory proof that either of these geological divisions are represented by any North American strata south of the 34th parallel of latitude.*

ART. LV.—*On the Hinge of Pelecypods and its Development, with an attempt toward a better subdivision of the group;* by WM. H. DALL, Paleontologist, U. S. Geol. Survey, and Curator Dept. of Mollusks, U. S. National Museum.

THE attempt to divide the class *Pelecypoda* or *Lamellibranchiata* into orders has so far been unsuccessful, or at least the subdivisions adopted have from time to time been found unsatisfactory, on account of the discovery of forms which combine in their organization characters which had previously been regarded as diagnostic of important subdivisions, such as orders.

This has resulted from the selection of characters as diagnostic which are really not fundamental in the evolutionary history of the minor groups. As we gradually become acquainted with the mutability of the adductor muscles, the gills, the arrangements for retracting the siphons and other factors in the mechanics of these organisms, the classification based upon their mutations has gradually ceased to satisfy students though one phase or another of it may still retain a place in ordinary text books.

* Reference is not here made to the "Dinosaur Sands" which lie at the base of the Comanche Cretaceous upon both sides of the Paleozoic area in Texas. These beds I have provisionally included in the Lower Cretaceous, but it is probable that they represent the Potomac formation of the Atlantic coast region, and it is regarded as possible that they represent the uppermost Jurassic of Europe.

To cite a few examples it will be remembered that the most persistent of the early systems for classifying these animals was based on the number of adductor muscles or the scars upon the shell by which they might be traced. At first the groups of Monomyarians or forms with one adductor, like the oyster, and Dimyarians with two adductors, like the ordinary edible clam, seemed sufficiently well distinguished. Later when transitional forms like the mussel and its allies were carefully studied a new group, *Heteromyaria* was erected for those which would not fit into either of the others.

But when it is considered that there are forms like *Dimya*, in which with a monomyarian organization two distinct adductors are found, one at each end of the shell; that in *Chlamydoconcha* we have a specially modified animal with no adductors at all; that in *Mulleria* we have the young (not larval) animal typically Dimyarian, and becoming in its adult stage as typically monomyarian in its muscular apparatus as an oyster; then it is sufficiently evident that better and more fundamental diagnostic characters should be found or the so-called orders given up.

Again, an attempt has been made to use the characters of one of the most mutable parts of the whole organism, namely the gill, as a basis for primary divisions of the group. I have shown elsewhere,* I venture to think conclusively, that this selection is ill-advised and cannot successfully solve the problem.

The simplicity or sinuation of the pallial line has been regarded as a character of high importance and has been used as diagnostic of divisions of primary importance. I have recently shown that, in certain groups, long siphons may exist with a simple pallial line, as in *Cuspidaria*; that in species without long siphons, members of the same family (*Poromyidæ*), and perhaps of the same genus, may show a simple or a strongly sinuated pallial line according to the modifications of certain muscular elements which certainly cannot be claimed to have any high systematic importance.

The question is further complicated by the fact that certain characters, which in general are indicative of very early evolutionary divergencies, may be simulated or assumed as very modern special modifications brought about in animals of diverse groups by natural selection under the influence of special circumstances. Species thus lately modified will very naturally be classed with those which bear the same or similar characters as the early result of very ancient ancestral divergencies, and, as a consequence, other characters not harmonizing, the systems are thrown into confusion. These are difficul-

* Bull. Mus. Comp. Zool., xviii, pp. 433–438, June, 1889.

ties among which the sum total of the organic characters must be our guide in attempting to decide. Only too often we may find, as knowledge increases, that our first judgment was more or less in error.

In reflecting upon the origin of the complicated mechanical arrangements in bivalves which we call the hinge, I have come to the conclusion that here, as in the cases of the mammalian foot and tooth, elaborated so clearly by Cope and Ryder, we have the result of influences of a mechanical nature operating upon an organ or apparatus in the process of development.

The hinge of a bivalve, reduced to its ultimate terms, consists of two more or less rigid edges of shell united by a flexible membrane or ligament.

The ligament may be wholly external or may be supplemented by an internal addendum (called the cartilage), which exerts a stress in the same direction within certain limits. The movements of the hinge are dependent upon the elasticity of the ligament and cartilage and upon force exerted by one or more adductor muscles uniting to the valves

The rigid edges or cardinal margins of the valves may be simple or modified by the presence of interlocking processes known as teeth, whose purpose is to regulate the direction of the valves in opening and closing.

There are three fundamental types of hinge: 1, the simple edentulous margin closing by simple apposition of the edges of the two valves; 2, the hinge in which the teeth are developed in a direction transverse to the cardinal margin; 3, the hinge in which the direction of the teeth is parallel to the margin. The mechanical features of the second and third types may be more or less combined in a single hinge, but the affinities of the particular form in which this may occur are usually not difficult to determine on a general survey of all its organic characters.

I am disposed to think that the time relations of the different types are those of the order in which I have cited them; the most perfect hinge, morphologically speaking, would be one which should combine the most effective features of the second and third types.

The archetypal form of bivalve may be imagined as small, with nearly equilateral, symmetrical, sub-circular valves with edentulous cardinal margin and a short external ligament nearly central between the umbones. This is the character of many larval bivalves at the present day, though it is probable that many of the forms now edentulous in the adult state, have passed through an evolutionary stage in which they had a more or less denticulate hinge-margin, while their present condition is one in which the hinge has diminished in complexity or, in other words, undergone degeneration.

Very few of the earliest known bivalves appear to have hinge teeth, yet this may be on account of our imperfect knowledge of many of them since they are often represented by fossils in which no evidence of the hinge structure is discernible. It is highly probable that the evolution of hinge-teeth closely followed the differentiation of the Pelecypod class and that the segregation of the muscular apparatus for closing the valves into two bunches or adductors was accomplished very early in its history.

The first bivalves are all small, as far as known, when compared with a majority of their descendants. It is highly probable that they possessed a developed foot and that their gills were either lamelliform on either side of an arterial stem, as in *Nucula*, *Solenomya* and many Gastropods, or filiform, as in *Dimya* and certain Pectens. The siphons were probably little developed and the lobes of the mantle rather widely separated or perhaps entirely free.

As long as the shell remained small and subglobular, the ligament short and wholly external, the imperfect character of the hinge was of less importance. With the essential difference between the anterior and the posterior halves of the animal, and especially with any material increase in the magnitude of the adult, more or less discrepancy would develop itself between the two ends of the shell, the subglobular form would disappear, and certain other consequences would follow. Either the ligament must increase with the size of the shell and become longer or its power would become inadequate for the proper performance of its functions.

Here I will turn aside for a moment from the direct line of argument to describe the mechanical relations of ligament and shell, a proper understanding of which is very necessary to the comprehension of the whole question.

With a wholly external ligament the operation of the valves is that of two appendages to the free ends of a C-shaped spring. The action of the muscles in pulling the valves together includes the bringing nearer to each other of the two extremities of the ligament which the latter by its elasticity resists, consequently the operation of the ligament is in the direction of opening the valves to a certain distance. Beyond this distance the separation of the valves tends to compress the ligament, which again resists, and therefore beyond the normal distance of separation the action of the ligament tends to prevent the valves from opening. This very simple matter may be observed by any one who will examine an ordinary clam with the ligament in fresh condition and whose adductor muscles have been severed.

When the ligament, in harmony with the elongation of the cardinal margin, becomes elongated it must be either straight or angulated. For obvious reasons a ligament forming a curve or the arc of a circle is mechanically impossible This any one may prove to his own satisfaction by putting two light wooden saucers edge to edge, convexity outward, and attaching a leather or paper ligament by cement. A curved ligament when the valves open will tear or break at once, either itself or the edge to which it is fixed. In other words, the axis of motion of the hinge must be in a straight line. If any part of the ligament diverges from the axial line, it must cease to take part in the axial motion and must be capable of stretching to an extent which will neutralize its angulation, or it will be broken or torn away. But if the thickness of the ligament increases ventrally, as may be the case when it is situated between the valves rather than as an arch above them, a certain portion may extend to and beyond the axial plane in a downward direction. The portion thus projecting will then partake of the axial motion in an opposite sense to that portion which remains above the axial line. It will be compressed when the latter is stretched by the closing of the valves and will expand as the opening of the valves allows the external portion to contract. This change may be brought about by a downward angulation of one end of the ligament (as in *Solenomya*) or as a simple downward growth, which may be central (as in *Neilonella* or *Galeomma*). The former may be the result of an angulation of the hinge-margin consequent on elongation or ventral extension. Its result is to separate a terminal segment of the original ligament, which segment may be totally detached or remain physically connected; while in either case its mechanical function has undergone a reversal of direction.

The second mode likewise removes a segment but in a vertical direction. This segment may be physically continuous throughout its upper portion with the lower portion of the superjacent ligament, it may be wholly detached, or it may be attached by one extremity while the other is separated; in the last case its direction will be oblique or at an acute angle with that of the original ligament. This detached segment whatever its position has always similar mechanical relations to the movement of the hinge and is called the cartilage. The separation of the cartilage from the ligament is generally either central or toward the shortest end of the hinge, which is usually the anterior, owing to the fact that when the size of a lamellibranch increases, the siphons, the ovaries, the visceral mass or the gills are the organs where proportionally increased growth is most likely to occur, and these are usually central or posterior to the umbones. In *Solenomya*, which is exceptional in having a posterior cartilage, the posterior portion is shortest.

The amount of shifting required to put part of the ligament on the ventral side of the axis of hinge motion, or cardinal axis, is extremely small. All stages of the changes involved may be observed in the *Nuculacea*, even to one not hitherto mentioned where the cartilage has been developed and has subsequently become obsolete or altogether disappeared (*Malletia*), while leaving some traces of its former presence in the shape of an empty and degenerate fossette (*Pleurodon*). It is noteworthy that this suborder, in which the shell gives us so many hints as to processes which we may imagine to be of great antiquity, should on other grounds be regarded as among the few which best retain traces in the soft parts of archaic stages of development.

With the lengthening and angulation of the cardinal margin the ligament gradually shifted to a point where it became posterior to the beaks. Perhaps it would be better to say that the portion in front of the beaks either became segmented off as a cartilage, or became obsolete and vanished, while the portion on the posterior side gradually elongated, as the elongation of the posterior hinge-margin rendered a longer ligament more useful. It has already been pointed out that a curved ligament would involve stresses leading to its own destruction. The curvature of the cardinal margin, now the common property of a vast majority of bivalves, was inevitable with increase in size and a symmetrical development of the anterior and posterior ends of the body. Consequently that the ligament should be shifted was a mechanical necessity, unless the evolution of the group was to be confined within extremely narrow limits as regards hinge characters.

The infolding of the ligament and the development of a cartilage and its supports would be especially likely to occur in forms with a thin edentulous hinge, where the least shifting would be necessary (*Solenomya*, *Anatina*) rather than in those with a broad flat hinge-margin. In harmony with this proposition we find the archaic forms with internal cartilage have generally a narrow edentulous cardinal border, the exceptions belonging to the more recently specialized types (*Mactra*, *Spondylus*); while the groups without an internal cartilage contain the broadest and heaviest types of hinge (*Pectunculus*, *Veneridæ*.)

The infolding of a cartilage which arose by longitudinal segmentation would leave a line of weakness in the arch of the umbones. In thin shells with strong adductors there would be a tendency to fracture here. This singular feature has been perpetuated in what may be termed the normal umbonal fissure of *Solenomya*, *Periploma* and similar forms. Traces of it are evident in *Thracia*, while the unfractured suture itself is visible in *Isocardia*, *Pachyrisma*, *Pecchiolia*.

In the thin-shelled *Cuspidariidæ* a special buttress is often developed to support the shell at this weak point. In the *Isocardiidæ* an independent cartilage was possibly never developed, but the infolding of the anterior part of the ligament went far enough to leave permanent traces on the shell. That it did not result in a cartilage if this was the case may possibly be due to the fact that, owing to the great size and spiral character of the umbones, the anterior part of the ligament was turned up instead of downward, and therefore did not tend to shift toward the interior.

If it is not clear how the thickening or vertical extension of the ligament below the cardinal axis should cause its separation into two parts, I need only recall the familiar experience of every one in breaking off a wire or piece of tin by bending it backward and forward on the line of the desired fracture. The mechanical principles and results in the two cases are precisely similar.

When finally developed in the same individual the ligament and cartilage work in identically the same manner but in different directions. The resistance of the ligament to compression prevents any straining of the adductors by a too wide opening of the valves. The same resistance in the cartilage prevents the ventral margins from crushing each other by sudden and violent contractions of the adductors when the animal is alarmed, and closes its valves.

The nymphæ, or processes to which the ligament is attached, and the fossette, or socket of the cartilage, have been strengthened and regulated by the development of various buttresses and other devices, varying in different groups. The cartilage in turn has its rigidity and strength increased in many species by the special development of shell substance known as the ossiculum.

To return to the development of the cardinal margin. The asymmetry of the shell and ligament relative to a vertical transverse plane passing through the umbones, would be promoted not only by the natural discrepancies between the anterior and posterior halves of the body, but by the mechanical effect of the projecting umbones. Where a shell opens laterally, in the strict sense of the word, unless the beaks are very inconspicuous, or are separated by a wide projection of the cardinal border (as in *Arca noæ*), they will strike against and wear out one another. This abnormal or accidental result is very constantly observable in many *Anatinidæ*, such as our own *Thracia Conradi*. But it must be a source of weakness and danger to the animal. If the ligament is shifted posteriorly the valves must open more obliquely, with a result that this dangerous friction will be avoided in most cases.

In a protective armor like the valves of bivalves, other things being equal, it will be obviously beneficial if not absolutely essential that it should offer as few weak joints or open spaces as possible. Burrowing animals, who themselves serve as a supplementary defence of their burrow, may be able to perpetuate gaping shells and exposed siphons without serious danger from their enemies. Those animals which burrow but slightly or live in material which enemies may also easily penetrate in their forays, will unquestionably benefit greatly by an accurate and exact closure of the valves. The intrusion of solid bodies can be to some extent guarded against by the action of the cilia or processes of the mantle margin, but such intrusion would be greatly facilitated by any organization of the hinge which would permit an independent rocking motion of the valves with respect to each other. The sudden closing which danger incites leaves no time for clearing out obstructions and the gap is especially liable to the incursion of gravel, etc., in species which live with the plane of junction of the valves in a vertical direction. In certain brachiopods such as *Glottidia* and *Discina* such a semi-rotary motion of the valves exists, but is less dangerous to them since the plane of junction with them appears to be generally horizontal.

To avoid these dangers and to guide the motion of the valves in closing, and to prevent their sliding upon one another after closing, Nature, through natural selection and physical stresses, has developed these cardinal processes which are known as teeth.

Attention has already been called to the fact that there can be but three fundamental types of hinge, which may be called the anodont, prionodont and orthodont, the latter term being used to indicate the forms in which the cardinal margin has become longitudinally plicate. Actually the pure orthodont type hardly exists; in nearly all forms traces of the prionodont characters are mingled with it. For those forms in which the archaic anodontism still persists as the characteristic of chief importance, though frequently modified by special mechanical contrivances which to a certain extent mask the type, I have proposed the term *Anomalodesmacea.* The fossette, cuilleron or spoon-shaped process for the cartilage is a separate development serving a special purpose; though influencing the teeth, if any exist, in its vicinity, it must not be confounded with them. The weakness of the anodont type has left an opening for the specialization and perfection of this process which, to a considerable extent in this group, assumes the functions which in groups without a cartilage are the special office of the teeth.

For those forms in which transverse plication of the hinge is the chief characteristic, though rarely wholly exclusive of orthodont influence, I have used the term *Prionodesmacea*. In some cases what may seem to be the chief features of the hinge as regards size and strength are orthodont, yet these I believe to be comparatively modern specializations illustrating the general tendency of evolutionary processes toward a teleodont hinge. In cases of doubt the sum of the characters will enable us to decide on the proper place for a given genus. It must not be supposed that, because the *names* suggested by a single set of characters are used to denominate the proposed orders, that therefore that set of characters is to be our sole criterion. Such too hasty assumptions are a relic of the days when the immutability of species was an orthodox dogma in biology, and doom to failure any system founded upon them.

For those forms in which the various types of hinge have become harmoniously combined, though in varying proportion contributing to the final mechanism, I have selected the designation of *Teleodesmacea*. These may be regarded as the highest and evolutionally the most perfect in type of hinge, though this perfection shows itself in a variety of forms. Prionodont traces remain with most of them but are never characteristic of the type.

The three groups I propose to call Orders. It is difficult to say whether they can be compared in systematic value with orders in other classes. All that can be said is that these three divisions are discernible in the very compact and homogeneous class which includes them, and it contains no other groups of equal value or significance.

Each Order as it now exists contains archaic and modern specialized types. Each indicates a tendency toward an ideal of fitness to the environment, which results in a certain parallelism of minor characters common to minor groups in each of the three orders. In each (we are coming to regard it as inevitable), certain members show affiliations with members of the other orders. In each there are certain groups which represent a relatively modern specialization carried so far as to be quite peculiar.

Pearliness or a truly nacreous character of shell substance is a source of weakness. This kind of shell is more fully permeated with animal matter, is more liable to decay and exfoliation and is more readily drilled by enemies than the arragonitic type of shell substance which conchologists call porcellanous. The tendency of evolution is to promote the porcellanous type. The older groups (*Prionodesmacea* and *Anomalodesmacea*) contain all the pearly Pelecypods, among the *Teleodesmacea* there is not a single one. Furthermore, in the two former orders the most specialized and, developmentally, the most modern forms are preferably porcellanous; those which we may reasonably regard as of more ancient type tend to pearliness. For example in the *Anomalodesmacea* the most striking instances of specialization are the Pholads, *Tubicolæ* and certain *Myacea*, all are earthy or at least not pearly. The *Anatinacea* which paleontologically are very ancient, are largely pearly. The *Prionodesmacea* have few porcellanous groups, but those which show this character, such as *Ostrea* and *Pecten*, generally stand at the nearer end of the long line of progressive modification. There are exceptions to this, such as *Tindaria* in the *Nuculacea* which is obtrusively porcellanous, while *Leda* and *Solenomya*, which retain so many archaic features in their soft parts, have almost lost the pearly layer while still falling short of the porcellanous character conspicuous in most of the *Teleodesmacea*. The Arcas conspicuously earthy in their shells are modern in their total characters compared with the pearly Nuculas. Turning to Gastropoda for a moment we find that *Pleurotomaria*, one of the very earliest types of that class which can be recognized in the now existing fauna is extremely pearly. On the whole the relation between the two types of shell substance if not constant enough to be called a rule is sufficiently so to be extremely suggestive.

I have already suggested the mechanism of the infolding which resulted in the cartilage and its supporting socket. It is a very difficult task to account for the initiation of all the types of teeth. A few suggestions may be ventured upon.

The radiating or transverse corrugations which we see in ribbed shells are not merely ornamental. They serve to add strength while they do not increase the weight as would a corresponding thickening of the shell. A familiar example of the same principle is afforded by the corrugated sheet metal so frequently used by builders. The ends of these ribs impinge on the margin of the shell and crenulate it when the shell is thin. *Crenella* is a notable example. Many *Mytilacea* exhibit a similar structure. These crenulations of the hinge line and margin are not to be distinguished from nascent teeth and have frequently been described as such by naturalists. *Nuculocardia* of Orbigny is a well known instance. The crenulations of the margin are useful in securing a close fit between the closed valves, whether at the cardinal or the basal margin. But they would be more useful at the cardinal margin because there they would prevent sliding of the valves upon one another before they were completely closed, as do the long teeth of the *Nuculacea*. Hence, it is probable that they would be perpetuated and specialized there even if the ribbing disappeared from the exterior of the valves. Greater stress arising from friction and pressure resisted, would tend towards the thickening, widening and even buttressing of the cardinal margin, until the hinge plate became developed and sufficiently strong to perform its functions with success. This is one of the ways in which a Prionodont hinge might be initiated.

The Anodont hinge, to reiterate, is a weak and unsatisfactory type. Its features could hardly continue to exist except in a burrowing and tubicolous generation. To some extent its features has been made up for by an asymmetry in the valves which permits a smaller valve to fit into a larger one. This is a very successful device as there can be, as long as the larger margin remains unbroken, no question of failure to close the valves. But the projecting margin of the larger valve is a weak feature, much more likely to get fractured than the convex combined edges of two. Once fractured the mollusk would be defenceless until he could mend the breach. Moreover, in moving about, a practice more common with Pelecypods than is generally realized, the asymmetry of the valves would be a nuisance, always tending to shift the traveler out of the line he might desire to take. We find, as we should expect, that the Anodont hinge is persistent with tribes which are borers, tube-dwellers, or burrowers; for the most part very sluggish creatures. In cases where the ventral margins of the valves do not meet, there is of course no especial call for a dentiferous hinge as the valves play the subordinate part of a dorsal shield. This is the case with *Solenomya* where the ventral hiatus is partly shielded by projecting epidermis. Most of these forms depend apparently quite as much on their activity and the protection of their burrow, as they do on that afforded by the valves of the shell. A reversion of the process is seen in the case of some groups like *Anodonta*, in which the edentulous hinge is the result of degeneration from a dentiferous type such as *Unio.* The dentiferous forms retain their teeth in the streams and rivers where they are subject to numerous casualties and much knocking about; while in the still water and soft mud of silent ponds the teeth vanish and the protective shell reaches its limit of practicable tenuity. One type of "cardinal" (as opposed to the so-called "lateral") teeth would arise through the modification of an Orthodont or a Prionodont hinge at one end (as in *Macrodon*) so that part of a row of teeth originally similar would come to differ from the rest. Many *Nuculacea* show stages of such a mode of change.

Another type would arise from the plications of the hinge parallel to and induced by the formation of a fossette or process for the internal cartilage. Such teeth or plications may be observed in most Pelecypods having an internal cartilage. All stages of development of this type may be observed, from the barely traceable parallel ridges of *Cuspidaria*, for instance, to the highly developed and specialized cardinal teeth in *Mactra*. Thus it will be observed the teeth called "cardinals" in Pelecypods are by no means all necessarily homologous; and it is even conceivable that cardinals of both types might come to be united in the hinge of a single species.

