THE
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JOURNAL OF SCIENCE.

Established by **BENJAMIN SILLIMAN** in 1818.

EDITORS
JAMES D. AND EDWARD S. DANA.

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

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

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA.

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WITH TEN PLATES.

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SCIENTIFIC INTELLIGENCE.

ERRATUM.—Page 468, line 11 should read: difficultly soluble or insoluble, etc.

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We have just received two consignments of nineteen boxes containing minerals collected and purchased by Prof. Foote, at various localities throughout France and Italy.

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A. E. FOOTE, M.D.,
MINERALS AND SCIENTIFIC BOOKS,
4116 Elm Avenue, **Philadelphia, Pa., U. S. A.**

Chas. D. Walcott.

THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. I. — *The Change of Heat Conductivity* on Passing Isothermally from Solid to Liquid;* by C. Barus.

1. *Preliminary.*—To fully investigate a problem like the present, the application of pressures is obviously necessary. In my work† on the continuity of solid and liquid I showed, however, that hysteresis rarely if ever fails to accompany change of state. Since therefore undercooling is not avoided, even when pressure changes the state of a body from solid to liquid at the same temperature, it seemed permissible to facilitate the experiments by selecting an undercooled liquid at the outset. In other words, thymol—and with this substance the following measurements were made—which can be kept either liquid or solid between 0° and 50° C., merely exhibits under atmospheric pressures and temperatures the same volume lag, that in more or less pronounced degree is common to most if not all crystalline bodies, at pressures and temperatures as a rule enormously higher. Apart from this it seems idle to ascribe to the molten liquid a more intimate relation to the solid than that possessed by the undercooled liquid, without distinctly specifying just what the relation is; and this at the present state of our knowledge of the solid and liquid molecule, is impossible. Vague notions about polymerism are little to the point. Without evidence to the contrary, I am at liberty to suppose that the liquid as well as the solid obey certain ideal physical laws; and these I may conceive to be pro-

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* This investigation was suggested by Mr. Clarence King.

† This Journal, xlii, p. 125, 1891; cf. p. 140.

longed indefinitely below the melting point in the former case, and indefinitely above fusion in the latter case (solid); and I can estimate the amount of error involved in such a supposition by actually comparing any given class of properties of the liquid above and below the melting point, by direct experiment.*

I may add finally that the application of pressure would enormously complicate the method of measurement, which even in its simplest form, is not without grave difficulties. Indeed the task of keeping thymol liquid between 4° and 15° in a copper vessel, proved to be most wearisome, and out of very many experiments only relatively few were obtained under thoroughly trustworthy conditions.

2. *Method employed.*—Seeing that the available substances are usually of low absolute conductivity (below $k = 500/10^6$), and keeping in mind the desideratum of a method which could eventually be used for bodies under pressure, I found none better suited to the present problem than the one which H. F. Weber† has so brilliantly and elaborately worked out. Weber places a thin, wide, plane-parallel plate or layer of the substance to be examined between and in close contact with two thick plates of copper, and it is proved that these are identical as to temperature, with the upper and lower isothermal of the layer. §9. The system is first heated so as to be at a given temperature throughout. It is then suddenly and permanently cooled at the lower surface (copper plate), and the time rate at which heat travels from the top plate to the bottom plate, through the intervening layer, is measured by a thermo-couple. From these data the absolute thermal conductivity of the layer may be computed when the constants of the system are known. To obviate convection in the case of liquids, all plane surfaces are placed horizontal, and cold surfaces are lowermost.

To cool the bottom plate Weber either bedded the system on a plane of ice, surrounding it by an ice environment, or lowered its temperature by a shower bath of hydrant water with a corresponding environment. It is not feasible to apply this method directly to thymol: clearly, in the first place all manner of disturbance or handling must tend to freeze the under-cooled liquid. In the second place freshly distilled thymol absorbs water or aqueous vapor at an initial rate of ·00032 g per cm^2 of free surface per hour, and the interval of undercooling is thereby decreased. At least in contact with copper in air, thymol soon becomes colored and unsuitable for the experiments. Failing therefore utterly in the attempt to

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* The continuation of the present research must for the above reasons await the warm weather.

† H. F. Weber: Wied. Ann., x, pp. 103, 304, 472, 1880.

obtain results for the liquid, §1, I modified the method so as to adopt it both for high temperature and low temperature environments, as follows.

Apparatus.

3. *General disposition.*—To obtain a circulation of water at any constant temperature not more than 30° or 40° above the temperature of the hydrant water, I used the device of boiler, graduated faucet and distributer, to be described in connection with my work on the volume expansion and the thermal capacity of thymol.[*]

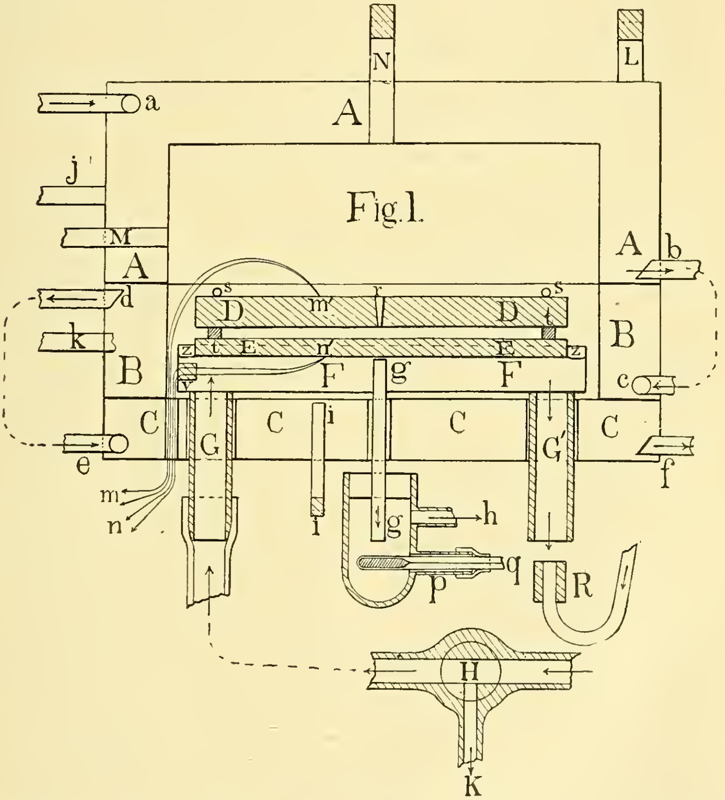

Fig. 1.—Vertical section of the apparatus for thermal conductivity, with all parts in place. Scale $\frac{1}{8}$.

In figure 1, *DD* and *EE* are the cylindrical copper plates between which the sample to be tried is sandwiched. The

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[*] See note in Proceed. Am. Acad., vol. xxvi, p. 313, 1892.

system is completely surrounded by a cylindrical box *ABC*, through the hollow walls of which the water continually circulates. In this way an environment of any constant temperature is obtained.

To heat or cool the lower plate *EE*, it is made the top of a shallow box *FF*, the bottom of which is perforated by influx and efflux tubes *G*, *G'*. §7.

The whole system, *ABC*, is heavily jacketed with blanketing (not shown), and a sink placed below the efflux tubes carries off the water.

4. *Environment.*—This consists of the three parts *AAA*, *BB* and *CCCC*, made of heavy tinned sheet iron, and capable of moving up and down and of being clamped in any vertical position along four upright slides (not shown). It is advisable to fix the bottom *CCCC* permanently, and the frame is provided with leveling screws so that the plates *DD* and *EE* may be adjusted to the horizontal, accurately.

The top *AAA* is virtually a bell jar. Water enters at *a* in jets directed toward the center as well as toward the right (tangentially) so as to keep up a circulation. It issues at *b*, and passes thence through a sufficient but short length of jacketed rubber tubing to the tubulure *c*, near the bottom of the ring *BB*. Rotation is here also kept up by tangential influx, and the water issuing at *d* near the top of *BB*, passes through rubber tubing to *e* on one side of the bottom *CCCC*, finally leaving this vessel at *f* on the other side. When not otherwise used, the water is carried to a level above *AAA*, to prevent siphonage. By making the environment of parts in this way, two advantages are secured: for apart from the greater thoroughness of circulation favorable to constancy of temperature, the parts may be raised so that the plates *DD* and *EE* may at all times be easily charged or inspected. In the actual apparatus the influx and efflux tubulures are to be in a vertical plane at right angles to the thermometer tubulures. *AAA* has four other tubulures: *j* (oblique) for the insertion of a thermometer into the circulating water, and *M* for registering the air temperature within; through *L* the air which always accumulates from hot water may be discharged, and through *N*, a wire may be inserted for raising and suspending the upper plate *DD*, §8. Similarly the tubulure *k* admits a thermometer into the water circulating in *BB*. Finally the bottom *CC* has two large and two small perforations, through which pass the tubes *G*, *G'*, and *gg*, as well as the wires of the thermo-couple, §6. The tubulure *ii* reaching nearly to the top, discharges accumulated air.

5. *Copper conduction plates.*—Both *DD* and *EE* are silver plated, making them less subject to the action of thymol. The

former (D) is $15{\cdot}23^{\mathrm{cm}}$ in diameter, $1{\cdot}300^{\mathrm{cm}}$ thick, turned accurately cylindrical and polished on its lower surface. Besides the central hole r, it has two small eyelets, ss, placed symmetrically on the same diameter, by aid of which the plate may be suspended, §8. Finally the junction m' of the thermo-couple $mm'm$ is soldered to the top of this plate, the wires passing through the tube in the bottom, CC.

The plate DD is supported on the upper polished plane surface of EE, by three plate glass spacers t, t, $\cdot 1^{\mathrm{cm}}$ to $\cdot 2^{\mathrm{cm}}$ high, and $\cdot 2 \times \cdot 2$ cm^2 square. EE is of the same diameter as DD, but only $\cdot 6^{\mathrm{cm}}$ thick. The sides of the box FF, of which EE is the top, project upward to form a gutter ZZ, in which the excess of charge is caught and may be siphoned off. In case of undercooled liquids this gutter is absolutely essential, and I found it advantageous to coat it with vulcanized rubber deposited from solution. Rough surfaces induce premature freezing. The box FF plants its three steel feet on plates of brass (not shown), imbedded in the top of CC, thus securing the necessary firmness of the conducting system. Finally the junction n', of a second thermo-couple $nn'n$, identical in every respect with $mm'm$, is soldered to the bottom surface of EE, and after passing through a sealed tubulure V in the side of FF, the wires pass out through CC.

One of the tubes GG which admit and withdraw large bulks of water, communicates through a massive *three-way* stop cock HK, with the faucet of the hydrant. The tubulure gg which nearly touches the bottom of E, discharges into a small cistern with two tubulures h and p, and a thermometer, q, here registers the temperature of the efflux through h.

To introduce the charge, liquid thymol is carefully poured in through r, by aid of a fine funnel tube. In case of copper plates this rarely succeeds at ordinary temperatures. I heated the plates during charging above the melting point of thymol, and then allowed them to cool in the closed environment. The charge is best frozen when quite cold and from the center outward, by contact with a crystal, inserted through r. Allowance must be made for the volume contraction, §14. In the following work with solid thymol, the glass spaces t, t, were left in place. I believe now that this is unfavorable to perfect adhesion between the solid layer and the copper plates, even though the cold plates were found to be thoroughly cemented together. A better plan would be that of placing the spacers near the edge, and of removing them as soon as a sufficient amount of thymol has solidified to sustain the upper plate.

6. *Thermo-couple.*—The thermo-couples m and n, of german silver and copper, being identical both as regards metal and dimensions, the temperatures of the upper or the lower plate

could be measured independently; or by soldering the german silver wires together and coupling the ends of the copper wires with the galvanometer, differences of temperature could be measured. The latter method was adopted since this differential quantity enters the formulæ. Great care must be taken to see that the charge is electrically a *non-conductor*. This is the case for thymol, but series of experiments which I made with water proved worthless because of this discrepancy. To calibrate the thermo-couples in question, duplicate sets of identical wires (metal and dimensions) were at hand. The galvanometer of my own make showed about 3 scale parts per degree C., and it was a periodic and nearly constant in sensitiveness.

7. *Heating and cooling.*—There are two methods available for heating the system of plates *D* and *E* uniformly throughout, to be used respectively, when the environment is of high temperature or of low temperature.

(1.) To heat the plates to the temperature of the (hot) environment, the stop-cock *H*, is closed relatively to *G*, and the efflux water from *f* led by jacketed rubber tubing, through the cork *R* into *G'*. The water thus fills *FF* and issues at *h*. Its temperature is read off at *q*. *DD* and *EE* soon reach the same temperature within ·01° C.

When the actual measurements are to be commenced, water from the hydrant is first passed through *H* and *K*, until its temperature is constant. The cock *R* is now loosened, and at a given signal *H* is suddenly opened into *G*. The great bulk of water now entering *FF*, forces out *R*, and floods the thermometer reservoir below *q*. Here therefore temperature is again registered by *q*.

(2.) In case of the cold (2°–6°) environment, hydrant water is passed directly through the tubes *a* to *f*, but the method of heating *D*, *E* is less simple. If *warm* water be passed through *R*, as before, the temperature of *E* would even after long waiting exceed that of *D*. For plates ·1^{cm} apart this persistent excess amounted to say ·9° C., varying with the distance between the plates, their internal and external conduction, etc. The discrepancy may, however, be obviated by using two supplies of warm water, one of which is a few degrees (3°–5°) hotter than the other. The hotter water* is first passed through *R* and *FF*. After the lapse of sufficient time the second hot water supply of constant but lower temperature is made to replace the other. Thus *EE* is slightly cooled at once, whereas *DD* only cools very gradually, but must eventually fall to a temperature below *E*. Observations are therefore commenced

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* Fletcher's "instantaneous water heater," furnishes a satisfactory circulation, for the temperature of this water need not be very constant.

(as before) when the thermo-couple shows no difference of the temperature between the plates.

8. *External conductivity.*—To determine the radiation constant h_1 I used two methods, in one of which the cold plate (D) was raised in an environment hot above and cold below; and in the second of which the hot plate (D) was raised in a uniformly cold environment. The latter is essentially that of Weber.

The environment being at any constant temperature, I removed the spacers t, t, and placed the copper plates in contact. A strong current of water circulating in FF, kept the plates at the same temperature differing from that of the environment. By aid of threads fastened to ss, and a wire, passing through N, the plate D was now raised and kept suspended by a clamp on the outside. During all this time the differential thermo-couple was in place and changes of temperature of the plate were thus registered.

Relatively to the slow external conduction, the suspended plate DD is always an isothermal region. Hence if M_1 be the mass, c_1 the specific heat, and u the temperature excess of the plate at the time t; if F_1 (top and sides) be the surface toward the hot environment and F (bottom) the surface toward the cold environment; if finally τ be the temperature excess of the hot environment and h_1 the external conductivity, then $M_1 c_1 du = h_1(F_1(\tau-u))dt - h_1 F u dt$, or $du/dt + h_1(F_1+F)u/M_1 c_1 = h_1 F_1 \tau/M_1 c_1$, a differential equation which after integration leads to

$$\ln \frac{F_1\tau/O-u'}{F_1\tau/O-u} = \frac{h_1 O}{M_1 c_1}(t-t') \quad . \; . \; . \; . \quad (1)$$

where $F+F_1=O$, and where u and u' correspond respectively to t and t'.

In this way I obtained the results of Table 1, where τ' is the initial temperature of the cold plates, and hence $\tau+\tau'$ the actual temperature of the environment, and $u+\tau'$ the actual temperatures of the suspended plate at the consecutive times. The table further contains $\delta t = t-t'$ and $\delta \log(F_1\tau/O-u) = \cdot 434 \ln(F_1\tau/O-u')/(F_1\tau/O-u)$, and finally the values of h_1.

TABLE 1.

	External conductivity.		Complex environment.		Cold plate raised.	
δt sec	$10^5 \times$ $\delta \log(F\tau/O-u)$	Mean $u+\tau'$ °C.	τ' °C.	$\tau+\tau'$ °C.	$h_1 \times 10^7$	Mean. $h_1 \times 10^7$
180	1811	6·6	5·7	30·5	1072	1082
180	1766	7·6	5·7	30·5	1045	
120	1270	8·5	5·7	30·5	1130	
180	1878	7·3	5·7	29·9	1112	1040
180	1792	7·8	5·7	29·9	1061	
180	1685	8·7	5·7	29·9	997	
180	1661	9·5	5·7	29·9	989	

In the second method the water circulating in the environment came directly from the hydrant, while warm water circulated through *FF*, below the contiguous plates. After the lapse of sufficient time the upper plate was raised as before and suspended. At the same time the *cold* water of the environment was passed through *FF*, thus making the temperature of the walls surrounding the plate *D* uniform almost instantly.

The conditions of cooling may be taken from equation (1) by making the temperature excess of the environment $\tau=0$. The equation reduces to $\ln u'/u=h_1O(t-t')/M_1c_1$.

Data of this kind are given in Table 2, where $\delta t=t-t'$ and $\delta \log u = \cdot434 \ln u'/u$, and where τ is the temperature of the environment and $u+\tau$, the actual temperature of the suspended plate. It will be seen that groups of consecutive observations were made after intervals of waiting, and that two independent series are in hand.

TABLE 2.

	External conductivity.		Uniform environment.		Hot plate raised.	
	δt °*C.*	$\delta \log u$	$u+\tau$ °*C.*	τ °*C.*	$h_1 \times 10^7$	Mean. $h_1 \times 10^7$
	180	1737	29·2	5.6	1028	935
	180	1632	29·4	5·6	966	
	180	1644	25·7	5·6	973	
Pause 23^m						
	180	1555	19·9	5·6	914	
	180	1559	18·9	5·6	923	
Pause 35^m						
	180	1435	13·9	5·6	849	
	180	1506	13·4	5·6	891	
	180	1653	29·9	5·6	979	919
	180	1671	28·0	5·6	989	
Pause 23^m						
	180	1590	21·4	5·6	941	
	180	1563	20·2	5·6	925	
Pause 21^m						
	180	1504	16·4	5·6	890	
	180	1546	15·6	5·6	915	
Pause 32^m						
	180	1343	11·5	5·6	795	

Mean : $h_1 = \cdot0000082 + \cdot0000007\,u$.

In both series in Table 2, h_1 varies with the temperature excess; and since these values are better than the data of Table 1, I have taken the mean equation for h_1 as appended to Table 2, for the reduction of the observations below.

Method of computation.

9. *General case of the environment.*—A short resumé of the changes of condition involved is here necessary, since for reasons specified in §2, I found it necessary to depart somewhat from the method of Weber.

In his masterly discussion of the flow of heat in the plates Weber shows that the two copper discs are isothermal regions identical to about 1 : 1000 with the upper and lower isothermal surfaces, respectively, of the enclosed non-metallic liquid, no matter what it be. Hence in addition to Fourier's well known equation of heat conduction, the following surface equations obtain for the upper plate: Given a set of cylindrical coördinates whose origin is in the upper surface of the lower plate, and whose axis coincides with the axis of the plates; let distance above the surface of reference, radius and azimuth of any point, whose temperature excess is u at the time t, be represented by x, r and φ, respectively. Let $r = R$ be the radius, Δ_1 the thickness, F_1 the exposed surface (top and sides), F the lower surface of the upper plate, M_1 its mass, c_1 its specific heat, and h_1 its external conductivity. Let Δ be the thickness of the layer of the charge, k its absolute heat conductivity, h its external conductivity, c its specific heat. Finally let U be the uniform temperature excess of the system at the time zero. Then the conditions in question are

1. $x = 0$, $u = 0$ for all values of t.
2. $x = \Delta$, u independent of r for all values of t.
3. $x = \Delta, - M_1 c_1 \left(\dfrac{du}{dt}\right)_{\Delta} = k\ F \left(\dfrac{du}{dx}\right)_{\Delta} + h_1 F_1 u_{\Delta}$
4. $r = R$, $k(du/dr)_{\mathrm{R}} + hu_{\mathrm{R}} = 0$
5. $t = 0$, $u = U$, for all the values of x and r.

Weber expands u in a series of mixed Bessel functions of the type

$$u = Ae^{-kq^2t/\rho c} \sin qx + Be^{-k(p^2+m^2)t/\rho c} \sin px J_0(mr)$$

and proves that by suitable spacing the copper discs, the value of u is almost wholly contained in the first term even after a few seconds. To determine the constant q, the insertion of the condition (3) is available: i. e., any of the infinite roots of the transcendental resulting, leads to a singular solution of the equation of heat conduction, and thus the complete primitive is given as the sum of all of these. But inasmuch as the squares of the succession of values q, q', ... increase rapidly, the singular solution and the complete primitive again soon coincide in the lapse of time. Thus the temperature excess of the upper plate (and it is here that the thermo-electric measurement is made) is after a short time (60^s),

$$u_\Delta = U \sin q\Delta e^{-kq^2t/\rho c}, \quad . \; . \; . \; . \; (6)$$

where q is the smallest root of the transcendental referred to.

10. *Continuation.*—Now the change to be made in these deductions in my own case, where the environment may have any temperature excess τ, given by replacing the condition (3) by the equation—

$$-F\Delta_1\rho_1c_1\left(\frac{du}{dt}\right)_\Delta = kF\left(\frac{du}{dx}\right)_\Delta + h_1F_1(u_\Delta - \tau) \quad . \; . \; . \; . \; (3')$$

where ρ_1 and ρ are respectively the densities of the copper plate and the charge. Imposing this condition on (6) I obtain

$$\Delta_1\rho_1c_1\frac{kq^2}{\rho c}\sin q\Delta = kq\cos q\Delta + h_1\frac{F_1}{F}\sin q\Delta - h_1\frac{F_1}{F}\frac{\tau}{U}\varepsilon^{ktq^2/\rho c}$$

or after further reduction

$$q\Delta \tan q\Delta = \frac{\Delta\rho c}{\Delta_1\rho_1c_1}\,\frac{1}{1-\frac{\Delta\rho c}{\Delta_1\rho_1c_1}\,\frac{h_1}{k}\,\frac{F_1}{F}\,\frac{1}{\Delta q^2}\left(1-\frac{\tau}{u}\right)} \quad . \; . \; . \; . \; (7)$$

Hence the value of q in (6) is to be the smallest root of (7).

If therefore consecutive temperatures, u, u', ... are measured at consecutive times t, t', ... equation (6) may be solved with reference to k as follows:

$$k = \frac{\rho c}{q^2}\,\frac{1}{t-t}\ln\frac{u'}{u} = \frac{\rho c}{q^2}\,2{\cdot}303\,\frac{\delta \log u}{\delta t} \quad . \; . \; . \; . \; (8)$$

Equations (7) and (8) show that the arithmetical results can only be obtained by successive approximation. Disregarding the corrective factor in (7) approximate values of k and q are first found. These are then put in (7) and (8) and closer values of k and q computed. I often repeated this operation again, taking full cognizance of the change of q with the mean temperature of the charge.

11. *Special cases.*—(1) If in (7) the temperature excess of the environment, $\tau = 0$, the conditions revert to those of Weber.

(2). If as in my case, the initial temperature be the same for the plates and the environment, or if initially $\tau = u$, the correction vanishes at the beginning of the work but increases in the lapse of time.

If $u = \tau$, throughout, the radiation correction would always vanish. Now it struck me that it might be very well worth while to construct an apparatus for $\tau = u$; for although ordinarily the correction for surface conduction is nearly enough given by the computed value, there are cases of exceptionally bad conduction (for instance in gases) where this is no longer fully the case. Suppose, however, the system be duplicated as in figure 2. Let the lower pair of plates, D, E, be like those of the above figure. Let the upper pair of plates D', E', be somewhat larger, and the conductor D', somewhat thinner and shallowly bell-shaped, so as to surround the plate D on all exposed sides. Then if $\Delta F\rho c/M_1c_1 = \Delta F'\rho'c'/M'_1c'_1$ the constants q and q' for the two systems will be identical to a second degree of approximation. Hence $u_\Delta = u_{\Delta'}$, and therefore as regards the plate D, $\tau = u$ at all times.

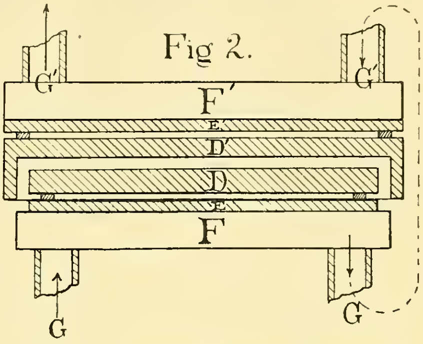

FIG. 2.—Duplicate apparatus for heat conduction.

In using this device for measuring conduction in gases, the environment $A\ B\ C$, figure 1, would have to be sealed hermetically, and the gas to be studied, introduced into the whole interior space, at any temperature (environment) or pressure desirable. In such a case, since $\Delta = \Delta'$, $\rho = \rho'$, $c = c'$, $c_1 = c_1'$ the simple conditions are

$$F/F' = M_1/M_1'$$

(4) If the environment be at a temperature intermediate between the initial and the final values u of a given pair of observations, then $1-\tau/u$ passes from positive to negative values, and the corrective may also vanish; but this case is superfluous here.

Returning for a moment to case (2), it is clear that the radiation corrective is least when the temperature gradient of the layer is steepest. So long therefore as the thermal variation of conductivity is not fully known, it is advisable to prefer small values both of U and Δ.

Experimental Results.

12. *Method of observation.*—If after the lapse of 60 minutes the plates were heated uniformly, the cold water faucet was suddenly opened; but observations of temperature (u) and time (t) were not commenced until a minute later. A good

chronometer beating half seconds was at hand for time measurement, and temperatures (since relative values enter the formulæ) were directly given by the deflections of the dead beat galvanometer, reduced to arcs. For charges 1^{cm} thick (Δ), observations were taken every 20^{sec}, for charges $\cdot15^{cm}$ thick every 30^{sec}, and for charges $\cdot19^{cm}$ thick every 60^{sec}. Usually 24 readings were made for each heating, which were then combined in four batches of 6 observations each. By joining the 1st and 4th, 2d and 5th, etc., I therefore obtained 12 data for k, with the mean temperature corresponding to each.

Readings of the zero of the galvanometer, and of the temperature of the environment were taken before and after the time measurements; temperatures of the hot bath at the beginning, temperatures of the cold bath at the end of the work.

13. *Exhibit.*—To avoid prolixity I will only give an example of the way in which the work was done. In addition to the corresponding increments of time (δt) and logarithmic temperature ($\delta \log u$), table 3 contains the (actual) temperatures, u_1 to u_6, of the upper plate at the beginning and end of each batch of six consecutive readings. Thus each value of k is a mean of three pairs of sufficient data. Furthermore τ is (*henceforth**) the actual temperature of the environment, U the initial temperature of the upper and lower plate, θ the temperature of the cold bath; and Θ finally is the mean temperature of the charge, the bottom being constantly cold ($\theta°$) and the top hot ($u°$). The table also contains the mean value of the corrective

$$m = 1/\left(1 - \Delta \rho c h_1 F_1 \left(1 - \frac{\tau}{u}\right) / \Delta_1 \rho_1 c_1 k F \Delta q^2\right)$$

of equation (7) §10.

The two cases in which the environment has the final (cold) or the initial (hot) temperature of the plates are distinguished as method I and II, respectively. In case of solid thymol both were tested and led to identical results. §17.

To obviate discrepancies due to imperfect adhesion, expansion, etc., of solid thymol, three different values of Δ are introduced as a check on the method.

14. *Constants.*—Supplementing §§ 8–10, I need only add that an allowance (f) of 5 per cent of F was made for the contraction of thymol on solidifying.

$F = 182\cdot3$ cm^2 $\qquad$ $\Delta_1 = 1\cdot300^{cm}$
$F_1 = 244\cdot5$ " $\qquad$ $\rho_1 = 8\cdot94$ "
$F - f = 173\cdot4$ " $\qquad$ $c_1 = \cdot933$ *g. cal.*

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* To avoid cumbersome notation.

15. *Specific heat and density.*—In a series of experiments described elsewhere* and considerably extended since, I found for solid thymol (if c and ρ denote specific heat, density, and temperature, respectively.)

$$c = {\cdot}311\ (1+{\cdot}00302\theta),$$
$$1/\rho = {\cdot}9631/(1-({\cdot}0002456+2\theta)\theta)$$

and for liquid thymol

$$c = {\cdot}447\ (1+{\cdot}00238\theta)$$
$$1/\rho = 1{\cdot}00113/(1-({\cdot}0007600+2\theta))\theta$$

Hence with sufficient accuracy for the present data the temperature factor of $c\rho$ for the solid was put $(1+{\cdot}0028\theta)$, and for the liquid $(1+{\cdot}0016\theta)$. In computing the correction factor in equation (7), §10, h_1 was therefore referred to surface temperatures of the upper plate, while the other quantities ρ, c, q, obtain for the mean temperature Θ of the charge.

TABLE 3. Heat condition of solid thymol. $\Delta = {\cdot}1070^{cm}$; *I*, Low temperature environment.†

u_1 to u_6 °C.	δt	$10^4 \times \delta \log u$	Mean Θ °C.	U °C.	θ °C.	τ °C.	$m \times 10^3$	$k \times 10^6$ g/cs
24·8–19·7	$5,^{m}0^{s}–6^{m}0^{s}$	805	14·1	27·8 28·7	5·9	6·2	961	356
	5,20–6,20	822						
	5,40–6,40	822						
18·8–15·4	7,0 –8, 0	825	11·6	—	5·9	6·2	963	356
	7,20–8,20	821						
	7,40–8,40	820						
14·8–12·4	9, 0–10,0	817	9·8	—	5·9	6·2	965	354
	9,20–10,20	811						
	9,40–10,40	815						
12·0–10·1	11,0–12,0	810	8·6	—	5·9	6·2	966	355
	11,20–12,20	812						
	11,40–12,40	827						
$\Delta = {\cdot}1070^{cm}$;		*II*, High temperature environment.‡						
23·7–19·1	$3^{m},0^{s}–4^{m}, 0^{s}$	780	13·6	27·8 27·8	5·9	28·5	1019	360
	3,20–4,20	785						
	3,40–4,40	790						
18·3–15·1	5, 0–6, 0	772	11·8	—	5·9	28·5	1043	360
	5,20–6,20	768						
	5,40–6,40	773						
14·6–12·4	7, 0–8, 0	747	9·7	—	5·9	28·5	1075	361
	7,20–8,20	755						
	7,40–8,40	743						
12·1–10·6	9, 0–10, 0	723	8·6	—	5·9	28·5	1120	360
	9,20–10,20	71[illegible]						
	9,40–10,40	709						

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* Proceed. Am. Acad , xxvi, p. 313, 1892.

† Plate *E* suddenly cooled at $4^{m}\ 0^{s}$.

‡ Plate *E* suddenly cooled at $2^{m}\ 0^{s}$.

17. *Digest.*—My data for k have been summarized in Table 4. In constructing mean values for k, for each heating, data below $10° = \theta$ are usually discarded, because in these cases the correction factor m can no longer be found without difficulty in view of the rapid variation of q. The table also contains the mean values for thermometric conductivity $(\kappa = k/\rho c)$ obtained (§15) by putting for the liquid at 13°, $\rho c = {\cdot}453$, and for the solid at 12° and at 11°, $\rho c = {\cdot}334$ and ·333 respectively, with the corresponding mean k for each spacing, Δ.

TABLE 4.—Conductivity of solid and of liquid thymol. Summary.

θ °C	$k \times 10^6$ g/cs	Mean $k \times 10^5$ g/cs	$k \times 10^6$ $\kappa \times 10^6$	Method
	Solid Thymol, $\Delta = {\cdot}192^{cm}$			
14·4	356	356	358	II
10·5	357		1072	
8·4	345			
7·4	318			
14·4	361	361	----	II
11·5	364	----	----	
9·7	356	----	----	
8·5	351	----	----	
7·7	335	----	----	
	Solid Thymol, $\Delta = {\cdot}153^{cm}$			
13·7	375	371	366	I
11·2	374	----	1096	
9·5	370	----	----	
8·5	365	----	----	
13·5	373	371	----	I
11·1	371	----	----	
9·5	369	----	----	
8·4	369	----	----	
14·8	371	373	----	II
12·1	377	----	----	
10·3	371	----	----	
9·2	375	----	----	
15·9	364	373	----	II
12·8	381	----	----	
10·8	375	----	----	
9·5	367	----	----	
16·2	330?	355	----	II
13·0	360	----	----	
10·9	350	----	----	
9·3	344	----	----	
16·1	348	353	----	II
12·8	356	----	----	
10·8	354	----	----	
9·3	344	----	----	
	Solid Thymol, $\Delta = {\cdot}107^{cm}$			
14·1	366	365	354	I
11·5	366	----	1063	
9·8	365	----	----	
8·6	364	----	----	
14·1	356	355	----	I
11·6	356	----	----	
θ °C.	$k \times 10^6$ g/cs	Mean $k \times 10^6$ g/cs	$k \times 10^6$ $\kappa \times 10^6$	Method
9·8	354	----	----	
8·6	355	----	----	
13·6	353	353	----	I
11·2	353	----	----	
9·5	346	----	----	
8·4	339	----	----	
13·6	360	360	----	II
11·8	360	----	----	
9·7	361	----	----	
8·6	360	----	----	
14·2	346	351	----	II
11·6	356	----	----	
9·8	351	----	----	
14·2	350	354	----	II
11·6	356	----	----	
9·8	355	----	----	
13·3	344	347	----	II
11·3	350	----	----	
9·7	347	----	----	
13·3	341	346	----	
11·2	348	----	----	
9·7	349	----	----	
	Liquid Thymol, $\Delta = {\cdot}107^{cm}$			
17·5	305	307	313	II
14·3	306	----	691	
12·0	311	----	----	
15·0	309	313	----	II
12·4	317	----	----	
10·5	313	----	----	
14·9	311	314	----	II
12·3	318	----	----	
10·5	313	----	----	
15·3	319	325	----	II
12·7	329	----	----	
10·8	328	----	----	
16·4	302	310	----	II
13·6	313	----	----	
11·7	315	----	----	
13·9	304	308	----	II
11·8	311	----	----	
10·2	309	----	----	

18. *Conclusion.*—The results of this long and tedious investigation may be stated in a few words. The mean values of the absolute heat conductivity, k, of thymol, obtained from the measurements as a whole are in g/cs.

$$\text{Solid thymol, } 12^\circ \quad 10^6 \times k = 359$$
$$\text{Liquid thymol, } 13^\circ, \quad 10^6 \times k' = 313$$

The mean values of thermometric heat conductivity κ, are in c^2/s,

$$\text{Solid thymol, } 12^\circ, \quad 10^6 \times \kappa = 1077$$
$$\text{Liquid thymol, } 13^\circ, \quad 10^6 \times \kappa = 691$$

Hence the increment of heat conductivity, encountered on passing from liquid to solid, at say 13°, referred to solid conductivity,

$$(k - k')/k = \cdot 13, \qquad (\kappa - \kappa')/\kappa = \cdot 36\ ;$$

and the corresponding increment referred to liquid conductivity is

$$(k - k')/k' = \cdot 15, \qquad (\kappa - \kappa')/\kappa' = \cdot 56$$

Now since in all questions relative to thermal flux, it is the thermometric conductivity which enters fundamentally into the considerations, the importance of the effect produced when any part of the substance changes state is obvious.

ART. II.—*On Polybasite and Tennantite from the Mollie Gibson Mine in Aspen, Colorado;* by S. L. PENFIELD and STANLEY H. PEARCE.

DURING the past year the Mollie Gibson Mine has been one of the most productive in Colorado. Our attention was first called to the specimens from there by Dr. Richard Pearce of Denver, who sent a few to New Haven for identification. Later Mr. C. E. Palmer, general Manager of the Mollie Gibson Consolidated Mining and Milling Company, generally supplied us with specimens and information concerning their occurrence. We take pleasure in expressing to both of these gentlemen our thanks for their courtesy. From Mr. Palmer's annual report to the stockholders for the year 1891, of his company we quote some figures, which are of interest as showing the wonderful richness of the mine. Most of the production dates from the month of March, when the rich ore was first encountered, and for the most part was taken from an area of about one half acre of territory, with a maximum depth of but 300 feet. Net weight of ore 9,080,570 lbs., carrying 2,053,149 ounces of silver, an average of 452·2 ounces per ton.

The rich ore occurs between a hanging wall of black carbonaceous shale and a foot wall of gray magnesian limestone, which is probably of lower carboniferous age. The ore is richest and most abundant immediately under the black shales. The minerals which have been observed at the mine are polybasite, tennantite, native silver (sometimes in very beautiful specimens), argentite, galena, sphalerite, siderite, barite and calcite.

Polybasite or "brittle silver" of the miners.

This is the most abundant silver mineral at the mine and occurs massive, with grayish black color and irregular fracture. Large quantities of it, nearly free from gangue, have been mined, assaying from 10,000 to 16,000 ounces of silver to the ton. A very abundant and conspicuous ore is a pink barite (" pink spar") with the polybasite disseminated, quite uniformly through it and assaying from 1800 to 2700 ounces of silver to the ton. The mineral also occurs as streaks and particles in the shales and limestones on the borders of the deposit, and even some seams of impure coal, above the shales, are quite rich in silver.

The massive polybasite is not a pure mineral as it appears at first sight to be. The analyses show a wide variation in the percentage of lead and do not yield a satisfactory formula until this metal is deducted in the form of galena, although the latter is no where visible in the material which was analyzed. The remaining impurity consists of a carbonate of iron and manganese, which is very evenly distributed, is black from carbonaceous material and not conspicuous in the metallic sulphide. The analysis is given beyond.

Some of the specimens consist of a fine grained, crystalline carbonate of iron, manganese and zinc, having a brown color and probably a variety of siderite. This seems to have been deposited over tabular crystals of polybasite, but it can not be broken away so as to show the crystalline form of the latter as it adheres quite tenaciously. Some of the polybasite crystals are surrounded first by a layer of siderite, then by a narrow zone of metallic mineral and then again by siderite. As this seemed to be the nearest approach to the pure crystallized silver mineral, which we were likely to obtain, great pains was taken to pick out a sufficient quantity for the following analysis.

Massive mineral. Analysis by S. H. Pearee. Specific gravity of three pieces 6·06, 5·92 and 6·10.					Crystals from siderite. Analysis by S. L. Penfield. Speeific gravity 6·080.		
	I.	II.	Average.				
S	15·77	15·88	15·83		S	17·42	
As	4·48	4·46	4·47		As	6·10	
Sb	0·13	----	0·13		Sb	0·26	
Ag	42·52	42·45	42·49		Ag	49·51	
Cu	9·21	9·15	9·18		Cu	12·92	
Zn	2·23	2·27	2·25		Zn	2·45	
Pb	20·84	20·82	20·83	= galena, PbS 24·05	Pb	10·58	= PbS 12·22
$FeCO_3$	2·57	2·57	2·57	4·13	$FeCO_3$	0·46	0·59
$MnCO_3$	0·98	1·07	1·03		$MnCO_3$	0·13	
$CaCO_3$	0·20	----	0·20				
Insol.	0·32	·34	0·33				
			99·31	Impurity 28·18		99·83	Impurity 12·81

The above analyses do not agree, nor in their present form can they be referred to any known species, but after deducting 28·18 per cent of impurities from the first and 12·81 from the second, and recalculating to one hundred the results are as follows:

	Massive mineral.	Crystals from siderite Sp. gr. corrected = 5·94	Ratio		Theoretical composition where $Ag_2 : Cu_2 : Zn = 263 : 117 : 43$
S	17·73	18·13			18·13
As	6·29	7·01 ÷ 150	= ·0467	·0479	7·08
Sb	0·18	0·30 ÷ 244	= ·0012		
Ag	59·73	56·90 ÷ 216	= ·263	·423	57·07
Cu	12·91	14·85 ÷ 126·8	= ·117		14·91
Zn	3·16	2·81 ÷ 65	= ·043		2·81
	100·00	100·00			100·00

The analyses are now similar and in the second, which was made on the purest material, the ratio of $(Ag_2+Cu_2+Zn):(As_2+Sb_2)=·423:·0479$ or $9·00:1·02$, almost exactly that required by the formula $9Ag_2S, As_2S_3$. As is always the case with this mineral, a rather large proportion of the Ag_2 has been replaced by Cu_2 and some by Zn. The analyses are also interesting as showing that this mineral is a nearly pure arsenical polybasite. H. Rose* gives one analysis of a variety from Chemnitz in Saxony, which agrees with ours in containing only a trace of antimony; with this exception, in all of the analyses which have been published, antimony predominates. Although polybasite has been known to occur in the United States, the only published analysis is one by F. A. Genth† of a crystal from the Terrible Lode, in Clear Creek Co., Colorado.

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* Pogg. Annalen, xxviii, 1833, p. 156.

† Proc. Amer. Phil. Society, xxiii, 1886, p. 39.

Tennantite or arsenical tetrahedrite. "Gray copper" in part of the miners.

Among the specimens of massive polybasite, just described, there were a few which contained patches of a steel gray mineral, differing only slightly in color from the blacker polybasite. No crystals were observed and it was necessary to pick very carefully, in order to secure sufficient pure material for the following analysis. The mineral gave a reddish streak, only a little darker in color than that of hematite. The analysis by Penfield is as follows:

	Specific gravity, 4·56			Theoretical composition where $Cu_2 : Ag_2 : Zn = 282 : 63 : 106$
S	25·04			25·66
As	17·18÷150	=·1145	·115	17·18
Sb	0·13÷244	=·0005		
Cu	35·72÷126·8	= ·282	·463	36·29
Ag	13·65÷216	= ·063		13·86
Zn	6·90÷ 65	= ·106		7·01
Fe	0·42÷ 56	= ·008		
Pb	0·86÷207	= ·004		
	99·90			100·00

The ratio of the metals to (As_2+Sb_2)=·463 : ·115 or 4·00 : 0·99, almost exactly that required by the formula $4Cu_2S$, As_2S_3. A part of the Cu_2 is replaced by Ag_2 and Zn. It is not certain whether the small quantities of Fe and Pb are impurities or whether they belong to the mineral. The analysis is interesting as it shows an unusually high percentage of silver.

Although tennantite has been known to occur in the United States, we can find no analyses, and very little mention of it in scientific literature.

According to information received from Dr. Pearce, and from our own experience, polybasite and tennantite are not rare silver ores in Colorado. Polybasite occurs well crystallized in the mines about Georgetown, at the Yankee Boy mine near Ouray, in the Marshall Basin near Telluride and probably at a number of mines in the Red Mountain District. Tennantite has been observed well crystallized at the mines about Central City and at the Freeland Lode and Crocett Mine near Idaho Springs.

Mineralogical Laboratory of the Sheffield Scientific School,
New Haven, Dec., 1891.

ART. III.—*Post-Laramie Deposits of Colorado;* by WHITMAN CROSS.

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Introductory.

AMONG questions in American geology which have given rise to prolonged discussion and controversy, few if any have been more prominent than that as to the age of the great Laramie Formation or Group of the Rocky Mountain region. This observation, made by Mr. Clarence King in the final report of the Fortieth Parallel survey, in 1878, is still more true to-day than it was at that time. When it is considered, however, that a very large part of the earlier publications were based upon mere geological reconnaissance, and that the area involved extends across the United States in its most inaccessible and least known portion, from Mexico to British America, it must be plain that controversies and misunderstandings were unavoidable, and indeed quite natural.

A few years ago it seemed to many geologists that the Laramie question was practically settled, or in a fair way to settlement. But, as certain areas of the West have been more carefully explored, the question has been in a measure reopened, but with a change in its phase, so that it is not now so much "To what age does the Laramie belong?" as it is "What belongs to the Laramie?" For the newer researches, whatever their direction, all tend to show that the Laramie has been a great omnibus division into which has been cast everything ascertained to lie between the marine Cretaceous and the lowest recognized Eocene deposits, together with a number of other formations whose positions were not determined. It is the aim of this paper to show that there exists at least one important group of formations which have been considered as belonging to the Laramie, but which are very markedly distinct from the formation to which that name properly belongs.

As far as the writer is aware the first definite proof that a given section assigned to the typical Laramie contained members separated by important unconformities and of widely different lithological character, was afforded by the work done in the vicinity of Denver, by the Colorado Division of the U. S. Geological Survey, in charge of Mr. S. F. Emmons. A preliminary account of these researches was presented to the Colorado Scientific Society, July 2, 1888, in articles by G. H.

Eldridge and the writer.* In this Journal for April, 1889, the second of these articles "The Denver Tertiary Formation," was published in revised form. During the last three years further discoveries bearing upon this question have been made in various fields by several observers, and it is desired to present here a connected statement of these new facts, together with a discussion of their significance.

Description of the Deposits.

Denver and Arapahoe Formations.—In the detailed examination of the Denver region above mentioned, it was found that the continuous so-called "Laramie" section exposed near Golden consisted of three divisions: 1°, a lower member, 700–800 feet thick, conformable with the Fox Hills, containing productive coal measures and a flora and fauna characteristic of the Laramie as commonly known; 2°, a middle member, 800 feet thick, unconformable with the lower member, characterized by a conglomerate which carries pebbles recognized as coming from the Laramie, Fox Hills, Niobrara, Benton, and Dakota, Cretaceous, the Jura, the Trias, and the Carboniferous; 3°, an upper member, 1400 feet thick, unconformable with the middle member, and characterized lithologically as composed very largely of debris of andesitic lavas, none of which appeared in the preceding deposits. To the middle member of this series Mr. Eldridge gave the name "The Arapahoe Beds;" to the upper member was assigned the name "The Denver Beds." It was found that the celebrated fossil-leaf horizon of Table Mountain, at Golden, belonged to the Denver beds and consequently that the "Laramie" flora of Golden, described by Lesquereux and Ward, belonged to two distinguishable horizons, and chiefly to the upper one. The Arapahoe and Denver beds were found to contain a vertebrate fauna not known in the coal measures below, and to this point reference will be made in a later section of this article.

The stratigraphical and lithological evidence above summarized indicated clearly that the Arapahoe and Denver beds were separated from the Laramie below by a long period of very important orographic disturbances, as attested by the pebbles in the Arapahoe conglomerate. As the fossil flora and fauna of the formations did not seem to be necessarily opposed, the two formations in question were referred in the publications cited to the early Eocene, and probably to a horizon

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* On some stratigraphical and structural features of the country about Denver, Colorado; by George H. Eldridge. The Denver Tertiary Formation; by Whitman Cross. Proc. Col. Sci. Soc., vol. iii, part I, pp. 86–133.

below any other recognized member of that division. Having thus briefly restated the stratigraphical evidence of the formations near Denver the developments of the last three years in other districts will be reviewed.

Huerfano Series.—In the Huerfano basin in southern Colorado Mr. R. C. Hills has discovered and described * a series of strata 7,100 feet in thickness which he refers to the Eocene, because their lower member is decidedly unconformable with the underlying well-known coal-bearing Laramie of southern Colorado, and because the upper division contains mammalian remains of the Bridger Eocene. For the whole series Mr. Hills submits the following scheme of division :

Huerfano Series (Eocene)	Huerfano beds, 3,300 feet	=Bridger Group.
	Cuchàra beds, 300 feet	Lower Eocene.
	Poison Cañon beds, 3,500 feet	

Great angular unconformity exists between the Laramie and the Poison Cañon beds, but none has been detected between the designated members of the new series. The Poison Cañon and Cuchara beds are at present separated from each other and from the Huerfano beds on lithological grounds only, the former consisting of "soft sandstones and fine conglomerates of a yellowish tint, with occasional bands of yellow clay or marl," while the latter is a well defined horizon of "pink and white massive sandstones." The Huerfano beds consist of "marls, clays, soft shales and sands, of red, gray, yellow, green and purple colors, red predominating." In these have been found remains of *Tillotherium*, *Hyrachyus*, *Glyptosaurus*, *Palæosyops*, and other forms which seem to correlate the strata containing them with the Bridger Eocene. This discovery of Eocene deposits, containing a well-marked mammalian fauna, on the eastern slope of the Rocky Mountains is certainly significant. And it is highly probable, as pointed out by Mr. Hills, that the Cuchara and Poison Cañon beds are contemporary with some of the other post-Laramie formations to be mentioned.

Gunnison County.—A fund of new observations bearing upon the present question is to be found in the address of Mr. R. C. Hills as retiring President of the Colorado Scientific Society, delivered December 15, 1890, but only very recently published.† In that portion of this address treating of the

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* The recently discovered Tertiary beds of the Huerfano river basin, Colorado (with map); Proc. Col. Scientific Society, vol. iii, part I, pp. 148–164, 1888.

Additional notes on the Huerfano beds; ibid, vol. iii, part II. pp. 217–223, 1889.

Remarks on the classification of the Huerfano Eocene. Read before the Col. Sci. Soc, Feb. 2, 1891. Not yet published in full.

† Orographic and structural features of Rocky Mountain geology, Proc. Col. Sci. Soc, vol. iii, part III, pp. 359–458. 1891.

period between the marine Cretaceous and the Wasatch Eocene, Mr. Hills gives much important original information concerning the Laramie and various post-Laramie formations.

The first one of these later deposits to be mentioned occurs in western Colorado on the western slope of the Elk Mountains. Its southern limit, as now known, is about Irwin, a few miles to the westward of Crested Butte in Gunnison County. It rests upon the normal Laramie carrying anthracite coal beds on the northern slopes of the Anthracite range, occupies a considerable area at the head of Anthracite creek, and thence extends northward for 80 miles to Grand river. The development on Anthracite creek comes within a district which has been examined in detail by the Colorado division of the U. S. Geological Survey. In the course of this work the provisional name of the "Ruby beds" was assigned to these strata on account of their prominent development in Ruby Peak, near Irwin, where their thickness exceeds 2,000 feet, and this name is used by Mr. Hills in his address in referring to them.

In the Irwin region the Laramie strata have a thickness of about 1500 feet. They are succeeded by 2000 feet of conglomerates, sands and shales, composed almost entirely of the debris of volcanic rocks of andesitic character, here much hardened and metamorphosed by later eruptive rocks which pierce them in numerous dikes. The basal member of the series is a conglomerate of small pebbles, which is usually uncomformable on a small scale with the Laramie, and also exhibits a great variability in constitution. In some places it consists entirely of andesitic pebbles, in others, of a mixture of such material with white, black or reddish chert pebbles, some of which show cavities representing crinoid stems. Again, the lower part of the conglomerate may be free from andesitic pebbles.

To the northward of the Irwin region Mr. Hills has traced out the Ruby beds, with a decreasing thickness reaching a minimum of 300 feet near the northern limit on Grand river. Concerning their development at this point Mr. Hills says: "South of the Great Hogback at Coal ridge, there is an abrupt change in the composition of the sediments previously regarded as Laramie. The firm gray sandstones of the coal measures are there succeeded by about 200 feet of soft white sandstones and yellow clays, followed by about 300 feet of tufaceous strata, more or less conglomeritic and usually loosely aggregated, but resting on a hard, coarse basal conglomerate about 40 feet thick made up wholly of eruptive debris. The tufaceous beds are in turn succeeded by 600 feet or more of shales and soft brownish sandstones which may be in part of Wasatch age." *

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* Op. cit., p. 390.

On Ohio creek, but a few miles beyond the southern limit of the Ruby beds, there are two small isolated patches of loose friable sandstones, grits, and fine conglomerates, resting on the coal-measures of the Laramie, and seemingly in small basins of erosion. Owing to the disturbances caused by adjacent laccolites it is impossible to see the relationship of the formations clearly. The chert pebbles of these beds contain crinoid stems and other apparently Carboniferous fossils, and are identical in character with those already mentioned as frequently found in the basal conglomerate of the Ruby beds near Irwin. These facts suggest that the chert pebbles of the Ruby conglomerate may be the residuum from the destruction of Ohio creek beds formerly existing to the north of the Anthracite range. Mr. Hills does not mention such pebbles in the section near Coal ridge above described, but he does suggest a possible correlation between the Ohio creek beds and the soft yellowish sandstones found at the north between the "firm gray sandstones of the coal-measures" and the Ruby conglomerate. He also thinks that the Carboniferous chert pebbles of the Ohio creek beds indicate a post-Laramie erosion of the entire Cretaceous section, exposing Carboniferous strata. Whether this hypothesis be established or not it is true that such materials are not seen in the Cretaceous beds above the Dakota conglomerate, and it is not known to the writer that they have been found at that horizon in this region, though not uncommon along the Front range and in Middle Park.

Mr. Hills has found that on Grand river the Ruby beds lie between the Wasatch and the Laramie. The lithological and stratigraphical evidence given there distinctly suggests that the Ruby beds may be the equivalent of the Denver formation, and less decidedly that the Ohio creek beds may possibly represent the Arapahoe formation. No fossils excepting carbonized plant stems have been found in the two new formations. The writer does not place much weight on the mere coincidence in eruptive character of the materials in the Ruby and Denver beds, beyond the marked fact which seems to be developing from experience that a number of formations of apparently the same stratigraphical position are thus characterized. It may finally come to be a criterion of considerable value.

Yampa River.—In northwestern Colorado on the Yampa river Mr. Hills finds reason to believe that there is a distinct formation between the Laramie proper and the Wasatch, but is at present able to give no positive evidence for this view except that the normal series of the Laramie has above it a formation "of soft sandy strata with some shales and clays" containing impure lignitic beds, and of general different physical appearance from the beds of the Laramie. Above these are unquestioned Wasatch beds.*

South Park.—Near Como in South Park, Colorado, Mr. Hills has found a very remarkable formation which will be best described in his own language: "While recently engaged in the examination of the small Laramie area in the South Park basin, I there observed unquestionable evidence of a former grand eruption, of a character not previously noted in that part of Colorado. The evidence consists in the occurrence of thick sheets of eruptive conglomerate, intruded partly into the marine Cretaceous and partly into the Laramie, to some extent above the workable coal. These sheets are continuous from Mine No. 5 near Como to the southern limit of the Laramie beds, a distance of fully fifteen miles, beyond which I did not trace the exposures. About three miles south of Mine No. 5, the intrusions above and below the coal beds coalesce and form a body of conglomerate several hundred feet thick completely cutting out the workable measures for nearly a mile. The material consists of rounded pebbles and bowlders of andesite embedded in a matrix of finer material of similar composition." . . . "The material itself may be regarded as the product of intense dynamic movement, probably brought to the surface as a hot conglomeritic mud, or in a condition to produce an explosive eruption, whenever, owing to diminished pressure, the contained water flashed into steam." . . . "The material then thrown out and scattered over the surface would be in a condition to be transported in large quantities to the nearest area of sedimentation—the Denver basin—and presumably at the very time when the Denver beds were laid down." †

It seems to the writer that the character ascribed to the South Park eruption is so novel and its extent so far a matter of speculation that it can at present hardly enter as an important factor into the question as to the origin of the eruptive materials of the Denver beds. The facts concerning the constitution of the Denver beds given in the original article do not allow of the adoption of Mr. Hills' suggestion. They demand a source near at hand and one whose location shall explain why eruptive material practically excludes Archæan material in fine, slowly deposited sediments, close to an Archæan shore-line.

Cañon City.—In his address Mr. Hills refers to remnants of a formation near Cañon City which seems related to the Denver formation. Through his kindness in personally communicating the news of his discovery, my colleague, Mr. G. H. Eldridge, was enabled in the season of 1890 to hurriedly

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* Op. cit., p. 389.

† Op. cit., pp. 393, 394.

examine the region, in connection with other field work, and kindly allows me to state the results. At Windy Gap, a few miles east of south from Cañon City, Mr. Eldridge found the normal section of the Laramie sandstones very steeply upturned, resting on Montana shales, while above them came a heavy conglomerate composed mainly of Archæan debris, but containing in addition pebbles recognized as belonging to various older sedimentary horizons, such as the Niobrara and Dakota Cretaceous, and the Jura. These conglomerates are also upturned, but, probably because they come directly in the fold, they are less steeply inclined than the Laramie. Angular unconformity with the Laramie was not determined. Separated from the conglomerate by a gap of 500 feet, in which there are no outcrops, are horizontal beds of conglomerate consisting of andesitic pebbles. As the fold is plainly abrupt, this position is not evidence of angular unconformity.

Mr. Eldridge did not have time to trace out either of these formations, which, though apparently remnants at the place observed, are probably represented elsewhere in the immediate vicinity. The fact was established, however, that two formations corresponding in stratigraphical position and lithological character to the Arapahoe and Denver beds exist near Cañon City.

Animas River.—Through the courtesy of Dr. C. A. White and his assistant, Mr. T. W. Stanton, I am enabled to state that the latter has recently found the formation crossing the Animas River about five miles south of Durango, Colorado, which is represented as Laramie upon the Hayden map, to consist of conglomerates, sandstones and shales, whose material is of andesitic rocks, as far as shown by the specimens collected. By referring to the Hayden atlas of Colorado, sheet 15, it will be seen that the coal-measures of this region were there referred to the Fox Hills, though their identity with the normal Laramie measures elsewhere in Colorado is at present probably unquestioned by any one.

On the western bank of the Animas River Mr. Stanton found a bed of conglomerate about 200 feet thick resting upon the coal-measures with apparent conformity. The specimens of this conglomerate collected by him are purplish or yellowish brown in color, the pebbles are of hornblende- or pyroxene-andesite, and the matrix is a gravel of the same character. Above the conglomerate are brown sandstones, very similar to the Denver sandstones of Table Mountain, and in one stratum some fossil leaves were found. The only identifiable species collected has been determined by Mr. F. H. Knowlton as *Magnolia tenuinervis* Lx. The specimen first described by Lesquereux came from the Denver beds of Table Mountain.

Since then the species has been repeatedly collected from the same beds and has also been detected at Black Butte, Wyoming.

That portion of the Hayden map representing the area to the westward from the Animas River is based upon the work of Mr. W. H. Holmes. In describing the series called the Laramie, to which the strata observed by Mr. Stanton evidently belong, Mr. Holmes usually refers to them as composed of brown sandstones, shales, and dark colored clays. In the section on the La Plata River* he assigns a thickness of 800 feet to the "Puerco marls" of Piñon mesa which overlie them, and 1120 feet to the coal-measure rocks below, which are called Fox Hills. Through the kindness of Mr. Holmes I have been allowed to examine his original field notes in this area, and find that the general resemblance of these "Laramie" strata to those at Table Mountain near Golden was recorded. There is, however, no definite evidence in these notes to confirm the generalization suggested by Mr. Stanton's observations that the strata between the "Puerco marls" and the coal-measures, west of the Animas River, are equivalents of the Denver beds, although the strata noted by him certainly occur in that part of the section.

In an article entitled: "The relations of the Puerco and Laramie deposits"† Professor E. D. Cope states that according to the observations of Mr. David Baldwin "the Laramie beds succeed [the Puerco] downward, conformably it is thought by Mr. Baldwin; and have a thickness of 2,000 feet at Animas City, New Mexico. [?] They rest on Fox Hills marine Cretaceous of less thickness. A few fossils sent from time to time by Mr. Baldwin identify the Laramie. This is especially done by the teeth of the dinosaurian genus *Dysganus* Cope, which is restricted to the Laramie formation everywhere. Also by the presence of the genera *Lælaps* and *Diclonius*, which in like manner do not extend upward into the Puerco beds. The *Lælaps* is principally represented by teeth, which resemble those of the *L. incrassatus* Cope, more than those of any other species . . . ." "The *Dysganus* agrees with the *D. encaustus* Cope, which, with the *Lælaps incrassatus*, was described from specimens from the Upper Missouri."

In recent "Notes on the Dinosauria of the Laramie"‡ Professor Cope describes a new Dinosaur, *Pteropelyx* "found near Cow Island, Montana, on the Upper Missouri, in 1876." "The genus *Pteropelyx* displays characters between the

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* Ninth Ann. Rep. U. S. G. & G. S. 1875, p. 248.

† American Naturalist, vol xix, p. 985, 1885.

‡ American Naturalist, vol. xxiii, p. 904, 1889.

Hadrosauridæ and Agathaumidæ" (= Ceratopsidæ, Marsh). He then remarks that it is to be compared with *Dysganus*. Now the original descriptions of the genera *Dysganus* and *Diclonius* and of the species *Lælaps incrassatus* are in an article entitled: "Descriptions of some vertebrate remains from the Fort Union beds of Montana,"* without any further statement in the text as to the geographical or geological position of the occurrence. The new dinosaurian genus *Monoclonius* was also described in this article. *Monoclonius* is now regarded as belonging to the horned Dinosaurs, and four species have been named by Professor Cope,† from Montana. One of these, *M. sphenocerus*, came from near Cow Island, on the Missouri, while another, *M. recurvicornis*, came from the "Judith River beds" on the north side of the Missouri River nearly opposite the mouth of Dog Creek. This last information is found in Professor Cope's report of the expedition during which all of these Dinosaurs appear to have been collected.‡

From the casual statements of localities and horizons above recapitulated it appears that somewhere in the 2000 feet of strata assigned by Professor Cope to the Laramie on the Animas River several species of Dinosaurs have been found, and that they most resemble a fauna collected in "Fort Union" beds near Cow Island, on the Upper Missouri River, in Montana, a locality which has furnished at least one species of the Ceratopsidæ. It is worthy of note that the so-called "Laramie" section below the Puerco on the Animas River contains strata resembling the Denver beds, and also Dinosaurian remains of types resembling, or associated in Montana with, the Ceratopsidæ. Whether the Dinosaurs occur in the Denver-like beds remains to be proven. It is certainly of importance to discover the character of the vertebrate fauna in beds thought to occur conformably below the Puerco.

Middle Park.—The Hayden atlas of Colorado represents a large continuous area of Laramie beds in Middle and North Parks, a representation based very largely upon the work of the late A. R. Marvine, during the seasons of 1873 and 1874. In the annual report for the former year Marvine describes in considerable detail the region of Middle Park, but this able and lamented geologist died before the notes of the next season's work could be put in shape for publication, and the data he then collected are practically lost to science. No publication of importance concerning the supposed Laramie beds of Middle Park has appeared since Marvine's report.

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* Proc. Acad. Nat. Sci. Phil., vol. xxviii, p. 248, 1876.

† "The Horned Dinosauria of the Laramie," Am. Naturalist, vol. xxiii, p. 715.

‡ Bulletin, U. S. G. & G. S., vol. iii, p. 565, 1877.

In his report on Middle Park Marvine describes very clearly the excellent section of the Cretaceous formations exposed in a synclinal basin cut across by the Grand River for eight miles above Hot Sulphur Springs. He also gives detailed maps, and sketches from the master hand of W. H. Holmes. He well understood the importance of the locality from the standpoint afforded by his interpretation of the stratigraphy, and since 1873 the "Laramie" of Middle Park has been cited as probably the only decided instance of great unconformity between this formation and the lower Cretaceous horizons.

To summarize Marvine's description of the Grand River section, he found the Cretaceous, from the Dakota to the Fox Hills, inclusive, exposed on both sides of the syncline mentioned. Then comes a formation occupying the center of the shallow syncline, which is described as follows:* "Above the Cretaceous No. 5, the next youngest rock is a local occurrence of volcanic doleritic material, consisting partially of subaqueous-arranged material—dolerite, tuff, and breccia—and partially as accompanying lava-flows; in all, reaching a maximum thickness of 800 or 900 feet." This formation is thereafter usually designated as "Doleritic breccia." "Resting upon the latter [the breccia] when it occurs, but elsewhere upon Cretaceous No. 5, and apparently conformable with the latter, except at one point where there is a decided unconformability, is a series of beds which reach a thickness of about 5500 feet." . . . . "They are composed in part of sandy shales, in places more or less argillaceous and quite soft, spaced rather regularly with more prominent and characteristic horizons of coarse sandstones, which are often inclined to grits and fine conglomerates. The texture of the latter is usually open and not firmly compacted, while the material of which they are composed is characteristically the debris of the Archæan rocks of the mountains, granitic debris prevailing." . . . "Impressions of deciduous leaves are quite numerous at favorable localities and small isolated patches, and one or two thin seams of carbonaceous material were also observed. No other fossils were observed in these beds. It has been strongly affected by the last great folding accompanying the formation of the Rocky Mountains, portions of it being abruptly upturned, together with the underlying sedimentary rocks. In position and character, therefore, this group of beds appears to be the equivalent of the lignitic group east of the mountains."

To the westward of this syncline, in which the formations are apparently conformable, Marvine found that the "lignitic beds" above the "breccia" in fact overlap the latter and rest successively on the inclined strata of the entire Cretaceous

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* Seventh Ann. Rep. U. S. G. and G. S., pp. 156, 157. 1874.

section, the Jura, and the Archæan. This was clear in the horizontal position of the "lignitic" strata of Mt. Bross which rest upon upturned Dakota and Ft. Benton strata, and of the ridge south of Hot Sulphur Springs. The relationships are expressed in the Hayden atlas and in the large scale maps accompanying Marvine's report, to which the reader must be referred for details. The "thin seams of carbonaceous material" mentioned by Marvine became coal beds in subsequent writings of other geologists, and the fossil plants said to have been collected here were identified by the paleobotanists as "Laramie," excepting a few which are described by Lesquereux without explanatory comment as coming from the Green River Eocene. The plainly provisional correlation of these beds with the coal-measure horizon east of the mountains by Marvine has not been questioned until recently.

It is evident to any one intimately acquainted with the Laramie proper that the description and statements of Marvine do not establish a satisfactory correlation between the Middle Park "lignitic" beds and the Laramie. In the light of the investigations of the Denver region the unconformity noted by Marvine and the thick beds of eruptive material at the base of the series suggested a different correlation. In the summer of 1889 Mr. George L. Cannon, Jr., of Denver, a geologist well acquainted with the local formations, was sent into Middle Park by Mr. Emmons to examine the so-called "lignitic formation" of Marvine. On the basis of Mr. Cannon's work it has already been stated by Mr. Emmons that the Middle Park series does not correspond with the true Laramie.* In October, 1891, the writer visited Middle Park, extending the observations of Mr. Cannon and determining still further the relationships of the formation in question. A paper giving the results of these examinations is in process of preparation, but the main features may be here summarized.

The statements of Marvine as to the unconformity existing between the "lignitic" beds and the Cretaceous section are very clearly correct. There are faults not noticed by him which complicate the local geology very much but they cannot explain the transgression of the newer beds across the entire Cretaceous section and to the Archæan. The unconformity is also shown by an examination of the Cretaceous horizon upon which the "doleritic breccia" rests in the section of the "breccia spoon," the syncline above mentioned. It is evident that no strata corresponding to the Laramie proper now exist in this section. Marvine refers the strata below the "breccia" to the Fox Hills, but gives no special reason for the assign-

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* Orographic Movements in the Rocky Mountains. Bull. G. S. A., vol. i, p. 281, 1890.

ment aside from the general stratigraphical position. Mr. Cannon, however, collected a number of fossil shells from the shales below the breccia about one mile east of Hot Sulphur Springs, and on the south side of Grand river, that is, on the western flank of the "breccia spoon." These shells were submitted to Dr. C. A. White for determination. The following species were found at 15 feet below the "breccia:" *Pteria parkensis* White, *Scaphites nodosus* Owen, sp., *Ostrea translucida* M. & H., *Leda* (*Yoldia*) *scitula* M. & H., *Inoceramus convexus* M. & H., *I. sagensis* Owen, *Baculites ovatus* Say, *B. compressus* Say?, *Placenticeras placenta*, De Kay, sp., and Dr. White is of the opinion that they indicate the lower or Ft. Pierre division of the Montana rather than the Fox Hills.

Marvine's description of the mechanical constitution of the "lignitic" series is generally applicable to the part above the "doleritic breccia," but as regards the character of the materials composing both parts of the series some important corrections are to be made. In the first place the "doleritic breccia" was unfortunately named, for the rocks composing the complex are andesites as far as examined, and the entire mass seems to be a water-arranged deposit containing finely preserved leaves in some of the most massive parts. The beds are very irregular in thickness, and are decidedly thicker on the eastern border of the area than on the western.

As to the great series succeeding the dark massive beds, Marvine was in error in stating that they consist entirely of Archæan debris, for they contain andesitic material in very variable amount for more than 2000 feet above the dark breccia, and the whole series is evidently one. The character of the eruptive material changes somewhat upward in the series, lighter colored and more acid rocks prevailing. Many beds in the terraces north of Grand river are sandstones or grits consisting of quartz and feldspar to a strongly prominent degree but none are entirely free from andesitic fragments, and conglomerates composed very largely of eruptive material often succeed quartzose sandstones. The strata in the divide between Middle and North Parks belong to the same series, according to Marvine. These were not visited by the writer, but the beds shown in the high ridges some eight miles north of Grand river, east of Whiteface Mountain, still carry a large amount of pinkish andesitic material. The same eruptive constituents were found in the strata of Mt. Bross, and of the ridges south of Hot Sulphur Springs; in fact, no beds of this complex were found to be wholly free from materials of this character.

No animal remains are reported from the series by Marvine, nor were any found by either Mr. Cannon or the present writer. Fossil plants are quite numerous in all parts of the series. Of those collected by the members of the Hayden survey a large majority came from Mt. Bross, and a few from distant localities on Willow and Troublesome Creeks, from strata referred to the same general horizon by Marvine. This material has been described by Lesquereux* but there has been such a serious confusion of localities in also assigning a number of other fossil plants to Middle Park, that little use can at present be made of these identifications. Collections of fossil plants made by Mr. Cannon and the writer in various horizons of this series have been provisionally identified by L. F. Ward and F. H. Knowlton. From these data it can be said that out of about 35 well defined species more than 20 are known in the Denver beds of Table Mountain, at Golden, a closer correspondence of floras than is shown with any other horizon. Until the investigation of the Laramie flora now in progress has been completed it is useless to enter into more definite comparisons.

The so-called Laramie beds of Middle Park seem from the foregoing facts to be the equivalent of the Denver beds. No strata corresponding to either the Arapahoe or Laramie proper are known in Middle Park, and the invertebrates collected by Mr. Cannon indicate that the upper part of the Montana is also wanting in the vicinity of Hot Sulphur Springs. Present information gives little ground for an estimate of the extent to which the missing formations were once developed in this region.

Age of the Lake-bed Deposits.

The facts of stratigraphy and lithology which have been recited show that in Colorado the great conformable series of Cretaceous formations ended with the coal-bearing Laramie strata. Deposition plainly ceased in this area because continental elevation, which had long been in progress, finally caused the retreat of the Laramie seas. The magnitude of this elevation, the time interval involved, and the question as to the identity of this particular movement with the great movement generally supposed to mark the ending of Mesozoic time in the Rocky Mountain area, are clearly problems of great importance. Confining discussion at present to the indisputable evidence of the deposits described, it is clear that when sedimentation began again in the region concerned it was in comparatively small seas or lakes. In the pebbles of the Arapahoe, Cañon City, and Ohio Creek beds, is found proof that adjacent landmasses consisted in part of upturned sedimentary rocks, and in the first named is the record of the

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* Monographs of the Hayden Survey, vol. vi, Tertiary Flora.

slow erosion of 14,000 feet of strata, from the Laramie down to the "Red beds" of the Trias.*

Succeeding the first period of lake-beds came a time of great volcanic outbursts over a very large area. The length of geologic time occupied may not have been very great, but the extent of country in which eruptions occurred at this time, and the great variety of lavas found in the Denver and Middle Park beds, argue for the decided importance of the event as a dynamic manifestation. The position of the Middle Park beds on the edges of the Cretaceous section below the Ft. Pierre, proves a period of erosion there which was no doubt contemporary with the Arapahoe epoch though its record is not known in deposits. Marvine assigns a thickness of over 6000 feet to the Middle Park beds (including the "breccia"), characterized through the lower half at least by volcanic material,—striking testimony to the extent of the eruptions and the duration of the period of deposition, which must have been one of subsidence, approximately equalling the thickness of beds deposited.

The question as to the age of the formations under discussion is the question as to the length and importance of the periods in which the events clearly recorded in their sediments took place. From the standpoint of structural and physical geology an adequate chronology will distinguish or separate this period from that of the coal-bearing Laramie; but according to the principles of geology the measure of the geologic time involved is to be sought in the fossils,—in a comparison of the life of the two periods which are to be distinguished. But at the very outset of such an attempt it becomes evident that a very large number of fossils said to occur "in the Laramie" are not at present available for such a purpose. This difficulty arises chiefly from the fact that the stratigraphical position of the beds of many localities where "Laramie" fossils have been found has not been at all clearly determined.

In their recent discussions of orographic movements Messrs. Emmons and Hills have treated the post-Laramie disturbance as that closing Cretaceous time. The former says: "With the exception of the great unconformity between the Archæan

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* The lithological evidence upon which the distinction of the local formations above mentioned has been largely made will probably make little impression upon some readers. It is a striking fact in many observations of the past and of the present in the western region, that the material constitution of coarse grained sandstones and conglomerates has been and is now practically ignored. But if a conglomerate in the apparently conformable Cretaceous section contains pebbles of Niobrara limestones, of the extremely characteristic Dakota conglomerate, of red Jurassic or Triassic sandstone, or of Carboniferous chert, a definite unconformity of great magnitude is made known which does not require proof in visible angular unconformity or in the fossils, though the latter undoubtedly will confirm it when they are known in sufficient detail.

and all overlying sediments, . . . no movement has left such definite evidence as that which followed the deposition of the coal-bearing rocks, to which the name Laramie has by universal consent been applied."* And while Mr. Hills thinks that some of the effects hitherto ascribed to the post-Laramie movement belong to that following the Bridger Eocene, his conclusion in regard to the Arapahoe, Denver and equivalent beds, is as follows: "From all the evidence available it appears that stratigraphically these beds are not Laramie, since to refer them to the Cretaceous would bring us face to face with the necessity of conceding an earlier date than post-Cretaceous to the Rocky Mountain revolution. Nor are they, paleontologically, a part of the recognized Eocene. Whence we must conclude that they are not assignable to either of these terranes, but should be regarded as transition beds deposited subsequent to the beginning of the post-Cretaceous movement, or probably during its progress and hence of post-Laramie age."†

The Denver beds contain a very large and well preserved fossil flora. So do the coal-measures of the Laramie in the same field, and more than 160 species have been described from this district by Lesquereux.‡ It has already been shown§ in describing the Denver beds that from the statements of this author only a very small percentage of the described species can be definitely assigned to one of the two plant-bearing horizons, nor is the desired information to be found on the labels or in the catalogue of the National Museum where the original specimens are now deposited. Examination has also shown a lamentable inaccuracy in designation of localities for the fossil plants of various other localities assigned to the Laramie. This is true especially of the plants from the Middle Park beds, as has been mentioned. The existing confusion is so great that no credible table can now be constructed from published data to show, excepting in a most general way, whether there is or is not a noteworthy difference between the known flora of the Denver and Middle Park beds and that of the Laramie proper. But on the basis of new and extensive collections from known horizons a thorough revision of this portion of the Laramie flora is now in progress in the paleobotanical department of the Geological Survey. Until the results of this revision can be made public a discussion of the

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* Orographic movements in the Rocky Mountains, Bull. G. S. A., I, p 285, 1890.

† Orographic and structural features of Rocky Mountain geology, Proc. Colo. Sci. Soc, vol. iii, Part III, p. 397.

‡ Monographs of the Hayden Survey: vol. vii, "The Tertiary Flora;" vol. viii, "The Cretaceous and Tertiary Floras;" also, Bull. Mus. Comp. Zool, Harvard College, vol. xvi, No. 3, 1888.

§ This Journal, vol. xxxvii, p. 272, 1889.

bearing of fossil plants in determining the age of the Denver and allied deposits is useless.

The few invertebrate fossils found in the Denver beds are, according to Dr. C. A. White,* of no special value in the present case. *Viviparus trochiformis* and *Goniobasis tenuicarinata* are the only specifically identifiable forms as yet known, while imperfect forms referable to *Corbicula*, *Physa*, and *Unio* accompany them.