The development of lateral teeth from transverse teeth is a very easy process of which a full exhibit might be made by arranging in a continuous series the valves of selected *Arcacea* and *Nuculacea*. It is probable however, that not all Orthodont dentition originated in this way. The thickening of the cardinal margin rendered necessary by the stresses involved in the mechanical operation of cardinal teeth or strong external ligaments, would render parallel plication of the thickened area along the margin not only easy but almost inevitable in some cases. The infolding of the edge of the mantle necessarily accompanying the production of a strong specialized socket for an internal cartilage would lead incidentally to occasional deposition of shelly matter in ridges parallel with the longer edges of such sockets. The greater efficiency in guiding the valves to effective closure, in proportion to the increased distance from the umbonal region, of such interlocking plications would tend through natural selection to the perpetuation of favorable variations and to their gradual removal farther and farther from the beaks until the most useful distance was attained.

When we consider the remarkable uniformity in hinge characters attained by the species with more perfected forms of hinge, through long series of individuals, it seems almost incredible that these results should be brought about by the action of a thin soft film of secretive tissue, which, unaided, could not hold itself erect. It is only when we remember that the result, in the main, is brought about through the action and reaction of certain definite mechanical stresses, propagated through the hard valvular skeleton and constantly imposed upon the softer tissues, that any adequate reason for the marvellous uniformity presents itself. There are certain groups such as the *Isocardiidæ* in which the hinge seems still to be in what may be termed a transition state. With these no such strict uniformity prevails. While the differences are not excessive, yet the hinge of each individual specimen compared with others of the same age will show individual characteristics and the changes which the hinge undergoes in the same individual between adolescence and old age are greater than one would ordinarily find in the whole membership of a species, say of the *Veneridæ*, taking all ages, above the larval stage into account.

We may now proceed to consider the groups of which these orders should be made up.

To the *Anomalodesmacea* I refer the *Anatinacea*, the *Myacea*, the *Ensiphonacea* or *Tubicolæ*, the *Solenomyacea* and the *Adesmacea*.

In the first three groups or suborders we have forms whose relationship will hardly be questioned, embracing also some instances of the most remarkable specialization of characters. To refer to a few I may mention *Aspergillum*, *Clavagella*, *Cuspidaria* and *Poromya*, using these names in their widest sense.

From several characters of the gills and other soft parts paralleled in the *Nuculacea*, *Solenomya* was at first affiliated by me with the Prionodonts. On mature consideration, while admitting that the last word on this subject has not yet been put on record, I am inclined to believe that this genus is an Anodont which has retained certain archaic features of the soft parts and represents in the *Anomalodesmacea* a survival analogous to that of the *Nuculacea* among the Prionodonts.

From a very early period the *Solenacea* have been associated with the forms now gathered in this order. Prof. Verrill has called attention to the fact that *Tagelus caribæus* and its allies have the organization of *Tellinacea*, and I have removed them to the vicinity of *Psammobia*, in my Check-list of the Marine shell-bearing Mollusks of the Southeastern coast of the United States.* But are the *Solenidæ* to be left behind? After due consideration I can see no sufficient reason for such a course, and conclude that the united siphons and burrowing habit, with its resulting specialization, do not warrant it. I have therefore excluded them.

In the *Adesmacea* or *Pholadacea* we have the most remarkable specialization of the hinge known in the whole class. The relations of the parts are best understood by a study of the open-shelled forms like *Zirphæa crispata* or *Barnea costata* and the young of the closed Pholads. In the adult forms of the latter specialization has proceeded so far that the true relations of the parts are more or less masked.

In *Barnea costata* we have the anterior dorsal margin of the valves reflected dorsally until the anterior adductors following the shell pass the axis of motion of the hinge and pull at the short end of the lever, tending to open the valves instead of to close them. The posterior adductors pull in the normal way and balance the anterior ones. The ligament is reduced to an ineffective film. The cartilage remains as a survival, but reduced to such dimensions as to be practically of no use. Its elastic properties are lost and it merely serves to connect two

* Bull. U. S. Nat. Mus., No. 37, 1889.

little processes, the feeble remnants of the original fossettes. An appendage analogous to and possibly homologous with an original ossiculum has (that view being taken) revolved around the cartilage, taken its place outside of the axis of motion of the hinge, and instead of keeping the valves from crushing each other by checking the closing stress of the adductors as in *Verticordia* or *Bushia* and other *Anatinacea*, it accomplishes the same end by locking over the reflected edges of the shell on the dorsal surface acting, like the anterior adductors, on the short instead of the long arm of the lever, and as before in a sense opposed to the action of the adductors. Though greatly specialized and modified this appendage retains something of the butterfly shape of a broad ossiculum.

An appendage, sometimes called the styliform process or apophysis, with its proximal end attached in the hollow of the beaks, has been homologized by Deshayes with the cardinal teeth. In *Pholas costata* it supports the posterior oral palpus which is very massive, and some of the internal viscera. If one of the umbonal laminæ of *Callocardia* were detached from its connection with the cardinal margin and allowed to project into the cavity of the valve, it would somewhat resemble the apophysis of *Pholas*. But on this view I am at a loss to explain the present connections of this process about the development of which little or nothing is known. How a cardinal tooth should come to be situated inside the mass of the body would seem to be hard to explain. The environment of the Pholads is of a very special character and the modifications of the organization march with the peculiar circumstances under which it exists. To enter into their mutual reactions would take much space and obscure the more general questions to which this paper is addressed.

It may be added that in this order as well as the others the particular constituency of each of the suborders, even the number and scope of the families, must be regarded as tinged with uncertainty from the magnitude of our ignorance. To properly ascertain and correlate the data in regard to the different genera and the families of which they are the members is a labor worthy of devotion, but which will yet require a large amount of original research.

In the *Prionodesmacea* the *Nuculacea* represent an archaic type in many of their features. So far as the hinge is concerned *Arca* (*Noæ* and related species) is perhaps the most fully and typically developed instance of Prionodont dentition. The Naiades declare in *Spatha* and *Iridina* their Prionodont origin, traces of which are to be seen in the transverse striation of the teeth of many species of *Unio*, even when lateral teeth have become well developed and preëminent. The same is true of *Trigonia* which has many points in common with Naiades. To the latter immediately *Mülleria* bears such a relation in its adult state as do the Monomyarian *Pecten* and *Ostrea* to the rest of the *Prionodesmacea* as a whole. The Prionodont character of the *Mytilacea* will not be questioned. Through them we pass to the *Pectinacea*, in which in *Spondylus* we have the finest instance of a Prionodont hinge with few teeth, as *Arca* is of one with many teeth. The original transverse grooving of the hinge is visible on the very young valves of many species of *Pecten*, *Janira*, etc. The *Ostracea* are the last term of specialization in this line; the *Anomiacea* are brought in by the total of their characters, though so far modified as to indicate little, by the hinge, of what I suppose to be their origin. Above all it must be admitted that the *Monomyaria* and *Heteromyaria* represent not fundamental types of structure but special modifications though geologically ancient. The presence of a prismatic layer of cretaceous otell substance, outside of the pearly layer, is also characteristic of most of the forms of this order.

The remaining forms representing the march of progress toward a mechanical perfection in hinge characters, though retaining traces (as in the striated teeth of some Mactras) of Prionodont ancestry which once dominated the dentition, constitute the order *Teleodesmacea*.

In the main, in the combination of hinge characters which they represent, the most striking features are the effective manner in which the orthodont laterals and prionodont cardinal teeth are subordinated to and supplement each others action, the occasional introduction of the internal cartilage in happy combination with the others and the general absence of nacre in the shell structure and archaic characters in the soft parts.

It is a question whether the *Rudistes* are to be considered a group apart, or, like the *Pholadacea* among the *Anomalodesmacea*, merely an erratic special development, of forms related to the *Chamacea*. Leaving the question to be settled by the special studies its difficulties call for, I conclude this paper with a tabular view of the orders and suborders into which the class is divided. One group, the *Leptonacea*, stands much in need of thorough study without which its component families and even its permanent standing must remain doubtful. With our present knowledge it is yet impossible to determine the number of families of which each suborder should be composed, or even how many groups are entitled to rank as families. But in the major groups I feel a certain amount of confidence that the present arrangement is in most respects more harmonious and in accord with the balance of characters than any of the systematic arrangements of the class which have been hitherto proposed.

CLASS PELECYPODA.

I. Order Anomalodesmacea.

Suborders.

1. Solenomyacea.
2. Anatinacea.
3. Myacea.
4. Ensiphonacea.
5. Adesmacea.

II. Order Prionodesmacea.

Suborders.

1. Nuculacea.
2. Arcacea.
3. Naiadacea.
4. Trigoniacea.
5. Mytilacea.
6. Pectinacea.
7. Anomiacea.
8. Ostracea.

III. Order Teleodesmacea.

Suborders.

1. Tellinacea.
2. Solenacea.
3. Mactracea.
4. Carditacea.
5. Cardiacea.
6. Chamacea.
7. Tridacnacea.
8. Leptonacea?
9. Lucinacea.
10. Isocardiacea?
11. Veneracea.

* *

? Rudista.

Supplementary Note.—When I first began to consider the relations of the teeth and other parts of the hinge, I naturally remembered the brief abstract of the important paper on the hinge of Bivalves by M. Neumayr which I had seen in the Zoological Record for 1883. I intentionally deferred a careful perusal of Neumayr's essay until I had entirely completed my own. Then a careful examination of his original afforded me great pleasure. It showed that in the matter of the influence of ribbing in promoting the nascence of teeth; in the discrimination of lateral plications, arising in connection with the fossette of the cartilage, from the true cardinal teeth; in the influence of the environment on the degeneration of hinge characters: in the estimate of the characters of the primitive bivalves; and some minor points we had arrived independently at the same conclusions and even illustrated them by identical or nearly identical examples. This is certainly strong presumptive evidence of the correctness of those inferences. In the points in which we differ, it seems to me that the differences arise from the fact that Neumayr has approached the subject more from the paleontological standpoint and has less considered, or has given less weight to biological considerations not imprinted on the shell; while in my own case from the nature of my previous studies I have been led to attack the problem from the other side. Recent investigations, available only since the date of Neumayr's paper, have thrown much light on the inosculation of characters not before known to interlace. Neumayr also, from my standpoint has insufficiently grasped the importance of the different processes involved in the production of the internal cartilage and its shelly coefficients on the one hand and the denticulation of the hinge margin on the other. These two processes, though they must often have proceeded simultaneously in the same genus, were not necessarily connected except in so far as by resulting stresses each might react on the hinge-product of the other. So instead of having a Desmodont type of hinge as opposed to a Prionodont, and, as Neumayr would say, a Heterodont (Teleodont) type, we may have either an Anodont (Paleoconch), a Prionodont (Taxodont), or a Teleodont (Heterodont) type of hinge, either with or without an internal cartilage and its accessories.

By the elaboration of this view, as attempted in the foregoing discussion, it seems to me the discrepancies so evident in Neumayr's system have been avoided; the types of hinge assigned their proper weight in the system; while those biological relations which are not fully reflected in the shelly parts, have not been slighted; though inevitably numerous improvements in detail will suggest themselves to students, or be effected by a future expansion of our knowledge.

As regards the Rudistes, if, as claimed by Woodward and others, they possessed an internal cartilage, it is probable that they must form a specially modified and extraordinary ramification of the *Chamacea.* If, however, as is claimed by some authors, there was no internal cartilage or external ligament and the smaller valve simply rose and fell under the control of adductor muscles guided by interlocking processes, it is evident, that this would establish an interrelation between the valves unlike anything among the Pelecypods, and only comparable, perhaps, with that of certain operculated corals. In the latter case the Rudistes would have to be regarded as ranking at least among the subclasses, if mollusca at all. My own impressions are that the first mentioned view is the more probably correct one.

The opinion is occasionally expressed in scientific literature that the shell is a "mere secretion of the mantle." This usually proceeds from some person who has not thoroughly studied the molluscan shell, or appreciated its relations to the animal. Such a statement is one of those half-truths which are more dangerous than pure error since the ballast of truth they contain will enable the error to navigate some distance, while the unfreighted error would capsize at once.

The shell is in one sense the product of secretion from the mantle, as the mammalian tooth is derived from the ectoderm of the jaw or the skeleton from the periosteum and cartilages. Both are that and much more. It would be as reasonable to say that a steam boiler in process of construction is the product of the boy inside who holds the rivet-heads, as to claim that the shell has no more significance than is implied in the term "secretion of the mantle."

The original theoretic protoconch may have been so, but, as soon as it came into being, its development was governed by the physical forces impinging upon it from all sides and through it influencing the growth and structure of the soft parts beneath. The Gastropod shell is the result of the action and reaction between the physical forces of the environment and the evolutionary tendencies of the organic individual. In the Pelecypod we have the mechanical stresses and reactions of one valve upon the other added to the category of influences. To some extent it is doubtless as true that the animal is moulded by its shell as it is that the shell is shaped by the soft parts of the animal. This results in that correlation of structure which has enabled students to, in the main, correctly judge of the relations of mollusks by their shell-characters, when the latter were intelligently studied and properly appreciated.

ART. LVI.—*The Magnetism of Nickel and Tungsten Alloys;** by JOHN TROWBRIDGE and SAMUEL SHELDON.

INTRODUCTORY.

THE fact that different kinds of steel, alloyed in small proportions with tungsten or wolfram, and magnetized to saturation, increase in specific magnetism,† has long been known. Whether the same effect would result from the use of nickel alloyed with tungsten has never been investigated. This paper has for its object a partial answer to the query. It was instigated by Mr. Wharton, proprietor of the American Nickel Works, whose chemist, Mr. Riddle, kindly prepared the alloys which have been employed. These alloys were in two groups. The first, received in November, 1888, consisted of three bars of the same shape, one being of pure nickel and the other two

* From the Proceedings of the American Academy of Arts and Sciences.
† Jour. Chem. Soc., 1868, xxi, 284, says 300 per cent.

having respectively 3 and 4 per cent of tungsten in alloy. These bars were rolled from cast ingots, which were toughened by the addition of magnesium after Fleitmann's method, the magnesium being added just before pouring. They were hot when rolled. The one of pure nickel was afterwards planed into regular shape. Those containing tungsten were too brittle to allow of this manipulation. They were, however, of sufficient regularity to permit accurate measurements. This group contained also an octagonally shaped bar with 8 per cent of tungsten, which was prepared like the others, and was afterwards ground into shape.

The second group, received in May, 1889, contained bars which were simple castings, made without the addition of magnesium, and consisted of pure nickel and alloys with 1, 2, 3, and 6 per cent of tungsten. All the bars in this group were extremely hard and brittle. In making them, tungsten oxide, of weight calculated to yield the desired percentage of tungsten in the resulting alloy, was placed with adequate carbon in the bottom of a graphite crucible and covered by the proper weight of pure grain nickel. All was then covered with borax, the lid of the crucible was placed on, and the crucible was heated until reduction and fusion were completed.

Method.

As the suspected influence of the tungsten would be to affect the magnetic moment of the bars, these were magnetized to saturation and their specific magnetism then determined, i. e., the magnetic moment for each gram of metal.

The magnetization was effected by placing the bars separately in a hollow coil whose length was 15 cm. and outside and inside diameters respectively 6 and 3 cm. It consisted of 6 layers of wire having 63 turns each. A dynamo current of 40 ampères was then sent through the coil for one minute, and the circuit then broken and the bars removed.

For the determination of the magnetic moment, use was made of a reflecting magnetometer, and deflections were observed with a telescope and scale at a scale-distance of 100 cm. Measurements of the horizontal intensity, H, of the earth's magnetism were first made. The results from these determinations by means of the first and second Gauss arrangements were, respectively,

$$H = 0{\cdot}1724 \text{ cm. g. s.}$$
$$H = 0{\cdot}1720 \quad \text{"}$$

The freshly magnetized bars were then placed in the second Gauss position relative to the magnetometer, and the angular deflection determined. The specific magnetism, S, was then calculated by the formula

$$S = \frac{r^3 H \tan \varphi}{m},$$

where

r = distance from bar to magnetometer = 72·68 cm.
H = earth's horizontal intensity = 0·1722.
m = mass of the bar.
φ = angular deflection of magnetometer.

Results.

The mean results of two sets of observations on Group I, and also upon a similar bar of soft tool steel are given in the following table:

GROUP I.

Composition.	Size in cms.	Mass in grams.	S [cm. $\frac{5}{2}$ g. $-\frac{1}{2}$ sec.$^{-1}$].
Pure Nickel	18 × 2·7 × 0·65	284·5	1·23
Ni + 3 % W	" " "	286·5	10·60
Ni + 4 % W	" " "	283·5	10·40
Tool Steel	15 × 2·5 × 0·5	159·5	7·46
Ni + 8 % W	(Octagonal 13 × 1·5)	144·0	5·25

Group II, of cast bars, gave the following results:

GROUP II.

Composition.	Size in cms.	Mass in gms.	S [cm. $\frac{5}{2}$ g. $-\frac{1}{2}$ sec.$^{-1}$].
Pure Nickel	18 × 1·8 × 1·6	459	1·05
Ni + 1 % W	" " "	455	1·92
Ni + 2 % W	" " "	454	1·70
Ni + 3 % W	" " "	463	1·75
Ni + 6 % W	" " "	465	1·15

The bars of both groups were, subsequent to the above observations, completely demagnetized, and then freshly magnetized. New determinations gave the same results as before. The demagnetization was accomplished by placing the bars inside two coils, which were traversed by currents from an alternating dynamo. The coils were then slowly drawn apart, and the bars maintained at a position central between them. After treatment in this manner, they showed no appreciable deflection when placed in position relative to the magnetometer.

The results tabulated indicate that tungsten greatly increases the magnetic moment of nickel, if the alloy be forged and rolled, but on the other hand has but small influence if they be simply cast. Furthermore, changes in the amount of tungsten do not appear to cause corresponding changes in the magnetic properties.

To see whether the remarkable effect in bars 2 and 3, as compared with bar 1, of Group I, was owing to some molecular condition of their surfaces induced by rolling, two bars from the same steel, one rolled and the other pressed, were magnetized and then measured. The ratio of the specific magnetism of pressed to rolled was as 9 to 5, the rolled having the smaller amount. The existing difference, in this case, is probably owing to a difference in hardness, rather than to any molecular condition of the surfaces.

The specific magnetisms of all the bars are small when compared with good steel magnets. Kohlrausch says that good magnets, of common form, should have $S = 40$. The bar of ordinary tool steel, however, retained but 7·46. Still it was soft, and by tempering would doubtless have doubled this value.

If forged nickel and tungsten can be made to maintain a specific magnetism of 10, it will form a useful addition to the resources of physical laboratories. From the high polish of which it is susceptible and its freedom from damaging atmospheric influences, it will be most happily suited for the manufacture of mirror magnets where magnetic damping is to be employed.

Jefferson Physical Laboratory.

Art. LVII.—*Note on the Measurement of the Internal Resistance of Batteries;* by B. O. Peirce and R. W. Willson.

That galvanic cells, even under constant temperature conditions, have no fixed internal resistance in the sense that a copper wire has resistance, but that what we *call* the internal resistance of a battery varies somewhat with the strength of the current which is passing through the battery, is well known.

As a consequence of this variableness the value of the resistance of even a so-called nonpolarisable cell, as determined by any of the older methods, depends upon the resistances of the outside circuits used in making the measurement.

By the use of alternating currents,* however, it is possible to get a value for the resistance of a battery, which remains constant even though the resistance in the bridge and the intensity of the current sent interruptedly through the primary coil of the inductive apparatus be made to vary between rather wide limits.

Some time ago we had occasion to measure the quantity of electricity which passed through the circuit when the poles of a battery were connected by a conductor of moderate resist-

*F. Kohlrausch, Pogg. Ann. Jubelband, p. 220, 1874. Pogg. Ann., cliv, p. 1, 1875. Wied. Ann., vi, p. 1, 1879. Wied. Ann., xi, p. 653, 1880.

ance for a definite short time, less than one ten-thousandth of a second.

We found that if we assumed the electromotive force of the battery to be the same during the short interval when the poles were closed as it was just before this interval when the poles were open, the value of the internal resistance given by the method of alternating currents would not account for our results and was therefore useless as a basis for computing the quantity of electricity which the battery could furnish under slightly different conditions. We thought it worth while, therefore, to make some direct measurements of the difference of potential between the poles of a battery while they were connected for short times by shunts of various resistances. By means of the apparatus described in a paper on the charging of condensers, which we published* a short time ago, we were able to keep the battery shunted for almost any interval at pleasure from 0·3 sec., down to 0·0001 sec., and during this interval to charge a condenser of suitable capacity by connecting its poles to the poles of the battery and then disconnecting them. The charge which the condenser received could then be measured at leisure by the help of a ballistic galvanometer.

Our method of procedure was generally this. We first charged the condenser at the open poles of the cell and measured the charge, we then charged it with the poles connected by a shunt of known resistance and measured the charge, and finally we again took observations with open battery poles to see whether the cell had become "fatigued" by the treatment to which it had been subjected.

Even though no sign of "fatigue" was shown by the process, we did not feel sure that the electromotive force of the cell had been the same in all the observations. Some previous experiments with water cells seemed to show that when the poles of such cells are connected, the electromotive force falls *in a very small fraction of a second* to a value which depends upon the current which the cell is delivering, and this value then *very slowly* diminishes as the time goes on. If the poles are closed for a short time only, say for half a second, the battery almost instantly acquires its old electromotive force when the circuit is broken. If, however, the circuit is kept closed for a number of minutes the battery becomes "fatigued" and a comparatively long time must elapse before it acquires again its old strength. For purposes of computation, however, we made the usual assumption that the electromotive force of the cell when its poles are closed for a very short interval only is the same as the electromotive force with open poles, and we computed B from the formula

* Proceedings of the Am. Academy of Arts and Sciences, for 1889, pp. 146–163.

$$V_R = \frac{V \cdot R}{B + R}$$

Where V_R is the difference of potential of the poles of the battery when they are connected by a resistance of R ohms. V is the difference of potential of the poles when open. The ratio of V_R to V was obtained by measuring the charges of the condenser in the two cases, and R was known.