The vertebrate fauna known from the Denver and Arapahoe beds is small, but its character is such as to raise some very broad questions for settlement before its value for purposes of detailed correlation can be determined. At the time the Denver and Arapahoe formations were described a considerable number of fossil bones had been found, and since that time additional material has been obtained by Mr. G. L. Cannon, Jr. All the material collected has been examined by Professor O. C. Marsh, who identifies fragments of turtles, crocodiles, and dinosaurs.† Only the latter are of especially recognized importance in this case. They belong for the most part to the remarkable new family, the Ceratopsidæ, of which so many wonderful forms have been described within the last three years, and it is necessary at this point to pass in review certain phases of the discoveries made by Professor Marsh, and the facts stated in the publications concerning them.

In a series of articles in the American Journal of Science beginning December, 1888, Prof. Marsh has described a wonderful new fauna said to occur in the Laramie of Montana, Wyoming and Colorado, the two most important elements of which are a group of horned Dinosaurs forming a new suborder, the Ceratopsia, and a large number of small mammals. The new Dinosaurs are closely related to Stegosaurus in many features of the skeleton, but the skull and dermal armor have become strangely modified and possess marked characteristics "not before seen in the Dinosauria." With the exception of a few isolated bones and teeth mentioned by Cope the mammalian fauna associated with these Dinosaurs is the first to be discovered in the American Cretaceous, and is closely allied to that known in the Jura, and widely different from that characterizing the Wasatch Eocene.‡

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* Cited in article describing the Denver Formation, this Journal, vol. xxxvii, p. 275.

† The fossil from the Denver beds originally described by Professor Marsh as *Bison alticornis* is now regarded by him as belonging to Ceratops (this Journal, xxxviii, 174, 1889).

‡ The writer wishes to acknowledge the courtesy and kindness of Professor Marsh in showing him a large number of the remarkable and important forms which have been found in the Ceratops beds, and in explaining the great problems they present to the evolutionist, together with their apparent bearing upon questions of historical geology.

In attempting to correlate the new formations of the Denver field by means of their vertebrate fossils it is necessary to know the horizon or horizons which have furnished the large new fauna recently described. A review of the papers published by Prof. Marsh shows, however, that except for fossils which came from the Denver region no detailed evidence is given as to the stratigraphical or geographical position of beds containing any of the fossils described. There are only the general statements that they "come from the typical Laramie of Wyoming" or "of Montana." All localities are correlated as belonging to one general horizon, "the Ceratops beds," and the assertion is made that: "This horizon is as strongly marked as that of the Atlantosaurus beds, and has now been traced for nearly eight hundred miles along the eastern base of the Rocky Mountains." And as to stratigraphical relation to lower beds, "Toward the north, it is underlaid by marine Cretaceous strata containing Fox Hill fossils, but farther south, various older formations are found immediately beneath it."* It certainly seems natural and it may almost be said probable that such a new and specialized group of animals should characterize a well marked geological horizon. But as far as the actual position of the Ceratops beds has been described, namely, in the Denver region, they are separated from the normal Laramie by a great unconformity, and it remains to be demonstrated that the new forms occur at all in the Laramie proper. It is believed to be a fact that in all the great Laramie formation of Colorado, where it has been studied more thoroughly and connectedly than anywhere else, no representatives of the Ceratopsidæ have been found; and that the same is true of the adjacent connected deposits in New Mexico and Utah. None of the species described by Prof. Marsh has been stated to come from the Laramie coal-measures of southern Wyoming, but it seems probable that the historic Dinosaur called *Agathaumas* by Cope, the discovery of which at Black Butte in 1872 played such an important part in deciding opinion as to the Cretaceous age of the Laramie, may prove to be of importance in the present discussion also. It is now thought by both Cope† and Marsh‡ that this form is a horned Dinosaur. If this is true the Ceratopsidæ are represented to the west of the Front range in what have been called typical Laramie strata by some authors. But it happens that the Black Butte locality is one concerning which geologists have differed considerably in their observations and opinions. A

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*This Journal, vol. xlii, p. 338, 1891.

†Amer. Naturalist, xxiii, p. 715, 1889.

‡This Journal, xliii, p. 83, 1892.

succession of several thousand feet of strata in this region has been referred to the Laramie, but Major Powell claims to have found an important physical break below the horizon containing the *Agathaumas*, as he expressly states,* and if this is true this Dinosaur may actually occur here in strata contemporaneous in time with the Arapahoe beds. In any case it remains to be proven that the "Ceratops beds" of Marsh, from the "eastern base of the Rocky Mountains" are stratigraphical equivalents of the horizon at Black Butte in which the *Agathaumas* was found.

This brings us to the questions: On what ground does Prof. Marsh assign the Ceratops beds to the Laramie? and, What does the Laramie properly embrace? The assignment rests, as far as published evidence goes, on the presence of a new fauna of strong Mesozoic affinities, in beds more recent than the Fox Hills, and unknown, with the possible exception noted above, in strata known to occupy the stratigraphical position assigned to the Laramie in its original definition. The general statement of Prof. Marsh that the Ceratopsidæ he has described "are found in the typical Laramie of Wyoming" is misleading in this sense, that, to any one acquainted with the literature of the subject, "the typical Laramie of Wyoming" must always be that formation in southwestern Wyoming to which Mr. Clarence King first applied the name, or its demonstrated equivalent. And it seems opportune to quote here the definition of the Laramie given by that author. After explaining, that on consultation with Hayden and without compromising differences of opinion as to the age of the beds in question, a common name had been adopted, he says: "Accordingly . . . it was amicably agreed between us [Hayden and King] that this series should receive the group name of Laramie, and that it should be held to include that series of beds which conformably overlies the Fox Hills." † Experience since this definition was set up has shown that over a very large area there is a great and important formation to which that definition strictly applies. And evidence continually accumulates to prove that this formation, which certainly must be called the Laramie, was the last of the series of conformable deposits belonging to the Cretaceous.

Returning to the question as to the evidence concerning the stratigraphical position of the "Ceratops beds," it is to be noted that in Montana and Wyoming they are said to occur on the eastern flank of the Rocky Mountains, in a district which

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* Geology of the Uinta Mountains. p. 72.

† Final reports of the Fortieth Parallel Survey, vol. i, Systematic Geology, p. 331.

has not been carefully explored as yet except for vertebrate fossils. And marked angular unconformity at the base of these beds might not be distinguishable if the shore line was too far removed from the localities examined. But even the general statement of Prof. Marsh seems to indicate a great actual unconformity, for he says, in the sentence quoted above, that, in some places not specified, "various older formations are found immediately beneath it" (i. e. the Ceratops horizon, called "the typical Laramie"). As invertebrates and plants are stated to be associated with the vertebrate fauna it seems quite necessary that their testimony, as well as all available stratigraphical and lithological details, should be given, before the beds in question can be satisfactorily correlated.

The cited statement of Prof. Marsh that "the Ceratops beds have now been traced nearly eight hundred miles along the eastern flanks of the Rocky Mountains" implies the actual connection of the formations of the Denver field with that containing the new fauna in Wyoming. But the area of the Denver beds is known to be quite limited, and the Arapahoe beds on the plains east of Denver are thin and erosion has entirely removed them in many places, exposing the underlying Laramie. It is, however, possible that they thicken again farther out on the plains, or reappear to the northward beyond the Platte valley. If the investigations of Prof. Marsh have actually connected the Ceratops beds of Wyoming with the Arapahoe beds of Colorado, this fact is of great importance as fixing the stratigraphical position of the Ceratops horizon as post-Laramie. If, however, the Ceratops beds of Wyoming are contemporary with the true Laramie, then they do not belong to the same epoch as the Denver and Arapahoe beds.

The above considerations show that the vertebrate fossils of the Arapahoe and Denver beds cannot at present be used as an argument either for or against the proposed separation of these lake-beds and their equivalents from the Laramie, because the new fauna recently described has not been identified, in published statements at least, in strata satisfactorily identified with the true Laramie on other ground than that of the new fossils themselves. It is clearly suggested by the known evidence that the new family of Dinosaurs may be found to be specially characteristic of the epoch to which the lake-beds described belong, as distinctive from that of the Laramie proper; that their remarkable specialization may have taken place largely as a result of the changed conditions following the great orographic movement closing the Laramie. Until more is known about the distribution of the Ceratopsidæ and their immediate ancestors in the Cretaceous series of formations, they certainly cannot be used as diagnostic fossils for any horizon.

The facts of stratigraphy and lithology demand that the interval between the Laramie and the lake-bed deposits should be recognized as a very important one. The known fossils do not aid us in determining the importance of that interval because their distribution with reference to it is so imperfectly established. Such seems to be the necessary verdict from the examination of the direct evidence available at present. Much collateral testimony might be introduced into this discussion, from observations in remote districts, but it seems undesirable and premature to consider such evidence at this time. Some of the reasons for this conclusion will appear in the more general discussion to follow.

Assuming that the lake-beds described in this article should be separated from the Laramie, the question as to whether they are Tertiary or Cretaceous is quite another problem. It was argued in the article on the Denver beds that the establishment of a profound orographic movement in the period succeeding the Laramie, followed by extensive and long-continued volcanic outbursts, indicated that the deposits of the Arapahoe and Denver epochs should be assigned to the Eocene. This was in harmony with the ideas to be found in all previous speculations as to what actually closed the Cretaceous period. At the time the article in question was written a few bones had been identified by Professor Marsh as belonging to Dinosaurs and other vertebrate forms of Mesozoic types, but the fact that these animals had survived a period of various dynamic disturbances of great magnitude seemed then to indicate that they were straggling survivors into earliest Eocene time rather than that the movement should be placed in the Cretaceous.

The facts presented in this paper make it plain that the discussion of this question involves now a discussion of the broader one as to the character and position of the line to be drawn between Mesozoic and Cenozoic deposits in the Rocky Mountain region, and as to the criteria to be used. And at present there is such a decided conflict between the results reached in applying different criteria that the necessity for more information on many points is clear. In illustration of this necessity a few of the recently expressed opinions upon this subject will be quoted.

Professor Marsh* in a recent publication on the Cretaceous mammalia and their associated vertebrate fossils, occurring in the Ceratops beds—"the Laramie of Wyoming"—says:

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* This Journal, vol. xliii, p. 249, March, 1892.

"These remains are not transitional between Mesozoic and Tertiary forms, but their affinities are with the former beyond a doubt; thus indicating a great faunal break between the time in the Cretaceous when they lived and the earliest known Tertiary, or between the Ceratops horizon and the Coryphodon beds of the Eocene Wasatch. The lower division of the Coryphodon beds, or lower Wasatch (Puerco), is clearly Tertiary, and the great break is between this horizon and the Ceratops beds of the Laramie." Concerning the abundant faunas of the two horizons, "the more the two are compared the stronger becomes the contrast between them. Instead of placing them close together, as some geologists seem inclined to do, it will be more profitable in future to search for the great series of intervening strata containing the forms that lead from one to the other." "Bearing in mind all that is known to-day of the development and succession of vertebrate life in America, from the early Silurian on to the present time, it is safe to say that the faunal break as now known between the Laramie and the lower Wasatch is far more profound than would be the case if the entire Jurassic and the Cretaceous below the Laramie were wanting."*

Professor E. D. Cope† in his "Synopsis of the Vertebrate Fauna of the Puerco series" (1888) considers the Puerco fauna as widely distinct from that of the Wasatch, and points out that among 106 species of vertebrates known from the Puerco not one is found either in the Wasatch or in the Laramie; that some important Mesozoic types end in the Puerco; that "two orders universally present in the Eocenes, the Perissodactyla and the Rodentia, are wanting from the Puerco"; and that many Puerco forms are plainly the ancestors of Eocene types. Shortly before this publication Professor Cope‡ had assigned the Puerco and Laramie to the "Post-Cretaceous" as expressing their relationship better than to class one with the Eocene and the other with the Cretaceous. It is worthy of note that the Puerco was assigned to the Eocene by Professor Cope§ as recently as 1883.

Professor Marsh refers the Puerco to the lower Wasatch=

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*Since the completion of this article Prof. Marsh has announced the presence of Ophidians and true Lacertilians with the gigantic dinosaurs of the Ceratops beds, "in the Laramie of Wyoming." No serpents have hitherto been found in America below the Eocene. (Notice of new reptiles from the Laramie Formation. This Journal, vol. xliii, p. 449, May, 1892.)

† Trans. Am. Phil. Soc., vol. xvi, pp. 298–361.

‡ The Relations of the Puerco and Laramie Deposits. Amer. Naturalist, vol. ix, p. 985, 1885. The Mesozoic and Cænozoic Realms of the Interior of North America. Ibid, vol. xxi, p. 445, 1887.

§ Monographs of the Hayden Survey, III, Tertiary Vertebrata, Book I, p. 4, 1883.

Lower Coryphodon beds, but Professor Cope says, in 1883: "Coryphodon is, so far, unknown," and in his last synopsis of the Puerco fauna (loc. cit.) he does not include that form.

Regarding the first mammalia described by Prof. Marsh "from the Laramie" Prof. Cope* has said: "These species are of identical character with the Puerco mammals, although there is no species identical with any in the Puerco, where there is not a single Cretaceous reptile. The mammals of the Laramie are, like the saurians, rather Cretaceous than Tertiary; but the character is not as pronounced."

The question as to the relations of the Laramie to the Eocene has recently been reviewed by Dr. C. A. White in the Correlation Essay on the Cretaceous prepared for the Fifth International Congress of Geologists,† and with the result that the Laramie "is held to represent both the close of the Cretaceous and the beginning of Tertiary time," with a probability that in certain known areas there has been continuous sedimentation from the coal-bearing Laramie through to the Wasatch Eocene or it equivalents. The molluscan fauna is said to favor such a conclusion.

Prof. J. S. Newberry ‡ has recently expressed the decided opinion that the diverse views of geologists concerning the Laramie have in large part "arisen from the fact that many writers on the subject have combined two distinct formations in the Laramie and have called them one, when they have almost nothing common, belong to different geological systems, and should never have been united." He then assigns the Fort Union beds of Montana to the Eocene, and the remainder of what has been called Laramie to the Cretaceous, asserting that the floras of the two "are totally distinct."

In discussing this paper Prof. L. F. Ward claimed that the Ft. Union flora was not absolutely distinct from that of the Laramie though very different, and that it might well be considered as Cretaceous.

Prof. Marsh states§ that "the Ft. Union Eocene beds on the Upper Missouri" rest immediately upon the "Ceratops beds." It would be interesting to know the flora of the "Ceratops beds" and the vertebrate fauna of the "Ft. Union beds" in this region. Prof. Cope has published a "Description of some vertebrate remains from the Ft. Union beds of Montana,"‖

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* Bull. Geol. Soc. of Am., vol. i, p. 532 (Dec. 1890). In discussion of a paper by J. S. Newberry, The Laramie Group.

† Correlation Papers. The Cretaceous, Bull. 82, U. S. Geological Survey, 1891. Compare pp. 262.

‡ The Laramie Group, Bull. Geol. Soc. of Am., vol. i, p. 524.

§ This Journal, xlii. p. 336.

‖ Proc. Acad. of Nat. Sci. of Phila., vol. xxviii, p. 248, 1876.

but without any statement of locality or stratigraphical data, so that his paper stands rather as an illustration of the common manner in which uncertainty and confusion have been introduced into the literature of the Laramie, rather than as evidence that Dinosaurs occur in beds containing the Ft. Union flora.

From these recent expressions of opinion concerning the Laramie in its comprehensive sense and of the period of time between the marine Cretaceous and the Puerco or lower Eocene, it is clear that paleontologists have sought to correlate the formation and characterize the period from the evidence of the flora or of a particular fauna. In some cases at least the opinion has been rendered upon biological grounds alone, and has been announced with great confidence, often with but the slightest reference to the results reached upon other paleontological evidence or to contrary opinions from the same evidence, with little regard for known facts of stratigraphy, and still less for the very important fact of utter ignorance concerning the actual relationships of some of the places, horizons, and faunas or floras dogmatically correlated. This variance of opinion is a natural result of the methods used, yet no one will dissent from the proposition that a correct knowledge of the history of this interesting period cannot be reached until all classes of evidence are carefully compared on a basis of unbiased and accurate observations in all directions.

The facts brought together in this paper point to one important epoch in the period under discussion which has not been duly recognized, to say the least. Its broad intrinsic importance has yet to be determined, and the writer wishes to distinctly express his appreciation of the fact that that importance must ultimately be measured in great degree through the effect exercised by the conditions of that epoch upon the life of the time. But the great importance of the orographic movement which has been identified, in relation to the physical history of a very large district, must also be borne in mind.

In conclusion, the writer wishes to advocate the restriction of the term Laramie, in accordance with its original definition, to the series of conformable beds succeeding the marine Montana Cretaceous, and the grouping of the post-Laramie lake-beds described, with their demonstrated equivalents, in another series to which a comprehensive name shall eventually be given. This course has already been proposed by Mr. Hills in his conclusion which has been cited (p. 33). The question as to whether the series shall be referred to the Cretaceous or to the Eocene cannot be finally settled until the various conflicting elements of the evidence have been adjusted on a basis of further and more exact information. But even if we assume that the lake-beds are Cretaceous, there remains a sufficient argument for restricting the scope of the term Laramie in the fact that to include the two or three series of deposits, with the long intervals between them, under one group name would make the latter unduly comprehensive and important in the scale of Cretaceous sub-divisions.*

ART. IV.—*On the Alkali-Metal Pentahalides;* by H. L. WELLS and H. L. WHEELER *With their Crystallography;* by S. L. PENFIELD.

IN the course of our investigations on the alkaline trihalides,† the compounds $CsCl . Cl_3I$, $RbCl . Cl_3I$ and $KCl . Cl_3I$ were encountered. The potassium compound had been described many years ago by Filhol.‡ This investigator prepared also the body $NH_4Cl . Cl_3I$ and obtained a similar magnesium compound, probably $MgCl_2 . 2Cl_3I . 5H_2O$. He failed in his attempts to make analogous compounds with sodium and a considerable number of the other common metals.

It was evident from the peculiar behavior of cæsium tribromide and triiodide, mention of which was made in one of our previous articles,§ that a still higher bromide and iodide existed. These have now been identified as pentahalides.

In addition to these bodies we have prepared the sodium and lithium analogues of Filhol's salt. They differ from all the other polyhalides that we have studied in containing water of crystallization.

A large number of other alkaline pentahalides are theoretically possible, but, although we have made numerous experiments with the view of making the most promising of these,

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* Canadian geologists have long recognized several important divisions in what they have called the Laramie. As their divisions cannot be accurately correlated as yet with those in the United States, owing to the very meagre information concerning the great complex of supposed Laramie strata in Montana, the writer has avoided a consideration of those points in this paper. It seems not unlikely that the divisions of the group made on combined stratigraphical and paleontological grounds in Canada will agree with those to be reached finally in this country. The "Edmonton" and "St. Mary River" beds seem to correspond to the Laramie proper, and the "Paskapoo" and "Porcupine Hills" beds to the Fort Union, but it is less clear that their "Willow Creek" or Middle Laramie of certain areas is equivalent to the post-Laramie lake-beds here described. "The uplifting of the Rock Mountains" is said by Mr. J. B. Tyrrell to have taken place "at the close of the Edmonton period." (Report on a part of Northern Alberta, p. 137, Ann. Rep. Geol. and Nat. Hist. Survey of Canada for 1886).

† This Journal, III, xliii, 17 and 475.

‡ J. Pharm., xxv (1839), 431.

§ This Journal, III, xliii, pp. 24 and 27.

we have been unable to prepare them. It may be stated that special efforts were made to obtain potassium and rubidium pentaiodides.

CsI_5.

This is produced, in an impure state as a black liquid solidifying at about 73°, by treating cæsium triiodide with hot water and also by treating solid iodine with a hot solution of cæsium iodide. Artificial mixtures of cæsium triiodide and iodine, representing compositions varying from CsI_4 to CsI_9, all melt at a uniform temperature of about 73°. It is evident from this that the composition of the black liquid cannot be determined from its melting-point.

Cæsium triiodide, which is readily soluble in alcohol, becomes much more soluble in that liquid in the presence of two atoms of iodine to the molecule. A very concentrated solution of this kind gives crystals of the pentaiodide by cooling, but a much better product is obtained by concentration over sulphuric acid, using a slight excess of iodine to allow for loss by volatilization. The crystals are well formed and have a brilliant black color. They can be distinguished from crystals of iodine, which may separate if too much of this substance has been used, by their brittleness as well as their form. The substance melts, not sharply, at 73°. It loses iodine on exposure about as rapidly as iodine itself volatilizes. It does not contain water or alcohol.

Samples of the crystals quickly dried with paper gave the following results on analysis :

	Made by cooling.	By evaporation, Separate products.		Calculated for CsI_5.
Cæsium	15·20	20·96	16·02	17·32
Iodine	----	----	----	82·68

$CsBr_5$.

When a concentrated solution of cæsium bromide is shaken up with a large excess of bromine there is no separation of cæsium tribromide, as is the case when the theoretical amount of bromine is used. A large part of the cæsium bromide goes into solution in the liquid bromine, and on taking up a sufficient quantity of cæsium bromide this solution becomes lighter in color than pure bromine.

A solution of cæsium bromide in bromine, made in the manner above indicated, was allowed to evaporate spontaneously at a temperature below 0°. A dark red solid finally separated and it was prepared for analysis by pressing with papers at the same low temperature. After the adhering bromine had been removed the substance gave off bromine-vapor very rapidly.

	Analysis gave	Calculated for $CsBr_5$.
Cæsium	29·93	24·95
Bromine	----	75·05

The analysis corresponds with the formula $CsBr_5$ as well as could be expected considering the great instability of the compound.

$CsCl \cdot Cl_3I$.

This substance can be prepared by dissolving 40 g. of cæsium chloride in a mixture of 600 c.c. of water and 200 c.c. of concentrated hydrochloric acid, adding 30 g. of iodine (one atom), passing chlorine to saturation, meanwhile keeping the solution warm enough to dissolve any of the compound which separates in the form of a yellow precipitate, and finally cooling to crystallization. The hydrochloric acid is used to prevent the simultaneous deposition of an acid cæsium iodate.

	Analysis gave.	Calculated for $CsCl \cdot Cl_3I$.
Cæsium	32·44	33·09
Chlorine	34·79	35·32
Iodine	31·11	31·59

The crystals are of a pale orange color. They are in the form of slender prisms, usually in parallel position forming plate-like groups. The body is sparingly soluble in water and can be recrystallized from it without much decomposition. It is nearly permanent in the air. On heating it is apparently converted into $CsCl \cdot ClI$, for it melts like that substance at 238° (uncorr.) in the open capillary tube.

$RbCl \cdot Cl_3I$.

This body can be conveniently prepared by adding 40 g. of iodine to a nearly saturated solution of 38 g. of rubidium chloride and passing in an excess of chlorine. The solution becomes warm from the reaction, and on cooling large orange-yellow plates are deposited.

	Analysis gave		Calculated for $RbCl \cdot Cl_3I$.
Rubidium	24·12	23·63	24·11
Chlorine	39·00	----	40·05
Iodine	35·31	----	35·83

The compound is soluble in alcohol, unaffected by ether. When rapidly heated in an open capillary tube it melts at 213° (uncorr.) undergoing some decomposition, and becomes completely white at about 270°. These numbers agree quite closely with the melting and whitening points of RbCl . ClI, so that it is evident that there is a loss of two atoms of chlorine before much further decomposition takes place. In view of this fact it is remarkable that, when samples of $RbCl . Cl_3I$ and RbCl . ClI were exposed to the air side by side for three months, the compound containing the greater amount of chlorine was almost completely decomposed while the other remained nearly unchanged. It is therefore probable that $RbCl . Cl_3I$ decomposes at ordinary temperatures by losing Cl_3I as a whole, while by heating another decomposition takes place.

$KCl . Cl_3I$.

This compound, first described by Filhol, has been prepared for the sake of studying its crystalline form. It is easily made by the method which has been given for the corresponding rubidium compound. The crystals obtained by cooling are in the form of very slender needles, but by evaporating the mother-liquor from these at ordinary temperature thicker prisms suitable for measurement can be obtained.

	Analysis gave	Calculated for $KCl . Cl_3I$.
Potassium	11·98	12·66
Chlorine	45·31	46·10
Iodine	42·50	41·23

$NaCl . Cl_3I . 2H_2O$.

To prepare this substance, sodium chloride and iodine in the calculated proportions are mixed with insufficient water to dissolve the sodium chloride even on heating, chlorine is added to saturation at a gentle heat and the liquid is filtered while still warm. The solution on cooling to a low winter temperature gives a crop of slender needles, but better crystals are obtained by evaporation in a desiccator. Some of the latter, quickly dried on paper, gave the following results on analysis:

	Found.	Calculated for $NaCl . Cl_3I . 2H_2O$.
Sodium	7·17	7·01
Chlorine	42·92	43·29
Iodine	38·23	38·71
Water	12·84*	10·97

The water was determined by direct weighing in a calcium chloride tube, the halogens being retained by an ignited mixture of lead oxide and lead chromate.

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* Determined in a separate sample.

The body is rapidly decomposed by exposure. It melts gradually between 70° and 90° and becomes white at about 115°. It is decomposed by strong alcohol and by ether.

$LiCl\,.\,Cl_3I\,.\,4H_2O$.

This was made by adding 60 g. of iodine to a hot saturated solution of 20 g. of lithium chloride in dilute hydrochloric acid, saturating with chlorine and cooling. A large quantity of long, yellow needles was thus obtained. On evaporating the mother-liquor in a desiccator larger prisms were deposited.

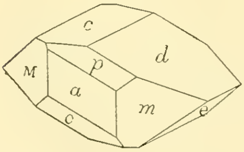
	Analysis gave		Calculated for $LiCl\,.\,Cl_3I\,.\,4H_2O$.
Lithium	2·03	2·16	2·01
Chlorine	39·96	39·94	40·80
Iodine	37·54	36·77	36·49
Water	20·93	----	20·68

On exposure to the air the substance quickly deliquesces, forming a yellow liquid. This gradually loses its color, finally leaving a solution of lithium chloride. The body melts at 70°–80° and becomes white at about 180°. The crystals of this compound were not measured.

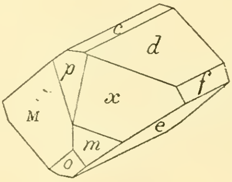
Crystallography.

The crystallization of CsI_5 is triclinic. By slow evaporation of a solution in a desiccator, crystals were obtained which were about 10^{mm} in diameter. Two crops were examined, in one of which the habit shown in fig. 1 prevailed while in the second the crystals were more highly modified like figs. 2 and 3.

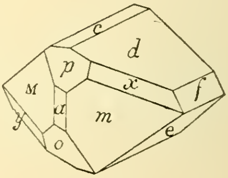
1.



2.



3.



The forms which were observed are:

$a,\ 100,\ i\text{-}\breve{\imath}$	$d,\ 011,\ 1\text{-}\breve{\imath}'$	$o,\ \bar{3}11,\ 3\text{-}\bar{3}'$
$c,\ 001,\ O$	$f,\ 041,\ 4\text{-}\breve{\imath}'$	$x,\ 341,\ -4\text{-}\breve{\tfrac{4}{3}}'$
$m,\ 110,\ I'$	$e,\ 0\bar{2}1,\ 2\text{-}\breve{\imath}$	$y,\ \bar{3}41,\ 4\text{-}\tfrac{4}{3}'$
$M,\ 1\bar{1}0,\ I$	$p,\ 311,\ -3\text{-}\bar{3}'$	

The axial ratio is as follows:

$$\breve{a} : \bar{b} : c' = 0·9890 : 1 : 0·42765$$

$$\alpha = 96°\ 56' \qquad \beta = 89°\ 55\tfrac{1}{2}' \qquad \gamma = 90°\ 21\tfrac{1}{2}'$$

The crystals gave good reflections of the signal on the goniometer. In the following tables the measurements which were chosen as fundamental are indicated by an asterisk.

		Measured.	Calculated.			Measured.	Calculated.
$a \wedge c$,	$100 \wedge 001 =$	*90° 2′		$c \wedge m$,	$001 \wedge 110 =$	85° 8′	85° 9′
$m \wedge M$,	$110 \wedge 1\bar{1}0 =$	*89 47		$c \wedge M$,	$001 \wedge 1\bar{1}0 =$	85 7	85 7½
$a \wedge m$,	$100 \wedge 110 =$	*44 43		$e \wedge m$,	$0\bar{2}1 \wedge \bar{1}\bar{1}0 =$	65 9	65 3
$c \wedge e$,	$001 \wedge 0\bar{2}1 =$	*43 26		$e \wedge M$,	$0\bar{2}1 \wedge 1\bar{1}0 =$	65 8	65 18
$e \wedge d$,	$0\bar{2}1 \wedge 011 =$	*65 25		$d \wedge m$,	$011 \wedge 110 =$	70 3	70 2
$a \wedge M$,	$100 \wedge 1\bar{1}0 =$	45 4	45° 4′	$d \wedge M$,	$011 \wedge \bar{1}10 =$	70 6	70 4
$a \wedge e$,	$100 \wedge 0\bar{2}1 =$	90 6	90 16	$p \wedge m$,	$311 \wedge 110 =$	40 41	40 41
$a \wedge d$,	$100 \wedge 011 =$	89 57	89 54	$f \wedge d$,	$041 \wedge 011 =$	32 30	32 37½
$a \wedge p$,	$100 \wedge 311 =$	41 18	41 19	$x \wedge m$,	$341 \wedge 110 =$	25 46	25 44½
$a \wedge o$,	$\bar{1}00 \wedge \bar{3}11 =$	41 31	41 25	$y \wedge M$,	$\bar{3}41 \wedge \bar{1}10 =$	25 56	25 52

4.

The form of $CsCl . Cl_3I$ is monoclinic. From a number of crystallizations this salt was always obtained in needles, sometimes over 20mm in length and having the habit shown in fig. 4.

The forms which were observed are:

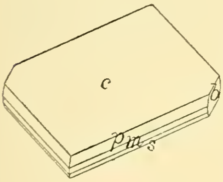
b, 010, *i-ì*
l, 210, $i\text{-}\bar{2}$
p, 212, $-1\text{-}\bar{2}$
q, 211, $-2\text{-}\bar{2}$
s, $\bar{2}11$, $2\text{-}\bar{2}$
d, 041, *4-ĭ*

The axial ratio is as follows:

$$\grave{a} : \bar{b} : \acute{c} = 0{\cdot}9423 : 1 : 0{\cdot}4277,\ \beta = 100 \wedge 001 = 86°\ 20'$$

		Measured.	Calculated.			Measured,	Calculated.
$l \wedge l$,	$210 \wedge 2\bar{1}0 =$	*50° 22′		$l \wedge s$,	$\bar{2}\bar{1}0 \wedge \bar{2}\bar{1}1 =$	28° 35′	28° 34′
$l \wedge p$,	$210 \wedge 212 =$	*44° 51		$p \wedge p$,	$212 \wedge 2\bar{1}2 =$	32° 59	33 2
$p \wedge s$,	$212 \wedge \bar{2}\bar{1}1 =$	*106 35		$p \wedge b$,	$212 \wedge 010 =$	73 31	73 29
$l \wedge q$,	$210 \wedge 211 =$	27 3	27° 7′	$b \wedge d$,	$010 \wedge 041 =$	31 0	30 21

5.



The crystallization of $RbCl . Cl_3I$ is monoclinic. This salt was crystallized a great many times and was always obtained in plates, sometimes over 20mm broad, but seldom 1mm thick. The habit is shown in fig. 5.

The forms which were observed are:

b, 010, *i-ì*
c, 001, *O*
m, 110, *I*
p, 111, −1
s, $\bar{1}11$, 1

The axial ratio is as follows:

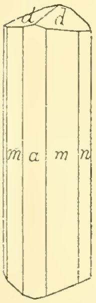
$$\grave{a} : \bar{b} : \acute{c} = 1{\cdot}1390 : 1 : 1{\cdot}975,\ \beta = 100 \wedge 001 = 67°\ 6\tfrac{1}{2}'$$

	Measured.		Measured.	Calculated,
$c \wedge m$, $001 \wedge 110$ =	*74° 26′	$c \wedge s$, $001 \wedge \bar{1}11$ =	82° 12′	82° 15′
$c \wedge p$, $001 \wedge 111$ =	*55 20	$s \wedge m$, $\bar{1}11 \wedge \bar{1}10$ =	23 20	23 19
$p \wedge p$, $111 \wedge 1\bar{1}1$ =	*76 21	$p \wedge m$, $111 \wedge 110$ =	19 5	19 6

With the polarizing microscope the plates show an extinction parallel to their diagonals. In convergent light nothing of the ring system can be seen, but a dark bar crosses the field in the direction of the symmetry plane, indicating that the plane of the optical axes is the clino-pinacoid.

The crystalline habits and axial ratios of $CsCl.Cl_3I$ and $RbCl.Cl_3I$ are wholly different and all attempts to find any similarity or mathematical relation between them has failed. We have endeavored to detect any hidden relation that might exist by examining separate crops of crystals, made from a solution containing both salts. Each form alone and mixtures of both were thus obtained, but no crystals of an intermediate form could be produced. One unmixed crop, having the form and angles of $CsCl.Cl_3I$, contained about sixteen per cent of $RbCl.Cl_3I$, while another, having the form and angles of $RbCl.Cl_3I$, contained about eleven per cent of $CsCl.Cl_3I$. These results show that isomorphous mixtures can be obtained of either form, depending upon which salt predominates, while the absence of any intermediate forms, and the inability to detect any mathematical relation between the two kinds of crystals, leads us to believe that the compounds are dimorphous.

6.



The form of $KCl.Cl_3I$ is monoclinic. This salt was repeatedly made in fine needle-like crystals, too small to measure, by allowing a warm saturated solution to crystallize. By slow evaporation in a desiccator, at ordinary temperatures, stouter prismatic crystals, over 20^{mm} long and 2^{mm} in diameter, were obtained having the habit shown in fig. 6. These gave excellent reflections and were measured without difficulty at winter temperature.

The forms which were observed are :

a, 100, $i\text{-}\bar{\imath}$
m, 110, I
n, 120, $i\text{-}\breve{2}$
d, 023, $\frac{2}{3}\text{-}\breve{\imath}$

The axial ratio is as follows :

$$\breve{a} : \bar{b} : \dot{c} = 0{\cdot}9268 : 1 : 0{\cdot}44725, \ \beta = 100 \wedge 001 = 84^\circ\ 18'$$

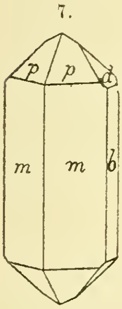
	Measured.		Measured.	Calculated.
$m \wedge m$, $110 \wedge 1\bar{1}0$ =	*85° 22′	$a \wedge d$, $100 \wedge 023$ =	*84° 32′	
$d \wedge d$, $023 \wedge 0\bar{2}3$ =	*33 3	$n \wedge n$, $120 \wedge \bar{1}20$ =	56 58	56° 56′

The positions and crystal symbols which have been adopted for this and the corresponding cæsium salt were chosen to show a similarity in the axial ratios. Both salts are alike in having a prismatic habit, but the forms which occur on each are quite different. If it were not for bringing out this similarity in axial ratios the crystallography of both salts could be simplified somewhat by giving to the dome *d* above the simpler indices 011 and by taking the prism and pyramids of the cæsium salt as belonging to the unit instead of to the macrodiagonal series.

The anhydrous alkali-metal pentahalides do not form a well-defined crystallographic series, yet there are relations between three of them which seem to us to be more than coincidences. The similarity is shown in the following table:

$CsCl.Cl_3I$	Monoclinic	$\grave{a}:\bar{b}:\dot{c} = 0{\cdot}9423 : 1 : 0{\cdot}4277, \quad \beta = 86° \; 20'$
$KCl.Cl_3I$	"	$\grave{a}:\bar{b}:\dot{c} = 0{\cdot}9268 : 1 : 0{\cdot}44725, \quad \beta = 84° \; 18'$
CsI_5	Triclinic	$\breve{a}:\bar{b}:\dot{c} = 0{\cdot}9890 : 1 : 0{\cdot}42765$ $\alpha = 96° \; 56', \; \beta = 89° \; 55\tfrac{1}{2}', \; \gamma = 90° \; 21\tfrac{1}{2}'$

7.



The crystallization of $NaCl.Cl_3I.2H_2O$ is orthorhombic. By slow evaporation of a solution in a desiccator crystals were formed over 10mm in length, having the habit shown in fig. 7.

The forms which were observed are:

b,	010,	*i*-$\breve{i}$	*p*,	111,	1
m,	110,	*I*	*d*,	021,	2-$\breve{i}$

The axial ratio is as follows:

$$\breve{a}:\bar{b}:\dot{c} = 0{\cdot}6745 : 1 : 0{\cdot}5263$$

The crystals were measured at a temperature near 0° C. and gave excellent reflections.

	Measured.		Measured.	Calculated,
$m \wedge m$, $110 \wedge 1\bar{1}0$	$= {}^{*}68° \; 0'$	$m \wedge b$, $110 \wedge 010$	$= 56° \; 0'$	$56° \; 0'$
$m \wedge p$, $110 \wedge 111$	$= {}^{*}46 \quad 44$	$b \wedge d$, $010 \wedge 021$	$= 43 \quad 29$	$43 \quad 32$

Sheffield Scientific School,
April, 1892.

Art. V.—*Fossils in the "Archæan" rocks of Central Piedmont Virginia;* by N. H. Darton, U. S. Geological Survey.

It is my purpose in this paper to announce the discovery of organic remains of Lower Silurian age in the roofing slate at Arvon, Buckingham County, Virginia.

Piedmont Virginia received considerable study from W. B. Rogers in the State Surveys of 1835 to 1840, but I know of no subsequent investigations of its structure. The region contains a great variety of rocks, comprising granites and gneisses in large part, mica schists, chlorite schists, slates, marbles, conglomerates and various basic intrusives. The clastics are considerably metamorphosed and apparently their structure is complicated.