Our experiments soon showed that it was not worth while to take the trouble to use extremely short times within the limits at our command. The same general facts were seen whether the time were one-half a second or one-thousandth of a second. In obtaining most of the results given in the following table the time of closure of the battery poles was about one quarter of a second: in the cases marked with a star, however, the differences of potential were measured by the aid of a quadrant electrometer and the poles were connected for upwards of 60 seconds.

Cells.	Resistances of various cells as obtained by measuring the difference of potential of the poles when open and when closed by shunts of given resistance. The resistances in ohms of the shunts used.									Resistances of the same cells as obtained by the use of alternate currents.
	20·	**10·**	**7·0**	**5·0**	**3·0**	**2·0**	**1·0**	**0·5**	**0·4**	
1 Daniell*		3·59		3·36	3·31	3·27	3·26			2·9
2 Daniell*	2·98	2·90		2·87	2·83	2·78	2·74			2·5
3 Daniell	3·0	3·0	2·7		2·4					2·1
4 Daniell		4·1	3·8	3·7	3·5	3·5				2·8
5 Gravity		3·4	3·3	3·2		3·0	2·7			2·2
6 Gravity	3·9	3·5	3·6	3·4		3·4				2·8
7 Laws			0·37	0·38	0·33	0·28	0·23			0·20
8 Ward & Sloane			0·4	0·4	0·4	0·4	0·4			0·18
9 Bunsen Bichr.		0·27		0·28	0·26	0·25	0·22		0·19	0·15
10 LeClanché		1·18	1·14	1·10	1·07	0·99	0·97	0·93		0·54
11 LeClanché		1·1	1·2	1·1	1·2	1·1	1·2		1·1	0·9
12 LeClanché		1·0	1·1	1·1		1·1	0·9			0·5
13 LeClanché		1·4	1·4	1·4	1·4	1·4	1·4			1·0

The results given in the table represent very fairly all that we have obtained. The value of the resistance of a cell obtained

NOTE.—Cells 1, 5, 6, 8 and 9 were of gallon size; the jars of the others would hold about 3 pints each. The zinc of each Daniell cell was immersed in a solution of zinc sulphate. The density of this solution in the case of cell 3 was 41° B. and that of the solution of copper sulphate in the same cell was 21° B. In No. 4, the density of each solution was 15° B. In cell 9 the zinc was immersed in a mixture of 1 part of sulphuric acid, and 20 parts of water, and the carbon in 1 part of potassium bichromate, 2 parts of sulphuric acid, and 10 parts of water.

The Hartmann & Braun bridge used for most of the measurements with alternating currents has a resistance of 1·56 ohms in the bridge wire, 34 ohms in the secondary coil of the inductive apparatus and 17·5 ohms in the telephone. With the pointer at the middle of the bridge-wire and the 1 ohm plug out, the resistance in the bridge between the points where in measuring the resistances of a battery its poles would be attached is 2·5 ohms. When the 10 ohm plug is out this resistance is 11·3 ohms. Another bridge by the same makers gave indications practically identical with those of the first bridge.

by the use of alternate currents was always smaller than that obtained by the other method, but the application of the method of alternate currents "fatigued" all but the so called constant cells. In the cases of most of the cells there was a tendency in what we have called the internal resistance to *decrease** as the strength of the current which the cell is delivering increases. Sometimes, however, this tendency did not appear until the resistance of the shunt became very small and the trustworthiness of the computed results were in consequence impaired.

It would be easy to suggest explanations for the results noted here, but we shall content ourselves with calling attention to the facts.

Jefferson Physical Laboratory.

ART. LVIII.—*Relation of the Uppermost Cretaceous Beds of the Eastern and Southern United States*, by ROBERT T. HILL; *and the Tertiary Cretaceous Parting of Arkansas and Texas;* by ROBERT T. HILL and R. A. F. PENROSE, Jr.

THE newest and most easterly outcrop of the marine Cretaceous formations west of the Mississippi is in the banks of the Ouachita river at the town of Arkadelphia, Arkansas, where it appears beneath the Tertiary† and Quaternary‡ strata which compose the prevalent and unconsolidated structure of the region.

This exposure, in the heart of the Atlantic timber belt, and surrounded by later formations is made by erosion, and may be termed a Cretaceous island. Continuing toward the southwest, the areal exposures of the Cretaceous become more and more extensive until in central and southwestern Texas they entirely succeed the Eocene sands and forests, and become the prevalent surface formation of the country. They increase not only in areal extent but also in thickness and in number of horizons, so that successively lower horizons are crossed, until, between Arkadelphia, Ark., and the Paleozoic area of Central Texas can be found a succession of Upper and Lower Cretaceous deposits, aggregating over 5,000 feet, as seen, and which may prove much greater when more accurate measurements can be made.

* The apparent resistance of almost any common cell, as obtained by Ohm's method or one of its modifications, is *larger* when the determination is made with small outside resistances in the circuit than when larger ones are used.

† The Great Northern Lignitic horizon of Hilgard (Eo-Lignitic of Heilprin). See The Neozoic Geology of Southwestern Arkansas, vol. ii. Annual Report of State Geologist of Arkansas, 1888.

‡ The Plateau Gravel formation. See same as above.

Along this section can be seen nearly every known horizon of the American Cretaceous east of the Sierras, except the Laramie (if this is Cretaceous), and even this can be seen along the Rio Grande in Southern Texas, as shown by White, but it is emphatically missing north of that region. This section, when completed, will be the typical one of the North American Cretaceous, and will be a standard of criticism and comparison for the rest of our country, for it is the area where the formations of the east meet those of the west and where they can be compared side by side. It comprises the thicknesses and details of both the upper and lower formations.* These beds constitute two continuous periods of sedimentation separated by an unconformity during which there was a great land epoch.

What is known of them up to date, as recently published, may be summarized as follows:

Appropriate local names are added as far as can at present be given for the two formations and their subdivisions:

THE UPPER, OR BLACK PRAIRIE FORMATION (GULF SERIES).

(*Black Prairie and Lower Cross Timbers Formation.*)

	Thickness.
5. Uppermost, arenaceous (glauconitic) beds. Cretaceous spots of Anderson county, along eastern margin of Cretaceous area in Texas. Rarely found. Has greatest development in Arkansas, as at Arkadelphia	+ 300*
4. Marly clay beds. (*E. Ponderosa* marls.) Main, or eastern area of the Black Waxy region, as seen in parts of Lamar, Fannin, Grayson, Collin, Dallas, Ellis, Nevarro, Falls, McLennan, Williamson, eastern Travis, Hays, Comal and Bexar counties and Arkansas ("Fort Pierre")	+1200
3. The Austin-Dallas Chalk, occurring in a very narrow strip immediately westward or interior of the above Sherman, McKinney, Waco, Austin (except 6th ward), and San Antonio are situated on this line. Also at Rocky Comfort, Arkansas, "Mobrara"	+ 600
2. The Eagle Ford Prairies, or "Fish Beds," immediately west of the foregoing, and composing the Black "hog wallow" prairie of Alvarado, Hillsboro, and the 6th ward of Austin ("Benton")	+ 300†
1. The Lower Cross Timber sand, which is the base of this formation north of the Brazos. No. 2 is the base south of that river ("Dakota")	+ 300†

* The word "formation" is here used to signify the structural product of a single, uninterrupted geological event.

The Lower, or Grand Prairie Formation (Comanche Series).

(*Grand Prairie and Upper Cross Timbers Formation.*)

This formation increases in thickness to the southward, and no general estimate of thickness is at present deemed advisable. Following is the section from Austin to Burnet:

	Thickness.
9. Shoal creek or (Vola) limestone	75
8. Green clays (Exogyra arietina clays), bed of Shoal creek	100
7. Washita limestone, railroad cut, west Pecan street extension, Austin, and extending parallel to the above, in a narrow line across the state, from Fort Washita, I. T., southward via Denison, Fort Worth, Salado, San Marcos, Heliotes, and west to Mexico	160
6. The Austin marble, or Caprotina limestone, west of Austin	+ 20
5. The paving flags, or lithographic horizon, west of city of Austin	+ 20
4. Barton Creek, or Caprina limestone. Barton creek above the ford; the high bluffs of the Colorado at and opposite Johnson's quarry, and the west bluff of Mount Bonnel	1000 †
3. The Nummulitic (Tinoporus) chalk, river bluffs near Bull creek	100 †
2. Fredricksburg division, including all the limestones and marls west of the above, which have not yet been differentiated	+ 1000 †
1. The Upper Cross Timber, or Trinity, sands	+ 300 ‡
Estimated Lower Cretaceous, Central Texas	2775
" Upper " " "	2100
Total	4875

The immediate objects of this paper are to call attention to (1) the beds of the uppermost or glauconitic division of the Upper Cretaceous, (2) to the important light they throw upon the Cretaceous beds of the Gulf and Atlantic States east of the Mississippi, and (3) to the complete nonconformity by erosion and deposition that exists between them and the basal beds of the Southern States Tertiary.

* Artesian wells have penetrated these clays to this thickness at Corsicana, Texas.

† This thickness of these horizons is the most modest estimate that can be given. Accurate measurements are now being made.

‡ My able assistant, Mr. J. A. Taff, who has recently made an accurate map and sections of this horizon, finds ores a thousand feet of thickness.

The sequence of sediments during the Upper Cretaceous subsidence and emergence I have shown to be as follows: 1. littoral sands, 2. clays becoming more and more calcareous, 3. chalks; (4) chalky clays, 5. sands. The sands of this last stage *are characterized throughout by the presence of glauconite in perceptible quantities*, an accompanying mineral which I have never seen in any of the Texas sediments of the lower beds. These glauconitic beds may be almost pure, siliceous sand with only a few grains of glauconite, as in the upper beds at Arkadelphia, or almost pure greensand with little siliceous sand as at Washington, Ark. Again, they may be imbedded in a firm calcarous matrix, as in the so-called "rotten limestone" which distinguishes it from the lower occurring chalk. The beds may be white, brown, green, blue, gray, or deep red, owing to varying of proportions of lime and moisture and the oxidation constantly going on, but the mineral glauconite is always present, and this presence (if glauconite be of organic origin) indicates some uniform condition of habitat during sedimentation which will be further shown in the discussion of the fossils.

Thirty miles west of south of Arkadelphia the Little Missouri, a stream parallel to the Ouachita cuts down to the same glauconitic strata, as shown by the stratigraphic and paleontologic identity. At the old town of Washington they are again exposed by the drainage of Town Creek. Thence southward they are concealed again by the Eo-Lignitic overlap, for two hundred miles, until the county of Anderson* is reached, wheie a hundred miles east of the main Cretaceous area in Texas they are exposed by the cutting of the Trinity River. This outcrop differs lithologically and paleontologically from the underlying beds of the main body of the Cretaceous extending westward through Texas to Mexico, but is identical with the Arkansas calcareous glauconitic beds above mentioned. These glauconitic beds insensibly gradate downward into the *Exogyra Ponderosa* clays, the top exposures of the main area of the Upper Cretaceous formations in Texas, and geographically they are the nearest western deposits to those of Mississippi and Alabama, the intervening area being obscured by Tertiary and Quaternay deposits. Upon careful comparison of fauna and sediment with those of the latter region there is found such a striking similarity that there can be no possible doubt of their general identity with Hilgard's section from the Ripley to the Tombigbee inclusive, although no correlation of minute horizons is attempted. The Mississippi and Alabama beds are characterized by the same fauna and structure, and the universal presence of glauconite which places them like the

* This exposure has been recently discovered by Dr. R. A. F. Penrose, Jr., of the Texas and Arkansas state surveys.

Arkansas glauconite beds above the Ponderosa marls and lower divisions of the Upper Cretaceous in Texas. The fauna of these uppermost glauconitic beds of Arkansas and Texas, described in my Arkansas report* is the characteristic fauna of the Mississippi beds, and not of the underlying Ponderosa marls, except a few connecting species

Continuing our investigations northward into the New Jersey region we find there the greatest development of these glauconitic beds and a continuation of the Arkansas fauna. Closer scrutiny shows that this correlation can be extended only to the lower marl beds of New Jersey for *the Arkansas representative, or continuation of the middle marl beds has been eroded and destroyed during the post Cretaceous land epoch (Laramie time) and the Tertiary overlap.* The paleontologic proof of this is indisputable, the molluscan faunas being almost identical. Among the lammelibranchite species common in America to Arkansas, Texas, Mississippi and the lower marl beds of New Jersey are the following:

Ostrea larva Lamck.
Exogyra costata (typical var.), Say.
Gryphæa vesicularis Lamck. and vareities, such as *G. vomer*, *G. convexa* and *G. pycnodonta.*
Comptonectes simplicum Con.
Neithea quinquecostata ?
Idonearca tippana Con.
Trigonia eufalensis Gabb.
Inoceramus barafini Mort.
Pachycardium spillmani Con.
Anomia argenta, and numerous other species.

None of these forms, according to Whitfield, except *G. vesicularis*, occur in New Jersey in other than the lower marl bed, while in Arkansas, Mississippi and Alabama they characterize the glauconitic division, and in Texas are barely represented by two species in the uppermost Ponderosa marl beds, but occurring in the island of Anderson county as in Arkansas.

Furthermore, none of the characteristic fossils of the New Jersey Cretaceous above the lower marl bed, such as *Terebratula harlani*, the *Belemnitella mucronata*, and the *Ammonites placenticeras* occur in the Arkansas-Texas Cretaceous,—only two specimens of *B. mucronata* having been found in that region, and there in the contact debris at the base of the Tertiary where they were preserved from destruction by their hard, siliceous composition.

In the light of the above paleontologic and lithologic facts, the only logical conclusion is that the uppermost beds of Arkansas are the southwestern representative, perhaps the

* Not having had the opportunity of reading the proof of that report, the author begs to be excused for the typographic errors in the list of fossils.

direct continuation of the lower marl beds of the New Jersey region, an opinion which is strengthened by the stratigraphic evidence, which shows a complete unconformity between the uppermost Cretaceous of Arkansas and Texas north of the Rio Grande. Also, that a large part of the glauconitic beds were eroded, and their debris redeposited in the Eo-Lignitic or basal beds of the Southern States Tertiary. The iron ores of the Southern tertiary are primarily derived from this source. This fact has been determined by most careful observation on the part of Mr. R. A. F. Penrose, Jr., and the writer, in Texas and in Arkansas. The contact in the latter region are described in full in my Arkansas report, while those in Texas will soon be published in Mr. Penrose's report to the State Geologist, Mr. E. T. Dumble. Not only is the Tertiary laid down upon the unequal eroded floor of the Cretaceous but it overlaps upon successively lower horizons to the southwest, so that the glauconitic beds in Texas (except those of the Lower Rio Grande), are only exposed in the "islands" above mentioned in the midst of the Eocene area.

In view of these facts, and the absence of the Laramie fauna of the interior, only two conclusions are plausible concerning that epoch in this region. (1.) That there was a narrow post-Cretaceous continental divide in the central Texas region (now an area of rapid denudation) occupied by the coal measures, which separated the waters of the Atlantic from the interior Laramie sea. (2.) That the sediments constituting the base of the Eo-Lignitic divisions of the Eocene of the Southern States, containing typical marine Claiborne fossils and a Laramie flora were synchronous with the brackish waters of the interior. The exact solution must be given by the paleo-botanist who will take up the study of the extensive vegetal remains of our Southern States Eocene.

In conclusion it is suggested that the term "Glauconitic" be applied to this uppermost division of the Upper Cretaceous of the eastern (Atlantic and Gulf) slopes of the United States, including the Eagle Pass and Anderson county beds of Texas, the "Arenaceous" division of my Arkansas section, the "Ripley," "Rotten Limestone," and "Tombigbee" (in part) divisions of the Mississippi-Alabama section, and the "Glauconitic" beds of the New Jersey region below the "Upper Marl beds." These are the probable representatives of the "Fox Hills" beds of the northwestern, or Meek and Hayden section, the lower subdivisions of which are so clearly represented in the Texas region.*

* The writer cannot concur in the proposed suggestion to abandon the Meek and Hayden subdivisions of the Upper Cretaceous. If the beds lose their identity in Colorado, they appear in Texas in a manner which only confirms the original Nebraska section in it characters and succession.

ART. LIX.—*A description of several Yttria and Thoria Minerals from Llano County, Texas;* by W. E. HIDDEN and J. B. MACKINTOSH.

History.—In July, 1886, the first piece of gadolinite (a mass of about 1½ lbs.) was accidentally discovered, by Mr. J. J. Barringer, in Llano County, Texas. It was noticed projecting from an outcropping of granite and was detached therefrom and preserved merely because of its peculiar appearance. Later Mr. Barringer commenced digging at the locality, and in a short time he unearthed a pocket of huge crystals and masses of this rare mineral aggregating not less than 500 kilos. This remarkable quantity was obtained by digging with pick and shovel, in the partly decomposed surface rock and all came from a space not over 4 ft. deep, 3 ft. wide and 8 ft. long.

Until August, 1888, the true nature of the mineral remained unknown and meanwhile it received such local names as "tin-ore," "black-jack zinc," "volcanic-glass," etc. Later the name "samarskite" was given to it and as such it was known until Mr. Barringer, upon sending it to New York in an endeavor to find a market for it, received the information that it was gadolinite. About this time it came under the notice of one of us, and an effort was made to develop the locality thoroughly. Thus far only the gadolinite had been found and no value having been attached to it the mineral had been free to all who desired "a few pounds of it." Of the large quantity obtained in 1886, only about 100 kilos then remained; the greater portion having been gradually distributed among local visitors. In January of this year, realizing that a locality that could produce the rare mineral gadolinite in such unprecedented masses as had already come under our notice, was worthy of careful investigation, we sent Mr. Wm. Niven, of New York, on a special visit to the region and it was the series of specimens collected by him that induced one of us to personally visit the locality. This was done during the past summer, two months being spent in prospecting the whole region; the results of this investigation are embodied in this announcement.

Description of locality.—The spot where the gadolinite has been found is nearly five miles southward from Bluffton, in Llano Co., Texas, and on the west bank of the Colorado River. The whole surrounding region for many miles is Archæan* (with occasional cappings of limestone), and granite, in various shades of color and texture, is the common country rock. A coarse textured deep-red granite is most abundant, and through it

* See "Geologic story of the Colorado River." R. T. Hill, in American Geologist, vol. iii, No. 5, pp. 291–2.

numerous and extensive quartz veins extend to the surface. Only in these veins have the ores of yttria, etc., been found and only in the wider swellings of these veins or where they have assumed the character of bold uplifts have masses of large size been found. Here is to be seen a mound-like elevation 100×150 feet in area projecting boldly from the surrounding granite and 27 feet in elevation above the river terrace. It is made up of huge blocks and masses of quartz, and red feldspar, all tightly massed together. The mound is nearly circular in form and the contact with the country granite is sharply defined. It is plainly seen to be a widening of a vein that can be traced in a southwesterly direction for some distance and one of a series to be seen at several locations in the near neighborhood.

The quartz masses are from 5 to 20 feet thick, with the interstices filled completely by a highly crystalline red feldspar. Between these irregular masses are found at times thin seams of a black iron-mica and with this mica and in the adjacent feldspar are found the various ores of the rare earths hereinafter to be noticed.

From all sides this mound has been entered with trenches and one or more of the yttria minerals have been found at every opening. At this writing it has been so much cut into by trenching that it is difficult to trace the original boundary. On the river side the mound is rather steep but in other directions its sides slope gradually. Its top is flat and consists of pure white quartz (bleached by weathering) and it is only on the slopes and at the base that the several rare minerals show themselves. The quartz and feldspar are very much stained with red oxide of iron and some yellow and green uranium compounds at the points where at present the larger mineral masses have been found and these stains have constituted a good guide to their discovery.

Up to the present time we have identified the following mineral species, but we will describe in detail only the more important in the present paper. The list of species includes quartz, hyalite, orthoclase, albite, biotite, muscovite, magnetite, martite, gadolinite (several varieties due to alteration), fergusonite (three varieties of hydrous species), allanite, molybdenite, molybdite, cyrtolite (several varieties), fluorite, gummite (two varieties), a carbonate of the rare earths (tengerite?), a thorium-yttrium-lead uranate, a hydrous uranium thoro-silicate, a yttrium-thorium silicate, a fetid gaseous compound (which we first observed upon breaking some of the material for analysis) and several minerals, found in small quantities, which we have not had the opportunity, to identify with certainty.

Quartz, is rarely found crystallized at this locality. Only one pocket of smoky crystals (coated with ferric-oxide), of noteworthy size and transparency, having been as yet found. Small druses of quartz-caps are often met with in the seams of the larger quartz masses.

HYALITE, in mammillary forms was observed coating the seams of the feldspar and quartz, in very small patches.

ORTHOCLASE, occurs massive and finely crystallized and in great variety of form. Twin crystals, of curious complexity, and simple forms are very common. Crystals of huge dimensions, a foot or more in length, more or less perfect, and smaller sizes abound, especially are they abundant on the contact of the vein with the granitic walling.

ALBITE is rare and occurs coating small cavities in the massive orthoclase. Crystals not above 1 inch diameter were observed.

BIOTITE (?), is very abundant and occurs in broad folia in the seams between the quartz and feldspar masses. Diagonal prismatic cleavage surfaces were common. It was intimately mixed with much magnetite and was often the matrix or foundation upon which the rarer minerals rested. Many alteration products were noticed.

MUSCOVITE is quite rare, and occurs as hexagonal implanted prisms only in the albitic cavities. These prisms seem to be made up of 3 or 6 sectors on a basal section. No examination chemical or optical has been made.

MAGNETITE is quite abundant, both massive and crystallized. It is always associated and intermixed with the biotite. Octahedral crystals with planes of the cube, rhombic-dodecahedron and of a trapezohedron were found abundantly, though superficially they were coated with a thin micaceous layer and some uranium hydrate.

MARTITE was very common, being an alteration from the magnetite. Crystals having a black color interiorly and preserving the cleavages of magnetite but having no magnetic properties were very commonly observed.