During a recent reconnaissance of the Piedmont plain west of Richmond, in connection with studies of its geomorphology, I found myself near the slate quarries at Arvon, and on visiting them I discovered the organic remains. The locality is on a small branch of Slate River four miles southwest of Bremo Bluff Station on the James River, in the northeastern corner of Buckingham County. The belt is one of several which occur in Piedmont Virginia. The slate is hard and durable and it is extensively quarried for the market. W. B. Rogers refers to these slates in the part on Virginia in Macfarlane's Geological Railway Guide and classifies them as Huronian, but on what grounds is not stated. I did not have time to study the local geologic relations of the slates, but it was noticed that they lie in a closely folded syncline in an altered sandstone which is in turn underlain by a highly altered conglomerate. This conglomerate increases in mass southward and finally gives rise to Willis Mountain, an elevated knob which stands out prominently above the Piedmont plains. The cleavage of the slate dips S. 70° E. $>85°$. The slates are cut by dikes of diabase which have caused some local shattering, and they also contain occasional knots of quartz in which Dr. G. H. Williams recently discovered the mineral anatase.*

The fossils occur in a narrow belt along which the bedding and cleavage coincide. This portion of the quarry is now in greater part buried under debris, but owing to the kindness of Mr. Williams, the superintendent, I was able to secure several slabs. The remains are solely of crinoids and the slabs bear many fragments of various parts of these organisms. The accompanying figures represent the more characteristic forms, faithfully reproduced by Mr. Hunter of the Geological Survey.

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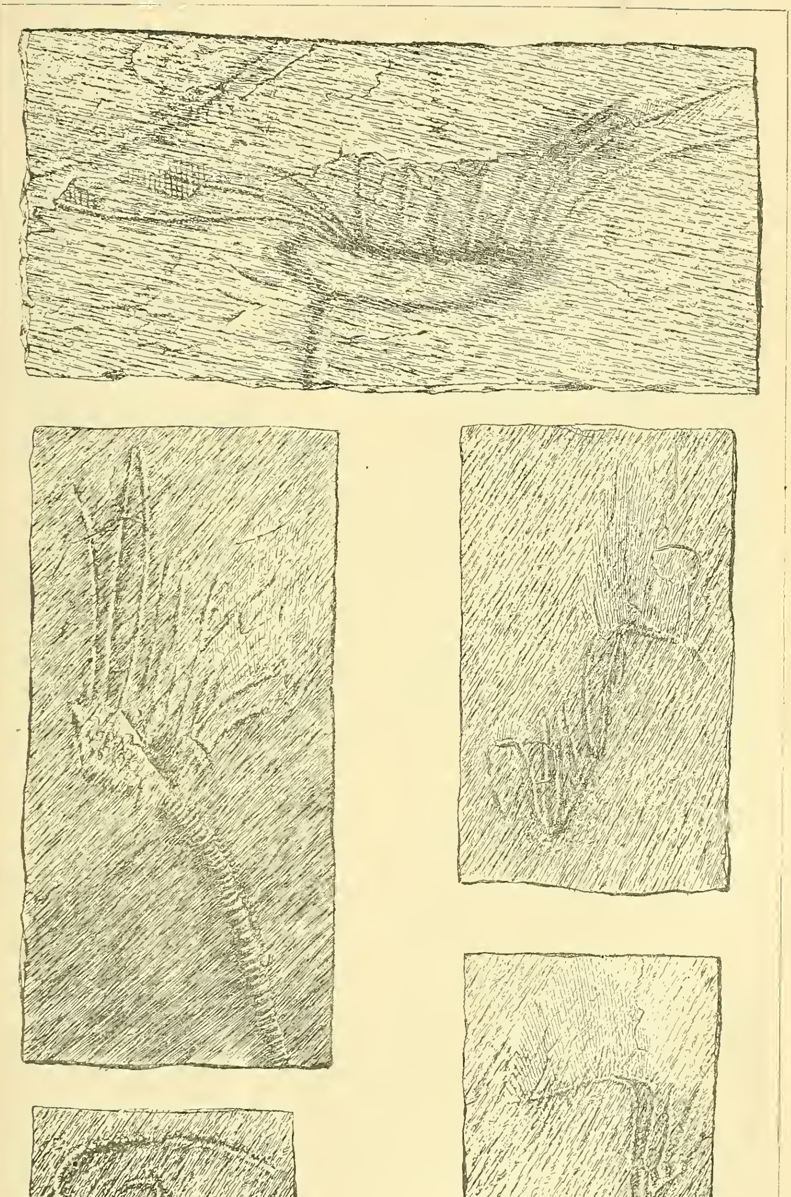
* This Journal, III, vol. xlii, pp. 431, 432.



The slabs were submitted to Mr. C. D. Walcott, who has kindly made the following statement regarding them: "I have studied the specimens of slate showing crinoidal remains and come to the conclusion that they belong to the Trenton-Lorraine or upper portion of the Ordovician fauna. One of the larger columns is closely allied to *Schizocrinus nodosus*, and some of the heads, although indistinct, approach closely to *Heterocrinus* and *Poterocrinus*. If these suggestions are correct, the slates are to be correlated with the Lorraine or Hudson series and in the same horizon with the Peach Bottom slates of Pennsylvania.

The occurrence of fossiliferous beds in the crystalline area of Virginia will greatly aid in the determination of the age and structure of its rocks, and the discovery at Arvon may be regarded as a most fortunate one. There are several other belts of slate in the Piedmont region, notably in Virginia, Maryland and Pennsylvania, and it seems probable that other similar localities may be discovered. I have recently explored one of these belts which comprises the easternmost rock outcrop along the edge of the coastal plain from north of Fredericksburg to a short way beyond the Occoquan River, but without finding fossils. This belt will be designated the "Quantico slates" on the "Fredericksburg" and "Mount Vernon" sheets of the U. S. Geological Survey. Its slates are similar to those of Arvon, but somewhat more altered, and they were at one time worked to some extent for roofing slate, although most of the beds contain more or less pyrite which renders them unserviceable for roofing.

ART. VI.—*Notes on the Cambrian Rocks of Virginia and the Southern Appalachians*; by CHAS. D. WALCOTT.

IN connection with the study of the Cambrian rocks and faunas of North America I made a hurried reconnaissance in the fall of 1891 of the sandstone series of central Virginia. In company with Mr. Bailey Willis and Prof. H. D. Campbell an examination was made of the Balcony Falls section along the line of the James River. It failed to bring to light any traces of organic remains other than the Scolithus that occurs in the massive quartzite below the ferriferous shale at the western end of the gorge. On the following day well preserved specimens of a species of Ptychoparia were discovered in the shale, by the roadside, about a mile south of Natural

Bridge and one-fourth of a mile north of Gilmore, on the James River. Crossing the James to the south side and opposite Gilmore, in company with Mr. Willis, a search was made for fossils in the strata above the Scolithus quartzite of the Balcony Falls section. At a point on a small brook about three-fourths of a mile from the river a calcareous sandstone was found to contain the heads of a species of Olenellus, like *Olenellus Thompsoni*, also *Hyolithes Americanus* and *H. communis.*

The discovery of these two horizons indicates that the 2000 feet of strata beneath the ferriferous shales of the Balcony Falls section are of Lower Cambrian age, and that the shales not far beneath the dolomitic limestones of the Natural Bridge section are also of Cambrian age. The study of the heads of Ptychoparia, found in the latter section, show them to be so closely related to species from the Middle Cambrian beds of Tennessee that it is impossible to correlate the shales with the Upper Cambrian zone. Neither is there sufficient evidence, owing to the great vertical range of the species of Ptychoparia of this type, to correlate the shales with the Middle Cambrian of Tennessee; at present we can only state that they are of Cambrian age, and that the Cambrian section includes the strata from the base of the dolomites, to the Archæan rocks at the base of the Balcony Falls section. It is not improbable that some of the lower portion of the upper massive dolomites may be of Cambrian age.

The Doe River and Nolichucky sections of northeastern Tennessee were next examined. Although no fossils were found in the lower quartzites and argillites, it is evident that these sections may be correlated with the Balcony Falls section of Virginia. In the Doe River section there is a Scolithus sandstone that occurs two thousand feet or more above the base of the section, and the superjacent series of calcareous and shaly beds are usually removed by erosion. The Nolichucky section appears to be a greater development of the same series as that exposed in the Doe River gorge.

In central Tennessee we were joined by Mr. M. R. Campbell and a large collection of Cambrian fossils was made in the vicinity of Rogersville, Tennessee, and many points relating to the stratigraphy of the Cambrian rocks of that region were determined by the finding of typical Cambrian fossils.

West of Cleveland, in East Tennessee, the Olenellus or Lower Cambrian fauna was found near the base of the Knox sandstone of Safford or the Rome sandstone of Hayes. Beneath the sandstone a considerable thickness of limestone occurs and subjacent to this 2000 feet or more of arenaceous and argillaceous shales in which the Olenellus fauna was found. In the central portion of the Rome sandstone series of the Cleveland section, 100 to 200 feet above the Olenellus fauna, a few species of the Middle Cambrian fauna were found, and higher up, in the shales and limestones above the sandstone, an abundant fauna that is now referred to the Middle Cambrian zone. The same succession of faunas was found in the section east from Post Oak Springs, Roane County, Tennessee. The Middle Cambrian fauna of the sandstone and also of the superjacent shales was found in the section ten miles east of Knoxville at Shook's gap through Bay's Mountain where the section is similar to that west of Cleveland. The same sequence of Middle Cambrian faunas was found in the Knox sandstone and the superjacent shales immediately north of Knoxville. Types of this fauna also occur in the Rome sandstone series at Rome, Georgia, and in the limestones and shales of the Coosa series, in Coosa Valley, north and south of Cedar Bluff, Alabama.

After returning from the field and when studying the faunas from the Tennessee and Coosa Valley sections, great doubt arose as to the correctness of placing the Coosa shales beneath the Rome sandstone in the stratigraphic section.*

Dr. Cooper Curtice who had studied the formations of the Coosa Valley, when collecting for the U. S. Geological Survey in 1885, was instructed to re-examine the sections of the Coosa Valley and those to the south, in Alabama. This expedition resulted in the discovery of the Olenellus fauna in the shale in the vicinity of Montevallo, Alabama, and in obtaining evidence showing that the greater portion of the Coosa shales and limestones of the Coosa Valley were above the Rome sandstone series.

The data obtained during the field season enable me to correlate and bring into their proper stratigraphic position the collections that have been made by geologists and for the U. S. Geological Survey from the Cambrian rocks of the Southern Appalachians, and to establish the fact that during Middle Cambrian time there was a great deposition of sediments that now form a series of shales and limestones nearly 3,000 feet in thickness. The Lower Cambrian is represented by the lower portions of the Rome sandstone, the limestone immediately subjacent and the series of variegated arenaceous and argillaceous shales forming the base of the series. A study of the fauna shows that the typical Upper Cambrian fauna of the Adirondack region of New York and the upper Mississippi Valley area of Wisconsin and Minnesota, has not yet been

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* The Overthrust Faults of the Southern Appalachians. Bull. Geol. Soc. America, vol. ii, February, 1891, p. 143, pl. 3; also, Bull. U. S. Geol. Survey, No. 81, 1891, p. 304.

found in the Appalachian region south of New York. In the central eastern Tennessee section the upper limit of the Middle Cambrian fauna is in a shaly band, not fifty feet below the cherty beds of the Knox dolomites which usually have been referred to the Lower Silurian (Ordovician). The recent discovery by Mr. M. R. Campbell of the typical Calciferous fauna of the New York section at an horizon 2000 feet up from the base of the dolomites negatives this reference and indicates that the Upper Cambrian in Tennessee is represented by the lower 2000 feet of the Knox dolomites in the southern portion of the Appalachian trough. In the vicinity of Rutland, Vermont, the upper portion of the Lower Cambrian and all of the Middle and Upper Cambrian, if present, are included in the dolomites and marbles above the "granular quartzite" and it is probable that the lower portion of the great limestone belt of Pennsylvania and Virginia is of Cambrian age.

The sediments of the massive quartzites of the Lower Cambrian that extend from Northern Vermont to Alabama, along the line of the eastern margin of the Cambrian paleo-Appalachian sea were evidently accumulated near the shore. At Balcony Falls, Virginia and Chilhowee Mountain,* Tennessee, the Olenellus fauna occurs in connection with the series, and it appears to be a fair inference that while the sandstones of Chilhowee, etc., were being deposited in the vicinity of the shore line the variegated shales and limestones of the Lower Cambrian were being deposited farther off shore in the sea to the west. This sea was shallow and from the distribution of the Rome sandstone series the inference is that much of the sediment was derived from the west. The close of the epoch in which the coarse sand was deposited along the Virginia portion of the shore was abrupt and the immediately superjacent deposits indicate a deepening of the sea. The Rome sandstone epoch was of relatively short duration although of wide geographic distribution in eastern Tennessee and northern Georgia and Alabama.

The conditions which resulted in the deposition of the Knox dolomites during Upper Cambrian time in the southern portion of the Appalachian trough were probably connected with the orographic movement that gave rise to the more striking phenomena in the northern portion of the Appalachian trough, and affected the deposition of the sediments over the interior of the continent.

In the valley of the St. Lawrence, especially at Point Levis, opposite Quebec, a bed of conglomerate occurs on the south shore of the St. Lawrence below Point Levis and also on the south shore of the Island of Orleans. This conglomerate

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* Bull. U. S. Geol. Survey, No. 81, 1891, p. 302.

includes bowlders of limestone carrying the Lower Cambrian fauna. It is from 1,500 to 2,000 feet below the conglomerate beds of Point Levis, which carry, in the lower beds, large bowlders of limestone in which the Middle and Upper Cambrian faunas occur. By the fossils contained in the matrix of the upper conglomerate series it is known that it is of Lower Ordovician age, and from this it is inferred that the lower conglomerate, carrying the Lower Cambrian fauna, occurs in strata corresponding to the Upper Cambrian zone. The presence of these bowlder conglomerates of Upper Cambrian and Lower Ordovician age proves that an orographic movement occurred in the valley of the St. Lawrence by which the Lower Cambrian and later Cambrian limestones were elevated and formed a portion of the shore line during Middle, late Cambrian and early Ordovician times.

From my recent studies of the Cambrian rocks and faunas over the interior of the continent, I conclude that the continent was depressed during the latter part of Middle Cambrian and the early part of Upper Cambrian times, so that the sea transgressed across the great interior of the continent and deposited the sediments of the interior continental province.

From the preceding statements it appears that toward the close of Middle Cambrian time and during Upper Cambrian time there was a decided continental movement, resulting in the depression of the interior continental plateau, and that this was accompanied by the formation of conglomerates of the older Cambrian rocks in the valley of the St. Lawrence and by a great deposition of sediments of later Cambrian time in the Southern Appalachian region. In a paper soon to be published by Mr. Arthur Keith of the U. S. Geological Survey evidence will be presented of an orographic movement in Eastern Tennessee during this period.

The fauna of later Middle Cambrian time, in Tennessee, Georgia and Alabama, is essentially the same as that of the basal Cambrian deposits about the Adirondack Mountains, the upper Mississippi Valley areas of Wisconsin and Minnesota, those about the Black Hills of Dakota, and the Llano Hills of Texas.

The fauna of the lowest horizon in Wisconsin includes *Hyolithes primordialis*, *Ptychoparia calymenoides*, *Agraulos* (?) *fecundus*, *Crepicephalus onustus*, and *Agraulos Woosteri*. In the next zone above, which is also included in the Middle Cambrian, the following species occur: *Lingula ampla*, *Lingulepis pinnaformis*, *Obolella polita*, *Hyolithes primordialis*, *Pemphigaspis bullata*, *Agnostus sp.*, *Crepicephalus Texanus*, *C. Iowensis*, *Ptychoparia connata*, *P. optatus*, *P.* (*Loncho-*

cephalus) *Chippewensis* = *P.* (*L.*) *minor*, *Amphion matutina*, and *Agraulos thea.*

The line of demarcation between the Upper and Middle Cambrian in Wisconsin is drawn between the beds carrying the preceding fauna and the superjacent strata. These two horizons also occur in the Potsdam sandstone about the Adirondack Mountains and in the Cambrian section of the Llano Hills of Texas.

It was not until after the recent work in the Cambrian of Tennessee, Alabama and Georgia and an extended comparison of the faunas with those of the Upper Mississippi Valley was made, that the line of demarcation between the Middle Cambrian and Upper Cambrian was drawn. The reasons for this will be more fully presented in a memoir now being prepared upon the Middle Cambrian rocks and faunas.

In this preliminary study I had the use of the unpublished geologic maps of eastern Tennessee that have been prepared by the Appalachian Division of the Geological Survey, and Mr. Bailey Willis gave me great assistance by placing at my service his extensive knowledge of the country and its geology. It is anticipated that the work on the Cambrian rocks and fossils will be continued in the Appalachians during the field season of 1892.

Art. VII.—*Synthesis of the minerals Crocoite and Phœnicochroite*; by C. Ludeking, Ph.D.

The synthesis of Crocoite and Phœnicochroite may be accomplished by exposing for several months to the air a solution of lead chromate in caustic potash in a flat dish or plate. It is possible thus to obtain a mixture of the crystals of the two. Without any difficulty whatever the individual crystals can be picked out separately by means of a pincette and obtained in a state for analysis.

The following are the analytical results obtained:

		Found.	Calculated.
Crocoite.	Pb	63·9	64·04 +
	CrO_4	35·2	35·96 —
		99·1	100·00
		Found.	Calculated.
Phœnicochroite.	Pb	71·2	71·43 —
	CrO_4	25·9	26·73 +

It appears therefore from this showing that the chemical composition of the artificial crystals approximates quite closely to the calculated values. Rather strong solutions of caustic potash should be used and much precipitated lead chromate dissolved.

The crystals obtained are rather small, but can readily be studied by means of a lens, or better, a microscope. They show many modifications of the primitive form, as do also the natural crystals.

I was able to obtain by the same method crystals of (2PbO) (H_2O), by exposing to the air for several months a saturated solution of litharge in caustic potash.*

It was intended to produce by this means cerussite. The reaction is of course quite clear. The carbon dioxide of the air acting upon the alkali converts it into carbonate which is not a solvent for PbO. Consequently this latter very slowly separates out as a crystalline hydrate, being slightly soluble itself, a necessary condition for crystallization.

So likewise the solution of $PbCrO_4$ in KOH on exposure to the air yielded crystals of crocoite and of phœnicochroite. The formation of the former is due simply to the slow abstraction of the solvent by the carbon dioxide of the air. The formation of the latter, the phœnicochroite, is on the contrary effected by another reaction, a portion of the chromic acid being appropriated by the KOH. The lead being thus deprived of the normal quantity of chromic acid, a basic compound, phœnicochroite, is formed.

On reflection it seemed that it might be possible to obtain each of these minerals alone instead of in mixture as above.

By using a large excess of very strong solution of KOH, phœnicochroite only was formed, or rather only very little crocoite. When on the contrary much $PbCrO_4$ is dissolved and in addition K_2CrO_4 is added to the KOH solution, crocoite alone is formed. I need not enter upon an explanation of these phenomena as they are almost self-evident. I shall now briefly describe the minerals obtained.

The $PbCrO_4$ crystals are oblique rhombic prisms with many modifications. The fracture is uncertain; luster adamantine; color hyacinth-red. They are stable in the air. The phœnicochroite crystals are tabular, of resinous luster, of cochineal color and appear to be orthorhombic. They, like the natural crystals have but little stability and soon change to a light yellow powder on exposure.

At Beresowsk, crocoite and phœnicochroite are associated. It is not impossible that they were formed also by the action of the carbon dioxide of the air upon an alkaline solution of $PbCrO_4$, as in my first experiment.

* Amer. Chem. Journ., vol. xiii, p. 120.

ART. VIII.—*A Hint with respect to the Origin of Terraces in Glaciated Regions;* by RALPH S. TARR.

THE exact method of formation of terraces in rivers flooded by the melting of the ice sheet, such rivers for instance as the Connecticut, does not appear to be definitely agreed upon by geologists. By some they are supposed to mark recent erosion in a drift-filled valley. That is, the supposition is that the glacially fed rivers were overloaded and actually built up their beds to the height of the higher terraces, and in this extensive deposit the present terraced valley has been carved. The other important theory is that the terraces mark high stages of floods—that they are flood plains at various stages of flooding.

It is not my purpose to enter into the subject in a critical manner and state the reasons *pro* and *con* which have been advanced by the advocates of these theories, but, rather, to record some observations in an entirely different region where the terraces of glaciated regions are being imitated, and where the general conditions are quite similar to those attending the formation of the terraces in glacial regions, as I understand those conditions. I refer to the valley of the Colorado in Central Texas.

The river is here superimposed upon a hard Silurian barrier which is effectually retarding its downcutting although the river is still well above base level. One of the effects of this retardation of development on the region upstream from the barrier is that a temporary base level is produced and the Colorado itself and the side stream are for a certain distance actually building up their beds. The effect of the barrier is thus felt for forty or fifty miles; but above this, the flow is rapid and the river is degrading its channel. Along the entire course the side streams are rapidly at work, and from these two sources much sediment is being furnished. Owing to the many soft beds of Cretaceous, Permian and Carboniferous through which these streams are flowing the amount of sediment supply is very great.

Another point of importance in this connection is the peculiarity of rainfall. The immediate region is sub-humid, the extreme head waters are in a truly arid region. Consequently, the water supply, during a great part of the year, is small in amount; but heavy rains, which are of annual occurrence, and often of greater frequency, bring to the river vast floods of water which the ordinary channel is totally unable to hold. Almost the entire rainfall has to be carried off; for the barren soil holds but little, and the violence of the rain speedily forms it into rills and rivulets even where no drainage lines previously existed. While this is written chiefly with reference to the arid headwaters it applies almost equally to all the streams, even those in the sub-humid belt. These tributaries during the greater part of the year consist of a few pools, often isolated, sometimes connected by a slowly trickling stream. These pools are enclosed commonly in bars or delta bars in the stream channel, formed during flood times, and the violence of these floods is attested by the presence of drift wood lodged in the pecan trees many feet above the low water stage of the stream. In the Colorado these are sometimes at an elevation of fifty feet above the low water surface.

If I am not mistaken, we have here all the essential conditions which were present at the time of the formation of the terrace deposits at the close of the Glacial period. There is a slope so moderate that the excessive sediment load cannot be transported, and the greatest excess of sediment comes at times of great flood, for the sudden downpour of water upon the arid plains carries along to the streams a vast bulk of sediment. There are, owing to the peculiarities of rainfall, periods of extreme high water and of extreme low water, and also occasional irregular periods of moderate rise. In the glacial regions the south-flowing stream had a moderate slope, probably less slope than at present. Vast quantities of sediment were furnished not alone by the supply from the ice itself but also from the beating of the rains and the washing action of the melting snows upon the barren soil recently uncovered from beneath the ice and as yet unclothed by vegetation. In the summer, excessive floods must have been furnished by the melting of the ice; in the winter the water flow was at a minimum; and in the spring and autumn, when the melting was moderate and somewhat spasmodic, floods of medium height occurred.

The parallel of conditions seems almost exact; let us see how the results coincide. In the Colorado the great floods rise forty and fifty feet and spread out over broad flood-plains on either side, and these flood plains are of fine silt, well stratified. This is the upper flood-plain terrace. In this flood-plain a broad channel is carved, which, in moderate floods, is either partly or completely filled by the water. It is however a double channel, for in it, either on one side or on the other, or even in the middle, there is a smaller channel about half its width and this is the ordinary channel,—the one in which water is always to be found. So, rising from this inner channel, one comes to a terrace which is formed by the moderate floods and which is always present on one side, sometimes on both. It is in general more sandy than the other or upper terrace first mentioned, which is reached by a steep ascent of fifteen or twenty feet.

Nor are these two terraces the only ones. Above the upper flood plain terrace is a third or still higher one which is much less distinct and more irregular and coarser in composition. It is formed by the wash of material from the bordering hill-side and the detritus brought in by the side streams. This, in the case of exceptionally high floods, is partly worked over so as to form an indistinct upper terrace.

I ask any student of the subject if this is not a description which would apply almost equally well to terraces in glacial regions. As I know the terraces of the Connecticut, there are one or two lower terraces sometimes present on one, sometimes on both sides of the river. Above these is a higher, broader, flood plain terrace, often of great breadth, and frequently extending over low divides,—just such a terrace as would be expected from a great flood which the ordinary river was absolutely unable to take care of. Still above this is an upper terrace, irregular in distribution, and in form, often of a coarse nature, and particularly so below the mouths of side streams where it is delta-like in form. This is a terrace comparable, on a larger and more perfectly developed scale, with the uppermost terrace of similar origin in the Colorado.

When I saw the terraces of the Colorado two years ago I was immediately impressed with the resemblance to the terraces of the Connecticut both in form and in cause, the difference being only in the source of the floods. Later I have examined the Connecticut terraces in Massachusetts with this resemblance in mind and it is so striking that I desire to put it on record, and to call attention to the fact that terraces are being formed on a smaller though not by any means an insignificant scale, which imitate the terraces of glacial regions in form and in general cause. In the one case the floods and sediment supply arise chiefly from the climatic accident of desiccation, while in the other they are the result of glacial accident. Otherwise the resemblance seems to be quite perfect.

ART. IX.—*On the Occurrence of a Quartz Bowlder in the Sharon Coal of Northeastern Ohio;* by EDWARD ORTON.

IT is well known that bowlders, ranging in size from a few cubic inches to several cubic feet, are occasionally met with in coal seams, buried partially or entirely in the substance of the coal. Facts of this sort have been reported both in this country and in England. The State of Ohio has furnished the largest number, if not all, of the cases reported in this country. In England, Mark Stirrup, Esq., Hon. Secretary of the Manchester Geological Society, has reported in the Transactions of this Society a number of such occurrences, all derived from mines in the neighborhood of Manchester.

The Ohio examples that have been hitherto put on record are without exception, so far as my observation goes, composed of gray quartzite, presenting the appearance of pretty thoroughly metamorphosed sandstones. By correspondence and comparison of specimens with Mr. Stirrup, I learn that the English bowlders of the coal agree very closely with ours in composition and general character.

All of these bowlders are well rounded and some that I have seen show remarkably smooth surfaces which suggest the polish due to glacier action rather than the abrading agency of water in motion. They are always partially covered with closely adhering coal, which shows more or less of the striated structure known as *slickensides.*

The Ohio bowlders have all been derived from a single coal seam, viz: the Middle Kittanning seam of our scale, and thus far, only from the western boundary of this seam, in Perry and Vinton counties. Furthermore, a single mine in the last named county, viz: the main mine at Zaleski, has furnished thus far all the specimens. According to the testimony of the superintendent and miners, scores of these bowlders have sometimes been found in working out a single room. The first example in Ohio was recorded by the late Prof. E. B. Andrews (Geol. Survey of Ohio, Rept. of Progress, 1870, p. 78.) This bowlder came from the mine named above.

By far the largest of this class of bowlders thus far known was found buried in the coal of the same seams at Shawnee, Perry Co., in 1876. The seam was normal above it and also below. The weight of this bowlder is not less than 400 lbs. It is preserved in the geological museum of the State University at Columbus.

A new example of these bowlders of the coal has lately been brought to light that differs so much from the examples previously reported that it deserves brief mention. It was found in the Marshall Mine of Mineral Ridge, Mahoning county, by Mr. F. C. Goff, of Cleveland, who is extensively engaged in mining and shipping coal, and it was removed from its bed by his own hands. The thickness of the coal seam is three feet and the bowlder lay two feet below the top. The seam was in no wise disturbed in its structure by the presence of the bowlder. The weight of the block in its present condition, after the removal of a few small fragments, is 10 lbs. 10 oz. It measures about eight inches in its longest dimension. The coal is very closely welded to it over part of its surface and it shows the usual *slickensided* appearance.

The noteworthy points in regard to this bowlder are the following, viz: (1) It is the first so far as I know that has been reported from this coal seam, viz: the Sharon Seam or the lowest coal of the Conglomerate Coal Measures of Pennsylvania and Ohio. (2) It is not a metamorphic sandstone or quartzite, like those previously named, but is an excellent example of vein quartz. (3) It has not been worn or shaped in any way by either water or glacial action, but is angular as if freshly broken from the parent mass.

No full and satisfactory explanation of this line of facts has yet been advanced. The quartzite above named could perhaps be accounted for without referring them in origin to the metamorphic rocks of the older regions of the continent. May not an ordinary sandstone pebble or bowlder of the Coal Measures have been converted into a quartzite by the solution of a portion of its silica through the agency of the organic acids that accompanied the formation of coal. But like the white quartz pebbles of the great Sharon Conglomerate that underlies this coal seam, the bowlder here described must be referred to the ledges of the eastern or northern mountain borders of the continent as it then existed. The pebbles of the conglomerate never exceed a few ounces in weight and their rounded forms and smooth surfaces bear witness to an immense amount of abrasion before they reached their present resting places; but the bowlder in question, with its weight of 11 lbs. and its sharp and unworn edges and with its anomalous location, certainly shows a very different history.

Columbus, Ohio, May 13th, 1892.

Art. X.—*A Method of Increasing the Range of the Capillary Electrometer;* by John Whitmore.

[Contributions from the Sloane Physical Laboratory of Yale College.]

The value of the capillary electrometer as an instrument of scientific research is now generally recognized, and its applications are becoming more numerous, both as an extremely delicate test for small electromotive forces and also, as recently pointed out by Burch,* as a means of studying variations of differences of potential. In view of these facts it is desirable that the range of this instrument be increased.

The characteristic curve of Lippmann's electrometer is slightly different from a straight line for electromotive forces from 0·00 to 0·45 volt, and consequently the instrument is most applicable to the measurement of potential-differences not exceeding 0·50 volt, although the direct measurements may be carried to about 1·00 volt, since 1·20 volts are required to produce continuous electrolysis in the instrument. The following experiments were undertaken in order to determine, if the range of the electrometer could be increased by arranging cells in series.

If a capillary tube is filled with alternate globules of mercury and dilute sulphuric acid, the difference of potential which can be maintained between the extremities of the series increases proportionally with the number of globules of mercury. Thus with three globules, this difference of potential is about three volts. If the terminals of the apparatus are connected with the poles of a battery, the globules immediately begin to move along the tube, and the motion continues until the opposing force produced by the polarization of the globules of mercury causes the electric current to cease. The extent of the movement of the globules increases with the electromotive force.

Since the end of each of the globules nearer the negative pole of the system, receives oxygen polarization and the other hydrogen polarization, one surface of the mercury is speedily oxidized. Such an oxidation causes the movement of the globules to become irregular, and prevents an accurate measurement of electromotive force. In Lippmann's electrometer, the surface of the mercury, which receives oxygen polarization, is about ten thousand times greater than that upon which hydrogen is accumulated, and by this means the surface density of the oxygen is diminished in the same ratio, and hence also the oxidation is decreased.

In order, therefore, to obtain a similar relation between the

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* Proc. Roy. Soc. of London, vol. xlviii, p. 89.

surfaces of the mercury, thistle tubes of the following description were prepared. The larger part, by the head of the thistle, had a diameter of about two centimeters, while the stem had a capillary bore of 0·6 millimeter. The tubes were so bent, that each was U-shaped. The lower portion of the tubes was filled with pure mercury, and the upper part with dilute sulphuric acid. The electric connections were so made, that the larger surfaces of the mercury received oxygen polarization.

By reason of the described arrangement, a difference of potential between the terminals of a cell causes the mercury column in the vertical portion of the capillary tube to descend, and this depression is easily measured. Hence cells thus constructed may be used singly as electrometers; and when joined in series, they form a convenient apparatus for the proposed investigation.

As a means of obtaining any desired fraction of the electromotive force of a Daniell cell, a standard box of high resistances and a few Daniell cells were arranged in series. Then the terminals of the electrometer were connected by movable contact pieces to the resistance box so that, as different resistances were inserted between the contact pieces, the electromotive force to which the electrometer was subjected was proportionally varied. During the course of the investigation, curves showing the relation between the deflection and the electromotive force were carefully drawn.

When two electrometer-cells of the form already described, were placed in series, the curve deviated but slightly from a straight line for electromotive forces from 0·0 to 0·9 volt. However as the electromotive force is made to exceed this, the deflections increase more slowly, and the entire curve when plotted was found to be of the well known form described by Lippmann. It is to be noted, however, if curves be drawn for a single cell and for two cells in series, that although the curves have the same form, the electromotive forces corresponding to any portion of the second curve are twice as great as those of the similar portion of the first curve. With three cells in series, the curve did not depart greatly from a straight line, until the difference of potential was about 1·35 volts, then the curve rapidly flattened and reached its maximum at about 2·7 volts.

These experiments show that the electromotive force is cut down by each additional cell, and hence that a series-electrometer may be thus constructed, which will conveniently measure the electromotive force of the single cells ordinarily used in the laboratory.

In order to discover how the total electromotive force, to which the electrometer is subjected, divides itself among the several cells, the difference of potential at the terminals of each of the three cells of a series was measured by means of Thomson's quadrant electrometer. It was thus observed that the potential fell regularly along the series for the lower electromotive forces. For example, when the total difference of potential was 0·9 volt, at the terminals of the first cell it was 0·3, and between the first and second 0·6 volt. The distribution of the potential among the different cells was less uniform after a total electromotive force of 1·2 volts was exceeded. This was possibly due to electrolytic conduction which occurred in the apparatus. Moreover the caliber of each of the capillary tubes was not exactly uniform throughout the entire length of the tube. Thus, these measurements clearly indicate, that with precisely similar cells, the fall of potential in each cell of the series is the same.

It was next sought to put the apparatus in a convenient form. Since it seemed desirable to dispense with the use of the cathetometer in reading the deflections of the mercury columns in order that the reading might be obtained more quickly, experiments were made with cells in which a small electromotive force produced a large deflection of the mercury columns. This is notably the case in the electrometer used by Pratt,* in which the capillary tube is placed nearly horizontal and its inclination, and hence also the sensitiveness of the instrument, can be varied at will. Thus the mercury column can be caused to move over a space of a centimeter for a difference of potential of 0·1 volt, and hence a deflection corresponding to a thousandth of a volt can be easily read directly on a scale placed behind the moving column.

Accordingly three cells of this form were joined in series and a difference of potential was maintained between the terminals of the series. It was found, however, that very often, when the electromotive force was applied, the mercury columns of the three cells, instead of moving together in one direction until the positions of equilibrium were reached, began a remarkable seesawing, the mercury column of one cell advancing while those of the other cells retreated. This balancing continued through a considerable interval of time, since, as the positions of equilibrium were approached the vibrations were very slow. Moreover a given electromotive force at different times caused the mercury columns of the several cells to arrange themselves differently, so that no measurement of electromotive force could be made by observing a single cell of the series. However, when simultaneous readings of the three cells were made, and the curves drawn, though these curves were irregular in form, yet the mean of the three curves was of the normal type.

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* This Journal, vol. xxxv, 1889.

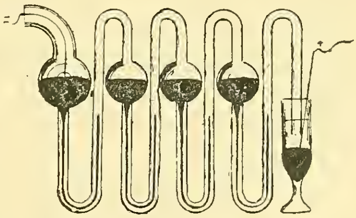
It was learned by means of a series of experiments that this irregular movement was in great measure caused by a difference in the capacity and sensitiveness of the different cells. For when cells of the same capacity were adjusted to the same sensitiveness and joined in series, the columns moved together without seesawing. The difficulty of preparing cells of precisely the same capacity and of adjusting them to the same sensitiveness is a serious objection to the employment of cells of this kind. Hence the electrometer composed of cells in which the movement of the mercury columns takes place in a vertical tube seemed on the whole more advantageous.

Several different forms were tried. One arrangement consisted of three conical tubes each drawn to a very fine bore. These were placed one above the other the capillary stem of each containing mercury and dipping into the acid of the next lower cell. The electrometer in this form is somewhat difficult to fill, and its action uncertain, owing to the formation of bubbles of gas in the capillary tubes.

To cause the movement of the mercury in all the cells to be simultaneous, and of the same extent, as well as to secure compactness and better insulation. the form, represented in fig. 1, was finally adopted.

A series of bulbs was blown, spaced at equal intervals along a capillary tube, the diameter of the bulbs being two centimeters, that of the tube 0·6 of a millimeter. Then the tube was so bent, that the whole contained as many U-shaped parts as there were cells. One arm of each U was provided with a bulb which was situated at a distance of two-thirds the height of the U from the base. The apparatus was easily filled by connecting it with an aspirator and drawing in sufficient pure mercury to half fill each bulb. Then by the same means dilute sulphuric acid was added until the capillary tubes and the upper portion of the bulbs were filled and all air bubbles excluded. Previous to the filling of the instrument, a solution of pure sulphuric acid and distilled water, consisting of four volumes of water to one of acid, was prepared, and allowed to stand until all the bubbles of gas formed by the mixture had disappeared. This was afterwards diluted, if necessary, with distilled water to the proper proportion.

1.



The operation of filling the electrometer was greatly facilitated by having the tube which entered the upper part of the last bulb of the series of much greater caliber than that of the others. In the instrument which was used, this tube had a diameter of about a centimeter, and its extremity was curved so that the terminal portion was at right angles to the vertical portion. Platinum wires were used as electrodes in the usual manner.

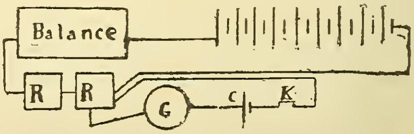
As Lippmann has noted, the electrometer acquires a charge during the operation of filling, and therefore the instrument should be short-circuited for an hour or more before using so that the charge may be wholly dissipated, and the mercury columns stand at their true zero position. After the instrument had been filled in the manner above described, it was firmly mounted and placed on a pier before the cathetometer. Then the curve showing the relation between the deflections was constructed. Thus the deflections of the mercury column for electromotive forces varying from zero to that of three Daniell cells were observed on the cathetometer scale in hundredths of a millimeter, the readings being taken for electromotive forces differing from each other by 0·1 of that of a Daniell cell.

From this curve the absolute value of the electromotive force corresponding to any deflection can be determined by taking the deflection produced by a standard Clark cell as a means of comparison. For example, it was found that the electromotive force of the Clark standard was 1·360 times that of a Daniell cell, and hence the electromotive force of the Daniell cell was 1·051 volts. Accordingly, when the curve, or empirical graduation of the instrument has been made, the voltage of other cells can be obtained immediately and with great facility. The curve gives directly the value of the cell in terms of the Daniell cell, and hence as shown above, the absolute value of the Daniell cell having been determined, that of the cell which was to be measured, is calculated by simple proportion.

It is noteworthy, that not only is this electrometer valuable as a means of quickly comparing low electromotive forces, but that a high degree of accuracy is attainable in this comparison. Thus a number of cells, which had been standing in the laboratory were measured with the capillary electrometer and immediately afterward the absolute values found by the compensation method. This method of measurement is shown in the annexed diagram, fig. 2. Thomson's electric balance gave the value of the strength of current.

The following table exhibits the results of the measurements.

2.



G, Galvanometer. R, R, Resistance Boxes.
C, Cell tested. K, Key.

Cell.	Thomson's Balance Method.	Capillary electrometer.
Silver Chloride	1·020 volts.	1·025 volts.
Dry Cell	1·446 "	1·440 "
Leclanché	1·453 "	1·458 "
Daniell	1·076 "	1·081 "

The deflection produced by the Daniell cell was 2·59^{mm} while the standard Clark cell moved the mercury column 3·20^{mm}.

Thus it is seen, that even with a cathetometer reading only to hundredths of a millimeter and having a telescope of low magnifying power, values correct to one-half of one per cent may be obtained.

The mercury columns of the electrometer move almost instantaneously to the position of equilibrium, and the exactness with which measurements may be made depends chiefly upon the magnifying power of the telescope of the cathetometer, and the precision with which its scale is graduated. It is doubtless possible to determine with this electrometer, the electromotive force of a cell correctly to 0·001 of a volt.

The accuracy with which measurements may be made may be increased somewhat by increasing the number of cells which are used in series. When four cells are employed the part of the curve corresponding to electromotive forces, which are in the neighborhood of 1·5 volts, is very nearly a straight line, and the curve ascends more rapidly than that characteristic of three cells. Hence a change in the deflection produced by a small variation in the electromotive force is more readily observed.

There is another advantage in using more cells than seem to be absolutely necessary. If the electrometer is used repeatedly to measure electromotive forces which are nearly equal to that which produces continuous electrolysis, the curve of the instrument is less constant from day to day, so that if great accuracy is wished for the curve should be redetermined.

If after long continued use it becomes desirable to refill the instrument, it is easily accomplished; since ordinarily the mercury need not be replaced, but can be sufficiently cleansed by drawing some acid of the standard solution through the electrometer by the aid of the aspirator.

The results of this investigation may be briefly stated as follows: The arrangement of capillary cells in series does not alter essentially their behavior, when they are subjected to an electromotive force. Hence, in each cell of a series of like cells, the fall of potential is the same. Moreover, when a current of electricity passes through this apparatus, the displacement of the mercury columns varies with the electromotive force, according to the same law as in a single cell, so that the curve showing the relation between the deflections and the electromotive force for any cell of the series is of the well-known form. Accordingly, by means of cells of proper construction, a simple and accurate series-electrometer may be made; such, also, that its range may be increased by increasing the number of component cells.

These experiments were made in the Sloane Laboratory of Yale College, at the suggestion and under the direction of Prof. A. W. Wright, to whom I express my thanks, for his assistance and kindly encouragement.

June 1, 1892.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Luminosity of Coal Gas Flames.*—An investigation has recently been made by Lewes as to the causes of the luminosity in the flame of ordinary coal gas Previous researches have proved beyond question the presence of solid particles in a luminous flame; leaving the mode of decomposition by which they are set free, for subsequent determination. Figures, obtained by the analysis of the flame gases taken at different heights, show that the hydrogen in the gas burns first, and that the saturated hydrocarbons also undergo a rapid decrease in quantity; while the unsaturated hydrocarbons diminish only very slowly until the top of the inner non-luminous zone has been reached, after which they quickly disappear. Carbon monoxide also increases largely up to the top of the luminous cone. Evidently this slow decrease of the unsaturated hydrocarbons in the inner zone suggests that the luminosity is due to these compounds, and especially to acetylene. Experiment showed that in the interior of the luminous flame the hydrocarbons begin at once to undergo decomposition giving rise to acetylene which constitutes over 70 per cent of the unsaturated hydrocarbons present at the top of the inner non-luminous zone. By means of a thermo couple it was found that in a flat flame consuming 7 cu. ft. of gas per hour, the temperature at a half inch from the burner was 500° and at the commencement of luminosity at the apex 1267°; while that at the center was 1014° rising to 1216° at the luminous edges. In the center of the luminous portion the temperature was 1166°, while at the top of the flame it was a maximum 1368°. Evidently then in the inner non-luminous zone, the hydrocarbons heated up by the combustion of the hydrogen and some of the methane, undergo certain changes which result in their conversion into acetylene; and this being an endothermic compound, breaks up when a sufficient temperature is attained. Owing however to the diluting action

of the nitrogen and other flame gases this does not take place until the top of the non-luminous zone is reached, where at a temperature of a little over 1000° the decomposition occurs with an increase of temperature, and the liberated carbon, being heated to incandescence, gives the luminosity to the flame. The author divides the flame into three zones. In the inner zone the temperature rises to 1000° to 1100° at the apex, and here the gaseous constituents undergo various decompositions culminating in the production of acetylene, and some hydrogen and carbon monoxide. In the middle or luminous zone the temperature ranges from 1100° to 1300°, and here the acetylene formed in the inner zone is decomposed with the deposition of carbon, which at the moment of separation is heated to incandescence by its own combustion as well as by that of the hydrogen and carbon monoxide and so gives luminosity to the flame. In the outer zone the cooling and diluting influence of the entering air render a thin layer non-luminous and finally extinguishes it. With reference to the loss of luminosity in the Bunsen flame the author attributes it: (1) to the chemical activity of the oxygen of the air which burns up the hydrocarbons before they can form acetylene; (2) to the diluting influence of the nitrogen which increases the temperature required to form acetylene; (3) to the cooling effect of the air introduced. —*J. Chem. Soc.*, lxi, 322, April, 1892. G. F. B.

2. *On the measurement of Osmotic Pressure.*—It is well known that the osmotic pressure of a salt solution calculated from the electrolytic dissociation formula of Arrhenius does not agree with that observed directly, but is always smaller. Thus for potassium nitrate, the osmotic pressure as observed by Pfeffer in a solution containing 0·8 gram in 100 grams, is 1304^{mm}, while that calculated is 2530. For a one per cent solution of potassium sulphate, the observed value is 1758^{mm}, the calculated is 2480. TAMMANN has investigated the cause of this, and has pointed out the fact that it is due to the permeability of the membrane of copper ferrocyanide used in the experimental determinations. Obviously if this membrane is not perfectly impermeable to the salt employed (or to its ions) the observed osmotic pressure will be less than it really is. Hence by determining the rate at which the salt is diffused through the membrane a correction may be obtained for the observed values. Moreover, according to the author, the copper ferrocyanide membrane may be obtained in two distinct forms. The first of these when fresh is transparent, elastic and extremely thin and allows water to pass through it freely. The second is opaque, dark brown in color, only slightly elastic and much less permeable to water. This form is produced when the solutions of copper sulphate and potassium ferrocyanide remain in contact with each other for a long time on the surface of a porous tile. The presence of sodium sulphate in the copper sulphate solution facilitates its formation. For the best results the solutions should be more concentrated than those suggested by Pfeffer; say a normal solution of copper sulphate and

a one-third normal solution of potassium ferrocyanide. The author proposes a modification of Pfeffer's method of determining osmotic pressure. It is based on the fact that if two solutions having different osmotic pressures be placed on opposite sides of a semi-permeable membrane, water will flow through the membrane into the solution whose osmotic pressure is the higher; so that by applying external pressure till balance is attained, the differential osmotic pressure is determined. The apparatus used is figured in the paper.—*Zeitschr. physikal. Chem.*, ix, 97, Feb., 1892. G. F. B.

3. *On the Coefficient of Molecular Depression of Phenol.*—Two numbers have been given for the molecular depression-constant of phenol; one by Raoult, obtained with phenol of a melting point 37·8°, by means of naphthalene, camphor, benzoic acid and thymol, which has the value 67·5; the other by Eykmann, which is 76. JUILLARD and CURCHOD, using a synthetically prepared specimen of phenol having a melting point 41·2°, find that the molecular depression-constant varies with the dissolved substance. Thus for example for water, β-naphthol, paratoluidine, aniline, nitrobenzene, phthalic anhydride, diphenic anhydride, α-naphthylamine, amyl alcohol, ricinic acid and salol, they get the value 68·5; while for normal ethereal salts, especially those of dibasic acids such as methyl diphthalate, ethyl succino-succinate, ethyl malonate, ethyl succinate, ethyl aceto-acetate, the value obtained is 75·81. In their experiments the amount of depression was determined in a long-necked thick glass flask of 40–50^{cc} capacity, by noting the solidifying point of the phenol after the addition of the other substance.—*Bull. Soc. Chem.*, III, vi, 237; *J. Chem. Soc.*, lxii, 555, May, 1892. G. F. B.

4. *On the determination of Vapor Density under Diminished Pressure.*—SCHALL has devised a method of determining the density of a vapor under diminished pressure, based on the fact that when gas is evolved in a bulb uniformly heated, this bulb being provided with a manometer, the increase of pressure is independent of the point at which the gas is evolved and is exactly proportional to the amount of gas or vapor produced, provided the space shut-off by the manometer may be considered constant. It is a modification of the method already described in this Journal.* The bulb used is moderately thick, of about 150^{cc} capacity, having two constrictions equidistant in its length to hinder the diffusion of the vapor into the neck, and provided with a lateral tube connected with a manometer, and intermediately with a bell jar for the evolution of carbon dioxide. For the method of using it and the calculation we must refer to the original paper.—*J. prakt. Ch.*, II, xlv, 134, 1892. G. F. B.

5. *Jahrbuch der Chemie.* Bericht über die wichtigsten Fortschritte der reinen und angewandten Chemie, herausgegeben von RICHARD MEYER, Braunschweig. I Jahrgang, 1891. 544 pp., 8vo. Frankfurt a. M., 1892 (H. Bechhold).—This new Jahrbuch

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* This Journal, III, xl, 415, November, 1890.

is designed to present the most important steps of progress in the various departments of chemistry for the past year. It differs from other publications of the kind, particularly the invaluable and long honored *Jahresbericht der Chemie,* in that it does not attempt an exhaustive treatment of the subject, but does give a well-selected digest, brief enough to be issued very promptly. This first volume was actually put on sale but a few months after the close of the year whose record it gives; this is a remarkable achievement and if this promptness can be maintained it will ensure the success of the work. The volume is divided into fourteen chapters written by nearly as many well-known authors most of whose names appear on the title page as regular co-editors. The following are subjects of some of the chapters: Physical Chemistry by W. Nernst, also Inorganic by G. Krüss, Organic by C. A. Bischoff, Physiological by F. Röhmann, etc.; on Metallurgy by E. F. Dürre, Technology of Carbohydrates and Fermentation processes by M. Märcker and L. Bühring, and of Fats by R. Bendedikt; Photography by J. M. Eder and E. Valenta. The book is handsomely printed and well bound in cloth.

6. *Chemical calculations with explanatory notes, problems and answers.* Specially adapted for use in Colleges and Science Schools, by R. Lloyd Whiteley; with a preface by F. Clowes. 100 pp. London and New York, 1892 (Longmans, Green & Co.) —This is a useful collection of well selected problems under the different departments of chemistry, accompanied by full explanations of the methods involved and the solution of typical cases; the answers to the problems are given in a supplementary chapter.

7. *Contributions to the knowledge of the discharge of the Ruhmkorff coil;* by Tom Moll; translated from the Beiblätter zu den Annalen der Physik und Chemie, xv, No. 2, 1891.—From the older investigations on the nature and duration of induction currents the author gives a description of the methods and results of Nyland, Rood, Cazin, Mayer and Holtz. He himself employed a photographic method; an image of the spark was thrown by a small concave mirror on a rapidly revolving circular disc which carried a sheet of sensitive paper. The time of closing the primary current and the velocity of rotation of the disc were registered on a revolving cylinder, which also received the trace of a vibrating tuning-fork. A large induction coil was used, its length being 57^{cm}, its diameter 21^{cm}; the strength of the primary current was measured with a tangent compass. As a general thing the electrodes furnishing the spark were connected with a Leyden jar having an interior coating of about 772 square centimeters. The external resistance in the secondary circuit was always the same and quite small.

By a study of the photographs thus produced the author ascertained the entire duration of the discharge, the intervals of time between the partial discharges and their mean, and this work was performed for sparks of various lengths, for primary currents of different strength, for various capacities of the Leyden jar and for different forms of electrodes.

It was found that as the length of the spark increases, the total duration diminishes, which is also the case with the number of partial sparks composing it, but the interval of time between the partial sparks increases. For long sparks the mean interval of time u between the partial sparks, was proportional to the square root of the spark length, $\sqrt{l}$. For short sparks, u appears to be greater than this law would demand; also the time-intervals between the two first partial discharges increase, as it appears, a little more rapidly than $\sqrt{l}$. When the length of the spark was made less than $0{\cdot}75^{\text{mm}}$ sparks were produced even on completing the primary circuit, but in this case the number of the partial discharges was much smaller and their mean distance apart greater, than when the circuit was broken.

When the strength of the primary current was diminished the number of the partial discharges and the total duration were quickly curtailed, but the mean time-interval of the partial discharges stood in an inverse ratio to the current's strength. This applies also to the value of the first time-interval.

As the capacity of the Leyden jar was increased the discharge consisted of a series of partial sparks with increasing time-intervals. When the capacity was diminished the number of the partial sparks increased and the discharge finally appeared partly continuous. Since this continuous light did not sufficiently affect the sensitive paper, the author made direct observations with a revolving mirror, and ascertained that the aureole was preceded by a few and followed by a greater number of partial sparks. As the capacity was made smaller, the number of these sparks was diminished, till finally the aureole formed the greatest part of the discharge. As long as the discharge was entirely disruptive, a diminution of the capacity diminished the time-interval between the partial sparks, but increased the total duration. For short sparks, however, the total duration appears to approach a constant quantity and to be independent of the capacity; it is about 0·023 sec.

As the electrodes were made more pointed the entire duration increased, also the number of the partial sparks, but the mean time-interval between them was diminished. When the electrodes were made very sharp, completion of the primary current produced sparks, but their number was small. All the experiments show that the time-interval between the partial sparks increases toward the end of the discharge, the last interval often being twice as great as its predecessor. The author has expressed the relation of the time-intervals, reckoning from the first partial spark, by an exponential function, and the agreement between calculation and observation is very good if the last three time-intervals are neglected.

The results in their main features agree very well with the observations of Rood, but differ from the others to a degree that is not insignificant. Mr. Moll studied the cause of these variations, and repeated the work of Nyland, Mayer and Holtz with arrangements similar to those used by these investigators. It proved in all these experiments that the nature of the discharge was a little altered by the mode of observation itself, since in the experiments of Nyland and Mayer the spark struck through a sheet of paper, and in those of Holtz the spark itself was in rotation. From these defects the arrangement of Rood is free.

If it is desired to give an explanation of the discharge of a Ruhmkorff inductorium, it is necessary at the outset to decide whether the partial sparks are directed in the same way or not. Mr. Moll allowed the sparks to fall on a rotating disc of paper, the electrodes on either side of the paper being at slightly different distances from the center of the disc. The holes made by the sparks were always opposite one of these electrodes, consequently all the sparks have the same direction.

Starting from this fact the author endeavors to explain the phenomena of the discharge by the assumption that the electricity cannot flow with sufficient rapidity to the electrodes, and that partial sparks are produced as soon as the difference of potential has reached a certain value, dependent on the distance of the electrodes apart, etc. The approximative statements which with the help of known facts one can easily deduce from these conditions, agree, as a whole, very well with the results previously found by experiment.—K. A.

8. *Photography in Colors.*—The Comptes Rendus for February, 1891, contained a note on color photography describing a method employed by M. G. Lippmann, who had been able to produce photographically the image of the spectrum with all its colors. M. G. LIPMANN has communicated further results to the Comptes Rendus for April 25 (No. 17, vol. cxiv). The following is a translation of his last communication:—In the first communication which I had the honor to make to the Academy on this subject, I stated that the sensitive films that I then employed failed in sensitiveness and isochromatism, and that these defects were the chief obstacle to the general application of the method that I suggested. Since then I have succeeded in improving the sensitive film, and, although much still remains to be done, the new results are sufficiently encouraging to permit me to place them before the Academy.

On the albumen-bromide of silver films, rendered orthochromatic by azalin and cyanin, I have obtained very brilliant photographs of spectra. All the colors appear at once, even the red, without the interposition of colored screens, and after an exposure varying from five to thirty seconds. On two of these *clichés* it has been remarked that the colors seen by transmission are very plainly complementary to those that are seen by reflection. The theory shows that the complex colors that adorn natural objects ought to be photographed just the same as the simple colors of a spectrum. The four *clichés* that I have the honor of submitting to the Academy represent faithfully some object sufficiently diverse, a stained glass window of four colors, red, green, blue, yellow: a group of draperies; a plate of oranges, surmounted by a red poppy; a many-colored parrot. These show that the shape is represented simultaneously with the colors. The draperies and the bird required from five to ten minutes' exposure to the electric light or the sun. The other objects were obtained after many hours of exposure to a diffuse light. The green of the foliage, the gray of the stone of a building are perfectly reproduced on another *cliché.* The blue of the sky, on the contrary, was represented as indigo. It remains then to perfect the orthochromatism of the plate, and to increase considerably its sensitiveness."—*Nature*, May 5, 1892. J. T.

9. *Dispersion of the Ultra Red Rays.*—At a meeting of the Physical Society in Berlin, March 11, Dr. RUBENS discussed this subject. He had extended his observations from wave-length $5{\cdot}7\mu$ to wave-length 8μ. The curves representing changes in index of refraction do not agree with Professor Langley's views on this subject. To wave-length $5{\cdot}3\mu$ Rubens's curves coincide with those of Langley. But beyond this point the interpolations of Professor Langley do not agree with Rubens's observations. J. T.

10. *Electrical Resistance of the Human Body.*—The frequent controversies which have taken place upon this subject, especially in relation to accidents from electrical currents, make a late paper by M. VON FREY (Verh. d. X. Congr. f. innere Medizin, Wiesbaden, 1891, p. 377) of considerable interest. The author employed Kohlrausch's method of determination of the electrical resistance of electolytes. The metric length in Kohlrausch's apparatus was supplanted by a circularly formed channel, the ends of which were not joined. This channel was filled with a sulphate of zinc solution. The conducting electrodes were greatly increased in size over those employed by Kohlrausch. With large electrodes suitably proportioned to the extent of surface of the wet hands, the resistance of the body from hand to hand was found to be small, 300 to 400 ohms. The author discusses the relation between the size of electrode and the resistance of the human skin. According to him the seat of the electric polarization of the body is in the outer surface and layers of the skin.—*Beiblätter Ann. der Physik und Chemie,* No. 4, 1892, p. 217. J. T.

II. GEOLOGY AND MINERALOGY.

1. *The History of Volcanic Action in the Area of the British Isles*, by Sir ARCHIBALD GEIKIE. Anniv. Address Geol. Soc. London, Feb. 19, 1892. 120 pp. 8vo.—This second part of Sir Archibald Geikie's Memoir on volcanic action in the British Islands treats of the evidences of such action and the volcanic phenomena and rocks, in connection with the Old Red Sandstone;

the Devonian of England and Wales; the Carboniferous, and the Permian. After the Permian period, no volcanic or igneous eruptions occurred again until the Tertiary.

In the author's summary of the remarkable facts he has presented, the following are some of the conclusions stated. The belts of volcanic activity are ranged nearly north and south, along the length of the British Isles from the south of Devonshire to the Shetlands; but no trace of them occurs through eastern England, from Berwick to Exeter, if we except the dikes in the northern counties. Moreover, the Central Highlands of Scotland were exempt through all the time.

In this western tract, volcanic activity was almost continuous from the Archæan to the close of the Paleozoic; and reappeared in the Tertiary. The absence from the Mesozoic accords with the general quiet over the European continent.

The sites of the eruptions were not determined by lines of faults; but there is this remarkable fact that they were confined to the low grounds and valleys, such as the great depression between the Highland Mountains and the Southern Uplands, which was the chief center of volcanic activity in Scotland during the later half of the Paleozoic. Again in the Tertiary, the great outpouring took place in the long depression between the Outer Hebrides and the mainland of Scotland. The volcanic action occurred on sinking rather than rising areas, that is, on areas where a great thickness of sediments were formed. There was a gradual diminution in the extent of the eruptions from the Silurian to the Permian, when there were only small scattered vents. In the earlier Paleozoic lava-eruptions were most abundant, while in the later in very many cases there were only ejections of ashes, making tufa-cones.

In each eruptive period the Tertiary included, there was a change sooner or later from basic to acidic lavas. When a second period commenced in the same region there was usually again the same succession—a beginning with basic and an ending with acidic. The eruptions of the Northwest Highlands were solely fissure eruptions; and the same kind prevailed in the Tertiary. At other periods the eruptions were connected with true volcanic vents. A great crater-like cavity was sometimes left, that became filled with the following rock-deposits.

2. *New Jersey Geological Report for* 1891, JOHN C. SMOCK, State Geologist. 270 pp. 8vo. Trenton, N. J., 1892.—This volume contains an extended account of the drift formations of New Jersey by Prof. R. D. Salisbury, illustrated by several phototypes of the region of the terminal moraine and of other bowlder scenes, and also by many wood-cuts, and a map. The paper is an important contribution to the general subject of glacial phenomena.

Mr. Lewis Woolman reports on the horizons of Artesian wells in Southern New Jersey and other parts of the Atlantic border. He mentions the occurrence of one or two upper horizons dependent on clay deposits, occurring in Cape May County; three wells at Sea Isle City affording water at depths of 35, 150 and 160 feet. At a greater depth varying from 382 to 697 feet, in the region of Atlantic City, water is obtained from fine hard clays and sandy clays over 300 feet thick; and this 300-foot stratum contains, through nearly every foot, great numbers of diatoms, so that it is a *Diatomaceous clay-bed.* The bed consequently is easily identified. Two levels of water-supply occur in it, one midway in it, and the other just below. The former at Atlantic City has a depth of 550 feet. The depth increases to the southeast at a rate of 25 or 26 feet a mile. A water-horizon beneath the clay-bed at Atlantic City has a depth of 700 to 720 feet. This Diatomaceous clay-bed extends under part of Delaware and Maryland. In the New Jersey Geological Report for 1890 Mr. Woolworth mentions the large Diatom bed near Richmond, Virginia, described by Prof. W. B. Rogers, as of the same character and as possibly related in position. He cites from Prof. Rogers the fact of diatoms brought up from a depth of 558 feet in a well-boring at Fortress Monroe.

3. *Progress of the Kentucky Geological Survey*, JOHN R. PROCTER, State Geologist.—A Report of progress on the work of the Survey for 1890, 1891 (to January, 1892) has been recently published. It announces that Prof. Crandall has been continuing the investigation of the Coal region of Eastern Kentucky, with reference to a general report on the coal-field as a whole, in which the extension and the equivalency of the various coal-beds will be treated. The study of the Coal-field and of the general geology of Western Kentucky has also gone forward under Prof. Loughridge, J. H. Crump, J. B. Hoeing and E. O. Ulrich, and their reports will soon be published on Livingston, Meade, Warren, Caldwell and Crittenden Counties.

4. *Kentucky Geological Survey: Report on Petroleum Natural Gas and Asphalt Rock of Western Kentucky;* by EDWARD ORTON. 233 pp. 8vo. Frankfort, Ky.—Prof. Orton, after reviewing in an instructive way the history of petroleum discoveries and the origin of mineral oil and gas, treats of their modes of geological occurrence, and the bearing of the facts on practical questions connected with exploration for gas and oil. Composition, fuel-value and uses are other subjects considered. Next the facts connected with the geology of Kentucky, its borings, wells, gas and petroleum, are given in detail. There is no better authority on the subject than Prof. Orton. A fine colored map of the geology of Kentucky accompanies the Report.

5. *Geological Survey of Alabama.*—Bulletin No. 2 (1892), on the Phosphates and Marls of Alabama, by Prof. E. A. Smith, State Geologist (82 pp. 8vo) has been issued.

6. *The Mannington Oil-field and the history of its development*, by I. C. WHITE (G. S. Amer., iii, 187.)—In this excellent paper Prof. White sustains the view brought out by him first in 1885, that success in boring for gas in Pennsylvania depends as a

general thing, on the existence of an anticline in the subjacent rocks.

7. *New Lower Silurian Lamellibranchiata, chiefly from Minnesota rocks;* E. O. ULRICH. From the Nineteenth Ann. Rept. Geol. and Nat. Hist. Surv. of Minnesota, March, 1892.—Thirty new species are added to the known fauna of these rocks. They are referred mainly to the genera Tellinomya, Modiolopsis, and Cypricardites. A new genus, Plethocardia, is proposed for two species related to the *Cyrtodonta cordiformis* of Billings. The author recognizes the confusion existing among the genera of Silurian lamellibranchs and his references are therefore somewhat provisional. C. E. B.

8. *Der Peloponnes, Versuch einer Landeskunde auf geologischer Grundlage, nach Ergebnissen einiger Reisen* von Dr. ALFRED PHILIPPSON. pp. 273–642, 8vo. Berlin, 1892 (R. Friedländer & Sohn).—This volume is the concluding Part II of the valuable work on the Peloponnesus noticed in vol. xlii of this Journal (page 173). It continues the topographic description of the country, and then treats of the geological structure, climate, vegetation, fauna, and other topics of general interest. The illustrations include maps and sections and a series, of four large colored topographic maps, which are both hypsometric and bathymetric.

9. *Chiastolite in fossiliferous metamorphic slates of Portugal.*—In an Upper Silurian slate of the Province of Minho, near Vallongo, Portugal, J. F. N. DELGADO has found along with Graptolites, multitudes of small crystals of chiastolite. Further, a Lower Silurian slate of Serra de Marão, containing a specimen of the trilobite *Illænus Lusitanicus* with portions of its test silicified, and a cast of a Redonia (probably *R. Duvaliana* Rou.), contains crystals of chiastolite in the rock and also in the casts of the fossils. Kjerulf has described a similar case from near Ekern, in the inferior part of the Lower Silurian, where the rock, which is profoundly altered, contains large numbers of chiastolite crystals along side of the graptolites.

10. *Striated Garnet from Buckfield, Maine;* by W. S. BAYLEY (communicated).—In glancing over the literature of garnets in Hintze's Handbuch der Mineralogie so few were the notices of striated garnets met with, that it is thought worth while to mention the existence of good examples of them in large numbers at Buckfield, Oxford Co., Maine. Unfortunately but one specimen from this locality remains in the writer's possession, but this is so similar in appearance to others obtained from the same place that its description will serve as a description of nearly all found there. The crystal to which reference is made is an icositetrahedron (211) about two inches in diameter, modified by small faces of the dodecahedron (110). All the planes are deeply striated parallel to the combination edge, 211 : 110, and these striations are so deep in the icositetrahedral faces that the reflections of the dodecahedron may easily be obtained from them. In

consequence of this oscillation between the two planes mentioned, the crystal appears to be made up of a lot of lozenge-shaped plates piled one upon another, with the smallest forming the dodecahedral bounding plane of the crystals, and the edges of the pile the deeply striated icositetrahedral faces. In small fragments the mineral is transparent and has the usual deep red color of almandine. Its exact method of occurrence is unknown.

11. *Blowpipe Analysis* by J. LANDAUER. Authorized English edition by JAMES TAYLOR. Second edition, revised and enlarged. 173 pp. 16mo. London and New York, 1892 (Macmillan and Co.).—This excellent little book has had a well-deserved recognition since the issue of the first edition in 1879, and in the present new edition it is still better equipped for usefulness.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Great Earthquake of Japan*, 1891; by Prof. JOHN MILNE, F.R.S., and Prof. W. K. BURTON, C.E., with plates by K. OGAWA. Yokohama, 1892.—On the morning of October 28, 1891, there occurred in Japan an earthquake, which, even in that much shaken country, is already known as "the Great Earthquake." Its greatest force was exerted in the neighborhood of Gifu and Nagoya, towns some fifteen miles west of Tokyo, but it was felt from Sendai on the north to Nagasaki on the south over an area of 92,000 square miles, and the area of complete destruction of buildings was 4200 square miles. The first and most severe shock occurred at Gifu at 6^h 38^m 11^s on the morning of October 28, and was followed by numerous minor shocks to the number of several thousand in the twelve days next following. One authority stated the number of persons killed in the prefectures of Aichi and Gifu at 7528, the wounded 9458, houses totally destroyed 82,000, partially destroyed 23,000, damage to property $20,000,000. A recent letter from Prof. Milne, puts the dead at 10,000 and the loss at $50,000,000.

It is this great earthquake which is illustrated in the series of plates whose title is given above and which forms an oblong quarto volume $29^{cm} \times 41^{cm}$ in size. The plates are heliotype copies of photographs, all but three of which were made by the authors for the Imperial University of Japan, and are copyrighted in its name. It is published by Lane Crawford & Co., Yokohama. The press work was done in Tokyo, and the paper on which it is printed is a product of the very district shaken by the earthquake. Indeed there was some delay in printing proofs owing to the difficulty of getting the paper in the disorganized state of all manufactures. It is handsomely bound in cloth and in general make up the book will compare favorably with the product of any western press. The first edition of 1000 copies has all been sold and a second edition with a few additional plates is in preparation.

It opens with ten pages of introduction on the nature of earthquakes in general and their relation to Japan, with brief mention of the salient incidents of the recent disaster, from which some of the statements above are taken. This is followed by thirty plates, varying a little in size, but mostly about $32^{cm} \times 21{\cdot}5^{cm}$ and each plate is accompanied by a brief description. These plates give very impressive illustrations of the destruction caused by the earthquake.

2. *Congress of Mathematicians and Astronomers.*—In connection with the Exposition to be held at Chicago in 1893, a "World's Congress Auxiliary" has been formed for the purpose of organizing a series of Congresses or Conventions to be held during the progress of the Exposition, which will bring together the leading scholars of the world for the mutual interchange of ideas on topics bearing on human progress.

As a part of this general plan a preliminary address has been recently issued from the division of Mathematics and Astronomy, of which Prof. George W. Hough is chairman, inviting the coöperation of all persons and societies interested in the department of physical science. Three chapters are proposed: I in Pure Mathematics, II in Astronomy, and III in Astro-physics. A series of topics is given in the circular by the committee, which are suggested for consideration. Advice and suggestions are desired as to the general conduct of the convention, and in particular as to the scientific questions to be discussed, and persons to present them. The suggestions and recommendations invited will be used in the formation of the program for the Congress.

The Chairmen of the Special Committees of the several chapters under the charge of the General Committee, are as follows:

Pure Mathematics, Prof. E. H. Moore, Chicago University, Chicago, Ill.

Astronomy, Prof. G. W. Hough, Dearborn Observatory, Northwestern University, Evanston, Ill. (who is also general chairman).

Astro-Physics, Prof. George E. Hale, Kenwood Astro-Physical Observatory, Chicago, Ill.

3. *American Association.*—The 41st meeting of the American Association for the Advancement of Science will be held in August next, commencing with Wednesday, the 17th, at Rochester, New York. All abstracts of papers should be sent to the Permanent Secretary, F. W. Putnam, Salem, Mass., until Aug. 7th, and after that time, to Powers' Hotel, Rochester, the hotel headquarters of the Association. The President of the meeting is Prof. Joseph LeConte, of Berkeley, California. The Local Secretary, Prof. H. L. Fairchild of the University of Rochester will give information, if desired, with regard to local arrangements, hotels, railway rates, etc. The Register will be opened in the University of Rochester on the 15th of August, and the meetings will be held in the buildings of the University.

The *Geological Society of America* will hold its August meeting at the same place on Monday and Tuesday, Aug. 15 and 16, Prof. G. K. Gilbert, President; The *American Microscopical Society*, on Aug. 9, 10, 11, 12, Prof. M. E. Ewell, Prest.; The *Society for the promotion of Agricultural Science*, on Aug. 15, 16, Prof. I. P. Roberts, Prest., and the *Association of Economic Entomologists*, on Aug. 15, 16, Dr. J. A. Lintner, President.

OBITUARY.

Lewis Morris Rutherfurd died on the 30th of May at his home, Tranquillity, New Jersey, in the seventy-sixth year of his age. He was born at Morrisania, N. Y., Nov. 25th, 1816, and was graduated at Williams College in 1834. He at first devoted himself to the practice of the law, but in 1843 he turned into the field of physical science in which he was to accomplish such good work. His interests lay chiefly in the direction of stellar photography and spectroscopic work, and in 1862 and 1863 he published (in this Journal) several important papers upon these subjects. One of these discussed the spectra of the stars, moon and the planets, which was one of the early contributions in this line and contained the first attempt to classify stars according to their spectra. He constructed about the same time a telescope for photographic work with specially corrected objective of 11¼ inches aperture, and in 1868 one of 13 inches; with the latter he made many admirable negatives of the sun, moon and star groups; his photographs of the lunar surface are remarkable for their beauty and perfection. He also constructed a micrometer for astronomical measurements, and in connection with photographs of stellar groups he made a large series of measures which in many cases constitute the earliest accurate observations of the clusters in question. A paper has recently been published* upon the "Rutherfurd Photographic Measures of the Group of the Pleiades," and it is stated that others are to follow giving the results of the Rutherfurd measures. Another work of great importance was the construction in 1890 of an accurate ruling engine with which he ruled diffraction gratings for spectroscopic work; these "Rutherfurd gratings" for many years played as important a part as do the "Rowland gratings" to-day.

Mr. Rutherfurd was one of the original members of the National Academy of Sciences. He was named by the President of the United States as one of the American delegates to the International Meridian Conference that met in Washington in October, 1885, and he took a prominent part in the work. In 1887 he was invited by the French Academy of Sciences to become a member of the International Conference on Astronomical Photography, held in Paris in 1887, and was appointed by the President of the National Academy of Sciences as its representative, but was obliged to decline the honor on account of his failing health. He was an Associate of the Royal Astronomical Society and, besides being a member of several scientific societies in this country and abroad, was the recipient of many medals, orders and diplomas.

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* By Harold Jacobs in the Annals N. Y. Acad. Sci., vol. vi, pp. 239–330, Feb. 1892.

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MINERALS—RECENT ARRIVALS.

Prof. Foote has shipped us from *Italy* the following choice specimens.

Hauerites in the gangue. The shaft from which the specimens were taken has not been worked for a year, having proved unprofitable, and though very deep is filled with poisonous gas. The owner demands a guarantee of $1,000 to re-open it and free it from gas without guaranteeing that any Hauerites will be found. Prof. Foote made two trips to the mine taking assistants to work over the dump and secured a number of good specimens in the gangue. He purchased all the single crystals to be obtained in *Catania*, *Raddusa*, and several other places, and offers them at the following low rates: Single perfect crystals, 10c. upward. Broken crystals and cleavages, 5c. upward. Groups of small crystals for the microscope, 10c. to 50c. Crystals in the clay gangue, 25c. upward.

From *Bottino* the following fine specimens were obtained and can be offered at exceedingly low prices: **Meneghinite** crystals, 5c. to 50c. **Meneghinite** groups, 15c. to $5.00. **Heteromorphite** (Feather ore) in beautiful capillary aggregations, 25c. to $3.50; small specimens, 5c. to 25c. From the same locality the rare variety of **Sphalerite**, called **Marmadite.** This variety is so distinct in composition that it is more important than many species. The crystals are well formed and very brilliant; usually associated with Feather ore. Groups, 25c. to $2.00.

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Sulphurs, Aragonites, Celestites, Selenite crystals and **Selenite** with **Sulphur** and **Aragonite** crystals showing in its limpid depths call forth the greatest admiration. They are in every size and form and at prices from 5c. upward. We offer better specimens for 25c. than have ever been sold for $1.00. Many fine brilliant single crystals. These are rare. **Faccellite, Euchlorite,** and many other rare species from *Vesuvius*.

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AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XI.—*On the Relations between the Surface Tensions of Liquids and their Chemical Constitution;* by C. E. LINEBARGER.

THE mathematical and physical parts of the subject of the surface tension of liquids have received much attention, and may be considered as having reached a high stage of development. The basis of the theory was laid by Young,[*] who regarded a liquid as bounded by a superficial film, behaving like a stretched membrane, and who showed that the form of the surface could be accounted for by taking into consideration the conflict between the surface tension and the other forces acting upon the liquid. This theory was elaborately worked out by Laplace,[†] Poisson,[‡] Gauss,[§] Hagen[‖] and many others. Numerous investigators have occupied themselves with the experimental verification of the theory and treatment and development of certain physical and mathematical questions pertaining to it.[¶] The bibliography relative to the phenomena of capillarity is very extensive; indeed, but few branches of physics have received more attention.

The chemical side of the question, on the other hand, has

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[*] An Essay on the Cohesion of Fluids, Phil. Transactions for 1805; and Young's Collected Works by Peacock, vol. i, p. 418.

[†] Sur l'action capillaire, Supplément au X livre du Traité de Mécanique Céleste. (1845), Paris.

[‡] Nouvelle theorie del'action capillaire (1831), Paris.

[§] Principia generalia theoriae figurae fluidorum in statu aequilibrii, Göttingen.

[‖] Ueber die Oberfläche der Flüssigkeiten, Berlin Acad. (1845).

[¶] For a historical sketch of the subject, see Quincke, Pogg. Ann., cv, I, and Maxwell, in Encyclopedia Britannica.

received comparatively little attention, although it is universally recognized that there must be an intimate connection between the capillarity and chemical constitution of liquids. Mendeléeff* seems to have been the first to have entered this field of investigation, being followed a few years later by Wilhemy;† the work of Quincke‡ on the surface tension of substances at their point of liquefaction should also be mentioned here. Robert Schiff,§ too, has published extensive and valuable facts and deduced therefrom some important conclusions in this domain of research. I will not enter now into a review of these investigations, as they will be frequently referred to in discussing my results.