GADOLINITE.—We have already detailed the events surrounding the discovery of this mineral in Texas. For a description we would refer to the paper by Dr. Genth * in the September number of this Journal. As Dr. Genth has stated, this gadolinite when unaltered "has a black color; in thin splinters it is translucent with a dark bottle green color; the fine powder is greenish-gray; fracture conchoidal to splintery. Sp. grav. 4·201–4·254."†

* Eakins found sp. g. = 4·239. Our own determination on a very compact mass gave us 4·306.

† Dr. Genth was misinformed by the party who supplied him with his "Burnet Co. gadolinite" as it has not as yet been discovered in that county, and the error of crediting Burnet Co. with having produced it was probably owing to the fact that it had been shipped from Burnet (Burnet Co.) which was the nearest R. R. point to the true locality some 19 miles distant.]

Most of the gadolinite is altered into a brownish-red mineral of waxy luster; some of the masses are entirely so altered, while in others the change has only taken place superficially. A further alteration has been to a yellowish-brown, earthy (ochreous) substance which upon drying in the open air becomes a very light powder. The average size of the masses of this Texas gadolinite has been in our experience about half a pound; though embedded crystals (hydrated) were noticed not above half an inch long by one-quarter inch wide (very acutely terminated) and as to large masses there were many of 5, 10 and 15 lbs. each. One double crystal weighed forty-two lbs. and was nearly free from matrix. Another huge pointed mass, in reality a crystal, weighed fully sixty pounds.* All of the gadolinite had at some time in the past presented smooth crystal surfaces (as the hydrated crust often gave evidences of), but very few masses were found without more or less exterior alteration. This alteration had roughened the underlying surface and had given a dark brick-red color to all the changed mineral.

On only three crystals were we enabled to find sufficiently smooth surfaces to give us even approximate angles, and these we here append:

$I \wedge I = 115°–117\frac{1}{2}°$	$O \wedge \frac{1}{2}\text{-}i = 145°–146°$
$I \wedge 1 = 156°–158\frac{1}{2}°$	$\frac{1}{2}\text{-}i \wedge \frac{1}{2}\text{-}i$ (ov. O) $= 111°–112°$
$1 \wedge 1 = 119°–119\frac{3}{4}°$	$O \wedge I = 90°–91°$
$1 \wedge O = 113°–113\frac{1}{2}°$	$1 \wedge 1$ (ov. $\frac{1}{2}\text{-}i$) $= 77°–79°$
$-1 \wedge +1$ (ov. O) $= 46°$	$\frac{1}{2}\text{-}i \wedge 1 = 123°–126°$

All the crystals observed were lengthened in the direction of the vertical axis (in one instance ten inches long), and the plus and minus 1 and 2 pyramids are present often to the total extinction of the basal pinacoid, making acute forms difficult to extract from the matrix in perfect condition. A distinctly monoclinic habit was apparent in many of the masses, and the pyramid 2 was often developed only upon the plus or minus side. The basal plane was only noticed in one instance. At another vein, one mile south, two crystals of gadolinite, of rare beauty and perfection, were found on the land of Mr. Hiram Casner; this goes to show that other discoveries of the rare minerals are possible in the neighborhood.

YTTRIALITE, *a new Thorium–Yttrium silicate.*

The mineral which we have named YTTRIALITE was discovered associated with, and often upon, the gadolinite, and but for its characteristic orange-yellow surface alteration (that of gadolinite immediately along side of it being invariably of a dull brick-red color) it might have continued to pass for "green-gadolinite," which was the local name given to it. Of these yellowish masses one weighed over ten pounds, and

* Stated on the authority of Mr. Barringer and many of his neighbors.

twenty kilos were found in all. Upon being broken open they are of an olive-green color, tending in places to a drab shade. Peculiar minute ragged lines permeate the mineral in all directions, causing an apparent muddiness or semi-opacity. No crystals have as yet been observed, but a seemingly orthorhombic symmetry was apparent in some of the masses. The mineral breaks easily in two directions with a shell-like fracture, but separates into small flakes very readily. (Gadolinite is broken only with difficulty.) Nothing like a cleavage has been noticed. A thin white crust of a mineral related to tengerite occupies the cracks in the mineral and this is equally true concerning the gadolinite of the locality as Genth has already noted. We have named the mineral *yttrialite*, in allusion to the prominent part played by the yttria earths in its composition.

The specific gravity is 4·575; hardness=5–5·5. It is readily soluble in hydrochloric acid. When heated over the Bunsen flame it decrepitates violently, and falls to powder upon being ignited over a blast, becoming snuff-brown, infusible and insoluble. These characteristics serve to at once distinguish it from gadolinite, which has specific gravity from 4·2 to 4·3 (Texas varieties), and which when heated glows vividly and swells into ragged fragments. The analysis shows several fractions of the yttria earths (A, B, C, D), which were separated by successive precipitations with sodium sulphate. The atomic weight of each fraction was determined, showing successive increase with each separation. The fractionation was discontinued after the fourth separation, as the amount of material was getting very small, but the atomic weight shows that the lanthanum and didymium are still mixed with an earth of higher atomic weight. The results obtained are as follows:

		Atomic weight.	Oxygen ratio.	
SiO_2	29·17 %			97·234 = 4
PbO	0·854		0·383	
ThO_2	12·00		9·108	
MnO	0·77		1·084	
FeO	2·89		4·014	
CaO	0·60		1·071	
Al_2O_3	0·55		1·617	
Ce_2O_3	1·86		1·722	72·918 = 3
(A) Y_2O_3	22·67	= 110·3	25·320	
(B) Y_2O_3	5·30	= 110·53	5·910	
(C) Y_2O_3	4·50	= 114·9	4·860	
(D) Y_2O_3	14·03	= 120·	14·616	
$(LaDi)_2O_3$, etc.	2·94	= 162·	2·370	
UO_3	0·83		0·843	
Ignition loss	0·79			
	99·754			

Total yttria earths = 46·50 % — erbia spectrum distinct.

Regarding the loss by ignition as non-essential, the oxygen ratio of all the bases to silica is exactly 3 : 4, which leads to the formula R_2O_3, $2SiO_2$, in which R_2O_3 may be replaced by its equivalent in RO, RO_2 or RO_3. There is no simple ratio between the sesquioxide and other bases. This mineral, therefore, differs from gadolinite in containing twice as much silica. It has other points of difference, viz: it contains no glucina, which has been regarded as a characteristic constituent of gadolinite, and there is a very large preponderance of sesquioxides among the bases. For comparison we append two analyses of gadolinite from this locality by Genth* and Eakins.†

GADOLINITE, LLANO CO., TEXAS.

	Genth.	Sp. G. = 4·254 Oxygen ratio.			Eakins.	Sp. G. = 4·239§ Oxygen ratio.		
SiO_2	22·80			76·00	23·79			79·30
ThO_2	----				0·58		0·44	
MnO	0·18	0·25			trace			
FeO	12·93	17·96			12·42	17·25		
GlO	9·19	36·61			11·33	45·18		
CaO	0·71	1·27	56·86		0·74	1·32	63·75	
MgO	0·11	0·27						121·13
K_2O	0·12	0·13			traces			
Na_2O	0·23	0·37		116·11				
Al_2O_3	0·31	0·90						
Fe_2O_3	----	----			0·96	1·80		
Ce_2O_3	2·66	2·46	59·25		2·62	2·43	56·94	
$(DiLa)_2O_3$	5·01	4·59			5·22	4·77	‖	
$(Y,Er)_2O_3$	44·45	51·30			41·55	47·94	‡¶	
H_2O	0·79				1·03			
P_2O_5	----				0·05			
Insoluble	0·93							
	100·42				100·29			

Regarding the water and phosphoric acid as accidental and using the molecular weight for the yttria earths determined by Eakins (260) for the calculation of Genth's analysis, we get the oxygen ratio of all the bases to silica of 3·055 : 2 and 3·054 : 2 respectively, giving the general formula R_2O_3, SiO_2 in which R_2O_3 may be replaced by its equivalent in RO and RO_2. Both of these analyses seem to show a tendency towards an equality of the sesquioxides to the monoxides, though there is a preponderance of sesquioxides in the one and of protoxides in the other. They differ also from our analysis of yttrialite in the small percentage of thoria, which in the latter amounts to one-eighth of the total bases in equivalency.

* F. A. Genth, this Journal, September, 1889.

† L. G. Eakins, private communication from Professor F. W. Clarke.

‡ Molecular weight = 260.

§ At 17° C.

‖ Didymium spectrum very strong.

¶ Erbium spectrum weak.

THORO-GUMMITE, *a hydrated uranium thoro-silicate.*

This mineral, of which we have been able to gather about one kilo, occurs intimately associated with fergusonite and cyrtolite, and masses up to three ounces have been found, though for the most part it is in very small pieces. It is of a dull yellowish-brown color, has hardness above that of gummite, or 4–4·5, and occurs commonly massive, though several well defined groups of zircon-shaped crystals have been discovered with angles near to those of zircon. It has a characteristic color, after ignition, becoming of a dull greenish hue, thus it is distinguished from freyalite, eucrasite and thorite, which species it otherwise resembles in some respects. Its specific gravity varies from 4·43 to 4·54. It is easily soluble in nitric acid. The analytical results are:

				Oxygen ratio.
SiO_2	13·085			43·62 = 2·000
UO_3	22·43			23·37 = 1·071
ThO_2	41·44		31·22	
Al_2O_3	0 965		2·83	
Fe_2O_3	0·845		1·59	
$(CeY)_2O_3$, etc.	6·69	Atomic weight = 135,	6·30	} 43 64 = 2·001
PbO	2·16		0·97	
CaO	0·41		0·73	
H_2O	7·88			43·78 = 2·008
P_2O_5	1·19			
Moisture	1·23			
	98·325			

Regarding phosphorus as non-essential and as combined with the slight excess of uranium, above that which is required by the formula which we derive, and with the undetermined and lost constituents, we get the oxygen ratio of $UO_3 : SiO_2 : ThO_2 : H_2O = 1 : 2 : 2 : 2$. The last three terms are in the proportion required by thorite, and we see that the molecule of the mineral may be regarded as made up of three molecules of thorite linked together by one of uranic oxide forming a compound molecule, which at first sight seemingly complex, is really of great simplicity.

Using graphic notation, the formula of the mineral is $\overset{VI}{U}O_6(ThO\overset{VI}{Si})_3(OH)_{12}$, or when written in the usual manner UO_3, $3ThO_2$, $3SiO_2$, $6H_2O$. The thoria and silica bear the same relation to the uranium, and it seems better to regard the mineral as a hydrated thoro-silicate of uranium, rather than as a urano-silicate of thorium, or as a double silicate of uranium and thorium, if indeed we might not go further and consider the whole as a duo-deci-atomic molecule of a complex inorganic acid. We name this mineral *thoro-gummite,* because it is a gummite in which the water has been replaced by the thorite molecule.

NIVENITE, *a hydrated thorium-yttrium-lead uranate.*

This mineral we found intimately associated with fergusonite and thoro-gummite. It is as yet a rare mineral at the locality. Its specific gravity is 8·01. H. = 5·5. It is velvet-black in color and when powdered becomes brown-black. After ignition it turns blue-black. As yet only massive pieces have been found, but some of these suggest that the species may be isometric in crystallization. It is easily soluble in nittic and sulphuric acids and some slight effervescence* was noticed upon dissolving the mineral. The analysis gave the following results :—

			Oxygen ratio.	
UO_3	46·75			48·69 = 12·
UO_2	19·89		14·62	37·33 = 9·20
ThO_2	7·57		5·74	
Y_2O_3, etc.	11·22	Atomic weight 124·2	11·34	
Fe_2O_3	0·58		1·08	
PbO	10·16		4·55	
(Ignition) loss H_2O	2·54			14·11 = 3·48
Insoluble	1·22			
	99·93			

The ratios found lead to the general formula 9RO, $4UO_3$, $3H_2O$ in which RO may be replaced by its equivalent in R_2O_3 and RO_2. If the iron be calculated as protoxide and a corresponding increase be made in the amount of uranic oxide, the ratio for UO_3 : RO : H_2O becomes 12 : 8·74 : 3·40. As it is not possible to determine the state of oxidation of the iron in presence of the two oxides of uranium, by any process known to us, we cannot give the exact ratio, as it exists, but would point out that if only 0·33 per cent of ferric oxide is present and the rest of the iron is present as protoxide, then the ratio of UO_3 to bases will be exactly that which is required by the formula.

This mineral is allied to the rare species cleveite† and bröggerite,‡ and we give below the analyses with the formulæ which we have calculated from them, so that the points of distinction may be made evident.

* Cf. Hillebrand, who has identified nitrogen in uraninite. This Journal, Oct., 1889, p. 329.

† Dana's Appendix, III, p. 28.

‡ This Journal, June, 1884, p. 493.

Cleveite. Specific Gravity = 7·49.

		Oxygen Ratio.			
UO_3	42·04%		43·79		
UO_2	23·89	17·56	21·17 (UO_2, ThO_2)	42·16	
ThO_2	4·76	3·61			
Y_2O_3	6·87	9·03	20·99 (Y_2O_3 to PbO)		
Er_2O_3	3·47	2·73			
Ce_2O_3	2·33	2·16			
Fe_2O_3	1·05	2·00			
FeO	---				
CaO	---				
PbO	11·31	5·07			
SiO_2	---				
H_2O	4·28		23·78		
	100·00				

Bröggerite. Specific Gravity = 8·73.

		Oxygen Ratio.			
UO_3	38·82%				40·44
UO_2	41·25	30·33	34·61 (UO_2, ThO_2)	44·18	
ThO_2	5·64	4·28			
Y_2O_3	2·42	3·18	9·57 (Y_2O_3 to PbO)		
Er_2O_3	----				
Ce_2O_3	0·35	0·33			
Fe_2O_3	----				
FeO	1·26	1·75			
CaO	0·30	0·54			
PbO	8·41	3·77			
SiO_2	0·81	2·70			
H_2O	0·83	4·61 (neglect)			
	100·09				

In the bröggerite analysis a small amount of silica occurs, which if supposed to exist as admixed silicate will reduce the excess of basic oxygen. Neglecting the water in bröggerite the oxygen ratio for these minerals will be therefore :—

	Bases. RO_2 (R_2O_3RO)	UO_3	H_2O
Cleveite,	1 + 1 = 2	2	1
Bröggerite,	1	1	

The comparison of the three formulæ shows the relationship clearly (RO including RO_2 and R_2O_3), as follows :—

Bröggerite	$3RO, UO_3$.
Cleveite	$6RO, 2UO_3, 3H_2O$.
Nivenite	$9RO, 4UO_3, 3H_2O$.

We have named this mineral *nivenite*, in recognition of the energy which Mr. Niven has displayed at this locality, and the assistance which he rendered us in obtaining the material for investigation.

Fergusonite.

This heretofore rare mineral occurs in large quantity at this new locality. Up to this date we have received over seventy kilos, some masses of which weighed over a pound. Broken prisms, rough in form, rarely showing terminal planes and masses of crystals interlacing each other is the manner of occurrence. The immediately associated minerals are cyrtolite and thoro-gummite and also magnetite. The gadolinite also sometimes encloses it. It also occurs alone in a matrix of orthoclase or of quartz. One large mass of this kind of gangue, upon being broken up, yielded over thirty kilos of pure mineral in the form of fragments, most of which were basal sections of crystals which had been originally four to eight inches long and about $1\frac{1}{2}^{cm}$ thick.

We have found two distinct varieties, of which we here append analyses and description.

Fergusonite, mono-hydrated.—Specific gravity = 5·67. Hardness 6–6·5, forms tetragonal, with acute octahedral terminations, a zirconoid plane hemihedrally developed and, rarely, the basal pinacoid. The crystals are rough and dull gray exteriorly but with a bronzy sub-metallic appearance on the surface of fracture, which is small conchoidal and brilliant. Thin splinters show a yellowish-brown translucence. Color bronzy hair-brown. Streak and powder dull brown. It is infusible but on ignition the powdered mineral changes to a pale olive-green color, and a momentary glow creeps over the mass at the point of redness. Fragments decrepitate violently when heated. With a microscope a peculiar light brown muddiness is noticed and the mineral is filled with minute streaks and spots of a darker shade, all of which may indicate incipient alteration.

Crystals often have a thin coating of, or are otherwise partly altered to, the tri-hydrated variety next described. It is decomposed when in fine powder by hydrochloric acid, with separation of columbic acid. The analytical results are as follows.

			Oxygen ratio.	
Cb_2O_5	46·27%			86·30
UO_3	1·54			1·59
ThO_2	3·38		2·56	
Al_2O_3	0·09		0·27	
Fe_2O_3	0·98	Atomic weights,	1·83	
(A) Y_2O_3*	23·95	110·55	26·70	
(B) Y_2O_3*	18·38	113·3	20·07	52·65
PbO	1·43		0·64	
ZnO	0·24		0·30	
CaO	0·10		0·18	
MgO	0·04		0·10	
Ignition H_2O	1·98		11·00	
110° C. H_2O	0·04		----	15·79
F	0·91	Atomic ratio,	4·79	
	99·33			
Less O = F	0·38			
	98·95			

Counting UO_3 as combined with a portion of the bases in the proportion R_2O_3–UO_3, we have for the oxygen ratio of the other constituents, counting fluorine as replacing hydroxyl,

$$Cb_2O_5 : R_2O_3 : \left(\begin{matrix}H_2O \\ F\end{matrix}\right) :: 86·30 : 51·06 : 15·79 \text{ or } 5·07 : 3 : 0·928$$

This leads to the formula Cb_2O_5, R_2O_3, H_2O; or if bases are counted as RO then $R_3Cb_2O_7(OH, F)_2$.

* Total Y_2O_3, etc., and Ce earths = 42·33.

We tested the columbic acid for titanic acid and tin, but although we obtained small quantities of precipitates they proved to be largely if not altogether columbic acid, and we did not detect the presence of any other substance. Tantalic acid was not looked for.

FERGUSONITE, tri-hydrated.—Specific gravity = 4·36–4·48; hardness about 5. Color deep brown, almost black, thin edges show a yellowish-brown translucence. Form and exterior appearance same as the species previously described. Streak and powder pale greenish-gray. On ignition turns light-brown but does not glow nor decrepitate like fergusonite. Is decomposed by hydrochloric acid with separation of columbic acid.

ANALYSIS.

			Oxygen ratio.	
Cb_2O_5	42·79			79·95
UO_3	3·12			3·24
UO_2	3·93		2·90	
ThO_2	0·83		0·62	
Al_2O_3	0·85		2·49	
Fe_2O_3	3·75	Atomic weight,	7·03	51·08
Y_2O_3, etc.	31·36	= 121·77	32·28	
PbO	1·94		0·87	
CaO	2·74		4·89	
Ignition H_2O	7·57		42·05	
110° C. H_2O	0·62		----	44·69
F	0·502	Atomic ratio,	2·64	
	100·002			
Less O = F	0·206			
	99·796			

Combining UO_3 as before with bases to form R_2O_3, UO_3, the oxygen ratio of the remainder will be

$$Cb_2O_5 : R_2O_3 : \left(\frac{H_2O}{F}\right) = 79·95 : 47·84 : 44·69 \text{ or } 5 : 2·992 : 2·795$$

This gives the formula $Cb_2O_5, R_2O_3, 3H_2O$, or counting bases as RO then $R_3Cb_2O_5(OH, F)_6$. On comparing the properties of the two minerals here described with typical fergusonite we notice a gradation from the one extreme to the other.

		Specific G.	Hardness.	When heated.
Fergusonite	$R_3Cb_2O_8$	5·838 (?)		
Mono-hydro-fergusonite	$R_3Cb_2O_7(OH)_2$	5·67	6·5	Pale olive-green, decrepitates.
Tri-hydro-fergusonite	$R_3Cb_2O_5(OH)_6$	4·36–4·48	5·	Light-brown does, not decrepitate.

Of other published analyses of fergusonite that of the Ytterby variety, by Nordenskiöld (Dana's System Min., p. 523), corresponds to the di-hydrated mineral. Since we find fluorine in the specimens we have analyzed from Texas, we are led to conclude that the water is not present as water of crystallization, but as hydroxyl which is partially replaced by the fluorine, and this being so we consider that the name fergusonite should be reserved for the anhydrous mineral, and that the various definite alteration products with two, four, six and perhaps more hydroxyls should be distinguished in some manner either by prefixing mono-hydro, di-hydro, etc., or by special names. It seems better that the first method of distinguishing them should be followed. We believe that we have observed a still higher alteration product in traces on some of the specimens we have obtained from Texas.

ALLANITE, has not as yet been found very abundantly at this locality and all of the ten kilos obtained was massive-nodular in form. Its surface alteration is very slight compared with that of the other allied minerals. Its color is shining pitchy-black. Powder and streak dull greenish-brown. Upon ignition it first turns red-brown and then becomes coal-black. It is opaque, except in the very thinnest splinters, when a greenish-brown translucence is evident. Specific gravity = 3·488. We have made no complete analysis as yet, but the specimen tested showed the presence of considerable quantities of the cerium-yttrium earths and of thoria, and we learned that it was completely soluble in acids with separation of gelatinous silica, either before or after igniting the mineral (like the associated gadolinite). The better masses have been found quite isolated from the other occurring minerals.

MOLYBDENITE, occurs sparingly in quite large folia, and in hexagonal tables, with the cyrtolite and fergusonite. Only a few ounces have been collected.

MOLYBDITE, was noticed in the cavities once occupied by molydenite and it often yet retained the plate-like form of the mineral from which it was derived by alteration. Its color was white to greenish-white. Specific gravity =4·004. On two specimens indistinct crystals have been found, having a light apple-green color and almost perfect transparency. Qualitative tests have shown the absence of any large amounts of anything but molybdic acid.

CYRTOLITE, has been found abundantly in both massive form and in good crystallizations. One hundred kilos have thus far been collected while mining the yttria minerals already herein described. This mineral here occurs in thick plates attached to the biotite and also constituting veins in the coarse pegmatite. It is often the matrix of the thoro-gummite and fergusonite. Specific gravity = 3·652. It occurs in tetragonal forms with all the planes rounded, and polysynthetic groupings of crystals are very common. Its color ranges from dull gray, through various shades of brown to deep brown and almost black. Hardness about 5. We shall defer further mention of this mineral until we have examined it more thoroughly.