Three principal methods have been employed in the determination of the surface tension of liquids; 1°, the *capillary tube method*, consisting in observing the height to which a liquid rises in a capillary tube of known bore; 2°, the *drop or bubble method*, consisting in the determination of the shape, and size of drops or bubbles formed in various circumstances; 3°—the method consisting in ascertaining the force necessary to pull a disk of known area from the surface of a liquid. These methods have, indeed, been very much modified in individual cases, but, in general, all may be referred to one or another of the foregoing. The results obtained by different methods have been found to be quite concordant.

Most of the determinations of surface tension have been made with *one* liquid in contact with air, the surface tension of which being so small, could be safely neglected. About the only investigations of the surface tensions of two liquids in contact are those of Quincke (who determined the shape of drops of one liquid resting in another, and the change in the height of a liquid in a capillary tube when subjected to the influence of another liquid, etc.) and of Guthrie.‖ These researches are entirely physical, chemical questions being hardly touched, yet as it was Guthrie's work which induced me to take up this subject, and as his methods resemble mine closely, I will describe some of his experiments and cite some of his conclusions.

From a glass ball, suspended in a funnel-shaped vessel, water was made to drop, the drops being caught in a graduated tube placed at the bottom of the vessel. Funnel and tube were filled successively with air, "turpentol," and benzene, and the flow of water so regulated that a drop fell every five seconds. It was found that there were required to fill the tube up to a

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* Compt. Rend., l, 52 and li, 97 (1860). † Pogg. Ann., cxxii, 55, (1864.)

‡ Pogg. Ann., cxxxv, 621. (1868) and *ib.* cxxxviii, 141. (1869.)

§ Liebig's Ann., ccxxiii, 47, (1884) and Gazz. chim. ital. xiv, 137, (1884.)

‖ Proc. Roy. Soc., xiii, 444 and xiv, 22.

fixed mark, 57 drops in air, 27 in "turpentol" and 7 in benzene. As the benzene and "turpentol" had nearly the same specific gravity (see Table I), it is impossible that the difference in the size of the drops should be due to this alone. Guthrie also determined the weight of drops of mercury in various media. I give his principal results in Table I.

TABLE I.

	Specific gravity.	Weight of drop of mercury in	Weight of drop of mercury in air.
Air	0·	0·7654 gram.	0·7654 gram.
Water	1·	0·6462 "	0·6975 "
Glycerine	1·245	0·5579 "	0·6151 "
Benzene	0·864	0·5601 "	0·5982 "
"Turpentol"	0·863	0·4071 "	0·4350 "

Here also, a great difference is observed in the weights of the drops of mercury in benzene and "turpentol;" and, although there is not much difference in the drop-size of glycerine and benzene, yet their specific gravities are far from being the same. Guthrie states as one of the principal results of his work that "the drop size of a liquid, which drops under like conditions through various media, does not depend wholly upon the density of the medium and consequent variation in the weight of the dropping liquid."

Evidently this behavior is due to the chemical constitution of the liquids examined, and the question arises, would not the determination of the surface tension between many other liquids afford valuable data in regard to their chemical constitution? The object of the present paper is to begin the answer to the question. It will require much work in order to find out what laws underlie these phenomena, and this article will contain but a description of the apparatus used, together with some indications of the direction that succeeding investigations should take. The results obtained with the liquids examined show that some importance may be attached to the thorough investigation of the subject.

Experiments of this kind should be carrried out with liquids which are totally or nearly insoluble in one another, but it is difficult, if not impossible, to find liquids fulfilling those conditions. All liquids, which have a perceptible vapor tension at the temperature at which a determination of solubility would be made, must dissolve one another to some extent; for as, in general, every liquid has the power of absorbing to some degree every gas or vapor, one liquid in this case would dissolve the vapor of the other, and it is impossible to distinguish between a solution of a substance in gaseous form and its solution in liquid form. This is shown by the fact that, if water be shaken up with an ethereal oil, although the liquids are regarded as insoluble in each other, yet the latter imparts its odor to the former. There are, however, numbers of pairs of liquids which are practically insoluble in each other; at least, we are unable by our analytical methods to detect the presence of one in the other—and it is the surface tension of these liquids that it is my purpose to investigate.

At the surface of two absolutely insoluble liquids, there would reign complete repulsion between the molecules; no molecule of one liquid would pass beyond a definite surface concentric with the surfaces of the liquids, and this surface would form an impenetrable barrier to molecules of each liquid. But in the case of liquids which dissolve one another a little, complete repulsion between the molecules prevails no longer, but on the contrary a slight attraction, so that now a molecule of one liquid may pass into the other. This would continue until the "tension" of solution of each liquid was reached. The question arises then, whether, in searching for stoichiometrical relations, the superficial tensions of liquids, saturated with each other, or pure, be employed. Leaving the discussion of the question for the present, we will in this paper make use of those superficial tensions determined with liquids uncontaminated with one another.

It is necessary in work of this kind to select one liquid as a standard of comparison, absolute measurements being less reliable than comparative. Mercury, as regards insolubility, is admirably adapted to the end in view, but I have not found it advantageous to employ it in measurements made by the method I adopted. I have therefore chosen water, the universal standard, as it is insoluble in a sufficient number of organic compounds to receive quite an extended use.

The method consisted in determining:—1°, the number of drops into which a certain volume of water divided in "dropping down" through liquids lighter than water and in "dropping up" through liquids heavier than water; 2°, the number of drops of a liquid "dropping down," if heavier than water, and "dropping up" if lighter, through that standard.*

The bulb of a small pipette was so shaped and ground that it fitted snugly (like a stopper in a bottle) in the neck of a cylindrical vessel, provided at its lower end with a stop cock. An inch above the bulb, a second much smaller bulb was blown, and between it and the larger bulb as well as an inch or so below the latter, marks were scratched. The lower stem of the pipette was bent out so as to run down close to the side of the cylindrical vessel nearly to the bottom, where it was turned

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* For an extension of the meaning of "drop," I refer to Guthrie's work (loc. cit.)

up through two right angles, the orifice being exactly in the axis of the cylinder, no matter how the pipette was inserted. It is of some importance that the orifice be always placed in such a position, that the drops may be discharged vertically. A second pipette with a straight stem, so as to discharge bubbles downwards, was also employed. To make a determination, the pipette (the curved-stemmed one, if the dropping liquid is the lighter, and the straight-stemmed one, if the dropping liquid is the heavier) is filled with one of the liquids by suction through a long rubber tube slipped over the upper end of the pipette and provided with a pinch cock. It is then inserted in the cylinder which has previously been filled with enough of the other liquid to stand an inch or so above the orifice of the pipette. The free end of the rubber tubing is slipped over a piece of glass tubing, so shaped that it can be held conveniently in the hand and closed with the thumb. The thumb is now kept tightly pressed over the tube, and the pinchcock opened. A few drops fall rapidly at first, before the pressure becomes sufficiently reduced. By lifting the thumb, air may be admitted and the liquid made to drop at any desired rate. After a little practice, the raising of the thumb and the counting of the drops are done almost instinctively. If the time of the growth of the drops is to be noted, a watch is placed at the side of the apparatus, and the falling of the drops made to coincide with the movements of the second-hand. This is very easily done. Suppose, for instance, one wants the drops to form at the rate of one a second. Then, by beginning to count when the second-hand crosses a quarter-minute mark, fifteen drops should have fallen when the second-hand passes the next quarter-minute mark, thirty drops, when it passes the next, and so on. In this way, with very little effort, a strict account of the time taken by the drops in forming can be kept. The number of drops, into which the volume comprised between the two marks divided was taken in every case. If the last drop before the mark was reached did not leave the residual liquid nearly flush with the mark, which was generally the case, another drop was allowed to form, and, by observing the volume it occupied in the stem of the pipette, an estimation to a quarter of a drop could be made, which was added to the number of drops counted. When one determination had been made, the pipette was removed, wiped free from the outside liquid, refilled and again inserted in the cylinder. The liquids in the outside vessel are easily drawn off separately by means of the stop-cock.

In regard to the accuracy of results obtained by this apparatus, it was found that determinations of drops forming at the same rate and dropping upwards, seldom differed, if the liquids were quite insoluble in each other, by more than one drop in a hundred. If, however, the liquids were somewhat soluble in each other, quite variable results would be obtained until the one liquid was saturated with the other. Thus water in dropping up through nitrobenzene which was not changed in three determinations gave for the first series: 1°, 136 drops —2°, 142 drops and 3°, 155 drops; and for the second 1°, 133 drops—2°, 146 drops and 3°, 161 drops. The first two determinations agree fairly well; they were made with water dropping through dry nitrobenzene. But as the nitrobenzene became more and more contaminated with water, the surface tension of the liquids changed as shown above in the number of drops. Three independent determinations of the number of drops of water saturated with nitrobenzene up through nitrobenzene saturated with water gave—1°, 112 drops—2°, 110·5 drops—3°, 111 drops,—which are entirely concordant. This slight solubility of liquids in one another complicates matters greatly, and renders stoichiometrical conclusions based upon results obtained by measurements of superficial tensions of liquids by the above method somewhat unreliable. Without doubt, however, by a further study of these phenomena, we shall learn how to make due allowance for such disturbing influences. Of the liquids which I have examined, not one, with the exception of nitrobenzene and bromoform, has given any too variable results.

The time of the growth of drops has a little influence upon their size. For an elaborate investigation of the influence of time upon drop-size I must refer to Guthrie's papers. In my experiments, it was impossible to choose a certain fixed rate at which all drops should form, since a large drop requires a longer time for formation than a small one; hence I made the drops form at such a rate as seemed necessary for the attainment of the maximum size.

In the case of liquids heavier than water, falling through water, the orifice of the pipette was wetted by the water, and hence the drops formed upon the inner circumference of the orifice, which, however, in my instrument differed very slightly from that of the outer. It was difficult to obtain concordant results in this case, since the drops could not be prevented from falling by "twos" and "threes." That is, a drop would commence to form slowly, when, all of a sudden, it would increase rapidly in size, fall off and be followed by another, which would, however, take a longer time for formation. There seems to be a sort of pull exercised by the first drop on the second. Sometimes two drops would issue rapidly from the orifice to be followed more slowly by a third. This, rendering the rate of formation irregular, caused the results to be somewhat variable, since the first drop was evidently smaller than the succeeding ones. Not so much confidence, then, is to be placed in the results obtained by the dropping of heavier liquids through lighter, as of lighter up through heavier ones, since in the latter case no such phenomena were observed.

In the dropping of the liquids, besides the main drop, a much smaller secondary drop would also form almost invariably. In general, the larger the main drops, the smaller the secondary drops, so that but a slight error is introduced in neglecting the latter, when the former are comparatively large. The formation of these secondary drops may be explained as follows: The main drop, just before breaking loose, is connected to the mass of the liquid by a short cylinder, the circumference of which is that of the orifice of the pipette. When the large drop tears itself from the connecting cylinder, a certain impulse or shock is communicated to the latter, so that it is severed from the mass of liquid, and under the action of superficial tension and gravitation assumes a spheroidal form, appearing as a drop. In this paper, I have not attempted to make any corrections for these secondary drops, although, without doubt, their appearance is intimately connected with the superficial tension of the liquid in question.

When water was dropped down through other liquids, it would run up around the orifice of the pipette so that the drops were larger than they should be, and consequently the results were quite variable. This was prevented by the following simple device. A test tube just small enough to enter the outer vessel of the dropping apparatus was cut off so as to form a tube open at both ends about two inches long. In one end was fitted a cork through which a hole was pierced so that the stem of the pipette could be thrust through it. In the other end was set a thin ring of cork made by cutting a cross-section of a good soft cork and filing it out. This ring was cut into four times so as to form four shallow clefts situated 90° apart. In these clefts were inserted fine-spun threads of glass, so that they crossed at the center of the ring. The orifice of the pipette was shoved down close enough to the intersection of the glass threads that a drop, when nearly half formed would touch it. The drop then, instead of running up the sides of the pipette would be confined to the orifice, the crossed threads serving as a support for the drop during its formation. With this little device, the determinations were entirely concordant.

We will first take up the discussion of the results obtained with liquids lighter than water. These were all hydrocarbons of the benzene series from the establishment of Kahlbaum labelled chemically pure. I made no special tests for their purity, as for my purpose they might be considered pure enough.

The results are given in Table I. In the first column are given the names, in the second the formulæ of the substances, while in the third are recorded their densities at 20° as found in the literature. The fourth column contains the weights in grams of drops of the respective hydrocarbons in water, and the fifth the weights of drops of water in the hydrocarbons.

I have not calculated the surface tension, as I did not know the radius of the orifice of the pipette; as it deals here of relative rather than absolute values, that is of little moment.

TABLE II.

I.	II.	III.	IV.	V.
Benzene	C_6H_6	0·879	0·0405	0·1932
Toluene	$C_6H_5 . CH_3$	0·865	0·0403	0·1920
o-xylene	$C_6H_4 . (CH_3)_2 1 \cdot 2$	0·75	0·0405	0·2010
m-xylene	$C_6H_4(CH_3)_2 \cdot 1 \cdot 3$	0·87	0·0406	0·1910
p-xylene	$C_6H_4(CH_3)_2 \cdot 1 \cdot 4$	0·862	0·0318	0·1579
Cumene	$C_6H_5 \cdot CH(CH_3)_2$	0·87	0·0262	0·1263
Pseudocumene	$C_6H_3 . (CH_3)_3 . 1 \cdot 3 \cdot 4$	0·86	0·0314	0·1536
Ethylbenzene	$C_6H_5 . C_2H_5$	0·866	0·0178	0·0826
Mesitylene	$C_6H_3 . (CH_3)_3 . 1 \cdot 3 \cdot 5$		0·0141	0·0725

We notice first that the determinations of the size of the drops of the hydrocarbons in water and of water in the hydrocarbons give relatively the same results. If the numbers in the fourth column be multiplied by *five*, the numbers in the fifth column are approximately obtained. This shows that the two methods give strictly comparable results.

The weights of the drops of benzene, toluene, *o*-xylene and *m*-xylene in water, as well as the weights of water-drops in them, are the same, if due allowance be made for unavoidable errors of observation. The superficial tensions of these organic liquids in contact with water have then equal values. In passing to *p*-xylene, there is a considerable decrease in the weights of the drops. This is evidently due to the *para*-position of one of the methyl groups, for pseudocumene, which contains a *meta*- as well as *para*-methyl group, has the same drop-size as *p*-xylene. While the introduction of a *meta*-methyl group in benzene derivatives seems without influence upon the superficial tension, the introduction of a *para*-methyl group exercises, on the contrary, a decided influence. Yet three *meta*-methyl groups, as in mesitylene, cause the surface tension to decrease greatly Again it is to be observed how different are the drop-sizes in the case of toluene or methyl-benzene and ethyl-benzene. Cumene or isopropylbenzene also has a surface tension greater than that of ethylbenzene, but less than that of toluene.

The laws which underlie these phenomena can be discovered only when the data are much more numerous, although with the above liquids important hints are given as to how those laws will be stated. We find further that the specific gravities of these hydrocarbons have but little, if any, influence upon their surface tensions. True, the differences of density are slight, but it is seen that benzene with the greatest and *o*-xylene with the least density have the same drop-size. And again, the weights of the drops of toluene and ethylbenzene, liquids of almost the same specific gravity, are widely different. Guthrie's first law, as stated above, seems to be verified by these facts.

Of the few liquids heavier than water which I examined, the majority have a similar constitution. These were all carefully purified and only portions boiling within a fraction of a degree taken. The results of the determinations are given in Table III., where Column I, gives the name and Col. II, the formula of the liquids. The specific gravities at 0° for the most part are entered in Col. III, and the weights of drops of water in the organic liquids in Col. IV. Cols. V and VI give the weights of the drops of the liquids into water, orifices of different sizes being used.

TABLE III.

I.	II.	III.	IV.	V.	VI.
Nitrobenzene	$C_6H_5 . NO_2$	1·2	0·0518	0·0328	
Carbon disulphide	CS_2	1·29	0·0667	0·0384	0·0461
Amyl bromide	$C_5H_{11} . Br$	1·28	0·0666	0·0382	0·0460
Ethyl bromide	C_2H_5Br	1·47	0·0236	0·0182	0·0221
Benzene bromide	$C_6H_5 . Br$	1·517	0·0283	0·0237	0·0280
Chloroform	$CHCl_3$	1·52	0·0229	0·0278	0·0362
Ethylene bromide	$C_2H_4Br_2$	2·18	0·0106	0·0137	0·0183
Bromoform	$CHBr$	2·83	0·0069		0·0176

If the numbers in Cols. V and VI, be plotted as ordinates and the corresponding densities as abscissas, the resulting curves will be seen to be parallel, showing similarity, as might be expected, in the results obtained with different sized orifices.

Regarding Col. II, we see that carbon disulphide and amyl bromide, liquids of the same specific gravity, have the same drop-size, while benzene bromide and chloroform, also liquids of about the same density, have quite different drop-sizes. A difference in the chemical constitution of these last two bodies may explain their difference in surface tension; we see also that, although the density of nitrobenzene is less than that of amyl bromide and carbon disulphide, its drop-size is not greater.

The influence of the specific gravity in the case of liquids heavier than water is much more marked than in the case of those lighter than it. Thus the table shows that with the exception of the benzene derivatives, the drop-sizes diminish quite regularly, as the specific gravities increase. The anomaly in the behavior of the benzene molecule is undoubtedly due to its constitution.

The foregoing work was performed with the purpose of developing and testing methods, rather than that of accumulating data; it is to be regarded as a series of "orientation" experiments, which have shown in what direction it is best to continue. Investigations of this sort will certainly throw a much clearer light upon the nature and workings of the molecular forces, a knowledge of which is of the greatest importance.

Chicago, Ill.

Art. XII.—*The Gold Deposit at Pine Hill, California;* by Waldemar Lindgren.

General Type.—Veins and seams of barite, carrying gold and silver, distributed through a kaolinized zone in diabase and diabase porphyrite.

The auriferous deposits of California have, as well known, two principal modes of occurrence: Secondary as gold-bearing gravels and sands of Tertiary or Pleistocene age, and primary as fissure veins, largely of late Mesozoic age. The latter occur in great variety of formations, but on the whole, avoid the large granite areas and seem to prefer the contact of sedimentary slates with eruptive, unaltered, or dynamically metamorphosed masses. The form of the auriferous veins also varies considerably between normal, regular fissure veins and networks of minute irregular fractures.

With all diversity in surroundings and form, the vein material or gangue and the mineral associations are simple and subject only to rare and slight variations. The gangue is nearly always quartz, the mineral association native gold, sulphides of iron, copper, lead, and zinc,—frequently also arsenical pyrites, rarely tellurides. Dolomite and calcite accompany the quartz at certain veins, but even then the quartz is usually the principal ore carrier.*

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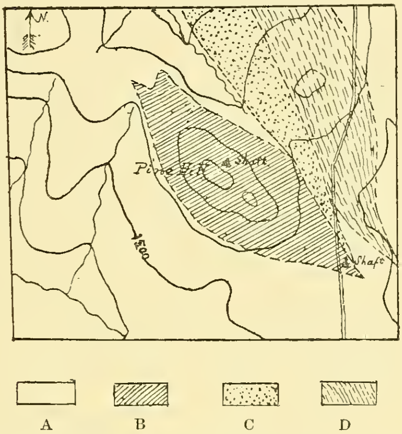
* The association of native gold with calcite in Shasta County, California, has been noted by Mr. G. F. Becker (Statistics of the Precious Metals, Tenth Census, vol. xiii, p. 24), and from Trinity County, California, by Mr. J. S. Diller (this Journal, vol. xxxix, 1890, p. 160).

The deposit to be described here differs strangely from the common type. Pine Hill is situated about eleven miles south-southwest of Grass Valley, in Nevada County, and a few miles north of Bear River; it is in the lower rolling foothills of the Sierra, and the summit of the little knoll bearing the above name rises to eighteen hundred feet above the level of the sea; from the top an extensive and beautiful view is obtained westward over the Sacramento valley, and eastward toward the crest of the snowy range.

1.



Sketch of Pine Hill and vicinity, Nevada Co., Cal.
Scale 2 inches = 1 mile. Contour Interval 100 feet.
A. Diabase or Porphyrite. B. Decomposed Zone.
C. Serpentine. D. Quartzite and Slate.

Toward the south and west a large area extends occupied by massive diabases and diabase porphyrites in which auriferous veins are but seldom met with; to the east of Pine Hill there is a somewhat complicated area of quartzites and clay slates, serpentines and gabbros sometimes dynamically metamorphosed and containing a few veins of gold quartz, usually very capricious as to the distribution of the metal. A part of this area is shown on the sketch. To the northwest, beyond the limits of the map, there is a large and massive area of granite, diorite and gabbro with very few auriferous deposits.

The diabase and diabase porphyrite which form the prevailing rock of the vicinity, are massive, fine grained and not a little affected by secondary processes giving rise to uralite, chlorite, secondary quartz, etc. The diabase porphyrites appear to prevail along the crest of the ridge, of which Pine

Hill forms the culminating point. Surrounding the latter there is an area of intense decomposition, somewhat ill defined but approximately one mile long and from one to two thousand feet wide, of a very different character from the ordinary chloritization and uralitization. The rocks within this area are converted to a soft, porous, reddish brown to yellowish mass, from which calcium, magnesium, iron and the alkali metals together with a part of the silica are removed; the ultimate product of this decomposition, which I think should be regarded as having been effected by thermal waters, alkaline in character, is a soft white nearly pure kaolin* or hydrated silicate of aluminium. If there exists a large quantity of this pure white kaolin it could no doubt be utilized for keramic art; the somewhat impure substance would do very well for the manufacture of ordinary pottery.

In many places the zone of decomposed and kaolinized diabase is impregnated with irregular veins and seams of barite or heavy spar, and with this mineral the gold is closely connected. The largest barite mass appears on the northeast side of the hill and about three hundred feet from the crest; a shaft fifty feet deep was sunk here a few years ago and some ore extracted. The deposit not being worked at the time of my visit, the shaft was inaccessible. It did not appear as if a well defined and extensive vein of barite were present, but rather as a local enlargement of one of the numerous smaller irregular barite seams. The ore on the dump was largely composed of barite mixed with limonite and decomposed country rock. No sulphurets, but a few stains of sulphate of copper were noticed. Although no normal vein quartz occurs, there are in various places seams and smaller masses of a fine granular aggregate of quartzitic appearance but doubtless due to secondary processes. Assays were made on a series of specimens, both of ore and country rock, by Dr. W. H. Melville, in the laboratory of the U. S. Geological Survey. Special precautions were taken to insure correct results and the exceptionally pure litharge used contained only 2 cents of silver to the ton.

The assays in general show a large relative amount of silver —more than is usual in the gold quartz veins. The proportion of gold to silver by weight varies from 1 : 1 down to 1 : 5, or in value from 20 : 1 to 4 : 1. The metal resulting from the reduction of this ore would be a doré bullion similar to that yielded by the Bodie (Mono County) quartz veins.

The assay of the ore from the dump, composed of barite

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*In a specimen of this white substance the water was determined quantitatively by Dr. E. A. Schneider, who obtained almost exactly the theoretical amount for kaolin, viz: 13·8 per cent H_2O.

and some limonite, gave a paying amount of gold with silver in the proportion of 1 : 2 by weight; a piece of very pure white barite selected for the purpose, and shown under the microscope to contain no visible gold or sulphurets, gave the same amount of gold, but much more silver, the proportion between the two metals being 1 : 5. Only a part of the silver exists as an alloy with gold, for a pan of the ore washed out gave a considerable quantity of quite *yellow* gold in very fine particles; hence it may be permitted to surmise that the silver partly occurs as a chloride. A piece of barite with much limonite gave an exceptionally high return with but little silver, the proportion being 1 : 1.

Near the crest of the hill there are several little prospect holes in the decomposed mass. One specimen shows a brownish to gray compact decomposed rock permeated with little seams of barite. This gave 0·063 oz. gold and 0·163 oz. silver to the ton, or $1.26 in gold and $0·16 in silver, the proportion in weight being about 1 : 3.

A specimen from the summit of Pine Hill is a soft crumbling mass largely composed of kaolin, pink or yellow in color and showing on fresh-fractured surfaces traces of the grain of the original rock. It was not expected that this mass would yield any results, but it proved to contain 0·0375 oz. gold, and 0·075 oz. silver per ton, or respectively $0.75 in gold and $0.07 in silver. No barite is visible in the rock, but a quantitative determination by Dr. E. A. Schneider showed it to contain 0·34 per cent $BaSO_4$.

At the southeast end of the decomposed area a shaft has been sunk to a depth of about one hundred feet, and traces of gold are reported to have been found.

It is thus reasonably certain that this whole altered mass of diabase and porphyrite is auriferous; that barite in very varying quantities is distributed through it, and that the quantity of the gold contained is approximately proportional to that of the barite, or, in other words, that the barite acts as the carrier of the gold. The primary mineral combination was probably native gold, pyrite, rich silver ores, and barite.

Whether the kaolinized zone is connected with large fissures, it is not possible to say from the present slight underground developments; on the surface, at least, there are no indications of such a connection, yet a channel must have existed for the passage of the waters effecting this far-reaching alteration of the rocks.

In the foothills of Yuba County and also in massive diabase there is a zone of extreme decomposition resembling somewhat the one here described, but associated with a considerable amount of secondary, fine grained, quartzose and chalcedonic rocks. The larger part of this area carries minute quantities of gold and silver, the latter predominating, the ratio being 1 : 6 by weight.

Native gold is but seldom associated with barite, and only, as far as I am aware, in silver-gold deposits in which the former metal predominates. Barite is a rare mineral in California, and does not occur in the normal gold quartz veins. Native gold with barite is mentioned as a rare occurrence from southern Colorado,* and Mr. Hanks, in his description of California minerals,† refers to a specimen of barite with gold from the Malakoff hydraulic mine, near North Bloomfield, Nevada County. It may be stated in this connection that there is a deposit of barite in clay slates seven miles east-northeast of North Bloomfield and cropping out on the North Bloomfield ditch. I am not aware, however, that it contains any gold.

Another instance of gold connected with barite is found in Yuba County at the junction of the North and Middle Yuba Rivers. A streak of chloritic schist, about twenty feet wide, is here impregnated with pyrite and chalcopyrite and traversed by seams of calcite and barite carrying the same minerals. The brown surface croppings carry native gold, but it is probably all derived from the decomposition of the pyrite.

U. S. Geological Survey, Washington, D. C., April, 1892.

ART. XIII.—*A new occurrence of Ptilolite*; by WHITMAN CROSS and L. G. EAKINS.

IN this Journal for August, 1886, we described the first observed occurrence of a new hydrous silicate of alumina, lime and alkalies, to which we gave the name *ptilolite*. The mineral was remarkable for its high percentage of silica, the analysis leading to the formula $R'Al_2Si_{10}O_{24} . 5H_2O$. Inasmuch as the polysilicic acid of this formula was elsewhere unknown, Prof. P. Groth‡ expressed the belief that the material analyzed must have been contaminated with chalcedony, upon which the ptilolite was deposited. While it has seemed to us that the care exercised and the method used in the purification of the original ptilolite material analyzed must exclude the possibility of such contamination, we are glad to be able to announce a second occurrence of this interesting mineral the investiga-

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* See the interesting paper by Mr. R. C. Hills, "Ore Deposits of Summit District, Colorado." Proc. Col. Scientific Soc., vol. i, p. 24.

† Fourth Annual Report California State Mining Bureau, p. 78.

‡ Tabellarische Uebersicht der Mineralien, 2d ed., p. 149, 1889.

tion of which fully confirms the earlier analysis. The work of L. V. Pirsson* upon mordenite has, however, fully confirmed the existence of silicates with the ratio between silica and bases which was found in the original ptilolite.

The new occurrence of ptilolite is in Custer County, Colorado, about three miles southeast of the mining town of Silver Cliff. The rock containing the ptilolite occupies but a few square feet of surface on a low ridge of rhyolitic breccia reaching out from the volcanic center of the Rosita Hills,† and we are indebted to Mr. Thomas Charlton of West Cliffe for calling our attention to the peculiar and seemingly insignificant occurrence. The rock is a dull green felsitic mass containing many nearly round vesicles most of which are less than 5^{mm} in diameter while a few are somewhat larger. They occupy about one-third of the rock. The dull green mass proves on microscopical examination to be a completely devitrified pitchstone, and it is probable that this vesicular rock is a remnant of the upper portion of a rhyolite flow seen at a lower level near by, though the connection is covered by "wash" and soil. The rock contains few phenocrysts of feldspar, but a fluidal structure curving about the vesicles is distinct. Devitrification proceeded from pearlitic cracks.

The vesicles of the rock have very smooth walls and most of them have a thin crumbling lining of a pale yellowish or white substance. A few cavities contain a shell of pale bluish glistening quartz crystals and some are entirely filled by this mineral. More abundant than the quartz is a colorless or pale blue mineral in minute thin tablets which are often grouped in sheaves or bundles. This mineral was identified as barite by chemical analysis.

Nearly all the vesicles contain a white mineral in extremely minute needles which form a loose, felt-like mass. Usually they fill the cavity and with a curved dissecting needle one can often remove a little white ball of the substance, apparently perfectly pure. The strong resemblance of this mineral to the ptilolite of Green Mountain was evident at first glance.

Microscopical study of the needles shows that they are transparent, colorless, seldom more than $\cdot 005^{mm}$ and often less than $\cdot 001^{mm}$ in thickness. Only when a number of the needles are arranged in parallel position in a bundle do they perceptibly affect polarized light. In such cases they extinguish ± to the length axis, and by the aid of the quartz plate a negative optical character can be made out.

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* On Mordenite, this Journal, vol. xl, p. 232, 1890.

† The geology of this region will be described in a forthcoming monograph of the U. S. Geological Survey. A geological sketch of the Rosita Hills, by Whitman Cross, was published in the Proceedings of the Colorado Scientific Society for 1890, p. 269.

The obtaining of material for chemical analysis was in this case even more difficult than with the original ptilolite. About six cubic feet of the rock was broken up and the tufts and balls of the downy mineral removed with a curved needle. After several days work with an assistant an amount was obtained which on final purification gave a trifle over half a gram of pure material. This final purification, as in the case of the original ptilolite, was made by stirring the mineral in water, breaking up the felt-like aggregates as far as possible, allowing the heavier portion to settle, and pouring off; this operation being repeated upon the residue until most of the ptilolite was washed out. The collected washings were allowed to settle over night, the bulk of the water syphoned off, and the stirring and pouring off repeated until a product was obtained in which no gritty substance whatever could be detected on careful testing with the rounded end of a glass rod. The material so obtained, after drying on the water bath, was left loosely covered, exposed to the air for several days. Dried for eight days over sulphuric acid it lost 3·84 per cent, all of which was regained in twenty-four hours in the air, and in this condition it was analyzed. Like the original mineral this new ptilolite is but very slightly attacked by hydrochloric acid, and the prolonged action of hot concentrated sulphuric acid is required for complete decomposition.

Analysis and ratios (Analyst, L. G. Eakins):

SiO_2	67·83		1·131	10·1
Al_2O_3	11·44		·112	1·0
CaO	3·30	·059	·109	·98
K_2O	0·64	·007		
Na_2O	2·63	·043		
H_2O	13·44		·747	6·67
	99·28			

The water was fractionated as follows:

At 110°	2·62	·301	1·79
125°	1·31	·073	·65
300°	5·41	·301	2·69
red heat	3·10	·172	1·54
	13·44		
Loss over H_2SO_4	3·84	·213	·190

For comparison with the above, the analyses and ratios of the original ptilolite and of mordenite are appended:

Ptilolite, Green Mt., Colo.		
SiO_2	70·35	10·06
Al_2O_3	11·90	1·00
CaO	3·87	·96
K_2O	2·83	
Na_2O	0·77	
H_2O	10·18	4·86
	99·90	

Mordenite (L. V. Pirsson)		
SiO_2	66·40	9·88
Al_2O_3	11·17	1·00
Fe_2O_3	0·57	
CaO	1·94	1·01
MgO	0·17	
K_2O	3·58	
Na_2O	2·27	
H_2O	13·31	6·60
	99·41	

The empirical formula derived from the analysis of the new ptilolite is: $R'Al_2Si_{10}O_{24}+6\frac{2}{3}H_2O$, which it will be noticed is the same as that of mordenite, but as Pirsson has already pointed out (loc. cit.), the two minerals are physically very unlike.

The two ptilolites themselves are entirely similar both in their manner of occurrence and in their physical properties. In chemical composition the only difference is that the new mineral contains 3·26 per cent more water than the old, with a proportional reduction of the other constituents; the molecular proportions of silica and bases being the same in both occurrences.

This excess of water may possibly be accounted for by the different conditions under which the two minerals were analyzed. The original analysis was made in Denver, the present one in Washington, that is, one in a very dry, the other in a very damp climate. Both minerals were air dried, and as both evidently hold a considerable part of the water very loosely, it seems not unreasonable to suggest that the dry Denver atmosphere may have had sufficient desiccating power to remove part of the water from the mineral analyzed there. In fact, on account of this atmospheric difference, water determinations in the two minerals, especially at low and medium temperatures would hardly be directly comparable, since it is now recognized that at a given temperature the relative humidity of the surrounding atmosphere may markedly influence not merely the rate, but also the total amount, of loss on drying.

The fractional determinations in the new ptilolite show that 3·10 per cent of the water is stable at 300° C., so that this may be basic. In the original material no such line of demarkation in the water was detected, although it was thought then that sufficient care was used, but one important factor was not then so well recognized as it is now, namely, the element of time in drying minerals of this type, and it may be that time enough was not given at each temperature before increasing it. The fact, however, that a comparatively high temperature was found necessary for the total expulsion of the water, would render it easy to admit the possible basicity of part of it in case other considerations made such an admission advisable in order to construct a rational formula for the mineral.

In mordenite no attempt seems to have been made to fractionate the water, except to determine the loss (3·6 per cent) at 100°, so here we have no evidence as to whether it may be basic in part or not.

The fact that in the new ptilolite we have direct evidence that a definite portion of the water may be basic, and that no good ground against such an assumption exists in the analysis of the original mineral, makes it necessary to carefully consider this point in any attempt to theorize upon the structure of the ptilolite molecule. Prof. Clarke has kindly written a note on the theoretical formula of ptilolite and of the allied mordenite, which appears in the succeeding pages.

In view of their similar mode of occurrence, of their identical physical properties, of their exact chemical agreement except as to water, and of the considerations concerning the water presented above, there can be no question but that these two downy minerals belong to one and the same species—ptilolite.

In comparing the analyses of mordenite and the two ptilolites a great variation in the amounts of lime, soda and potash is noticeable. In mordenite the molecular ratio is $CaO : K_2O : Na_2O = 1 : 1 : 1$; but no simple ratio exists in ptilolite.

The Green Mountain mineral is relatively poor in soda, the Silver Cliff mineral in potash, and the mordenite in lime, facts which seem very strange when we consider the rocks in which the minerals occur. Mordenite occurs in a basalt, but is richest in potash and poorest in lime; the original ptilolite occurs in an andesite of medium composition and is poorest in soda; and the new mineral occurs in a devitrified pitchstone and is poorest in potash. The last instance is most remarkable, for the pitchstones of the region about are usually rich in potash and contain but very small amounts of lime. Analysis of the greenish felsitic mass in which the ptilolite occurs shows, however, that the entire rock has in this case undergone a decomposition which brings it to a constitution similar to that of ptilolite. The lime, at least, of this ptilolite was not derived from the surrounding rock, unless secondarily. The analysis of the rock containing the ptilolite of Silver Cliff is as follows (Analyst, L. G. Eakins):

SiO_2	65·67
Al_2O_3	13·48
Fe_2O_3	1·51
MnO	tr.
BaO	·32
CaO	2·41
MgO	·31
K_2O	2·42
Na_2O	1·52
SO_3	·28
P_2O_5	tr.
H_2O	12·27
	100·19

APPENDIX.—*Note on the Constitution of Ptilolite and Mordenite;* by F. W. CLARKE.

THE data given in the foregoing paper by Cross and Eakins, especially as regards the dehydration of ptilolite, lead to quite simple formulæ for the three minerals under discussion. The moment that we recognize the fact that part of the water in each mineral may be basic, the apparent anomalies disappear; and the compounds reduce at once to similar salts of the acid $H_2Si_2O_5$, which acid is well known in the species petalite and milarite. Both ptilolite and mordenite become simply representable by the general formula

$$Al_2(Si_2O_5)_5R'_4+n\text{Aq}.$$

the only serious uncertainties being in respect to the hydration.

In brief, the following salts appear to be represented in the three minerals, commingled in simple ratios:

1. $Al_2(Si_2O_5)_5CaH_2\ .\ 3\ \text{aq}.$
2. $Al_2(Si_2O_5)_5CaH_2\ .\ 6\ \text{aq}.$
3. $Al_2(Si_2O_5)_5K_2H_2\ .\ 6\ \text{aq}.$
4. $Al_2(Si_2O_5)_5Na_2H_2\ .\ 6\ \text{aq}.$

Three of these are entirely alike in type: but the first, containing only half the normal quantity of crystalline water, is assumed in order to account for the low hydration of the original, Green Mt. ptilolite. Upon this basis the three minerals investigated may be assigned the following theoretical compositions:

Ptilolite, Green Mt.,	molecules	1 and 3,	in ratio of	3 : 2
" Silver Cliff	"	2 " 4,	" "	1 : 1
Mordenite,	"	2, 3, 4,	" "	1 : 1 : 1

Reducing soda to potash in the Green Mt. ptilolite, and potash to its equivalent of soda in the Silver Cliff minerals, and recalculating to 100 per cent, we get a fair comparison between the actual analyses and theory.

Ptilolite.

	Green Mt.		Silver Cliff.	
	Found.	Calc.	Found.	Calc.
SiO_2	70·15	69·22	68·45	67·64
Al_2O_3	11·86	11·77	11·55	11·50
CaO	3·86	3·88	3·35	3·16
K_2O	3·98	4·34	----	----
Na_2O	----	----	3·09	3·49
H_2O	10·15	10·79	13·56	14·21
	100·00	100·00	100·00	100·00

In mordenite, reducing Fe_2O_3 to Al_2O_3 and MgO to CaO, the comparison comes out as follows:

	Found.	Calc.
SiO_2	66·88	66·77
Al_2O_3	11·62	11·35
CaO	2·17	2·07
K_2O	3·62	3·49
Na_2O	2·29	2·30
H_2O	13·42	14·02
	100·00	100·00

Considering the scarcity of material, and the difficulties attending its purification, these agreements are in the main satisfactory. In the water determinations, however, there is an uncertainty. In the theoretical composition assigned to the Silver Cliff ptilolite, one seventh of the water, a trifle under two per cent, is basic. But 3·10 per cent were found to be stable at 300°. What weight can be assigned to this discrepancy is not yet determinable, but it can hardly be regarded as an insuperable objection to the proposed formulæ. The general character of the salts, their essential types, seems to be fairly well established.

ART. XIV.—*The separation of Magnesium Chloride from the Chlorides of Sodium and Potassium by means of Amyl Alcohol;* by R. B. RIGGS.

THIS separation depends on the insolubility of the chlorides of sodium and potassium and the solubility of magnesium chloride in amyl alcohol. That the alkaline chlorides are insoluble in this reagent has already been shown by Gooch in his paper* on the separation of sodium and potassium from lithium by the action of amyl alcohol on their chlorides. In the same paper attention is also called to the solubility of anhydrous magnesium chloride. The difficulty, if there be any, lies in dehydrating this chloride. Attempts to dehydrate magnesium chloride by direct heat result in a more or less complete decomposition. This is also found to be the case where the salt, in a solution containing no free acid, is rendered anhydrous by means of boiling amyl alcohol. The amount decomposed, in this latter case, is however relatively small. The decomposition products are the oxide and hydrochloric acid. It is therefore necessary either to introduce conditions which will prevent such decomposition or to find a means of redissolving any oxide that may be formed. The use of hydrochloric acid gas was deemed impracticable. To use the acid solution was regarded as objectionable† because, in so doing, water, the very substance to be driven out, would be brought into the solution. Experiments were made in which, after the water of the magnesium chloride solution had been nearly or quite expelled by boiling with amyl alcohol, a few drops of benzyl chloride were added and the dehydration completed. The salt dissolved without leaving a residue. So little benzyl chloride was used that it did not seem probable that its use could materially affect the solubility of the chlorides of potassium and sodium. Working on this supposition a series of separations were made the results of which are given below.

Standardized solutions of the several salts were used. The solution of magnesium chloride was prepared from the carbonate, which had been twice precipitated from moderately strong solutions of the chloride. The chloride thus made was free from alkalies and wholly soluble in amyl alcohol. The strength of this solution was found by treating weighed por-

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* Am. Chem. Jour., vol. ix, p. 33.

† This objection was afterwards found to be groundless.

tions with sulphuric acid in excess, evaporating, igniting and weighing as sulphate.*

The potassium chloride was obtained from the chlorate. The chloride of sodium was prepared from sodium hydrate (obtained from sodium) and further purified by precipitation by hydrochloric acid.

Both solutions were standardized by evaporating weighed portions to dryness, drying at about 300° C. and weighing.

The solutions, thus standardized, were found to contain respectively 0·5293 grm. NaCl, 0·5412 grm. KCl and the equivalent of 0·4146 grm. MgO to the 100 grams.

Three series of separations, containing severally mixtures of magnesium chloride and one or the other or both of the alkaline chlorides, were made. The solutions were evaporated nearly to dryness. The residue, if any, was taken up with the smallest possible quantity of water and a few drops of hydrochloric acid. 30–40^{cc} of amyl alcohol were then added and the water was expelled by bringing the alcohol to the boiling (128°–130° C.) Eight or ten drops of benzyl chloride were added and the solution was evaporated to about 10^{cc}. A perforated crucible, an asbestus felt and pressure were used in filtering. The filtrate was transferred to a weighed platinum dish and the alcohol driven off by evaporation on a water bath. As soon as the solution became viscous water was added and the evaporation repeated. The residue was finally taken up with water and sulphuric acid was added in slight excess. This solution was evaporated to dryness and the residue ignited and weighed as sulphate. The amyl alcohol precipitate was dissolved and transferred to a weighed platinum dish, evaporated to dryness and heated in an air bath at a temperature of about 300° C. and weighed.

The solubility corrections, as determined by Gooch,† were introduced, viz: For every 10^{cc} of amyl alcohol solution, exclusive of washings, 0·00051 grm. was added to the weight of the insoluble chlorides in case the residue was potassium chloride, 0·00041 grm. in case it was sodium chloride and 0·00092 grm. in case both were present. Equivalent amounts were taken from the weight of the magnesium sulphate.

The results of these separations, including determinations in many cases of the amounts of magnesia carried by the chloride precipitates, are here given.

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* Several determinations as phosphate were made which, though agreeing together. gave somewhat lower results than were obtained by weighing the magnesium as sulphate. This may be due to impurities in the chloride or, as is more probable, it may be owing to the slight solubility of the phosphate

† Am. Chem. Jour., vol. ix. p. 48.

	Weight of KCl taken. grm.	Weight of KCl found. grm.	Corr. weight of KCl found. grm.	Error in corr. weight of KCl found. grm.	Weight of MgO found in KCl. grm.
(1)	0·1076	0·1075	0·1079	0·0003 +	0·0002
(2)	0·1084	0·1080	0·1083	0·0001 —	trace
(3)	0·1083	0·1079	0·1083	0·0000	0·0001
(4)	0·1077	0·1071	0·1076	0·0001 —	0·0001
(5)	0·1082	0·1075	0·1080	0·0002 —	0·0002
(6)	0·1085	0·1079	0·1083	0·0002 —	not det.
(7)	0·1628	0·1613	0·1622	0·0006 —	0·0004
(8)	0·1630	0·1614	0·1622	0·0008 —	0·0003
(9)	0·0109	0·0106	0·0110	0·0001 +	not det.
(10)	0·0116	0·0114	0·0118	0·0002 +	0·0001

	Weight of MgO taken. grm.	Weight of $MgSO_4$ found. grm.	Corr. weight of $MgSO_4$ found. grm.	Corr. weight of MgO_4 found. grm.	Error in corr. weight of MgO found. grm.
(1)	0·0092	0·0278	0·0274	0·0091	0·0001 —
(2)	0·0094	0·0275	0·0272	0·0091	0·0003 —
(3)	0·0417	0·1249	0·1245	0·0415	0·0002 —
(4)	0·0421	0·1264	0·1259	0·0420	0·0001 —
(5)	0·0828	0·2482	0·2476	0·0825	0·0003 —
(6)	0·0835	0·2509	0·2503	0·0834	0·0001 —
(7)	0·1662	0·5008	0·4998	0·1666	0·0004 +
(8)	0·1661	0·4986	0·4977	0·1659	0·0002 —
(9)	0·0830	0·2492	0·2488	0·0829	0·0001 —
(10)	0·0834	0·2494	0·2490	0·0830	0·0004 —

	Weight of NaCl taken. grm.	Weight of NaCl found. grm.	Corr. weight of NaCl found. grm.	Error in corr. weight of NaCl found. grm.	Weight of MgO found in NaCl. grm.
(11)	0·1113	0·1114	0·1116	0·0003 +	not det.
(12)	0·1066	0·1061	0·1065	0·0001 —	0·0002
(13)	0·1066	0·1058	0·1063	0·0003 —	trace
(14)	0·1064	0·1056	0·1062	0·0002 —	0·0001

	Weight of MgO taken. grm.	Weight of $MgSO_4$ found. grm.	Corr. weight of $MgSO_4$ found. grm.	Corr. weight of MgO found. grm.	Error in corr. weight of MgO found. grm.
(11)	0·0836	0·2496	0·2493	0·0831	0·0005 —
(12)	0·0835	0·2504	0·2499	0·0833	0·0002 —
(13)	0·1663	0·4979	0·4973	0·1658	0·0005 -
(14)	0·1665	0·4977	0·4970	0·1657	0·0008 —

	Weight of KCl taken. grm.	Weight of NaCl taken. grm.	Weight of chlorides found. grm.	Corr. weight of chlorides found. grm.	Error in corr. weight of chlorides found. grm.	Weight of MgO found in chlorides. grm.
(15)	0·0544	0·0529	0·1066	0·1076	0·0003 +	trace
(16)	0·0545	0·0531	0·1068	0·1077	0·0001 +	0·0004
(17)	0·1087	0·1063	0·2131	0·2142	0·0008 —	0·0002
(18)	0·1085	0·1063	0·2122	0·2134	0·0014 —	trace
(19)	0·1083	0·1064	0·2118	0·2137	0·0010	not det.

	Weight of MgO taken. grm.	Weight of $MgSO_4$ found. grm.	Corr. weight of $MgSO_4$ found. grm.	Corr. weight of MgO found. grm.	Error in corr. weight of MgO found. grm.
(15)	0·0827	0·2487	0·2475	0·0825	0·0002 —
(16)	0·0830	0·2495	0·2484	0·0828	0·0002 —
(17)	0·1664	0·5000	0·4987	0·1662	0·0002 —
(18)	0·1663	0·5007	0·4995	0·1665	0·0002 +
(19)	0·1660	0·5010	0·4987	0·1662	0·0002 +

These results speak for themselves. It is evident that we have here a fairly good quantitative method. The errors are generally negative. This is to be expected. The large negative errors in the weights of the insoluble chlorides, in experiments (26)–(28), are probably due to loss from manipulation. 0·2 grams of either the insoluble chlorides or magnesia are perhaps too large quantities to deal with.

10^{cc} of amyl alcohol hold 1·14 grm. of magnesium chloride in solution at 14° C. and 1·23 grm. at 50° C. In the majority of the experiments the residual volumes of alcohol were less than 10^{cc}. They might with safety have been further reduced, thus reducing the solubility corrections.

In experiments (7), (8), (13), (14), (18) and (19) two precipitations of the insoluble chlorides were made, decanting the liquid, washing the residue, redissolving it and repeating the precipitation. The advisability of this is questionable. A more complete separation may be thus effected but the possibilities of loss from manipulation seem to counterbalance this advantage. Almost the same degree of completeness of separation may be attained by redissolving the precipitate with as little water and acid as possible and repeating the precipitation in the original solution.

In dehydrating the mixed chlorides it was noticed that the nature of the precipitate depended much on the relative amounts of the magnesium and the insoluble chlorides. Roughly speaking, when the weight of magnesia is equal to or exceeds that of the insoluble chlorides, the precipitate is thrown out as a fine powder. When however the insoluble chlorides are greatly in excess, the tendency to obey the laws in accordance with which they crystallize asserts itself and we have a more or less coarsely granular deposit. This is especially true in the case of sodium chloride. These facts have a bearing on the question of completeness of separation.

Consider the amounts of magnesia found in the alkalies. They bear no relation to the amount of magnesium chlorides involved. It seems probable that the magnesia there found has been carried mechanically, and that it is not there as the result of decomposition. How can we better explain the finding of magnesia in the insoluble chlorides of experiment (1) where but 9 mgrm. of magnesia were involved. Here it is essentially the result of inclusion.

The desirability of adding water to the amyl alcohol solution of magnesium chloride before completing the evaporation is to be emphasized. By so doing it is possible to expel the alcohol so completely that even those experiments where there was the maximum amount of magnesia gave no trouble from carbonization.

In adding sulphuric acid a great excess is to be avoided. In the above experiments about twice the amount demanded by theory was used. The result, in the end, is economy of time and less danger of loss. It is better to add sulphuric acid a second time and repeat the evaporation, ignition and weighing. In the experiments involving an amount of magnesium equivalent to 0·16 grm. of the oxide, the ignited sulphate was found in a few instances to increase its weight after a second treatment with sulphuric acid. The lesser amounts were almost without exception wholly converted into the sulphate by a single treatment.

In the course of the work it was found that amyl alcohol and concentrated hydrochloric acid mix in all proportions. Furthermore if amyl alcohol containing but a small quantity of the acid be boiled down to but a small fraction of its original volume the residue contains chlorine in some form. 30^{cc} of the alcohol, to which $0{\cdot}2^{cc}$ of concentrated hydrochloric had been added, having been reduced to 2^{cc} gave a decided test for chlorine. This suggested the possibility that the use of benzyl chloride was unnecessary. For, if amyl alcohol mixes with the concentrated acid and on being evaporated retains more or less of it to the last, the conditions which would prevent the decomposition of magnesium chloride are maintained. The easy solubility of the anhydrous magnesium chloride is beyond question. Possibly then, in the above experiments, the addition of benzyl chloride was uncalled for as in every case hydrochloric acid had been previously added to the salt solutions. To decide the question a few separations were made without the benzyl chloride. Otherwise the conditions and methods were the same.

	Weight of KCl taken. grm.	Weight of KCl found. grm.	Corr. weight of KCl found. grm.	Error in corr. weight of KCl found. grm.	Weight of MgO found in KCl. grm.
(20)	0·1079	0·1078	0·1082	0·0003 +	trace
(21)	0·1081	0·1074	0·1079	0·0002 —	trace
(22)	0·1081	0·1076	0·1080	0·0001 —	0·0004
(23)	0·1080	0·1074	0·1079	0·0001 —	0·0003
(24)	0·1080	0·1071	0·1079	0·0001 —	0·0004
(25)	0·1076	0·1061	0·1070	0·0006 —	0·0002

	Weight of NaCl taken. grm.	Weight of NaCl found. grm.	Corr. weight of NaCl found. grm.	Error in corr. weight of NaCl found. grm.	Weight of MgO found in NaCl. grm.
(26)	0·1582	0·1576	0·1583	0·0001 +	trace
(27)	0·1591	0·1576	0·1582	0·0009 —	trace

	Weight of MgO taken. grm.	Weight of $MgSO_4$ found. grm.	Corr. weight of $MgSO_4$ found. grm.	Corr. weight of MgO found. grm.	Error in corr. weight of MgO found. grm.
(20)	0·0419	0·1250	0·1245	0·0415	0·0004 —
(21)	0·0418	0·1262	0·1257	0·0419	0·0001 +
(22)	0·0835	0·2508	0·2504	0·0835	0·0000
(23)	0·0827	0·2498	0·2493	0·0831	0·0004 +
(24)	0·1665	0·4996	0·4987	0·1662	0·0003 —
(25)	0·1667	0·5005	0·4995	0·1665	0·0002 —
(26)	0·1669	0·5009	0·5001	0·1667	0·0002 —
(27)	0·1662	0·4980	0·4973	0·1658	0·0004 —

It is evident that the benzyl chloride is not needed, further that its presence in the solution is harmless.

Summary.—In separating magnesium chloride from the chlorides of sodium and potassium, the treatment is as follows: evaporate the solution nearly or quite to dryness. Dissolve the residue in as little water as possible and add a few drops of hydrochloric acid. Then add 30–40^{cc} of amyl alcohol and expel the water by bringing the alcohol to the boiling. Continue the boiling until the volume of the solution is reduced to 10^{cc} or even considerably less. In filtering it is of great advantage to use a perforated crucible and an asbestus felt and to filter under pressure. In case the total chlorides exceed 0·2 grm. it may be advisable to decant the liquid, wash the residue, redissolve and repeat the precipitation. If this be not done the precipitate should be redissolved with the least possible quantity of water, a few drops of hydrochloric acid added and the precipitation repeated in the original solution. The filtrate is transferred to a weighed platinum dish and evaporated. Water is added before the alcohol has been expelled and the evaporation continued. The residue is dissolved in water. Sulphuric acid is added in slight excess. This solution is evaporated to dryness, the residue ignited and weighed and the treatment with sulphuric acid is repeated. The residue of insoluble chlorides may be transferred to the weighed perforated crucible and dried at a temperature below their melting points or it may be dissolved and the solution transferred to a weighed platinum dish, evaporated and the residue dried, as above, and weighed.

Chemical Laboratory, Trinity College,
Hartford, April, 1892.

ART. XV.—*The Great Shear-zone near Avalanche Lake in the Adirondacks*; by J. F. KEMP.

IN July, 1889, the writer was in the region of Lake Champlain, accompanied by V. F. Marsters, while gathering notes upon the igneous dikes so plentiful along its shores.* Our attention was directed to the great trap dike which is recorded near Avalanche Lake in the Adirondacks, and we made a trip into the woods to examine it. Although, when viewed from a distance this rock mass appeared as an undoubted dike, yet as soon as it was examined in a hand specimen on the spot, it was pronounced at once to be no true intrusion, but to constitute a shear-zone,† or zone of wall rock, dynamically metamorphosed along a fault. Subsequent microscopic examination has corroborated this view and the case in point is an interesting and somewhat unique exhibition of this phenomenon.

Avalanche Lake, a small body of water, is the very head of one of the feeders to the Hudson River. The pass by which it is reached from the north is on the watershed which diverts the northerly drainage into the Ausable River. The pass opens directly into the Lake, which is fed by springs. It is a narrow cañon between vertical walls of massive rock similar to the better known and larger Indian Pass farther west. It is five miles into the woods from the Adirondack Lodge. On the

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* A short digest of our results has appeared in the Transactions of the New York Academy of Sciences, vol. xi, p. 13, 1891. A full account will be printed elsewhere.

† For the use of this term compare Ch. Callaway, On the secondary minerals at shear zones, in the crystalline rocks of the Malvern Hills, Quart. J. Geol. Soc., Aug. 1889.

west of the lake is Mt. McIntyre, on the east are Mt. Colden and Avalanche Mts., which two are separated by the shear-zone. The twin mountain is also called Mt. McMartin. The lake and supposed dike were early discovered and recorded in connection with the mining enterprise that was started at Lake Henderson a few miles south.* The neighboring mountains, Colden, McMartin, etc., were named from the promoters of the mining enterprise. Redfield records that both the expeditions were accompanied by one of the recently appointed State geologists, the first by James Hall, and the second by E. Emmons.

The accompanying sketch has been traced directly from a photograph, taken from a point of view across the lake. It and the first micro-drawing were kindly made by Mr. Arthur Hollick. A sketch which but remotely resembles the original is given by Emmons in his report, p. 215 (also Ann. Rep. 1838, Atlas, plate 4.) The two peaks are dome-shaped knobs of massive rock, practically bare of vegetation and cleft from base to summit by the so-called dike. The latter forms a recess which is deeper at the lake than at the summit. At the

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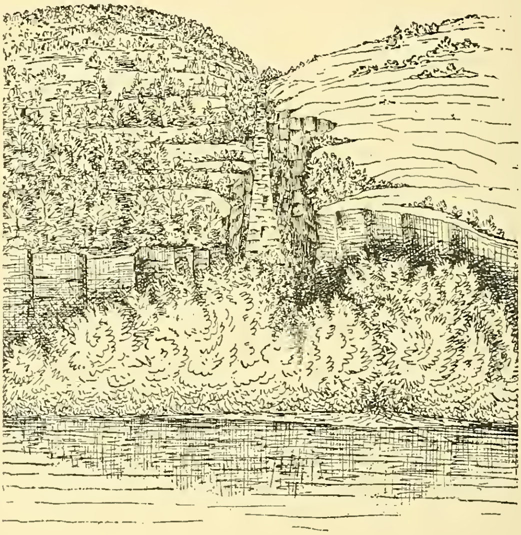

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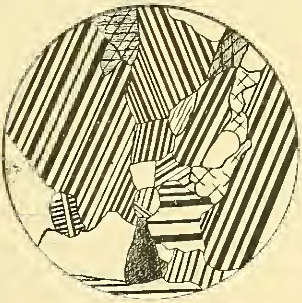
* W. C. Redfield: Some account of two visits to the Mountains of Essex Co., N. Y., 1836–37, etc., this Journ., I, xxxiii, 301. Second Ann. Rep. N. Y. State Survey, 1838, p. 225; Atlas plate IV. Emmons's Final Rep. on the 2nd Dist., p. 215.

lake it is 75 feet across. The walls are vertical. The so-called dike terminates in the lake where it is doubtless cut off by the cross fault that outlined the pass. It strikes N. 50–60 W.

The general rock of the mountains is a lighter colored variety of the plagioclase rock which is commonly but not always correctly called norite. Sections from the wall of the pass show coarse plagioclase in much the largest part, with which is probably a little orthoclase. The feldspar contains many minute inclusions which are probably small crystals of the dark silicates and iron ores, exhibiting thus a common character of the feldspars of rocks belonging to the gabbro family. The dark silicate is a brownish green hornblende of strong pleochroism. It occurs in shreds and irregular masses. Rather more abundant is a colorless enstatite of massive habit. The slide gives evidence of dynamic fractures and strains, but is far less broken than the rock of the shear-zone. The somewhat parallel arrangement of the hornblende occasions a very coarse gneissic structure. Under the microscope the enstatite follows a similar foliation. A slide from the north wall of the shear-zone exhibits much the same. It is chiefly plagioclase, with a little hornblende, enstatite and a little magnetite. The plagioclase has suffered some dynamic strains and shows faulting of twin lamellæ. Figure 2 is a drawing with the camera lucida. The heavy outlines mark the crystal boundaries as seen without crossed nicols, after which the twinning has been put in. The cleavages indicate the bisilicates, the rhombic is hornblende, the rectangular enstatite.

2.



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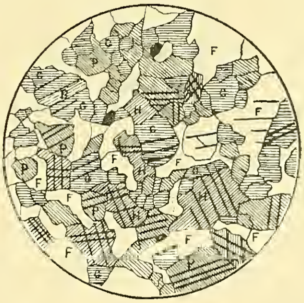

The rock of the shear-zone is dark gray in color and contrasted with the walls which are lighter. It thus resembles trap. In the hand specimen it is seen at once to be largely made up of garnets and this fact cast the first doubt on its igneous character. It also has the appearance of a rather massive hornblende schist or of a gneiss. Chips were taken from the edge of the zone and at intervals of ten feet across. They show some slight variations in mineralogical composition but they are essentially all the same rock. There is no evidence of the common chilling along the walls and coarser crystallization in the center, such as we see in dikes, but the structure is quite uniform throughout. The rock consists of broken irregular masses of plagioclase, $0{\cdot}1$–$0{\cdot}5^{mm}$, of shreds of hypersthene, green, non-pleochroic, monoclinic pyroxene, pink garnet, greenish-brown hornblende, biotite and magnetite. The individual minerals are nearly in this order of abundance, but in the aggregate the dark silicates far surpass the feldspar. This is shown in fig. 3. The first four named, including plagioclase, are in excess. The plagioclase frequently shows abundant evidence of crushing and indeed as fig. 3, indicates all the minerals are irregular and broken. Fig. 3, was drawn with a camera lucida. The actual field is 4^{mm}. The impossibility of indicating in faithful line work the differences of the minerals has prompted putting initials on them. G is garnet; F, feldspar; A, amphibole; H, hypersthene; B, biotite and the hachures are uniform for each.

The hypersthene with pink to green pleochroism repeatedly passes into garnet which has a tint much like its pink. The same cracks run through both and it is not always possible to be sure when the pink shows, which mineral is present, until either the pleochroism or the isotropic character is proved. Two such are shown in fig. 3, one in the center, one in the lower right-hand quadrant. Pleochroic hypersthene passes in a similar way into non-pleochroic pyroxene. The same cleavage cracks pierce both, but the extinction angles are different, rising in the latter to various angles from 27°–44°. In instances the hornblende seems also to have resulted from the hypersthene. Biotite favors the neighborhood of magnetite, but in fig. 3 is shown cutting a garnet mass in two. It is comparatively rare.

It may be said, therefore, that in the walls we have a coarsely crystalline rock, containing plagioclase, hornblende and magnetite, but chiefly the first named. In the shear-zone, the dark silicates, hypersthene, green monoclinic pyroxene and garnet are collectively most abundant and with them is considerable plagioclase, a little hornblende, biotite and magnetite. The hypersthene passes into the monoclinic pyroxene and into garnet both of which are considered to be derived from it. That the feldspar has also helped to furnish these minerals, probably by contributions of calcium and aluminium, is a well-nigh irresistible conclusion from the way it is distributed in isolated patches through them. Dynamic effects are abundant.

The strip of the shear-zone may have been more basic originally than the walls, and may have contained more bisilicates or else infiltration has rendered it more basic. Alternations from light to dark so-called norite are not uncommon in the mountains, especially where the rocks are gneissoid. Being dynamically affected by faulting its minerals were crushed to the shreds in which we now see them and the secondary ones resulted. The hypersthene is regarded as an original mineral because it is abundant in the less disturbed districts and is a more distinctively igneous mineral than those derived from it. It cannot be denied, however, that the sheared zone may have been an original dike. If so its mineralogy and structure have been completely reorganized. So far as observations go, diabase dikes are quite plentiful in the outskirts of the mountains, but in neither of these characters does the shear-zone bear indication of ever having been diabase. The dynamic metamorphism of diabase has been shown in numerous instances in this country and abroad to yield amphibolites. The shear-zone is more like an eklogite than anything else. Moreover an intrusion of norite as a dike is a new phenomenon for this region whose noritic exposures are singular massive or gneissoid and send out so far as known, no dikes whatever. It is stated by Redfield that other and smaller dikes similar to the large one occur on Mt. McIntyre and frequently appear in the beds of brooks. He refers the lines of drainage to the greater relative decomposition of the supposed dikes. While no other one was seen by the writer which would be analogous to the shear zone, these smaller occurrences ought to prove to be diabase or some similar rock if they really are intrusions.

A mineral aggregate similar to that of the shear-zone was met on Trembleau Point just south of Port Kent, and in the railways cuts. The country rock, which contains coarse plagioclase and monoclinic pyroxene as well as hypersthene, passes at times into dark, gneissoid bands, easily mistaken at first glance for trap which also seams the cuts in all directions. In the slides these bands are practically identical with the Avalanche shear-zone although at times containing more biotite. They make no recesses because freshly exposed.

A case of a shear-zone was also met at Hammondville in the No. 7 slope of the iron mines. The workings run down following a bed of magnetite, for 700–800 feet. They penetrate three narrow diabase dikes, by each of which the ore is faulted about 15 feet. The workings finally met another dark strip and the ore was cut off. A specimen was gathered under the impression that it was trap, but the section shows crushed remnants of the gneiss which is the wall rock. It is mostly chloritic alteration products, with shattered and strained grains of quartz, sheared micas and recognizable fragments of plagioclase in the midst of decomposition material furnished by them. As the fault was in a different kind of rock from the shear-zones in norite, its products are somewhat different, and the great proportion of hydrated silicates give the impression that the shear-zones earlier described may be the result of a secondary metamorphism which the one at Hammondville has not experienced. This fault broke the ore and drill holes have failed to find it again. Experience in mining the adjacent Penfield bed has shown that the ore is cut off where the workings extend under a neighboring gully, and suggests that these topographical features are due in instances at least to faults. Such an explanation has proved true in many regions elsewhere* and will probably be applicable to some valleys of large size in the Adirondacks.

Crushed strips along faults are well known in mining districts and have often furnished the receptacles for ores, as at Butte, Montana.† The drift of modern opinion refers to them an increasing number of so-called fissure veins. Where conditions are unfavorable for vein formation dynamic metamorphism results. The work of Lossen, G. H. Williams, Teall and many others has shown the widespread effects of dynamic metamorphism, but a somewhat careful review has failed to reveal descriptions of any instances of such restricted effect and such mineralogical results as are exhibited on Avalanche Lake.

Geological Laboratory, Columbia College.

Art. XVI.—*On Herderite from Hebron, Maine*; by H. L. Wells and S. L. Penfield.

During the summer of 1891 we received from Mr. L. K. Stone of Paris, Maine, a small mineral specimen for identification. The unknown mineral consisted of a few yellowish white crystals on albite. They were about 3–5^{mm} in length and their total weight probably did not exceed 2 or 3 grams. Mr. Stone stated that this was the only specimen of the mineral that had been found. and that it was discovered in 1890 at the pollucite locality in Hebron.

A preliminary examination proved that the mineral was a phosphate, very slowly soluble in hydrochloric acid and yield-

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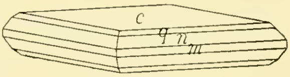
* J. H. Kinahan, Valleys and their Relations to Fissures, Fractures and Faults. London: Trübner & Co.

† S. F. Emmons, Notes on the Geology of Butte, Trans. Inst. Min. Eng., July, 1887, and Structural Relations of Ore Deposits, idem. xvi, 804.

ing nearly neutral water in a closed tube. The latter reaction is entirely different from that of the Stoneham herderite, which gives off very acid water and etches the glass decidedly. Before the blowpipe in the platinum forceps it turned white, sprouted and fused at about 3 to a white enamel, coloring the flame very pale green. Only a few fragmentary crystals could be found which were suitable for measurement. The crystals had the habit shown in the accompanying figure. They were attached so that only the faces at one extremity of the macro-axis were developed and were grouped in nearly parallel position but with the basal planes slightly divergent.



The forms which were observed are:

c, 001, O; m, 110, I; n, 331, 3 and q, 332, $\frac{3}{2}$

The basal planes were irregular and yielded no satisfactory reflections of the signal, while m and q were small and frequently wanting. All of the faces except c were usually striated.

The measurements which were made are given below. The calculated values are derived from the axial ratio established by Prof. E. S. Dana* from the Stoneham herderite.

					Calculated.
$n \wedge n$,	$331 \wedge 33\bar{1} =$	45° 7′	*45° 10′	45° 26′	45°. 6′
$n \wedge n$,	$331 \wedge \bar{3}31 =$	*102° 22′	103° 7′		103° 24′
$n \wedge m$,	$331 \wedge 110 =$	22° 14′	22° 53′		22° 33′
$n \wedge q$,	$331 \wedge 332 =$	16° 50′	16° 32′		17° 9′

Herderite was not suggested to us by the preliminary examination, and the measurements showed such a close relation to the angles of childrenite, that we fully expected the mineral to be some new variety of the latter, possibly a beryllium childrenite. It was not till the results of the quantitative analysis were obtained that we became aware of the true character of the mineral.

The similarity in crystalline form between childrenite and herderite is as follows:

Childrenite.		Corresponding forms on herderite.	
b,	010, $i\text{-}\breve{i}$	c,	001, O
	101, $1\text{-}\bar{i}$	m,	110, I
p,	111, 1	n,	331, 3
s,	121, $2\text{-}\breve{2}$	q,	332, $\frac{3}{2}$

Childrenite $a:b:c = {\cdot}7780 : 1 : {\cdot}5257$
Herderite in corresponding position $a:b:c = {\cdot}7752 : 1 : {\cdot}4929$

The axial ratio of the herderite was derived from the angles marked by asterisks in the above table of measurements. The

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* This Journal, III, xxvii, 229.

angle $331 \wedge \bar{3}31$ could not be measured with certainty as the crystal, which was selected as best, gave double reflections from one of the faces. The angle 102° 22′ was selected as fundamental as it was from the brightest reflection, while 103° 7′ agrees better with the calculated angle of herderite.

The resemblance between the two minerals is remarkable, but since no chemical relation between them apparently exists, except that both are phosphates, the similarity in form may be accidental.

The whole specimen, except two or three small crystals, was sacrificed for a chemical examination. The material was so intimately mixed with albite that the greater part of it had to be separated by Thoulet's solution. The specific gravity of a pure crystal as shown by the heavy solution was 2·975, that of the Stoneham herderite was 3·006. The material used for analysis varied between 2·980 and 2·853.

A careful qualitative analysis showed the presence of beryllium oxide and the absence of all other bases except lime. The phosphoric acid determination was made in a separate portion by the molybdic acid method. The beryllium oxide and water were determined by methods analogous to that described by one of us for the analysis of herderite.* Unfortunately the determination of lime was a failure and there was not enough material for making a new determination. The fluorine was determined by weighing silicon fluoride, using a modification of Fresenius' apparatus.

The results of the analysis are as follows:

	Found.	Deducting Insol.	Calculated for $CaBeOHPO_4$.
P_2O_5	40·81	43·08	44·10
BeO	15·32	16·18	15·53
CaO†	[32·54]	[34·35]	34·78
H_2O	5·83	6·15	5·59
F	·40	·42	----
Insol.	5·27	----	----
	100·17	100·18	100·00

The analysis shows the mineral to be a new and interesting variety of herderite almost free from fluorine. The result confirms the idea advanced by Penfield and Harper that fluorine and hydroxyl are mutually replaceable in herderite, and the formula deduced by them for the mineral is confirmed.

Sheffield Scientific School, March, 1892.

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* Penfield and Harper, this Journal, III, xxxii, 107.

† By difference.

ART. XVII.—*A method for the Iodometric Determination of Nitrates*; by F. A. GOOCH and H. W. GRUENER.

[Contributions from the Kent Chemical Laboratory of Yale College—XV.]

IT has been shown by DeKoninck and Nihoul* that nitrates may be decomposed completely by the prolonged action of gaseous hydrochloric acid, and determined with accuracy by measuring the iodine set free when the products of decomposition, carefully kept from atmospheric contamination, act upon potassium iodide. These investigators recognized the difficulties attending the use of gaseous hydrochloric acid in analytical processes, and endeavored unsuccessfully to substitute the strong aqueous solution for the gaseous acid. The work to be described in the following account was performed in the search for a simpler method for the iodometric determination of nitrates.

According to a process recently developed in this laboratory† chloric acid may be determined with the greatest ease. It was shown that in the interaction of a chlorate with potassium iodide, arsenic acid, and sulphuric acid, in regulated quantities in aqueous solution and at the boiling temperature, the first action of the hydriodic acid set free from the iodide by the sulphuric acid is upon the chloric acid, and that not until this action is completed is the arsenic acid attacked and reduced with the simultaneous liberation of a corresponding amount of iodine. If the arsenic acid is taken in quantity sufficient to insure the final decomposition of the entire amount of iodide present, the arsenious acid found at the end of the action is an exact measure of the amount of iodide which escaped the action of the chlorate; and, the quantity of iodide originally taken being known, the amount acted upon by the chlorate, and so the amount of the chlorate itself, becomes known. The arsenious acid is determinable with great accuracy iodometrically, and the chief advantage of the process lies in the fact that the titration is made upon the residue, and that, no collection of the distillate being necessary, the sole apparatus employed in the process proper is an Erlenmeyer beaker and a bulbed tube hung in its neck as a trap to prevent mechanical loss.

This process we endeavored to apply to the determination of nitrates, but under none of the many variations of form and changes of conditions under which we tested it, were we able to secure complete decomposition of the nitrate without so

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* Zeitschr. für angewandte Chemie, 1890, p. 477.

† Gooch and Smith, this Journal, vol. xlii, p. 220.

increasing the strength of the sulphuric acid that it was acted upon by hydriodic acid with the consequent unregistered escape of products of decomposition.

The endeavor to substitute a process essentially similar in principle, in which hydrochloric and antimonic acids should replace the sulphuric and arsenic acids proved likewise unsuccessful.

Abandoning therefore all attempts to so arrange the process that the oxidizing action of the nitrate should be registered in the residue, search was made for a reagent which should be capable of inducing easy decomposition of nitrates (after the manner of ferrous salts in acid solution) and yet (unlike ferrous salts) should be so readily restored to its primitive condition that the products of the oxidizing action of the nitrate should finally pass entirely to the distillate and be registered there. We have found the desired combination of qualities in manganous chloride dissolved to saturation in concentrated hydrochloric acid. This reagent is acted upon but slowly by nitrates at the ordinary temperature, but upon warming the nitrate begins at once to decompose with the formation of a higher chloride of manganese and liberation of nitric oxide. Ultimately if the heating is continued the chlorine of the higher chlorides is evolved and manganous chloride remains. During the process of heating the color of the solution passes from the original characteristic green through darker shades to black and returns by the reverse changes to the original tint. The decomposition of the nitrate extends under the conditions to the last traces, but the breaking up of the nitrates with the formation of the higher chloride, does not take place completely in the presence of water amounting to more than a third of the volume of the solution, and an action already established in strong acid is reversed by the addition of a large amount of water. Chlorates, peroxides, and other substances which liberate oxygen or chlorine when in contact with strong hydrochloric acid induce similar phenomena, but in the absence of such other substances the reaction serves to detect nitrates when present in fairly small amounts (perhaps one part in sixty thousand) as shown in the accompanying table :

KNO_3 taken.	$MnCl_2 . 4H_2O$ in strong HCl	Color developed.
0·01000 grm.	10 cm^3	Black.
0·00500	5	Black.
0·00100	5	Dark brown.
0·00050	5	Dark green.
0·00025	5	Deepened tint.
0·00015	5	Deepened tint.
0·00005	5	None.
0·00000	5	None.

In the first attempts to apply this reaction to the quantitative estimation of nitrates, 10 cm^3 of the manganous mixture, the pure weighed nitrate, and an excesss of potassium iodide were put in a tubulated retort fitted with a hollow ground stopper drawn out at both ends so as to serve for the introduction of carbon dioxide evolved in a Kipp's generator charged with marble and acid previously boiled. The neck of the retort passed through a rubber stopper nearly to the bottom of a side-neck Erlenmeyer flask, used as a receiver, in the mouth of which the stopper fitted tightly. The side-neck of the receiver was joined by a rubber connector with a bent glass tube passing through a rubber stopper and reaching nearly to the bottom of a side-neck test tube into the mouth of which the stopper was fitted.