FLUORITE, occurs in some abundance. Masses of a pale greenish kind were found weighing fifty pounds tightly embedded in the pegmatite. Purple and white shades have also been found. A very opaque dark-purple kind has been found in small masses. Its property of phosphorescing (green) when gently heated has given rise to a great local interest in this particular mineral.

GUMMITE, occurs sparingly, but we have not as yet been able to find it in a sufficiently pure condition for examination. Several varieties have been seen, and "yttro-gummite" is very probably one of them.

TENGERITE (?)—In the cracks and fissures of the gadolinite and yttrialite a white mineral rich in CO_2 is often noticed. We have seen it in globular-radiated incrustations and in one instance in distinct transparent isolated crystals. Dr. Genth has already noted its occurrence and, as he observes, there is not enough now obtainable to show its composition except by qualitative tests.

FETID GAS.—Upon breaking some of the cyrtolite, while at the mine, a fetid odor, quite different from H_2S, was noticed. Simply rubbing two massive specimens together is sufficient to develop this very disagreeable smell.

In conclusion, we take this opportunity to thank Mr Barringer, for his kind attentions and generous services extended to Mr. Niven and to one of us while visiting this very interesting locality.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Spectroscopic discrimination of the Rarer Earths.*—In his annual address as President of the Chemical Society, CROOKES has given a history of the so-called rare earths as they have been brought to light and discriminated by the aid of the spectroscope. In an interesting table he gives a list of the so-called "rare elements" with which he has been specially occupied for the last seven or eight years; arranging in parallel columns the names by which they are generally known, their atomic masses, the formulas of the oxides, the manner in which they come under the domain of spectroscopy, and the components or meta-elements into which some of them have been decomposed, first in 1886 by himself and then in 1887 by Krüss and Nilson. At first spectroscopic examination was applied directly to sub-

stances, natural or artificial, which had not undergone any special preparation. The idea next occurred of attempting to split up substances supposed to be simple into heterogeneous constituents before appealing to the spectroscope. The refined chemical processes used for this operation may be summarized under the name of fractionation whether they be fractional precipitations, crystallizations or decompositions. A combination of such delicate and prolonged chemical processes with spectroscopic examination applied to bodies showing absorption spectra soon led to important discoveries. In two juxtaposed plates, the author shows the normal didymium absorption spectrum as it was generally recognized down to 1878 compared with the whole of the absorption bands belonging to bodies subsequently separated from didymium by fractionation. In 1878, Delafontaine, by a series of chemical fractionations, separated from the didymium of samarskite an earth which he called decipia; and nine months later Lecoq de Boisbaudran announced the discovery of samarium as a constituent of the samarskite didymium, and showed that samarium is characterized by the bands of decipium together with two additional ones. In 1885, on the other hand, Auer, by fractionally crystallizing the mixed nitrates of ammonium, didymium and lanthanum, showed that it was possible in this way to cleave didymium in a certain direction and to separate it into two other bodies, one giving green salts, and called neodymium; and the other giving pink salts and called praseodymium. The spectrum of the former consists of the whole of the bands in the red with part of the large one in the yellow and the second one in the violet; that of the latter takes the other part of the yellow band and all the rest of the green and blue. But if these two spectra be subtracted from the old didymium spectrum two bands are left; and hence the fair inference that yet a third body is present in didymium to which these bands are due. In Crookes's own laboratory, moreover, didymium has undergone yet other changes; though it is still doubtful whether neodymium and praseodymium have themselves been decomposed or whether didymium itself is capable of being resolved differently according to the manner in which it is treated. Having worked on the spectrum of didymium from allanite, cerite, euxenite, fluocerite, gadolinite, hielmite, samarskite, yttrotitanite, etc., the author says: "the further I carry the examination the more the conclusion is forced upon me that didymium must not be regarded as compounded of two elements only but rather as an aggregation of many closely allied bodies." In 1886 he found decided indications of the possibility of depriving didymium of band after band until only the deep line in the blue is left. This single band element he calls Da. Subsequently Krüss and Nilson by examining rare earths from different sources came to the conclusion that the elements giving absorption spectra and known as didymium, samarium, holmium, thulium, erbium and dysprosium were not homogeneous but that each one contained almost as many separate constituents as it produced bands of absorption; didymium, for example, being capable of resolution into at least nine separate components. In carrying on their work these chemists have adopted Crookes's suggestion and have endeavored to select minerals in which the particular element desired has been accumulated by nature's processes. Thus, for example, the fergusonite from Arendal shows six of the bands of holmium, that from Ytterby four and that from Hitterö only three. This mineral from Ytterby, moreover, contains the element provisionally named $X\alpha$; but this element is absent in the mineral from the other two localities. The extraordinary complexity of some of these minerals is shown by the fact that after removing the ordinary metals, euxenite contains the rare elments Ce, La, Di, Sm, Yt, Er, Tr, Ho, Tm, Th, De, Sc, Dy, Be, Nb and Ta.

Passing to spectra produced by the phosphorescence of molecular bombardment, the author takes up first the yttrium group. Yttrium itself he concludes may be split up certainly into five and probably into six constituents. In one plate its complete phosphorescence spectrum is shown and in a second one below it the simple spectra of the separate components into which yttria can be separated by fractionation. As the result of many years work and of several thousand fractionations of old yttria, the author exhibited a series of nineteen phosphorescence spectra, the center one being approximately that of the crude earth, and those above and below representing the shading off in one direction or the other of the lines given by the several fractions. "To make the diagram more accurately represent what actually occurs in the laboratory it would be necessary," he tells us, "to place between each of these nineteen spectra about 1000 intermediate spectra." "A study of this diagram," he says, "will, I think, convince any impartial observer that the lessons it conveys fully bear out my contention that samarium, gadolininm, mosandrum and yttrium are not actual chemical elements but are compounded of certain simpler bodies which may conveniently be called meta-elements." Hence he concludes that our notions of a chemical element must be enlarged; "hitherto the elemental molecule has been regarded as an aggregate of two or more atoms and no account has been taken of the manner in which these atoms have been agglomerated. The structure of a chemical element is certainly more complicated than has hitherto been supposed. We may reasonably suspect that between the molecules we are accustomed to deal with in chemical reactions, and the component or ultimate atoms, there intervene sub-molecules, sub-aggregates of atoms or meta-elements, differing from each other according to the position they occupy in the very complex structure called 'old yttrium.'" This "assumption of compound molecules will perhaps account for the facts and thus legitimate itself as a good working hypothesis, whilst it does not seem so bold an alternative as the assumption of eight or nine new elements."

A remarkable modification of phosphorescence spectroscopy is produced by the previous addition of other earths to the specially phosphorescent earths. Lime is a good example of this. Alone it phosphoresces with a continuous spectrum ; but if mixed with yttria the phosphorescing energy of the lime does not extend over the whole spectrum, but concentrates itself on strengthening the yttria bands ; these bands becoming broader and less well defined as the quantity of the lime increases. The same is true of the samarium spectrum, the addition of lime bringing out its main phosphorescent bands, three in number, red, orange and green, nearly equidistant. On the other hand the presence of lime suppresses the sharp line Sδ, the most striking feature in the phosphorescent spectrum of samarium sulphate ; while the presence of yttria deadens the other lines, but brings out the line Sδ more strongly. The modification induced in the normal spectrum of one earth by the mixture of various quantities of others, when treated as anhydrous sulphates, is strikingly shown in the case of a mixture of samaria with yttria. The presence of even 40 per cent of yttria practically obliterates its spectrum. Strontia, baryta, glucina, thoria, magnesia, lanthana, alumina and the oxides of zinc, cadmium, lead, bismuth and antimony all give characteristic spectra with samaria. " A recent discovery of some beautiful spectra given by the rare earths when their pure oxides are highly calcined, shows the remarkable changes produced in the spectra of these earths when two or more are observed in combination." Alumina is especially active in inducing new spectra when mixed with the rare earths. Within the past twelve months, quite a moderate amount of fractionation has enabled the author to penetrate below the surface of the red glow common to crude alumina and to see traces of a most complicated sharp line spectrum. " By pushing one particular process of fractionation to a considerable extent, I have obtained evidence of a body which is the cause of some of these lines. The new body is probably one of the rare elements or meta-elements closely connected with decipia, for I have reproduced the spectrum very fairly by adding decipia to alumina. It is not yttria erbia, samaria, didymia, lanthana, holmia, thulia, gadolinia, or ytterbia, since the spectrum of each of these when mixed with alumina while very beautiful, differs entirely from the decipia-alumina spectrum.

In conclusion, the author considers the question, " What is an element and how shall it be recognized when met ?" It must be remembered that a single operation, be it crystallization, precipitation, fusion, partial solution, etc., can only separate a mixture of several bodies into two parts, just as the addition of a reagent only divides a mixture into two portions a precipitate and a solution ; and these divisions will be effected along different lines according to the reagent employed. Thus by crystallizing didymium nitrate (in Auer's way) we divide the components into two parts. By fusing didymium nitrate we divide its components in a different way. But so long as different methods of attack split up a body differently, it is evident that we have not yet got down to "bed rock." Moreover, a compound molecule may easily act as an element. Didymium for example has a definite atomic mass, has well defined salts and has been subjected to the closest scrutiny by some of the ablest chemists in the world; and as a seeming element it emerged from every trial. But subjected to a new method of attack it decomposes at once. "We have in fact a certain number of reagents, operations, processes, etc., in use. If a body resist all these and behave otherwise as a simple substance we are apt to take it at its own valuation and call it an element. But for all that, it may as we see be compound, and as soon as a new and appropriate method of attack is devised, we find it can be split up with comparative ease." "Until these important and difficult questions can be decided," he continues, "I have preferred to open what may figuratively be called a suspense account, wherein we may provisionally enter all these doubtful bodies as 'meta-elements.'" The meta-elements may have more than a provisional value, however. Mr. Crookes points out that it is becoming more and more probable that between the atom and the compound, we have a gradation of molecules of different ranks which may pass for elementary bodies. It might be the easier plan so soon as a constituent of these earths can be chemically and spectroscopically distinguishable from its next of kin, to give it a name and to claim for it elemental rank. "But it seems to me the duty of a man of science to treat every subject not in the manner which may earn for him the greatest temporary *κῦδος* but in that which will be of most service to science."—*J. Chem. Soc.*, lv, 255–285, May, 1889. G. F. B.

2. *Commercial Organic Analysis;* a Treatise on the Properties, proximate analytical Examination and modes of Assaying the various Organic Chemicals and Products employed in the Arts, Manufactures, Medicine, etc. By ALFRED H. ALLEN, F.I.C., F.C.S., etc., etc. 2nd Edition, revised and enlarged. Vol. III, Part I. Acid derivatives of Phenols, Aromatic Acids, Tannins, Dyes and Coloring matters. 8vo, pp. viii, 431. Philadelphia, 1889 (P. Blakiston, Son & Co.).—This volume of Mr. Allen's excellent work fully sustains the reputation of previous ones. After a hundred or more pages devoted to the general characters and constitution of aromatic acids, and their consideration in detail, the author passes to the consideration of dyes and coloring matters, beginning with the nitro- and nitroso-bodies, aurine and the phthaleins, passing to the azo-compounds, the rosanilines and saffranines, and then to the anthracene colors; ending with a chapter on coloring matters of natural origin, chapters on the examination and recognition of coloring matters and the examination of dyed fibers conclude the book. The entire work will be completed in another part. It bears evidence of care and thorough work on every page and has already become a standard upon the subjects

of which it treats. The publishers have presented the book to the public in an attractive form.

3. *A Text Book of Organic Chemistry;* by A. BERNTHSEN, Ph.D. Translated by George M'Gowan, Ph.D. London, 1889. (Blackie & Son.) This new text book merits high commendation. Its author was formerly Professor of Organic Chemistry at Heidelberg and is at present director of the Baden Aniline and Alkali Manufactory in Ludwigshafen-am-Rhein. He is well and favorably known not only as a teacher but also for his remarkable investigations in organic coloring matters. The translation has been faithfully made by Dr. M'Gowan of the University College of N. Wales, Bangor, and both gentlemen have contributed to bring the book up to date. L. H. F.

4. *The spectrum of Hydrogen.*—MM. L. Thomas and Ch. Trépied obtain the lines $H\alpha$. $H\beta$ by passing a stream of hydrogen gas between the carbon terminals of a voltaic arc. They state that these lines can also be obtained by the use of steam injected between the terminals. See Trowbridge and Sabine, this Journal, Feb., 1889.—*Comptes Rendus*, p. 524. J. T.

5. *Spectrum of gases at low temperature.*—H. K. R. Koch shows that the spectra of air, oxygen and hydrogen do not change when the temperature of the environment in which the electrical discharge takes place is $-100°$ C. Any change therefore observable in the spectra of the northern light in polar regions cannot be attributed to the temperature of the environment, but must be due to other causes.—*Ann. der Physik und Chemie*, No. 10, 1889, pp. 213–216. J. T.

6. *New Photographic lens.*—M. Ch. V. Zenger employs two correction lenses of magnesium glass of the same focal length, one concave and the other convex. The focal length of the system is the same as that of the spherical mirror. The time of exposure for stars of the same size is reduced to a third or a quarter. —*Comptes Rendus*, No. 12, Sept. 16, 1889, p. 474. J. T.

7. *Pin-hole Photography.*—A paper on this subject was read at the late meeting of the British Association by Lord Rayleigh, who showed that a simple aperture was as effective as the best possible lens in forming an image, if the focal length (f) was sufficiently great. Conversely, if f be given the aperture may be made so small that the use of the lens will give no advantage. In some recent experiments the focal length was about nine feet and the aperture $\frac{1}{16}$ of an inch. The resulting photographs showed detail not materially less than that observable by the ordinary eye. There would be no difficulty in working with an aperture equal to the pupil of the eye, with a focal length of 66 feet, if extraneous light could be excluded.—*Nature*, Oct. 10, 1889, p. 584. J. T.

8. *Blue color of the sky.*—M. Crova in collaboration with M. Houdaille has conducted a series of observations at Mount Ventoux on this subject. The apparatus employed was a modification of Crova's spectrophotometer (Annales de Chimie et de

Physique, 5th series xix, p. 472). It was found, 1. The curves which result from the observations indicate that at sunrise there is a predominance of the more refrangible rays. These rays diminish at midday, and augment again at sunset, never attaining during the afternoon hours the values attained during the morning hours. 2. The curves vary from day to day, in regard to the more refrangible rays, with the state of the atmosphere. The maximum of blue color varies with the maximum of heat. The color is generally less intense in the afternoon than in the morning. M. Crova leads us to conclude that in general the sky is richer in blue rays than the sun. Certain observations were made under a cloudy sky. The author states that the light was less rich in blue rays than the blue sky but that it was more blue than the light of the sun.—*Comptes Rendus*, No. 13, Sept. 23, 1889, p. 493. J. T.

9. *Passage of Electricity through gases.*—At the late meeting of the British Association, Professor Arthur Shuster gave an account of his investigations on the distribution of potential in the neighborhood of the negative pole of discharge of electricity through rarified gases. "Knowing the rate of fall of potential, it can be determined whether there is any bodily electrification in any part of the negative glow. It was found that the kathode is surrounded by an atmosphere of positively electrified gaseous particles extending to the outer edges of the so-called dark space. According to the author's views, this atmosphere corresponds to the polarized layer adjoining the negative electrode in an electrolyte. The cause of the sudden difference in luminosity between the dark space and the negative glow has also been investigated, and it has been found that negative particles projected from the kathode pass unhindered through the dark space, while their velocity is quickly reduced in the glow proper, the translatory energy being thus changed with energy of vibration."—*Nature*, Oct. 10, 1889, p. 586. J. T.

10. *Purification of Sewage by Electricity.*—A paper was read before the British Association, at its late meeting, on this subject, by Mr. W. Webster, who showed that the effect produced was due to the gases set free in the electrolysis of the sewage water. The constituent parts of sodium, magnesium and other chlorides are split up, nascent chlorine and oxygen are set free at the positive and the bases at the negative pole.—*Nature*, Oct. 24, 1889, p. 631. J. T.

11. *Elementary Lessons in Heat;* by S. E. Tillman, Professor of Chemistry, U. S. Military Academy. 160 pp. 8vo. Philadelphia, 1889 (J. B. Lippincott Company).—These lessons, prepared for the students of the U. S. Military Academy, give in concise form the general principles of heat. The ground covered is about the same as that usually taken in the larger elementary text-books, without too much mathematical analysis for the ordinary student, and omitting the excess of descriptive and pictorial matter too often present. Suitable use is made of the results of recent work in the department of heat.

II. Geology and Mineralogy.

1. *The Tertiary Flora of Australia;* by Dr. Constantin, Baron von Ettingshausen. English translation, edited by R. Etheridge, Jr. Sidney, 1888.—The appearance of an English translation of Baron von Ettingshausen's two important memoirs on the later fossil floras of Australia will do much to extend the knowledge of this subject. The memoirs originally appeared in the Denkschriften of the Vienna Academy (vols. xlvii, 1883, and liii, 1886), and were chiefly based on collections made by the Geological Survey of New South Wales, in the Memoirs of which the translation appears. An analysis of the results was prepared some time since, and will be found in the Eighth Annual Report of the U. S. Geological Survey (pp. 812–814), soon to appear. The useful tables of distribution accompanying the original memoirs are introduced, and to that of the second part is appended a similar table of the Tertiary plants of New Zealand, belonging to a paper of later date (Denkscriften Wien. Akad., vol. liii, 1887) on the fossil flora of New Zealand, but the descriptions and figures of that memoir are not included in the present work. The first part was translated by Mr. Arvid Neilson, and the second by the author. Some valuable stratigraphical notes by the editor are appended. The illustrations are reproduced from the original litho-plates, of which there are fifteen, but the figures are often too much crowded. These papers have afforded the author a new occasion to express his well-known views as to the homogeneity of all Tertiary floras, and that of Australia, he claims, resembles that of Europe and the Arctic regions more closely than it does the present living flora of Australia.

L. F. W.

2. *Royal Society of Canada.*—Volume VI of the Transactions of this society contains a paper on the Huronian of Canada by R. Bell; on Nematophyton by D. P. Penhallow, with an introductory note by Sir Wm. Dawson, which concludes that *Prototaxites* or *Nematophyton* has no relation to the vascular plants, and that it is beyond doubt an Alga; on remarkable organisms of the Upper Silurian and Devonian of New Brunswick by G. F. Matthew, namely, an Upper Silurian fish, *Diplaspis Acadica*, an Upper Silurian Ceratiocaris, an Eurypterid, a Devonian species of insect, *Geroneura Wilsoni;* on Vancouver Island Cretaceous plants, by Sir W. and G. M. Dawson; on Devonian fossil fishes, Part II, by J. F. Whiteaves; on the Nymphæaceæ by G. Lawson.

3. *Contributions to Canadian Palæontology, Canada.*—Geol. and N. H. Survey, vol. i, Part II, by J. F. Whiteaves. The fossils described by Mr. Whiteaves are from the Hamilton formation of Ontario, the Triassic of British Columbia, and the Cretaceous of British Columbia, Northwest Territory and Manitoba. A list of all the known Hamilton species of Ontario is also given.

4. *Chemical and Physical studies in the Metamorphism of Rocks*, by A. Irving, D. Sc., thesis written for the Doctorate in

Science in the University of London. 138 pp. 8vo. London, 1889. (Longmans, Green & Co.).—Treats especially of the origin of the Archæan rocks under pre-Archæan and Archæan conditions, the author being incredulous as to later or ordinary regional metamorphism.

5. *Eudialyte* (?) from an Arkansas locality. Preliminary notice by W. E. HIDDEN and J. B. MACKINTOSH. (Communicated.) We are indebted to Mr. Wm. Niven of New York, for a very characteristic specimen of this rare species which he found during the past summer in the vicinity of Magnet Cove, Arkansas. It occurs in nodular form in a very tough matrix of feldspar and hornblende, with which some titanite is also associated. The masses are of a fine rose-red color and, excepting as they are flawed and cracked, are perfectly transparent. Sp. G.=2·893. H=5·+(scratched by scapolite). It is easily soluble in HCl, leaving gelatinous silica. The solution shows with turmeric paper the usual zirconia reaction. The presence of soda, lime, oxide of iron and zirconia were also proved by qualitative analysis on half a gram of material. The mineral, as thus far seen, has a yellowish border (which may be due to alteration) and contains small cavities in which are implanted minute dull greenish crystals of an unrecognizable mineral. Until a quantitative analysis has been made, we think that the above data warrants us in referring this mineral to eudialyte, and more especially since Shepard* credited this locality, long ago, with having produced this species.

6. *Catalogue of Minerals and Synonyms alphabetically arranged for the use of Museums;* by T. EGLESTON, Ph.D. 198 pp. Washington, 1889 (Bulletin U. S. National Museum, No. 33).—The author has industriously brought together a large number of mineral names and synonyms from many sources, and although no critical treatment of them is attempted, collectors will find the work very useful.

7. *Materialien zur Mineralogie Russlands*, von N. von KOKSCHAROW, vol. x, pp. 97–224. St. Petersburg, 1889.—Mineralogists will welcome this last addition to the mineralogy of Russia, both for what it contains and, too, as a proof that the veteran author is still carrying on his work with vigor. The species chiefly discussed are euclase, herderite and sylvanite.

8. *Index der Krystallformen der Mineralien;* von Dr. VICTOR GOLDSCHMIDT, Zweiter Band, Heft 5.—This recently issued part of Goldschmidt's great work includes the species from lanarkite to lunnite.

9. *Einleitung in die Chemische Krystallographie;* von Dr. A. FOCK. 126 pp. 8vo, Leipzig, 1888 (Wm. Engelmann).—The subject of crystallography is usually treated almost exclusively as a geometrical subject; at the same time there have not been wanting discussions of a broader range and of late years much progress has been made in connecting form and chemical

* Dana, Syst. Min., p. 249.

composition. The portion of the subject taken by the author is on the latter side and, as treated by him, it is a field that has not been occupied before. Some of the topics discussed are the physical laws of crystallization, the origin and growth of crystals, the formation of artificial crystals, and the relation between form and composition including isomorphism, physical isomerism, and isogonism.

10. *Composition of uraninite.*—In the note on this subject on p. 329 of this volume, line 17 from beginning, NO_2 is a misprint for UO_2.

III. Botany.

1. *What is a Phyllodium?*—An examination of two plants of the Brazilian species, *Oxalis bupleurifolia*, grown from cuttings, has led the writer to review the literature of the subject of phyllodia, chiefly with reference to one point. The smaller of the plants in question has flattened petioles without any distinct trace of leaflets at the end. The other has petioles flattened in the same way, and more than half of these have small leaflets, varying in number from one to three. But all of these flattened petioles in both cases have a distinct upper and lower surface, thus presenting the aspect of ordinary leaves, instead of having an upper and a lower edge. They stand in the same plane as the leaflets.

The following definition of the term phyllodium is taken from Gray's Text-book, vol. i, p. 110: "A petiole-blade . . . . . is named a Phyllodium. Occurring only in Exogens, phyllodia are generally distinguished from true blades by the parallel venation, *and* always by their normally vertical dilatation;* that is, they, without a twist, present their edges instead of their faces to the earth and sky." Among the examples cited, are the Acacias of Australia, and "several South American species of oxalis."

It will be noticed that in the definition, verticality is not qualified. In this respect the definition follows the ordinary usage, based largely upon the authority of DeCandolle, Organographie végétale, Paris, 1827, p. 282. "Ceux-ci sont planes, coriaces, fermes, toujours entier sur les bords, munis de nervures longitudinales, qui sont les traces des fibres dont le pétiole est composé, *et habituellement placés sur la tige dans un sens contraire aux vraies feuilles*, c'est-à-dire que leur plan est à-peu-près vertical, au-lieu d'être horizontal, ou en d'autre termes, que leurs surface sont latérales, au-lieu d'être l'une supérieure, l'autre inférieure.

Il est des espèces qui, pendant la durée entière de leur vie, portent mélangés des pétioles chargés de folioles ordinaires, et ordinaires, et des pétioles transformés en *phyllodium.* Telles sont les Acacia heterophylla, sophorae, etc. Quelques-uns portent sur leur bord supérieur une ou deux glandes qui indiquent la place où le ramifications chargées de folioles doivent prendre naissance.

* The italics in these citations are not in the original.—G. L. G.

Tous ces charactères indiquent leur nature pétiolaire; mais les fibres de ces pétioles sont assez écartées pour admettre un peu de parenchyme, et pour porter des stomates; d'où résulte que ces organes jouent physiologiquement le rôle de limbe. Des transformations analogues ont lieu dans quelques espèces d'oxalis; telle est, par example, *l'Oxalis bupleurifolia*, et l'Oxalis fruticosa."

The verticality is insisted on in both of these definitions, and yet, species of Oxalis, in which the flattened petioles are *not* vertical, are adduced as illustrations of phyllodia. Plainly the definition should be reconstructed, or the illustrations omitted.

In the descriptions of the species of Oxalis given in The Flora of Brazil,* Progel, the editor of the Order Oxalideæ, uniformly applies the term Phyllodium to the flattened petioles even where they are not vertical, but lie in the same plane as ordinary leaves.

If, now, we turn to the definitions of Phyllodium by another author, Balfour, we shall see that the feature of verticality is not insisted on as universal, but is regarded as a special case.

In the "Class-Book of Botany" (Edin., 1854, p. 134), we find the following: "In some Australian plants belonging to the genera Acacia and Eucalyptus (sic) the petiole is flattened and becomes a foliar expansion which occupies the place of true leaves. Such petioles have received the name of Phyllodia. The trees bearing them give a peculiar character to some of the forests of New Holland. These phyllodia are usually placed vertically presenting their edges to the sky and earth, and their venation is parallel. Trees producing naked vertical phyllodia only have a singular effect as regards light and shade. Travelers have noticed this in some of the Australian forests . . . . Some shrubby species of Wood-sorrel exhibit phyllodia which are either naked or bear ternate leaflets. *These phyllodia are often placed like leaves, with their flat surfaces towards the sky and earth.*"

Moreover, if we go back to the Théorie élémentaire by DeCandolle, a work published in 1813, we shall observe that the verticality of the Phyllodium was not regarded as essential. The following extract is taken from the second edition of the Théorie élémentaire, published in 1819 (p. 362):

Pétiole foliacé ou Phyllodium.—Je donne ce nom aux pétioles de certaines feuilles composées ou très-découpées, qui prennent tellement d'extension, qu'ils semblent de véritables feuilles, et que leurs folioles ou leur limbe avortent en tout ou en partie, par exemple, dans les Acacies de la Nouvelle-Hollande; cet accident se présente aussi dans les feuilles submergées des Alisma et de la Sagittaire; il arrive peut-être constamment dans celles des Buplèures, etc.

In view of this discrepancy it seems advisable to remove from the definition of Phyllodium the restriction of verticality, and apply the term Phyllodium to all cases of flattened petioles, where there is great reduction of the blade.†

* Flora Brasiliensis, (vol. xii, II, p. 515). † Ann. Bot., May, 1889.

The suggestion of Professor Bower that the general term *Phyllopodium* be introduced to designate the eentral portion of the framework of the leaf appears to be well-advised, and in the ease mentioned would remove all ambiguity.

It remains to say something relative to one of the eases cited by Balfour, namely the species of *Eucalyptus*, which he adduees as illustrations of Phyllodia. These are not flattened petioles, but are true leaves with a well-marked twist, whieh in some instanees is so great as to give to them a vertical aspeet. This twisting was observed long ago by Robert Brown (Mise. Works, Ray Soeiety, vol. i. p. 62), who says: "They (that is, Aeaeia and Eucalyptus), agree very generally also, though belonging to very different families, in a part of their eeonomy whieh eontributes somewhat to the peeuliar charaeter of Australian forests, namely, in the leaves or the parts performing the funetions of leaves being vertieal or presenting their margin and not their surfaee towards the stem; both surfaces having eonsequently the same relation to light. This eeonomy whieh uniformly takes place in the Aeaeiæ, as in them the result of the vertical dilatation of foliaeeous footstalk, while in Euealyptus, where, though very general it is by no means universal, it proceeds from the twist of the footstalk of the leaf."

Allusion must now be made to a convietion whieh has been deepening in the mind of the present writer, that the vertical Phyllodia of Aeaeias, and the vertieally twisted leaves of Myrtaeeae are correlated with the so-ealled "sleep positions" of leaves, whereby the amount of surfaee exposed to direct loss of heat at night is materially lessened.*

Sueh, I venture to suggest, may be regarded as permanent sleep positions.† Comparison of the vertieal Phyllodia with those which lie in the plane of ordinary leaf-blades, indieates that the latter belong to plants whieh, like the South Amerieau speeies of Oxalis, grow in shaded places, and are therefore more or less sheltered from direet loss of heat by radiation. The information whieh ean be gathered from various authors, in regard to the different speeies of Euealyptus in which there is eonspieuous vertieality through the twist at the base, indicates that here also we have a kindred adaptation. But the faets thus far aeeessible in regard to the different speeies with respeet to this point are too meagre to enable me to regard this as more than a suspicion whieh will repay further investigation. The writer will weleome any information bearing on the degree of vertieality presented by the leaves of all Myrtaeeae, and on the elimatal surroundings of the different species. G. L. G.

* It must not be overlooked that the vertical position has perhaps more extended relations to the loss of moisture during the day.

† Compare Darwin. The Power of Movement in Plants, Am. Ed., p. 328.

IV. Miscellaneous Scientific Intelligence.

1. *The National Academy* held its semi-annual session in Philadelphia, commencing with the 12th of November. The following is a list of the papers presented:

W. Gibbs and H. A. Hare: On the Results of the Systematic study of the Action of definitely related Chemical Compounds upon Animals.
B. A. Gould: On the new Prototypes of the Kilogram and the Meter.
James Hall: Present state of our knowledge in reference to a revision of the Genera of Brachiopoda for the Palæontology of New York, vol. viii.
George F. Barker: On Zinc Storage Batteries.
A. Hall: On Saturn and its Ring.
S. P. Langley: On the Economy of Energy in the Glow-worm.
O. N. Rood: On Photometry of Colored Light.
W. Gibbs: On certain Pyrophosphates.
E. D. Cope: On the Vertebrata of the Miocene of the Cypress Hills of Canada.
W. K. Brooks: On the Early stages of Echinoderms.
A. A. Michelson: On Relative Wave-lengths.
E. C. Pickering: On the Spectrum of Zeta Ursæ Majoris.
J. A. Ryder:* On the Persistence and meaning of the Bi-concave centrum of the Vertebræ of Vertebrates.
Theodore Gill: On the peculiar Ordinal modification as exemplified by Fishes of the family Halisauridæ.
W. H Brewer: On the Heredity of Acquired Characters.
Arthur Michael: On the "Positive-negative" Hypothesis in its application to Organic Chemistry.
S. Newcomb: On the Results of the Transits of Venus observed in 1761 and 1769; On the Theory of Cosmical Temperature.
J. W. Powell: The Desert Ranges.
H. C. Wood: On Hypnotic Cases without Suggestion.
J. S. Newberry: On the Laramie Group.
O. C. Marsh: On the Skull of the gigantic Ceratopsidæ; American Mesozoic Mammals.

2. *New Bulletins of the U. S. National Museum, published by the Smithsonian Institution in* 1889.—No. 34. The *Batrachia of North America*, by E. D. Cope. 525 pp.—A complete treatise, illustrated by 86 plates, besides many cuts in the text.

No. 35. *Bibliographical Catalogue of the described Transformations of N. A. Lepidoptera*, by Henry Edwards. 147 pp.

No. 36. *Contributions to the Natural History of the Cetaceans; a Review of the Family Delphinidæ*, by Frederick W. True. 191 pp. Illustrated by 47 plates.

No. 37. *Preliminary Catalogue of the shell-bearing Marine Mollusks and Brachiopods of the Southeastern coast of the United States*, by Wm. H. Dall. 221 pp., Illustrated by 74 plates.

OBITUARY.

George H. Cook.—The death of Professor Cook, State Geologist of New Jersey and Vice-President of Rutgers College at New Brunswick, New Jersey, on the 22d of September last, is announced on page 336. His successive annual Geological Reports of the State of New Jersey, continued for the past twenty-

* Presented by Mr. T. Gill.

four years, have given occasion for an annual notice in this Journal of the very faithful and valuable work he has done for the science. In 1888 appeared the first volume of the Final Report, and the second was completed, and is in the press. It is a serious loss that he did not live to finish the closing volumes and give his matured views on the various subjects illustrated by the facts he had long been collecting. He lived to see the topographical survey ended and the maps published, and had the satisfaction of knowing that New Jersey was the first State to be thus thoroughly surveyed. His work was always practical as well as scientific, and greatly valued for its contributions to the economical interests of the State. The subjects of the iron ore beds, clays, marls, and all contributions of geology to the arts interested him no less than the geological structure of the country. The change of level by a slow subsidence along the Atlantic shore was one of the topics he studied with care and with results of the highest interest. He was the organizer of the State Board of Agriculture of New Jersey, a member of the State Board of Health, and in 1886 was made chief director of the New Jersey State Weather service. He was also long the President of the New Brunswick Board of Water Commissioners.

Dr. Cook was born in Hanover, New Jersey, in the year 1817. He entered the Troy Polytechnic Institute in 1839, and was one of the many students that derived, from the enthusiasm and practical instruction of Amos Eaton, their first impetus in geological science. In 1842 he was senior professor and acting President of the Institute, Professor Eaton having died in May of that year. He was for awhile principal of the Albany Academy. In 1852 he left this position for the chair of Chemistry and Natural Philosophy in Rutgers College; and in 1864 was placed at the head of the New Jersey Geological Survey.

Professor Cook was honored with the degree of Doctor of Philosophy from the University of the City of New York and of Doctor of Laws from Union College. He was a man of great excellence of character, unassuming, always commanding the confidence and calling out the highest esteem among those with whom he came in contact. He leaves a widow and two children.

Leo Lesquereux.—Professor Leo Lesquereux, eminent in the department of Fossil Plants, died on the 20th of October last at Columbus, Ohio. He was born in Fleurier, Canton of Neuchatel, Switzerland, in 1806. His parents were V. Aimé and Marie Ann Lesquereux, whose ancestors were Huguenots, fugitives from France after the edict of Nantes. His education, collegiate and academical, was received at the college and academy at Neuchatel, where he was a fellow student of Guyot. In youth he was by nature and disposition, a naturalist, though he was educated for theology. At the age of 26 he had the great misfortune to become deaf, and from then for twelve years worked as an engraver of watch cases and a manufacturer of watch springs. He first became known in science as a bryologist and by researches on the peat formations. In 1845 he was commissioned by the government of Prussia to make explorations on the peat bogs of Europe, and his report on the subject appeared in 1844.

In 1848 he came to the United States and became a resident of Columbus, where he published different works on Mosses, in connection with Mr. W. S. Sullivant. From 1852 to 1885 Professor Lesquereux was attached as botanical paleontologist to geological surveys. His published memoirs and volumes exceed fifty in number. Of them, the more important are the following: Reports in connection with the First Geological Survey of Pennsylvania, 1858; with that of Arkansas, (1860); with that of Illinois, vols. II and IV (1866 to 1880); that of Mississippi, the Tertiary Plants (1863); the United States Geological and Geographical Survey of the Territories under Dr. F. V. Hayden, including a Monograph of the Cretaceous Flora of the Dakota Group, (1874), a Monograph of the Tertiary Flora (1878), and a Monograph of the Cretaceous and Tertiary Flora, 1883; with that of the second Geological Survey of Pennsylvania, on the Coal Flora of Pennsylvania and the United States, three volumes, one an atlas of plates, 1880–1884. He published also a Monograph of the Pliocene Flora of the Auriferous Gravel Deposits of the Sierra Nevada, 1875, and a Manual of the Mosses of North America (this last in connection with Mr. Thomas P. James of Cambridge). He was a member of the United States National Academy and of twenty scientific societies of Europe and of the United States, corresponding member of the Geological Society of London; corresponding member of the Geological Society of Belgium, honorary professor of the Academy of Neuchatel, etc. For the past five years he has remained at home, surrounded by his books and specimens of fossil plants that were constantly arriving for his study and determination, always regretting that his age prevented him from continuing in the field.

He was married in 1830 to a lady of rank, of Eisenach, Baroness Sophia von Wolffskeel, daughter of General von Wolffskeel. He leaves three sons and one daughter.

James Prescott Joule.—Dr. Joule of Manchester, the eminent English physicist, died on the 11th of October, at the age of 70. He led a quiet life with little prominence before the public, but few workers in physical science have been able to accomplish so much as he, or have left behind so enduring a record. His experimental researches covered a wide range of subjects and are always of high order, but his contributions to the mechanical theory of heat and the conservation of energy stand out above all the rest as of a truly epoch-making character. Two volumes of his collected papers have been published recently (1884 and 1887) under his editorship, which have put the results of his industrious and fruitful life in convenient and accessible form.

APPENDIX.

ART. LX.—*The Skull of the Gigantic Ceratopsidæ;** by O. C. MARSH. (With Plate XII.)

THE huge horned Dinosaurs, from the Cretaceous, recently described by the writer,† have now been investigated with some care, and much additional light has been thrown upon their structure and affinities. A large amount of new material has been secured, including several skulls, nearly complete, as well as various portions of the skeleton.

The geological deposits, also, in which their remains are found have been carefully explored during the past season, and the known localities of importance examined by the writer, to ascertain what other fossils occur in them, and what were the special conditions which preserved so many relics of this unique fauna.

The geological horizon of these strange reptiles is a distinct one in the upper Cretaceous, and has now been traced nearly eight hundred miles along the eastern flank of the Rocky Mountains. It is marked almost everywhere by remains of these reptiles, and hence the strata containing them may be called the Ceratops beds. They are fresh-water or brackish deposits, which form a part of the so-called Laramie, but are below the uppermost beds referred to that group. In some places, at least, they rest upon marine beds which contain invertebrate fossils characteristic of the Fox Hills deposits.

* Abstract of a paper read before the National Academy of Sciences, Philadelphia, November 14, 1889.

† This Journal, vol. xxxvi, p. 477, December, 1888; vol. xxxvii, p. 334, April, 1889; and vol. xxxviii, p. 173, August, 1889.

The fossils associated with the *Ceratopsidæ* are mainly Dinosaurs, representing two or three orders, and several families. Plesiosaurs, crocodiles and turtles of Cretaceous types, and many smaller reptiles, have left their remains in the same deposits. Numerous small mammals, also of ancient types, a few birds, and many fishes, are likewise entombed in this formation. Invertebrate fossils and plants are not uncommon in the same horizon.

The *Ceratopsidæ*, as the most important of this assemblage, will be first described fully by the writer, under the auspices of the United States Geological Survey. In the present paper, the skull of one of these gigantic reptiles is briefly described, and figured, as a typical example of the group.

The Skull.

The skull of *Triceratops*, the best known genus of the family, has many remarkable features. First of all, its size, in the largest individuals, exceeds that of any land-animal, living or extinct, hitherto discovered, and is only surpassed by that of some of the Cetaceans. The skull represented in Plate XII, the type of the species, is that of a comparatively young animal, but is about six feet in length. The type of *Triceratops horridus* was fully adult, and probably an old individual. The skull, when complete, must have been over eight feet in length. Two other skulls, both nearly perfect, now under examination by the writer, fully equal in bulk the two already described, and other similar specimens from the same horizon maintain equal average dimensions.

Another striking feature in the skull of this genus is its armature. This consisted of a sharp cutting beak in front, a strong horn on the nose, a pair of very large pointed horns on the top of the head, and a row of sharp projections around the margin of the posterior crest. All these had a horny covering of great strength and power. For offense or defense, they formed together an armor for the head as complete as any known. This armature dominated the skull, and in a great measure determined its form and structure.

The skull itself is wedge-shaped in form, especially when seen from above. The facial portion is very narrow, and much prolonged in front, as shown in Plate XII, figure 2. In the frontal region, the skull is massive, and greatly strengthened to support the large and lofty horn-cores, which formed the central feature of the armature. The huge, expanded parietal crest, which overshadowed the back of the skull and neck, was evidently of secondary growth, a practical necessity for the attachment of the powerful ligaments and muscles that supported the head.

The front part of the skull shows a very high degree of specialization, and the lower jaws have been modified in connection with it. In front of the premaxillaries, there is a large massive bone, not before seen in any vertebrate, which has been called by the writer, the rostral bone (*os rostrale*). It covers the anterior margins of the premaxillaries, and its sharp inferior edge is continuous with their lower border. This bone is much compressed, and its surface very rugose, showing that it was covered with a strong horny beak. It is a dermal ossification, and corresponds to the pre-dentary bone below. The latter, in this genus, is also sharp and rugose, and likewise was protected by a strong horny covering. The two together closely resemble the beak of some of the turtles, and as a whole must have formed a most powerful weapon of offense.

In the skull figured on Plate XII, the rostral bone was free, and was not secured. This was also true of the pre-dentary bone, and the nasal horn-core. Hence these parts are represented in outline, taken from another specimen, in which they are all present, and in good preservation.

The premaxillary bones are large, and much compressed transversely. Their inner surfaces are flat, and meet each other closely on the median line. In old specimens, they are firmly coössified with each other, and with the rostral bone. They send upward a strong process to support the massive nasals. Another process, long and slender, extends upward and backward, forming a suture with the maxillary behind, and uniting in front with a descending branch of the nasal. The premaxillaries are much excavated externally for the narial aperture, and form its lower margin. They are entirely edentulous.

The maxillaries are thick, massive bones of moderate size, and subtriangular in outline when seen from the side. Their front margin is bounded mainly by the premaxillaries. They meet the pre-frontal and lachrymal above, and also the jugal. The alveolar border is narrow, and the teeth small, with only a single row in use at the same time. The teeth resemble, in general form, those of *Hadrosaurus*.

The nasal bones are large and massive, and greatly thickened anteriorly to support the nasal horn-core. In the skull figured on Plate XII, these bones are separate, but in older individuals, they are firmly coössified with each other, and with the frontals. The nasal horn-core ossifies from a separate centre, but in adult animals, it unites closely with the nasals, all traces of the connection being lost. It varies much in form in different species.

The frontals form the central region of the skull, and have been greatly strengthened to support the enormous horn-cores which tower above them. These elevations rest mainly on the frontal bones, but the supra-orbitals, the post-orbitals, and the post-frontals, have, apparently, all been absorbed by the frontals, to form the solid foundation for the horn-cores.

These horn-cores are hollow at the base, and in form, position, and external texture, agree closely with the corresponding parts of the *Bovidæ*. They vary much in shape and size, in different species. They were evidently covered with massive, pointed horns, forming most powerful and effective weapons.

The orbit is at the base of the horn-core, and is surrounded, especially above, by a very thick margin. It is oval in outline, and of moderate size. Its position and form are shown in Plate XII, figure 1, *b*.

The enormous posterior crest is formed mainly by the parietals, which meet the frontals immediately behind the horn-cores. The margin is protected by a series of special ossifications, which, in life, had a thick horny covering. These peculiar ossicles, which extend around the whole of the crest, may be called the epoccipital bones (Plate XII, figures 1 and 2, *e*). In old animals, they are firmly coössified with the bones on which they rest.

The lateral portions of the crest are formed by the squamosals, which meet the parietals in an open suture. Anteriorly, they join the frontal elements which form the base of the horn-core, and laterally, they unite with the jugal. The supra-temporal fossæ lie between the squamosals and the parietals, as shown on Plate XII, figure 2, *c*.

The base of the skull has been modified in conformity with its upper surface. The basi-occipital is especially massive, and strong at every point. The occipital condyle is very large, and its articular face, nearly spherical, indicating great freedom of motion. The basi-occipital processes are short and stout. The basi-pterygoid processes are longer, and less robust. The foramen magnum is very small, about one-half the diameter of the occipital condyle. The brain-cavity is especially diminutive, smaller in proportion to the skull, than in any other known reptile.

The exoccipitals are also robust, and firmly coössified with the basi-occipital. The supra-occipital is inclined forward, and its external surface is excavated into deep cavities. It is firmly coössified with the parietals above, and with the exoccipitals on the sides. The post-temporal fossæ are quite small.

The quadrate is robust, and its head much compressed. The latter is held firmly in a deep groove of the squamosal. The anterior wing of the quadrate is large and thin, and closely united with the broad blade of the pterygoid.

The quadrato-jugal is a solid, compressed bone, uniting the quadrate with the large descending process of the jugal. In the genus *Triceratops*, the quadrato-jugal does not unite with the squamosal. In *Ceratops*, which includes some of the smaller, less specialized, forms of the family, the squamosal is firmly united to the quadrato-jugal by suture. Above this point, it shows a number of elevations, which are wanting in *Triceratops*.

The quadrato-jugal arch in this group is strong, and curves upward, the jugal uniting with the maxillary, not at its posterior extremity, but at its upper surface, as shown in Plate XII, figure 1. This greatly strengthens the center of the skull which supports the horn-cores, and also tends to modify materially the elements of the palate below. The pterygoids, in addition to their strong union with the quadrate, send outward a branch, which curves around the end of the maxillary. This virtually takes the place of the transverse bone. The latter is thus aborted, and is represented only by a small, free ossicle resting upon the posterior extremity of the maxillary.

The lower jaw shows no specialization of great importance, with the exception of the pre-dentary bone already described. There is, however, a very massive coronoid process rising from the posterior part of the dentary, which is well shown in Plate XII, figure 1. The articular, angular, and surangular bones, are all short and strong, and the splenial is comparatively slender. The angle of the lower jaw projects but little behind the quadrate.

The unique characters of the skull of the *Ceratopsidæ* are especially the following:

(1) The presence of a rostral bone, and the modification of the pre-dentary to form a sharp, cutting beak.

(2) The frontal horn-cores, which form the central feature of the armature.

(3) The huge, expanded parietal crest.

(4) The epoccipital bones.

(5) The aborted transverse bone.

These are all features not before seen in the *Dinosauria*, and show that the family is a very distinct one.

The peculiar armature of the skull has a parallel in the genus *Phrynosoma*, among the lizards, and *Meiolania*, among the turtles, and it is of special interest to find it also represented in the Dinosaurs, just before their extinction

Such a high specialization of the skull, resulting in its enormous development, profoundly affected the rest of the skeleton. Precisely as the heavy armature dominated the skull, so the huge head gradually overbalanced the body, and must have led to its destruction. As the head increased in size to bear its armor, the neck first of all, then the fore limbs, and later the whole skeleton, was specially modified to support it. These features will be discussed in a later communication, but to the present description of the skull should be added the fact that the anterior cervical vertebræ were firmly coössified with each other, an important character not before observed in Dinosaurs.

The skull represented on the accompanying plate is the type specimen of *Triceratops flabellatus*, Marsh. It was found in the Ceratops beds of Wyoming by Mr. J. B Hatcher, who also discovered the type of the genus *Ceratops*, in the same horizon in Montana.

INDEX TO VOLUME XXXVIII.*

* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, BOOKS, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

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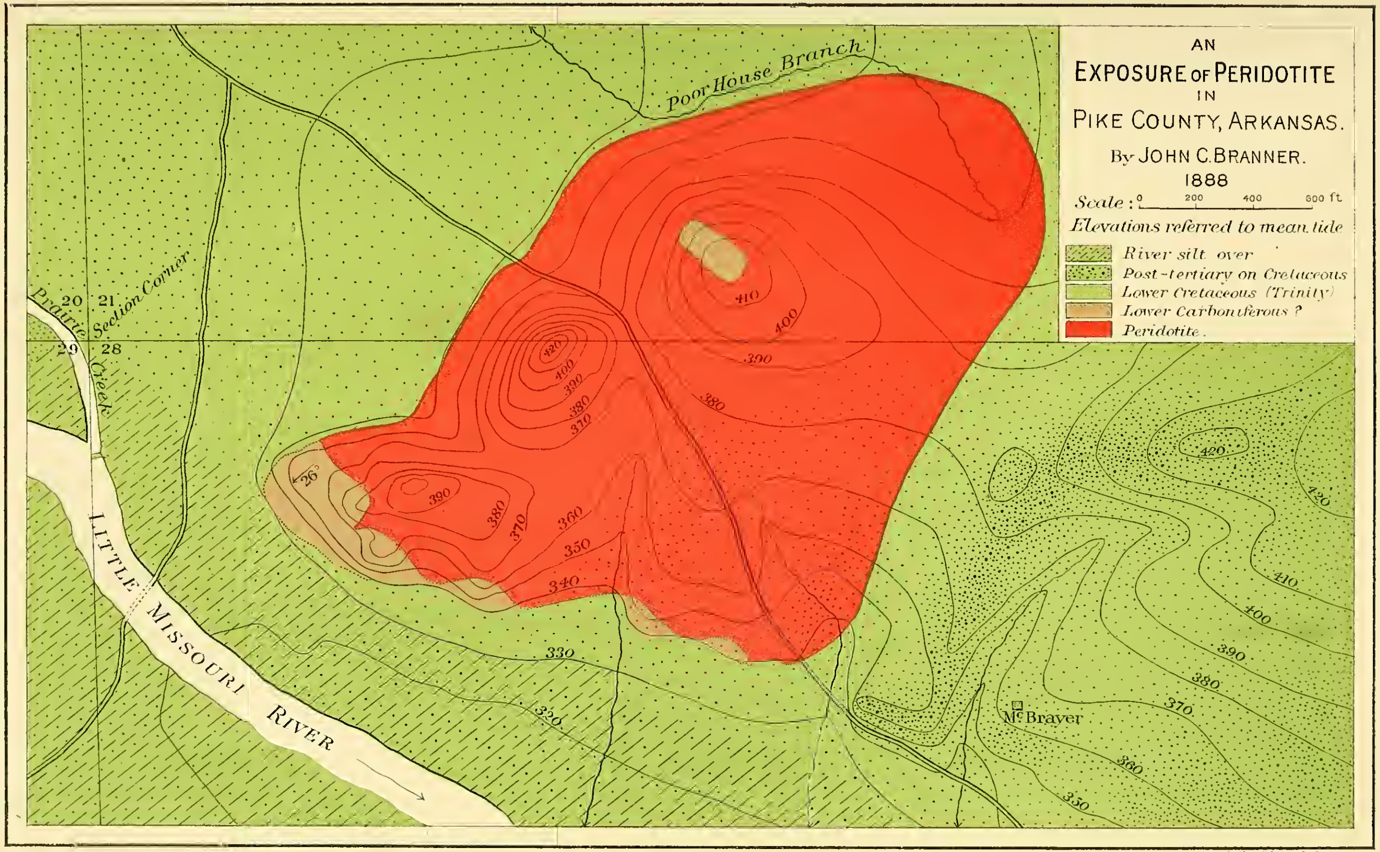

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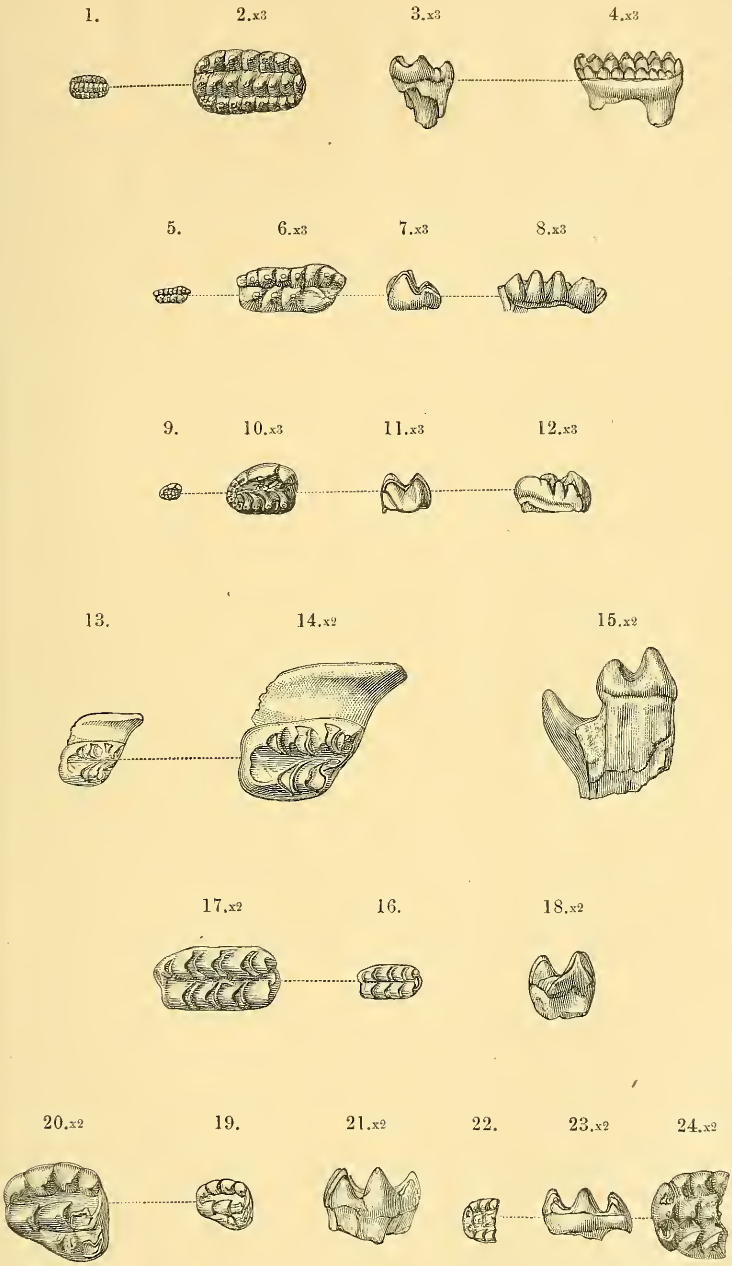

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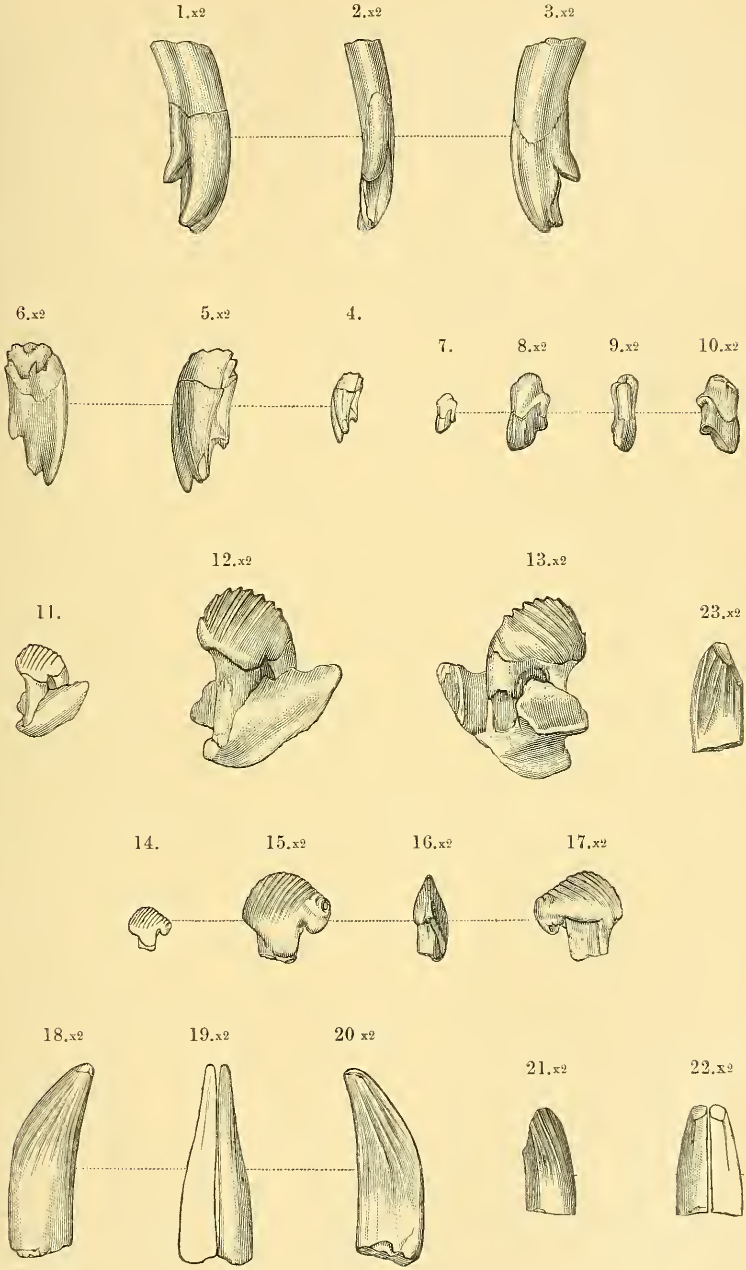

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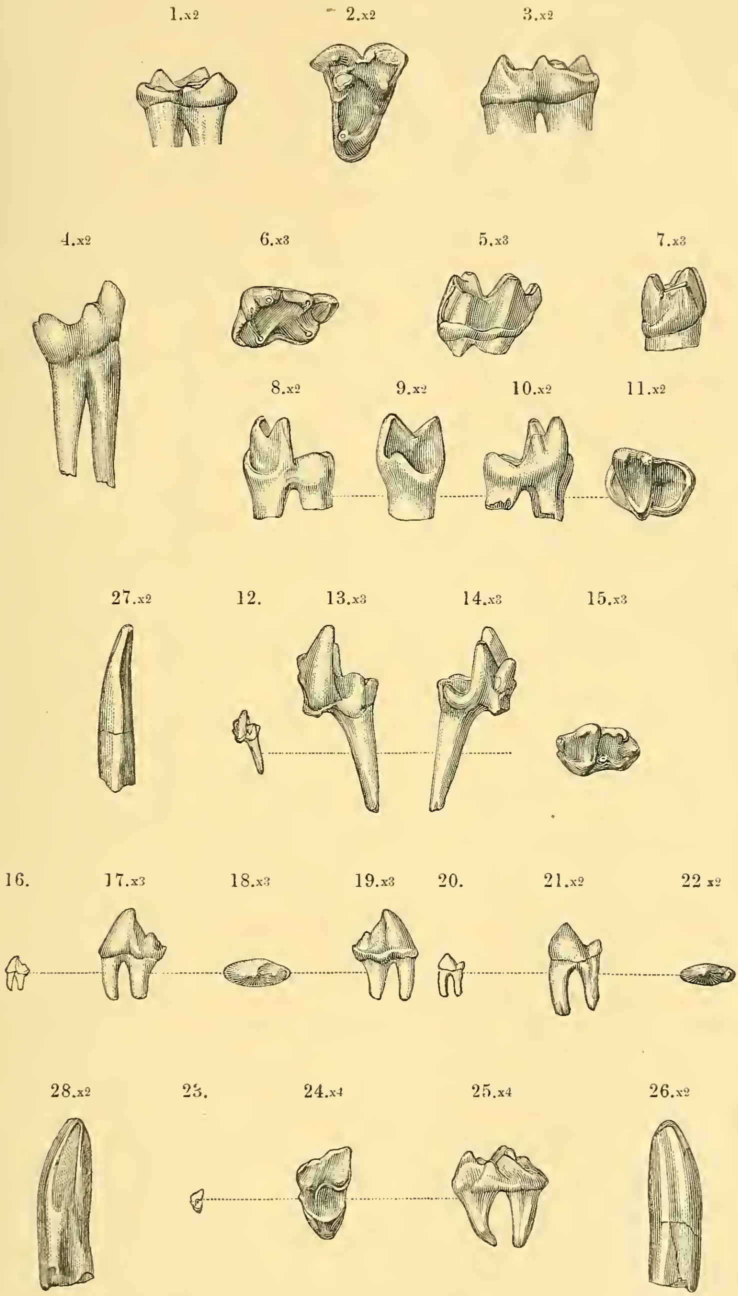

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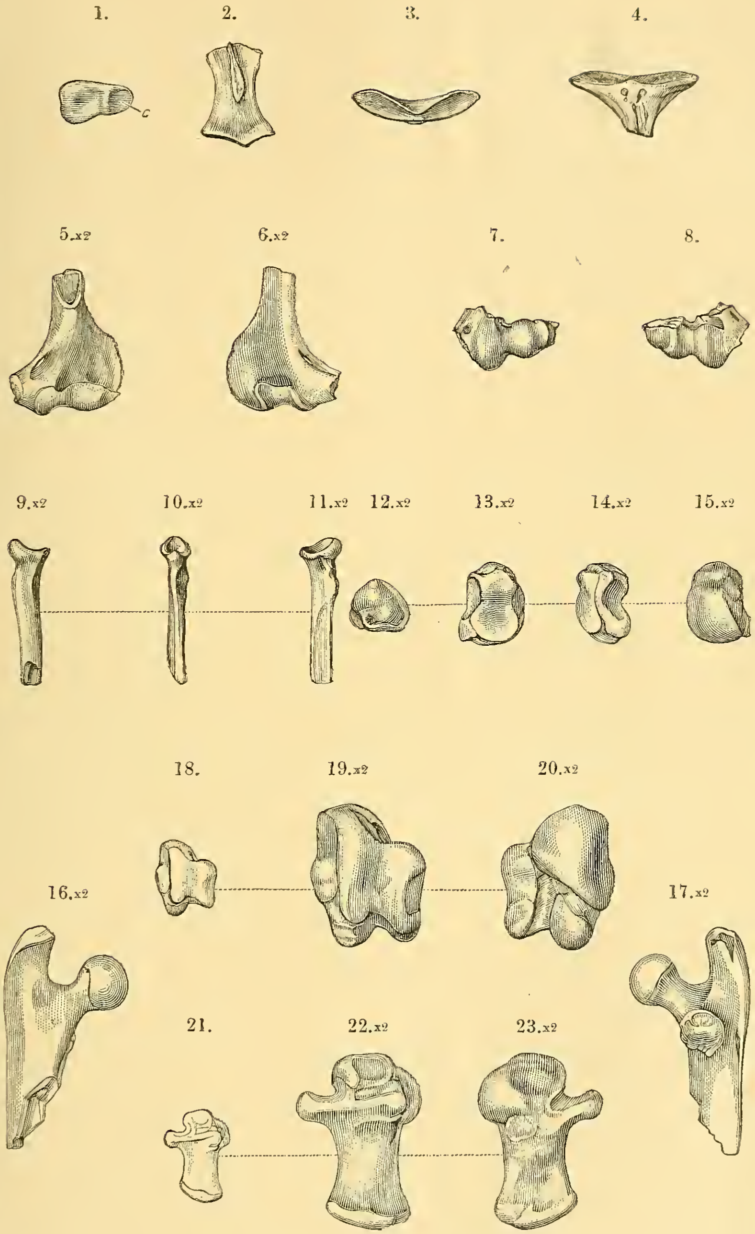

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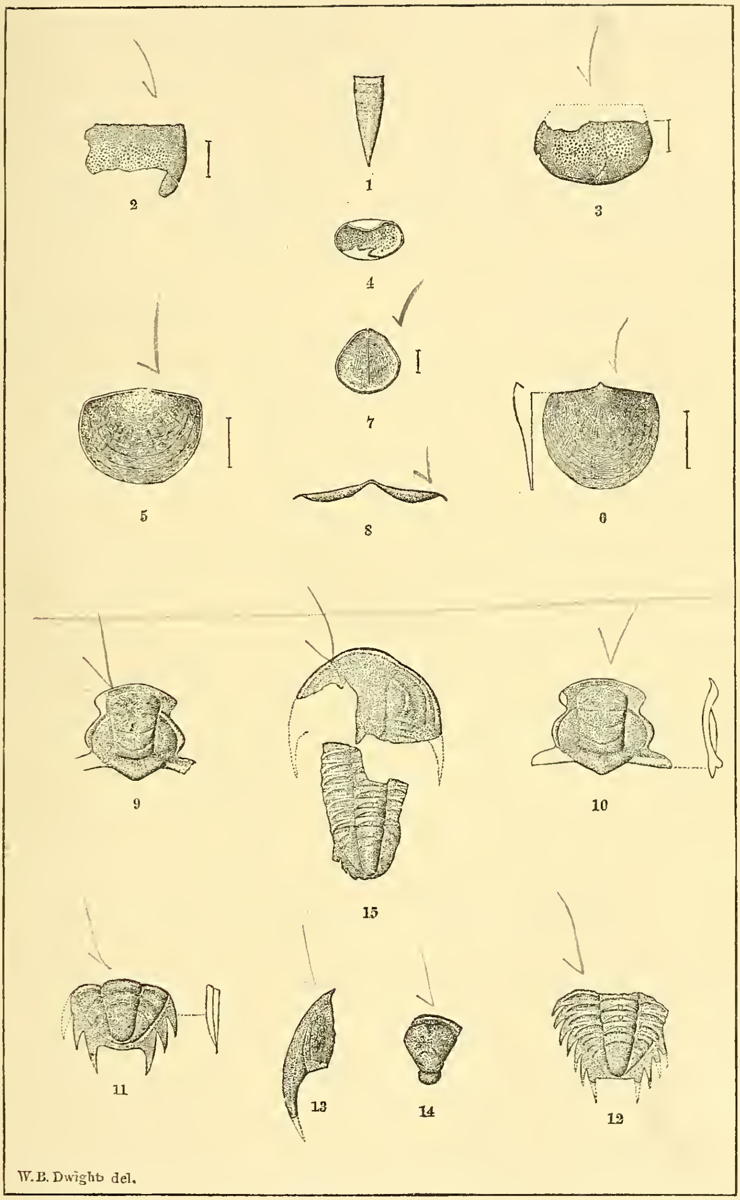
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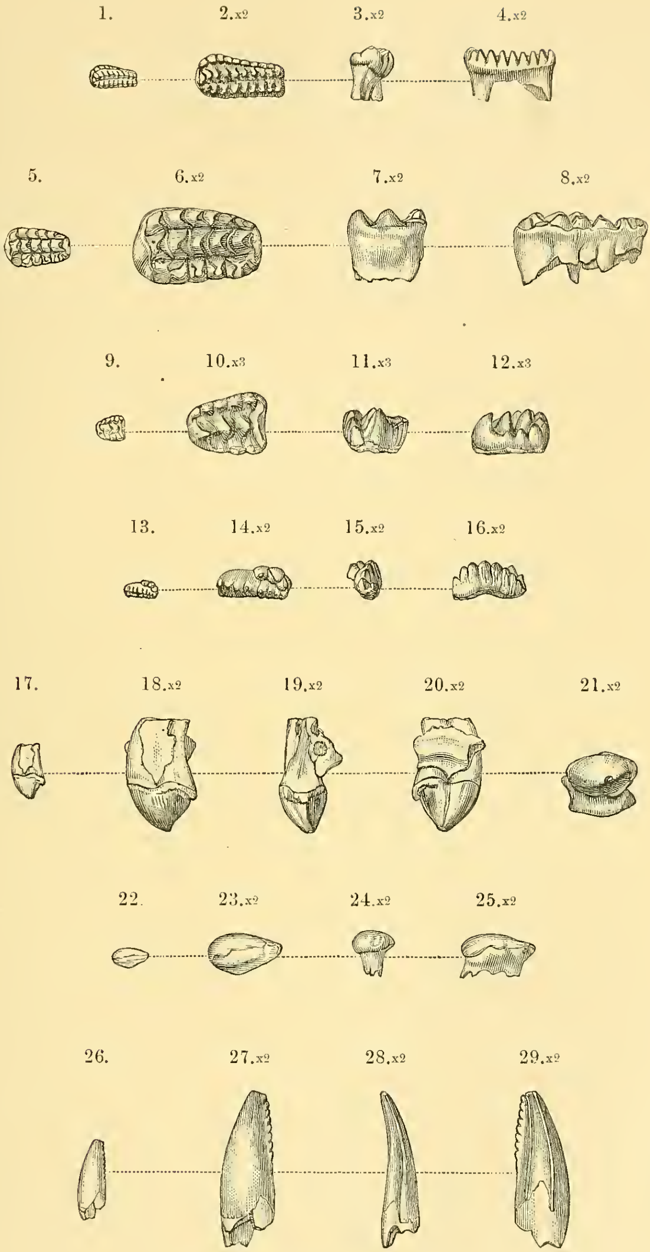

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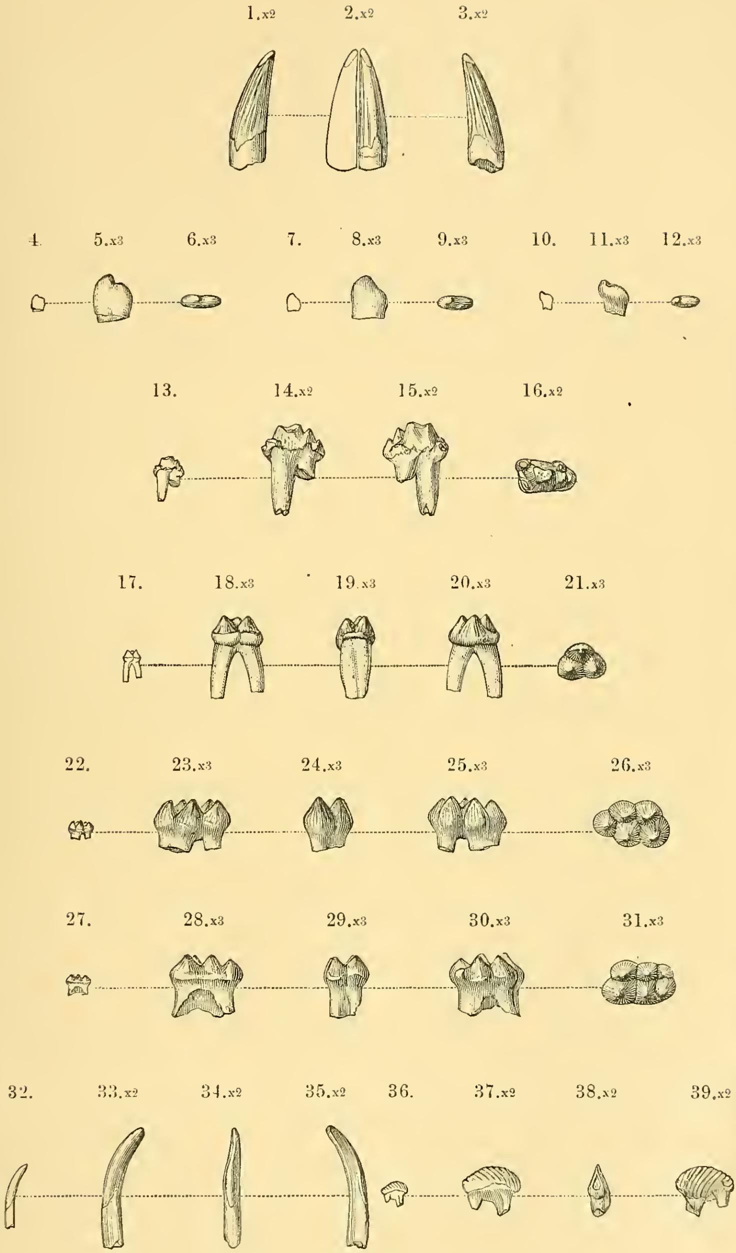

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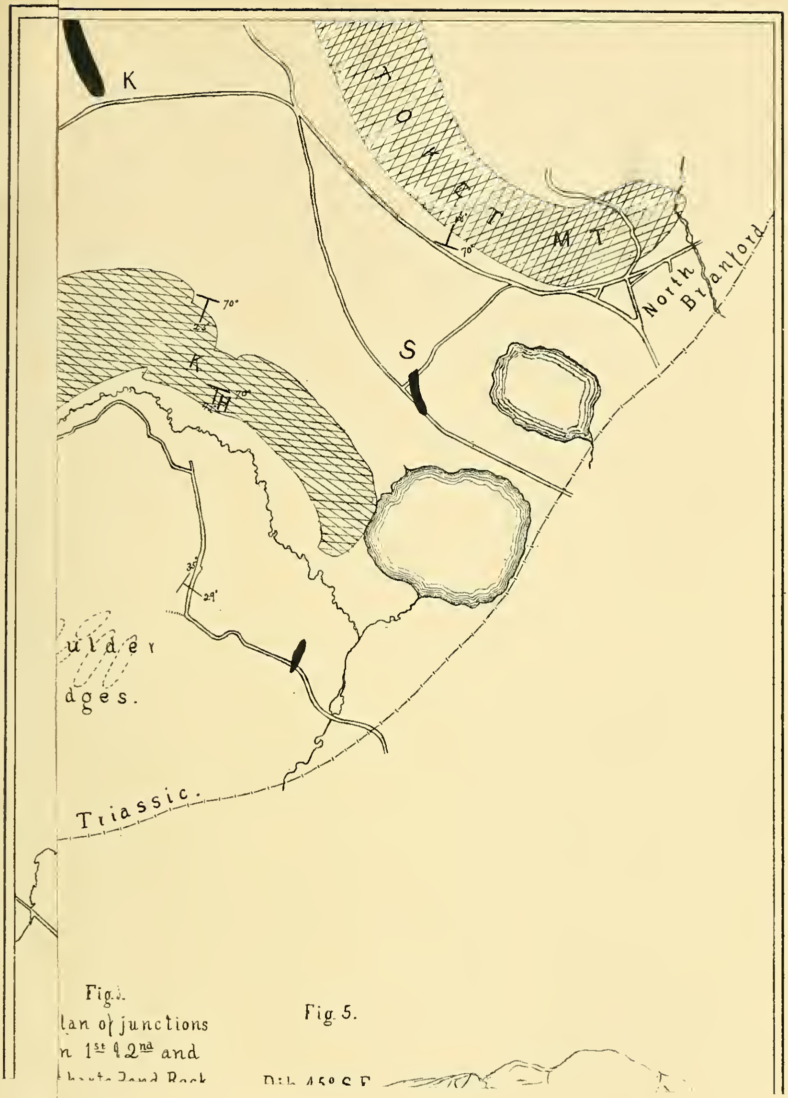
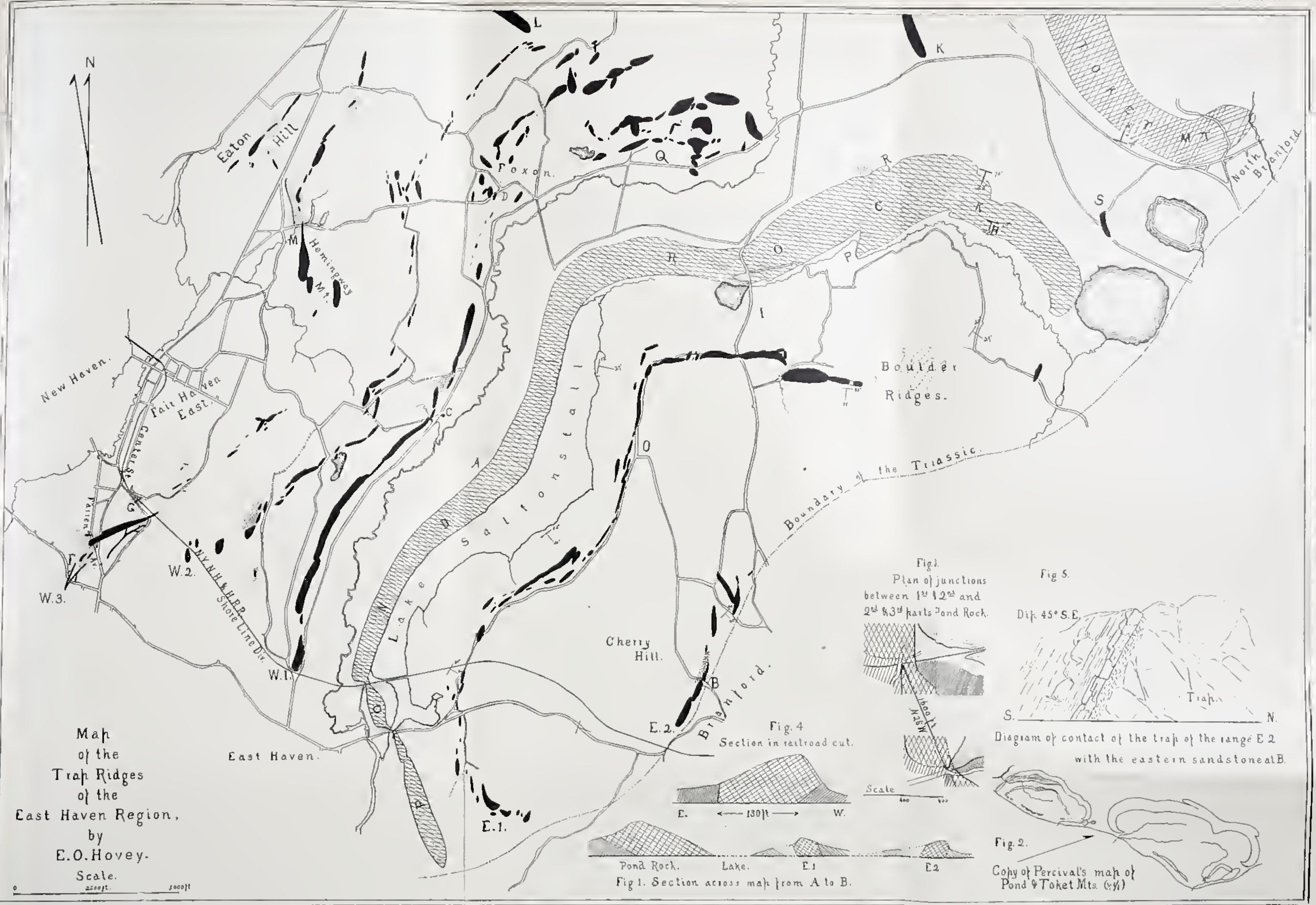


Ordinates = Galvanometer deflections.



Map of the Trap Ridges of the East Haven Region, by E. O. Hovey.
Scale.
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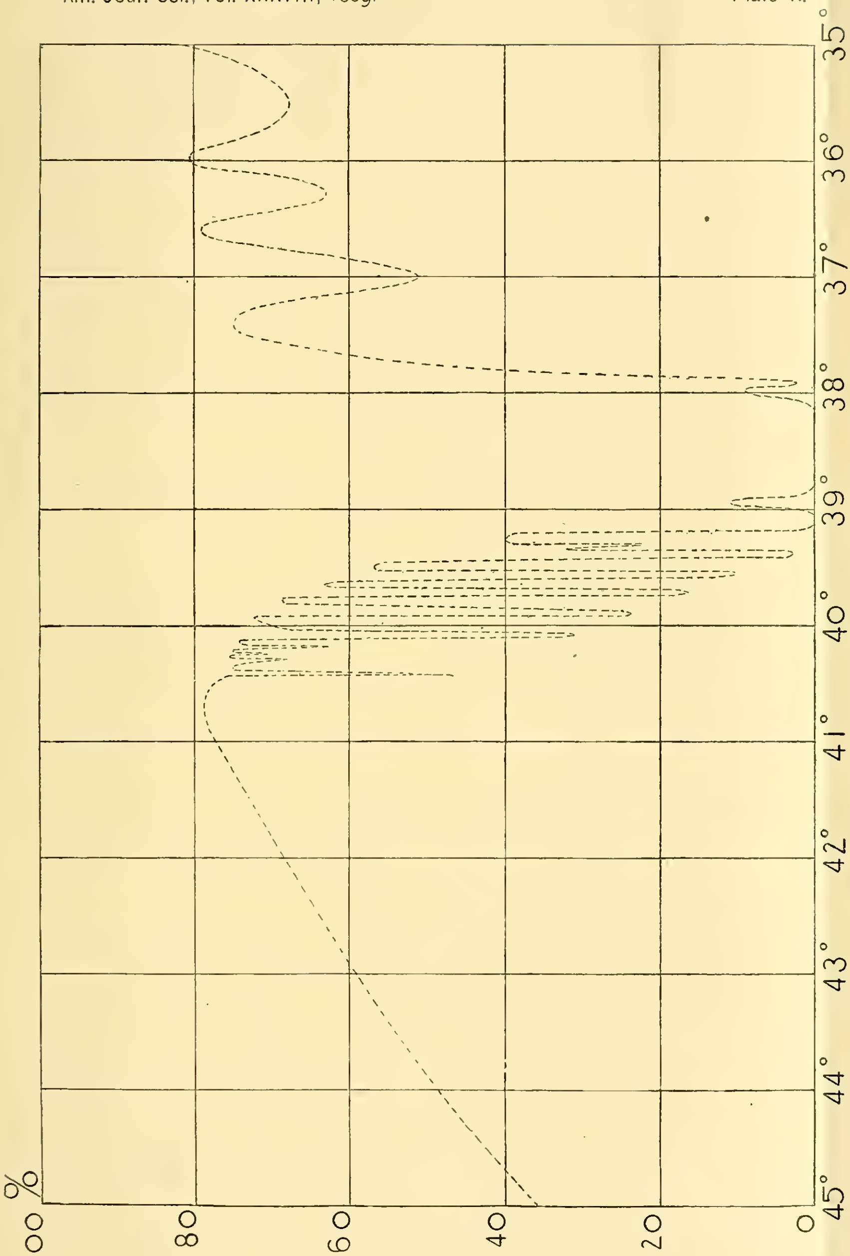
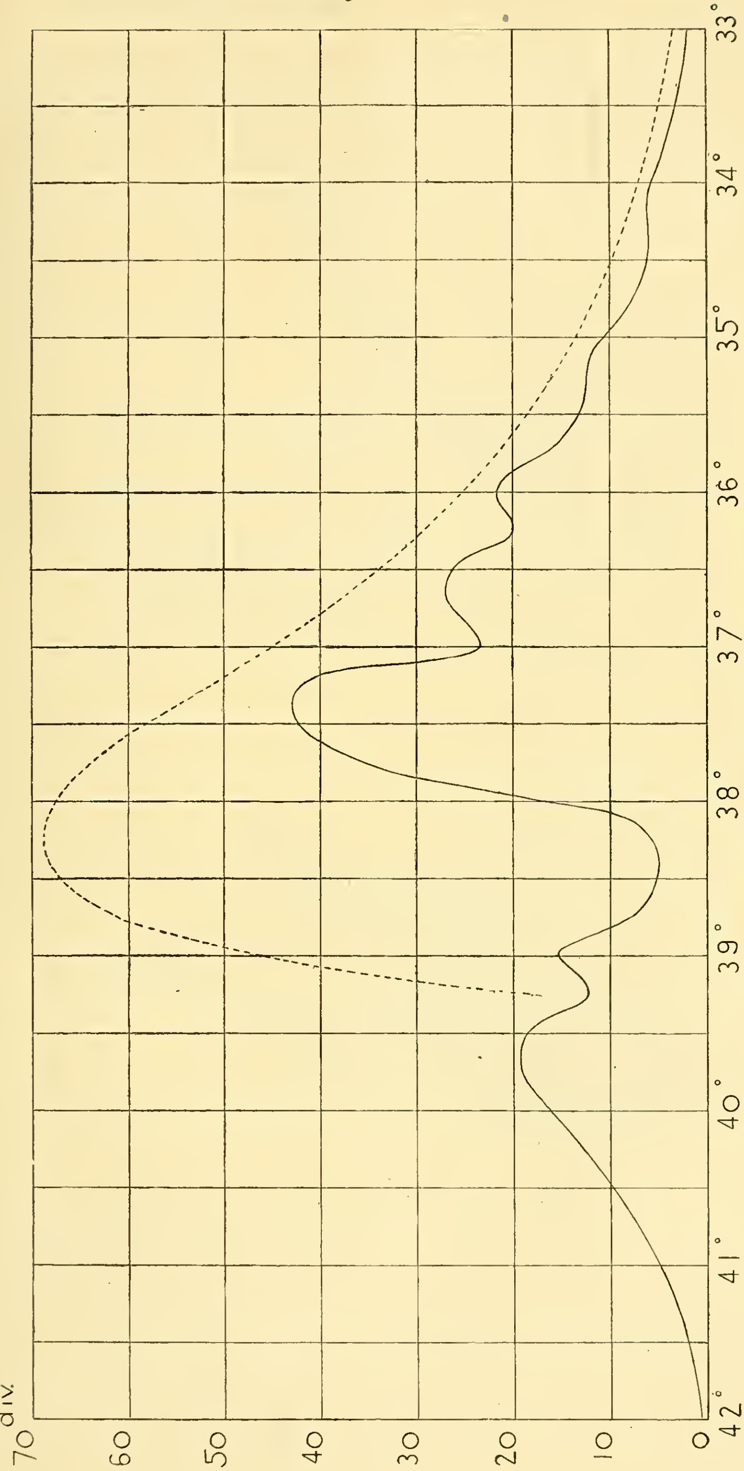


TRANSMISSION OF RADIATION BY THE EARTH'S ATMOSPHERE.

Abscissæ = Rock-salt deviations.
Ordinates = Percentage of transmission.



DISTRIBUTION OF ENERGY IN THE LUNAR SPECTRUM.

Abscissæ=Rock-salt deviations.
Ordinates=Galvanometer deflections.

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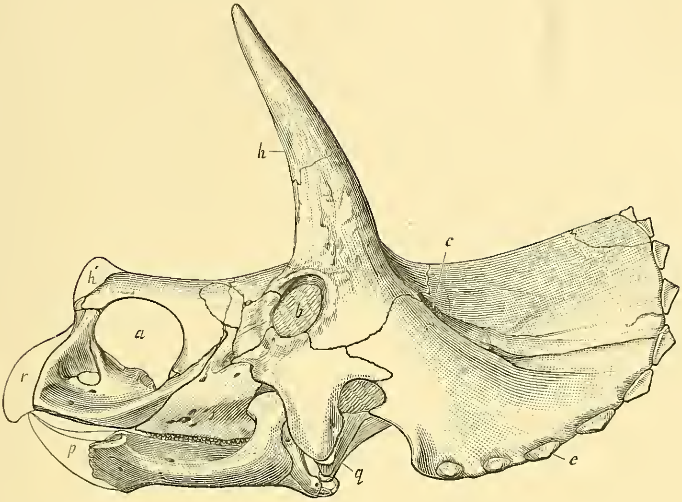

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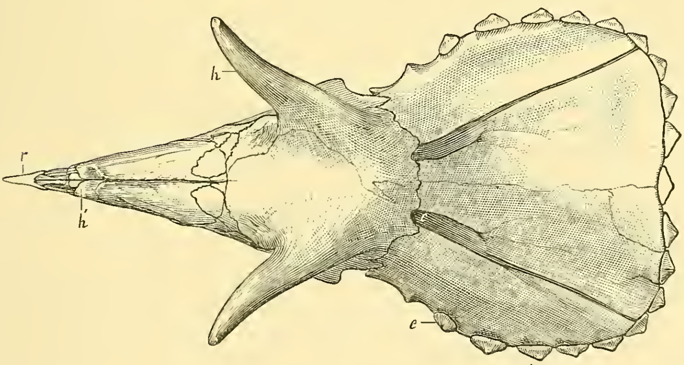

TRICERATOPS FLABELLATUS, Marsh. $\frac{1}{20}$ natural size.

FIGURE 1.—The skull; seen from the side.

FIGURE 2.—The same; seen from above.

a, nasal opening; *b*, orbit; *c*, supra-temporal fossa; *e*, epoccipital bone; *h*, frontal horn-core; *h'*, nasal horn-core; *p*, pre-dentary bone; *q*, quadrate; *r*, rostral bone.

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SCIENTIFIC INTELLIGENCE.

ERRATUM.

The notes at the bottom of p. 476 should be transposed.

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