The first receiver contained hydrogen sodium carbonate in excess of the amount needed to neutralize the acid in the retort as it should distil over, a considerable quantity of potassium iodide (about 3 grm.) to aid in dissolving condensed iodine, and arsenious oxide in known amount and in excess of the quantity necessary to convert to hydriodic acid the free iodine evolved. The second smaller receiver was partly filled with a dilute solution of potassium iodide and hydrogen sodium carbonate. The current of carbon dioxide was started immediately upon introducing the contents of the retort, and the air was safely removed before the darkening of color, which begins to appear very soon, had spread through the liquid. Heat was applied, and the evolution of nitric oxide and later that of iodine began. The distillation was continued until nearly all the liquid had passed over. Finally, the contents of both receivers were united and titrated against decinormal iodine. The excess of arsenious oxide remaining unoxidized was taken as the measure of the iodine liberated and, accordingly, of the nitrate decomposed, upon the presumption that two molecules of the nitrate liberate ultimately six atoms of iodine according to the equation

$$2HNO_3 + 6H\text{-}I = 4H_2O + 2NO + 3I\text{-}I.$$

The choice of the solution for the retention of the halogen evolved was dictated by the consideration, in the first place, that very little iodine could pass through the alkaline arsenite to come into contact with the rubber stopper of the receiver on the way to the second absorbing liquid, and, secondly, that higher oxides of nitrogen reformed by the action of traces of air possibly introduced with the carbon dioxide or imperfectly removed by it could not liberate iodine from an iodide in in alkaline solution.

The iodide was introduced into the retort because having chosen to collect the halogen in alkaline solution it became necessary to take steps to break up, before it should reach the receiver, all nitrosyl chloride, the formation of which our experience in former lines of work not here detailed had led us to expect under the circumstances. In acid solution containing an iodide, nitrosyl chloride liberates iodine and is registered; in alkaline solution it breaks up with the formation of a chloride and a nitrite, the latter having no immediate action upon the arsenite. The results of experiments made in this manner are recorded in the accompanying table.

TABLE I.

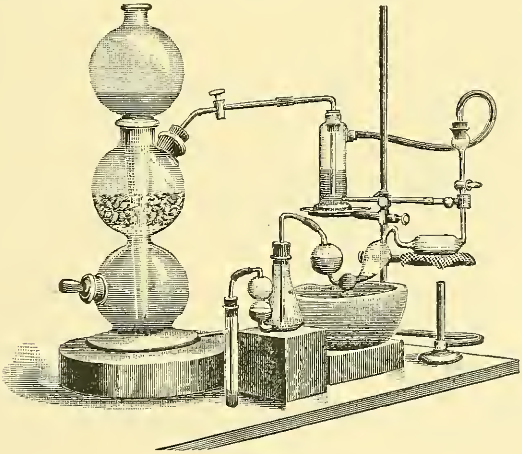
KNO_3 taken.	KI in retort.	$MnCl_2$ mixture.	KNO_3 found.	Error.
0·1036 grm.	0·8 grm.	10 cm^3	0·1009 grm.	0·0027 grm.—
0·1083 "	0·8 "	10 "	0·1082 "	0·0001 " —
0·1064 "	0·8 "	10 "	0·1053 "	0·0011 " —
0·1068 "	0·8 "	10 "	0·1033 "	0·0035 " —
0·0551 "	0·8 "	10 "	0·0531 "	0·0020 " —

The experiments of Table II were carried out in a manner essentially similar to that of the experiments of Table I, excepting the single point that the iodine evolved in the process of decomposition of the nitrate was received in potassium iodide instead of in an alkaline arsenite. The contents of the receivers were united, made alkaline with hydrogen sodium carbonate, treated with an excess of decinormal arsenious acid, and the unoxidized arsenious acid was determined by decinormal iodine.

TABLE II.

KNO_3 taken.	KI in retort.	$MnCl_2$ mixture.	KNO_3 found.	Error.
0·2039 grm.	1·6 grm.	20 cm^3	0·2025 grm.	0·0014 grm.—
0·1060 "	0·8 "	10 "	0·1035 "	0·0025 " —
0·1036 "	0·8 "	10 "	0·1016 "	0·0020 " —
0·1013 "	0·8 "	10 "	0·1002 "	0·0011 " —
0·0521 "	0·5 "	10 "	0·0521 "	0·0000 " —
0·0235 "	0·5 "	5 "	0·0227 "	0·0008 " —
0·0273 "	0·5 "	5 "	0·0262 "	0·0011 " —
0·0136 "	0·2 "	5 "	0·0132 "	0·0004 " —
0·0011 "	0·2 "	5 "	0·0009 "	0·0002 " —

The errors of both sets of experiments, those of Table I and those of Table II, are considerable, all lie in the same direction, and are indicative of too low registering of the action of the nitrate, since of the complete decomposition of the nitrate there can be no reasonable doubt in view of the proved behaviour of the manganese salt toward small amounts of nitrates. To us it seemed probable that the explanation of these results was to be sought in the failure of the titration in alkaline solution to indicate completely all the final products of the action of the nitrate. The formation, even in small amounts, of compounds of nitric oxide with iodine analogous to those which we know to be formed with bromine and chlorine, or the partial reoxidation of the nitric oxides by the action of iodine with the aid of water, an action which we recognize as possible under certain conditions of dilution, would account satisfactorily for the deficiency in the results of titration effected in alkaline solution. Upon this presumption the simple and obvious modification of titrating in acid solution should correct the error. Accordingly in the following series of experiments the plan of collecting the halogen and titrating in alkaline solution was abandoned, and since the addition of an iodide to the retort was no longer essential this practice was discontinued. The products of the action of the nitrate upon the manganese mixture—chlorine, nitric oxide and perhaps nitrosyl chloride,—were received directly in potassium iodide, and the iodine set free was titrated by sodium thiosulphate, itself standardized against iodine of known value with respect to a standard solution of decinormal arsenious oxide.



With the abandonment of the plan of putting the alkaline arsenite into the receiver the tendency of the iodine to pass onward to the second receiver is augmented and the possible action of the rubber stopper of the receiver becomes correspondingly dangerous. We modified the apparatus, therefore, so that only glass should occur where by any possibility rubber connections might act upon the free halogen. In place of the ordinary retort we adopted a form of apparatus made use of formerly by one of us in the quantitative distillation of boric acid under the action of methyl alcohol—a pipette bent and fitted as shown in the figure. To this apparatus was sealed a Varrentrapp and Will nitrogen bulb, the exit tube of which was drawn out so that it might be pushed well within the inlet tube of the second receiver—a Will and Varrentrapp absorption flask—and held in place by an outside rubber connector. The third receiver acts simply as a trap to exclude air from the absorption apparatus proper. In conducting the experiment the receivers were charged with solutions of potassium iodide, the first containing three grams, the second one gram, and the third only a fraction of a gram for every tenth of a gram of nitrate used. The first receiver was kept cool during the process by immersion in water. The introduction of the nitrate and manganous mixture following it was made easy and safe by applying gentle suction to the end of the absorption train. The current of carbon dioxide was started immediately after putting in the manganous mixture, and after a suitable time had elapsed for the removal of air heat was applied to the retort and the distillation was continued until nearly all the liquid had passed over. Finally the contents of the receivers were united, the washing of the bulbs was effected easily and expeditiously by passing the wash-water directly through retort and receiver (the introduction of the manganese chloride into the distillate being not at all prejudicial to the accuracy of the titration), and the estimation of free iodine made by sodium thiosulphate as described. The results of the experiments conducted in this manner are given in Table III.

These results are fairly satisfactory. The mean error of the entire series is practically nothing. The manipulation is easy and rapid.

In brief, the process which gives us these results consists in the distillation of the mixture of the nitrate with a saturated solution of crystallized manganous chloride in strong hydrochloric acid in an atmosphere of carbon dioxide, the passage of the products of action into potassium iodide, and the titration of the liberated iodine by sodium thiosulphate. It is important to take precautions to prevent the contact of the free halogen with rubber stoppers or connectors, and any apparatus, suitable for ordinary quantitative distillation and absorption, which meets this condition will probably answer the requirements of the process. Our own preference is for the apparatus described and figured.

TABLE III.

KNO_3 taken.	$MnCl_2$ mixture.	KNO_3 found.	Error in terms of KNO_3.	Error in terms of HNO_3.
0·2038 grm.	20 cm^3	0·2047 grm.	0·0009 grm. +	0·0005 grm. +
0·2053 “	20 “	0·2057 “	0·0004 “ +	0·0003 “ +
0·1032 “	10 “	0·1035 “	0·0003 “ +	0·0002 “ +
0·1017 “	10 “	0·1004 “	0·0013 “ —	0·0008 “ —
0·1049 “	10 “	0·1049 “	0·0000 “	0·0000 “
0·1027 “	10 “	0·1023 “	0·0004 “ —	0·0003 “ —
0·0524 “	10 “	0·0526 “	0·0002 “ +	0·0001 “ +
0·0513 “	10 “	0·0512 “	0·0001 “ —	0·0001 “ —
0·0354 “	10 “	0·0350 “	0·0004 “ —	0·0003 “ —
0·0232 “	10 “	0·0230 “	0·0002 “ —	0·0001 “ —
0·0107 “	5 “	0·0106 “	0·0004 “ —	0·0001 “ —
0·0127 “	5 “	0·0130 “	0·0003 “ +	0·0002 “ +
0·0145 “	5 “	0·0143 “	0·0002 “ —	0·0001 “ —
0·0053 “	5 “	0·0052 “	0·0001 “ —	0·0001 “ —
0·0043 “	5 “	0·0047 “	0·0004 “ +	0·0003 “ +
0·0014 “	5 “	0·0018 “	0·0004 “ +	0·0003 “ +
0·0000 “	5 “	0·0000 “	0·0000 “	0·0000 “

The titration should be completed as soon as may be after admitting air to the distillate in order that traces of dissolved nitric oxide may not be reoxidized and again react upon the iodide present to liberate more iodine.

ART. XVIII.—*On some Alkaline Iodates;* by H. L. WHEELER. *With Crystallographic Notes;* by S. L. PENFIELD.

WHILE work on the compounds of iodine trichloride with alkaline chlorides* was in progress in this laboratory, it was noticed in making $KCl . Cl_3I$, $RbCl . Cl_3I$ and $CsCl . Cl_3I$ that white crystals were often formed under certain conditions. These compounds proved to be $KCl . KIO_3 . HIO_3$, $RbCl . HIO_3$ and $2CsIO_3 . I_2O_5$. Since they were not analogous, although formed under similar conditions, and since the rubidium and cæsium salts have not been described, an investigation of them was undertaken. Attempts to prepare these compounds by other methods led to the discovery of several other iodates. The new compounds that have been prepared are as follows:

$RbIO_3$
$RbIO_3 . HIO_3$
$RbIO_3 . 2HIO_3$
$RbCl . HIO_3$
$3RbCl . 2HIO_3$

$CsIO_3$
$2CsIO_3 . I_2O_5$
$2CsIO_3 . I_2O_5 . 2HIO_3$
$CsCl . HIO_3$

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* This Journal, xliv, 42.

The compound which separated from the solution of the potassium pentahalide has already been described, but since this is a new method of preparation and since there are conflicting statements concerning its state of hydration, it has been re-investigated.

The results of the investigation of the rubidium salts show that the normal iodate is the only one of the series that can be recrystallized unaltered from an aqueous solution. In the case of the cæsium compounds, the normal iodate and the salt $2CsIO_3 . I_2O_5$ are not decomposed by water. The other cæsium iodates give $2CsIO_3 . I_2O_5$ when recrystallized from water and not the normal iodate, thus showing an interesting difference between the rubidium and cæsium compounds.

It is the tendency of the acid rubidium iodates to separate in a higher state of hydration than the corresponding cæsium compounds.

It is also an interesting fact that the formation of the compounds of normal chloride and iodic acid was not observed on mixing the constituents. In the case of rubidium, products were obtained which proved to be $RbIO_3$, $RbIO_3 . HIO_3$ or $RbIO_3 . 2HIO_3$ according to the concentration of the solutions and the excess of RbCl or HIO_3. On the other hand by adding hydrochloric acid to a solution of rubidium iodate, if the acid is dilute $RbIO_3, 2HIO_3$ is formed, if concentrated the iodate is completely decomposed. Similar experiments undertaken with cæsium chloride and iodic acid, did not give the peculiar double compound $CsCl . HIO_3$ but resulted, in each case, in the formation of $2CsIO_3 . I_2O_5$.

Method of Analysis.

After the substances were prepared for analysis as described in detail beyond, the halogens were determined by first reducing the solution of iodate with sulphur dioxide then precipitating with silver nitrate in the presence of nitric acid. This precipitate was then heated in a stream of chlorine, thus combining the test for chlorine and its determination in one operation. In the filtrate from the silver precipitate the alkali metal was determined as sulphate after the removal of the excess of silver by means of hydrogen sulphide. Oxygen was determined in a separate portion by precipitation with silver sulphate, drying the precipitate at 100° and then determining the loss on ignition. Duplicate halogen determinations were then made in this residue. In the case of the compounds containing the group I_2O_5, where an error would be introduced if the oxygen was determined in this manner, the substance itself was ignited and the oxygen calculated from the loss.

The presence of water in these compounds was determined by directly weighing it in a calcium-chloride tube, the substance being ignited in a combustion tube containing a mixture of lead chromate and lead oxide.

Normal rubidium iodate, $RbIO_3$.—This compound was made by adding one molecule of iodine pentoxide in either strong or dilute aqueous solution, to a solution of one molecule of rubidium carbonate. If the solutions are strong, the iodate separates as a sandy precipitate, but if they are hot and dilute it separates on cooling in small grains or as a crystalline crust. At 23° 100 parts of water dissolve 2·1 parts of the salt. The compound, after filtering on the pump, washing with a little water and drying on paper, gave the following results on analysis:

	Found.	Calculated for $RbIO_3$.
Rubidium,	32·17	32·82
Iodine,	48·50	48·75
Oxygen,	20·59	18·43

The salt when heated decrepitates strongly, melts, gives off oxygen but no iodine, and the residue is rubidium iodide. Hydrochloric acid readily dissolves it in the cold to a faint yellow-colored solution which increases in color on standing. On warming, chlorine is evolved and the solution turns bright yellow from the formation of iodine trichloride. If boiled with strong hydrochloric acid, $RbCl \cdot ClI$* is formed which separates on cooling.

The formation of normal rubidium iodate was also observed: when a hot dilute aqueous solution of iodine trichloride was treated with rubidium carbonate. The compound thus obtained gave 48·43 per cent of iodine on analysis. Also by dissolving the acid iodate in a strong hot solution of rubidium chloride and allowing the mixture to crystallize. This was identified by a rubidium determination which gave 32·58 per cent. In general the iodates of rubidium all give this body when they are dissolved in hot water and the solutions left to crystallize. The products obtained in this manner decrepitated on heating and did not give off iodine. A rubidium determination in the substance obtained from $RbCl \cdot HIO_8$ gave 32·76 per cent; from $3RbCl \cdot 2HIO_3$, 32·22 per cent.

Acid rubidium iodate, $RbIO_3HIO_3$.—This was obtained by mixing warm solutions of one molecule of iodine pentoxide and two molecules of rubidium chloride. The compound generally separates on cooling as a heavy crystalline powder. It is difficultly soluble in cold water. Hot water dissolves it more readily and on cooling, the normal iodate separates. It

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* This Journal, xliii, 475.

is insoluble in alcohol. The crystals were filtered on a pump and washed with a little cold water and then pressed on paper. An analysis of these dried at 100° gave the following results, the oxygen being determined by difference.

		Calculated for $RbIO_3 . HIO_3$.
Rubidium,	20·13	19·58
Iodine,	58·12	58·19
Oxygen,	21·46	21·99
Hydrogen,	·29	·23

The reaction which takes place in the preparation of this compound is probably according to the following equation :

$$RbCl + 2HIO_3 = RbIO_3 . HIO_3 + HCl,$$

The hydrochloric acid thus liberated reacts on a part of the iodic acid, chlorine is evolved and the solution becomes yellow. When heated it does not decrepitate, but melts to a yellow mass, gives off water, then iodine and finally froths with the evolution of oxygen. The residue consists of rubidium iodide.

Diacid rubidium iodate, $RbIO_3 . 2HIO_3$.—For the preparation of this compound 5 grams of $RbIO_3$ were dissolved in 50 cc. of water with the aid of heat, then 13 grams of iodine pentoxide in 50 cc. of water were added, the mixture boiled down to half its volume and allowed to cool. The body separates as a heavy crystalline powder. It is difficultly soluble in cold water. When dissolved in hot water and the solution left to crystalline $RbIO_3$ separates. The product obtained as stated above was separated from the mother liquor by filtering on the pump, washed with a little cold water and dried at 100°.

	Found.		Calculated for $RbIO_3 . 2HIO_3$.
Rubidium,	13·93	14·13	13·96
Iodine,	61·91	62·48	62·20
Oxygen,	23·74		23·51
Hydrogen,	·42		·33

This compound does not lose water at 100°. When heated it does not decrepitate, but melts, gives off water, then iodine and oxygen, leaving a residue of rubidium iodide. The compound was also obtained by adding 10 cc. of hydrochloric acid sp. gr. 1·1 to 5 grams of $RbIO_3$ in 20 cc. of water. The mixture was warmed until all the $RbIO_3$ dissolved. It gave a faint yellow solution which slowly deepened in color. On standing, a well crystallized product of the compound under consideration was obtained containing 14·13 per cent of rubidium and 62·19 per cent of iodine.

The addition of a saturated solution of rubidium chloride to syrupy iodic acid produces a precipitate which dissolves again in the excess of iodic acid. When more rubidium chloride is added, the whole being kept over a lamp, a point is reached where a precipitate begins to form in the hot solution. This is the compound in question. It was identified by a rubidium and an iodine determination. This gave 14·17 per cent of rubidium and 61·83 per cent of iodine.

$RbCl . HIO_3$.—This salt can be made by simply allowing a saturated solution of $RbCl . Cl_3I$ to stand for some hours, when large colorless prisms form, attached to the plates of $RbCl . Cl_3I$. The solution, after removing the crystals, warming to dissolve the pentahalide and pressing chlorine in again, does not yield a further deposit of the substance. This is explained by the fact that so much hydrochloric acid is formed in the solution that the formation of this compound is prevented. The crystals remain unaltered on exposure to the air. On treatment with cold water they are decomposed, losing their luster and becoming white. The solution has an acid reaction towards litmus. The hot saturated solution of this compound gives the normal iodate on cooling. The material for analysis was mechanically separated from adhering $RbCl . Cl_3I$ and dried in the air.

	Found.		Calculated for $RbCl . HIO_3$.
Rubidium,	28·88		28·78
Iodine,	42·29	42·62	42·76
Chlorine,	12·09	12·13	11·95
Oxygen,	16·33		16·16
Hydrogen,		·26	·33

This salt can also be prepared by adding a strong aqueous solution of rubidium hydrate to a strong solution of iodine trichloride in water. This gives at first a precipitate of the compound $3RbCl . 2HIO_3$, and the solution left at rest for a few days gives the large well developed crystals of $RbCl . HIO_3$ unmixed with $RbCl . Cl_3I$. These were identified by their crystalline form.

On warming the crystals with hydrochloric acid $RbCl . Cl_3I$ is formed, probably according to the following equation:

$$RbCl . HIO_3 + 5HCl = RbCl . Cl_3I + 3H_2O + Cl_2$$

and the $RbCl . Cl_3I$ on further heating gives $RbCl . ClI$ with the liberation of chlorine. When the substance is heated it melts, gives off water, chloride of iodine, and oxygen the residue consists of rubidium chloride and iodide. A determination of the halogens in this residue gave 3·52 per cent of chlorine and 53·66 per cent of iodine.

$3RbCl . 2HIO_3$.—This compound, which is analogous to the sodium compound $3NaCl . 2NaIO_3 . 9H_2O$ described by Rammelsberg* and also to the salt $3NaI . 2NaIO_3 . 19H_2O$ obtained by Penny† or $3NaI . 2NaIO_3 . 20H_2O$ according to Marignac,‡ except that it contains no water of crystallization, was prepared by two methods. It was obtained by the addition of a hot, strong aqueous solution of rubidium hydroxide to a strong solution of iodide trichloride, the latter being in excess. The mixture was then filtered hot and on cooling, a mass of fine needles separated. The mother liquor on standing yielded the large crystals of $RbCl . HIO_3$. The needles are stable in the air and at 100°. From the hot saturated aqueous solution of the compound the normal iodate separates on cooling.

The formation of this compound was also observed on adding a strong solution of rubidium carbonate to a hot saturated solution of $RbCl . Cl_3I$, the latter being in excess. The colorless slender transparent needles thus obtained generally separate in groups radiating from a point on the surface of the yellow crystals of $RbCl . Cl_3I$. After separating the colorless crystals mechanically from the pentahalide they were air-dried on paper and then analyzed, while the material obtained according to the previous method was dried at 100°.

	From RbOH and ICl_3.		From Rb_2CO_3 and $RbCl . Cl_3I$.		Calculated for $3RbCl . 2HIO_3$.
Rubidium,	35·41	34·58	35·78		35·87
Iodine,	35·27	36·00	35·87	35·81	35·52
Chlorine,	14·99	14·82	15·26	15·16	14·90
Oxygen,		13·15		13·64	13·43
Hydrogen,		·29		·30	·28

When heated, the substance does not decrepitate but melts, gives off chloride of iodine and the residue consists of a mixture of rubidium chloride and iodide. A sample of this residue gave on analysis 9·68 per cent of chlorine and 38·91 per cent of iodine.

Normal Cæsium iodate $CsIO_3$.—This was prepared by adding a moderately strong aqueous solution of iodic acid to a strong solution of cæsium carbonate, care being taken to have the carbonate in excess. When all the iodic acid had been added, the solution was boiled. On cooling, a crystalline mass separated consisting apparently of small cubes. At 24°, 100 parts water dissolve 2·6 parts of the salt. It is insoluble in alcohol. The body was prepared for analysis by filtering on the pump, washing with cold water and then pressing on paper and drying at 100°.

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* Pogg. Ann, xliv, 548; cxv, 584.

† Ann. Ch. Pharm., xxxvii, 202.

‡ Jahresb., 1857, 124: Ann. Min., V, ix, 1.

			Calculated for $CsIO_3$.
Cæsium,	43·08	43·53	43·18
Iodine,	40·84		41·23
Oxygen,	15·74		15·59

This was also obtained in attempts to prepare a cæsium salt corresponding to $3RbCl . 2HIO_3$ by adding cæsium hydrate or carbonate in moderately strong aqueous solution to a strong solution of iodine trichloride in excess, when it at once separated in the form of a white sandy precipitate, which under the microscope was seen to consist of transparent grains of indefinite form. Unless the iodine trichloride is nearly saturated with the carbonate, $CsCl . Cl_3I$ or $CsCl . ClI$* is obtained mixed with the iodate. An iodine and oxygen determination in the air-dried salt gave 40·55 and 40·83 per cent of iodine and 15·67 per cent of oxygen. When this iodate is heated it does not give off iodine but melts and evolves oxygen. The residue is cæsium iodide.

$2CsIO_3 . I_2O_5$.—This substance can be prepared in pure condition and in large quantity by mixing a moderately dilute aqueous solution of two molecules of cæsium chloride with one molecule of iodine pentoxide dissolved in a little water. Any precipitate that may have been produced is dissolved by the aid of heat and more water if necessary. On cooling, the compound separates as a sandy powder. This can be washed with water or recrystallized from hot water without decomposition. It can also be recrystallized from dilute solutions of iodic acid. At 21° 100 parts of water dissolve 2·5 parts of this salt. It is insoluble in alcohol. The material for analysis was air-dried after pressing on paper.

	Found.	Calculated for $2CsIO_3 . I_2O_5$.
Cæsium,	27·93	28·00
Iodine,	53·42	53·47
Oxygen,	18·69	18·53

This compound invariably separates along with the crystals of $CsCl . Cl_3I$, when the latter is prepared in the absence of hydrochloric acid. The yield is not very large. It is thus obtained in the form of small rounded white nodules which on close inspection are seen to occur in pairs, the two nodules being on opposite sides of a thin layer of the pentahalide. They were mechanically separated from the pentahalide, no water being used to wash the compound when prepared for analysis. The following results are sufficient for its identification.

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* This Journal, III, xliii, 17, and xliv, 42.

Cæsium	29·11
Iodine	50·21
Oxygen	18·99
Chlorine	3·24

This compound was also obtained by the following methods. By mixing 6 grams of $CsIO_3$, 20 cc. of water and 10 cc. of HCl sp. gr. 1·1. The mixture was boiled, it became yellow and chlorine was evolved. When cooled the substance separated as a crystalline crust. It was identified by a determination of cæsium which gave 28·40 per cent.

The compounds $2CsIO_3 . I_2O_5 . 2HIO_3$ and $CsCl . HIO_3$ give this body when their hot saturated solutions are cooled. A cæsium determination in the products thus obtained gave 27·94 and 28·12 per cent respectively.

When this body is treated with hydrochloric acid, sp. gr. 1·1, the solution becomes yellow, evolves chlorine on warming, and when concentrated on the water bath yields on cooling well crystallized $CsCl . ClI$. Analysis gave 50·63 per cent of cæsium chloride, calculated for $CsCl . ClI$ 50·90 per cent.

When heated in a closed tube it gives no sign of water, gives off iodine then melts with the evolution of iodine and oxygen. The residue consists of cæsium iodide.

$2CsIO_3 . I_2O_5 . 2HIO_3$.—This body was obtained by adding 5 grams of $2CsIO_3 . I_2O_5$ to a boiling solution of 25 grams of iodine pentoxide in sufficient water to form a syrup. Water was then added and the precipitate thus produced proved to be the compound in question. Thus produced it separates as a finely divided amorphous precipitate which can be dried in the air or at 100° without losing water. It is difficultly soluble in water and when crystallized from an aqueous solution gives $2CsIO_3 . I_2O_5$. An analysis of the substance dried at 100° gave

	Found.	Calculated for $2C_3IO_3I_2O_5 . 2HIO_3$.
Cæsium,	19·71	20·43
Iodine,	57·68	58·52
Oxygen,	20·41	20·89
Hydrogen,	·12	·16

Water determinations in samples dried in the air on paper gave 1·45 and 1·38 per cent; theory requires 1·44.

When the substance is heated it gives off water and iodine, then oxygen, the residue consisting of cæsium iodide.

$CsCl . HIO_3$.—This was obtained in an attempt to increase the yield of $2CsIO_3 . I_2O_5$ by adding a rather small quantity of cæsium carbonate to a hot saturated solution of $CsCl . Cl_3I$, when on cooling and allowing the mixture to stand, colorless, flat, transparent prisms separated on the yellow crystals of $CsCl . Cl_3I$ previously formed. These colorless prisms were picked out from the solution dried on paper and separated mechanically, as far as possible from any adhering $CsCl . Cl_3I$. These on analysis gave the following results.

	Found.		Calculated for $CsCl . HIO_3$.
Cæsium	38·09		38·60
Iodine	36·08	36·29	36·86
Chlorine	11·69	11·82	10·31
Oxygen	13·85		13·94
Hydrogen	.30		·29

The crystals remain unaltered on exposure to dry air but on treating them with water they immediately become opaque. On recrystallizing from water they give $2CsIO_3 . I_2O_5$. When the substance is heated it gives off water and iodine chloride, melts, and gives off oxygen, the residue consisting of chloride and iodide of cæsium. When it is warmed with hydrochloric acid it undergoes the same decomposition as the corresponding rubidium compound.

$KCl . KIO_3 . HIO_3$.—This compound has previously been prepared by treating KIO_3 with hydrochloric acid, or a solution of iodine trichloride with potassium hydrate or carbonate. It has been described by Serullas[*] and Rammelsberg[†] as anhydrous and the formula $2KCl . 2KIO_3 . I_2O_5$ was assigned to the salt. Millon[‡] from his determination of potash in this salt concluded that the substance contained a molecule of water, but he made no determination of it. Finally, Marignac[§] who examined it more carefully, made a determination of the water by drying the substance at 100°, then igniting it in a tube with metallic copper and collecting, and weighing the water by means of a sulphuric acid tube.

The compound obtained from a solution of $KCl . Cl_3I$ separated in shining transparent prisms, stable in the air. It contained water corresponding to the formula $2KCl . 2KIO_3 . I_2O_5 . H_2O$ or $KCl . KIO_3 . HIO_3$. An analysis of the air-dried salt gave the following results.

	Found.		Calculated for $KCl . KIO_3 . KIO_3$.
Potassium	16·94	16·83	16·82
Iodine	54·46		54·66
Chlorine	7·72		7·64
Oxygen			20·66
Hydrogen	·20		·22

[*] Ann. Ch. Phys., II, xliii, 113.
[†] Ann. Ch. Phys , III, ix. 407.
[‡] Pogg. Ann., xcvii.
[§] Jahresb., 1856, 298. Ann. Min., V, ix, 1.

This compound and the one obtained by Marignac are therefore identical.

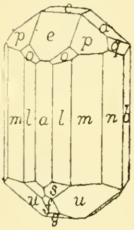
On ignition it gives off water, iodine chloride and oxygen, the residue consisting of potassium iodide and chloride. An analysis of this residue gave 2·39 per cent. chlorine and 70·87 per cent. iodine.

The author takes occasion here to express his obligations to Professor H. L. Wells for the use of the material in this investigation and for valuable suggestions, also to Professor S. L. Penfield who has kindly furnished the crystallographical descriptions.

Notes on the Crystalline form of $RbCl\,.\,HIO_3$ *and* $CsCl\,.\,HIO_3$*;* by S. L. Penfield.

$RbCl\,.\,HIO_3$.

1.



The form of $RbCl\,.\,HIO_3$ is monoclinic. The crystals are highly modified, doubly terminated prisms, fig. 1. The faces gave fair reflections and the measurements which were chosen as fundamental are marked by an asterisk in the table of angles.

The axial ratio and forms are as follows:

$$\grave{a} : \bar{b} : \dot{c} = 0{\cdot}9830 : 1 : 0{\cdot}7577, \quad \beta = 100 \wedge 001 = 87^\circ\ 56'$$

a, 100, $i\text{-}\bar{i}$	l, 320, $i\text{-}\bar{\tfrac{3}{2}}$	d, 011, $1\text{-}\grave{i}$	g, $\bar{1}02$, $\tfrac{1}{2}\text{-}\bar{i}$	q, 142, $-2\text{-}\grave{4}$
b, 010, $i\text{-}\grave{i}$	m, 110, I	e, 101, $-1\text{-}\bar{i}$	o, 211, $-2\text{-}\bar{2}$	s, $\bar{2}11$, $2\text{-}\bar{2}$
c, 001, 0	n, 120, $i\text{-}\grave{2}$	f, $\bar{1}01$, $1\text{-}\bar{i}$	p, 111, -1	u, $\bar{1}11$, 1.

	Measured.	Calculated.		Measured.	Calculated.
$a \wedge c$, $100 \wedge 001 =$	*87° 56′		$a \wedge d$, $100 \wedge 011 =$	88° 29	88° 21′
$a \wedge e$, $100 \wedge 101 =$	*51 5		$a \wedge s$, $\bar{1}00 \wedge \bar{2}11 =$	38 32	39 47
$c \wedge d$, $001 \wedge 011 =$	*37 8		$a \wedge u$, $\bar{1}00 \wedge \bar{1}11 =$	59 57	59 38
$a \wedge l$, $100 \wedge 320 =$	33 13	33° 13′	$e \wedge p$, $101 \wedge 111 =$	30 28	30 31
$a \wedge m$, $100 \wedge 110 =$	44 7	44 29½	$f \wedge u$, $\bar{1}01 \wedge \bar{1}11 =$	31 22½	31 24
$a \wedge n$, $100 \wedge 120 =$	62 42	63 1½	$p \wedge q$, $111 \wedge 142 =$	26 36	26 30
$a \wedge o$, $100 \wedge 211 =$	38 19	38 28½	$c \wedge g$, $001 \wedge \bar{1}02 =$	21 17	21 20
$a \wedge p$, $100 \wedge 111 =$	57 13	57 14	$c \wedge f$, $001 \wedge \bar{1}01 =$	38 26	38 23½

$CsCl\,.\,HIO_3$.

2.

The form of $CsCl\,.\,HIO_3$ is monoclinic. The crystals, from the one crop which was examined, were about 5 mm. in length and had the habit shown in fig. 2. They were attached at one end and usually grew in radiating and divergent groups. The faces were not very perfect and only approximate measurements could be made. Those which were chosen as fundamental are:

$m \wedge m$, $110 \wedge \bar{1}10 = 90^\circ\ 12'$ $m \wedge p$, $110 \wedge 221 = 24^\circ\ 37'$ $a \wedge p$, $100 \wedge 221 = 49^\circ\ 53'$

The axial ratio and forms are as follows:

$$\grave{a} : \bar{b} : \dot{c} = 0{\cdot}9965 : 1 : 0{\cdot}7698 \qquad \beta = 100 \wedge 001 = 89^\circ\ 53\tfrac{1}{2}'$$

a, 100, $i\text{-}\bar{i}$	m, 110, I	d, 403, $-\frac{4}{3}\text{-}\bar{i}$	s, $\bar{4}03$, $\frac{4}{3}\text{-}\bar{i}$	p, 221, -2
c, 001, 0	n, 130, $i\text{-}\grave{3}$	e, 203, $-\frac{2}{3}\text{-}\bar{i}$	u, $\bar{2}03$, $\frac{2}{3}\text{-}\bar{i}$	o, 263, $-2\text{-}\grave{3}$

The pyramids p and o were frequently wanting. The orthodomes d, e, s and u were very constant in their development and gave to the crystals an orthorhombic habit. Owing to the curved and striated character of the faces the symmetry could not be satisfactorily determined by measurement, but the optical properties showed that the crystals were truly monoclinic. In polarized light the tables show an extinction parallel to the ortho- axis and in convergent light one of the optical axes and the acute bisectrix can be seen near the limits of the field. The plane of the optical axes is the clinopinacoid.

These two salts, although entirely different in crystalline habit, are very similar in their axial ratios.

Sheffield Scientific School,
April, 1892.

ART. XIX.—*Development of the Brachiopoda.* Part II. Classification of the Stages of Growth and Decline; by CHARLES E. BEECHER. (With Plate I.)

A BRIEF review of the known embryology of the Brachiopoda is desirable, in order to account for some of the differences presented by adult forms in the several divisions of the class. This knowledge is far from complete, and is confined to a few species, but much of interest bearing on the later development of the organism may be obtained.

The important memoirs of Morse,*[18, 19] Kovalevski,[15] Lacaze-Duthiers,[16] and Shipley,[22] contain nearly all that is known regarding the early embryology of brachiopods. The genera included in the works of these authors comprise Cistella, Terebratulina, Liothyrina, and Lacazella. Later larval stages of the genus Glottidia have been fully described by Brooks.[4] Müller,[20] also, has given a description and figures

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* The works referred to by numbers are cited in full in the list appended to this article.

of a larval form doubtfully referred to Discinisca. The results of these observers must at present be taken without reservation, and are thus made use of in the present paper.

Something is known, therefore, of the early stages in each of the four groups or orders proposed by the writer.[1] The Atremata, Neotremata, and Protremata are represented by a single genus only in each; Glottidia, Discinisca, and Lacazella, respectively; and the Telotremata, by Cistella, Terebratulina, and Liothyrina. Were Glottidia and Discinisca as well known as Cistella, Terebratulina, and Lacazella, some comparisons could undoubtedly be made which would enlighten many obscure points of anatomy and morphology, as well as give clearer insight into the history and origin of each group.

Cistella and Terebratulina are taken as standards of the embryological development on account of the completeness with which they have been studied, and because their points of difference are not great. Lacazella shows such peculiar features, that its history must be discussed separately. The nepionic Glottidia and Discinisca, too, present characters which evidently had an early history somewhat different from Cistella or Terebratulina.

In taking up the review of the observed stages of growth, an attempt will be made to fix their limitations. To this end the admirable nomenclature proposed by Hyatt[9, 10] is here adopted, as it is more convenient and of wider application and significance than the terms heretofore used. Thus far this system has been employed principally in studies relating to the mollusca, and its application to the Brachiopoda will necessarily require some illustration and explanation. In the preface to "Genesis of the Arietidæ," Hyatt has presented a summary of the theoretical opinions resulting mainly from his studies in the Cephalopoda. It is believed that nearly the same ground may be covered in the Brachiopoda, and thus the truth of these deductions will receive further evidence from another class of organisms.

Embryonic stages.

The true embryonic stages are classified by Hyatt as *Protembryo*, *Mesembryo*, *Metembryo*, *Neoembryo*, and *Typembryo*. To these Jackson[11] has added the *Phylembryo*, taking it from the later stages of the Typembryo to represent the period when the animal can be referred definitely to the class to which it belongs.

The succeeding stages in the growth of the animal to maturity are termed by Hyatt *nepionic* (young), *nealogic* (adolescent), and *ephebolic* (mature), while old age characters are called *geratologic*. The subject of geratology is further divided into the *clinologic* and *nostologic* stages.

The application of this nomenclature of the stages of growth and decline to the Brachiopoda is shown on the following pages.

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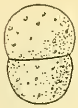

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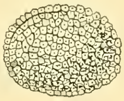

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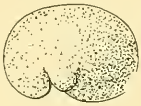

Cistella neapolitana Scacchi.

FIGURE 1.—Protembryo. Unsegmented ovum.
FIGURE 2.—Protembryo. Ovum composed of two spheres.
FIGURE 3.—Mesembryo. Blastosphere.
FIGURE 4.—Metembryo. Gastrula. (1-4, after Shipley.)

The *Protembryo*, as in other groups of organisms, includes the ovum and its segmented stages preceding the formation of a blastula cavity. Figures 1, 2, show protembryonic stages of Cistella. The eggs are spherical, pyriform or ovoid, and the segmentation proceeds in a regular manner, resulting in a blastosphere composed of equal parts.

The *Mesembryo*, or blastosphere, figure 3, has been observed in Cistella, Terebratulina, and Lacazella. The blastula cavity is small.

The *Metembryo*, or gastrula stage, figure 4, is developed from the blastosphere in two ways; (*a*) by embolic invagination in Cistella and Terebratulina (Kovalevski and Shipley), and (*b*) by delamination in Lacazella (Kovalevski). At the close of this stage, the archenteron in Cistella is trilobed, consisting of a central cavity, or mesenteron, connecting on each side with the body cavity.

The *Neoembryo*, represented by the trochosphere and segmented ciliated cephalula stages, has been more fully observed than any of the preceding. The first advance from the completed gastrula is in the separation of the mesenteron from the body cavity, and the division of the organism into two segments or lobes, the cephalic and caudal, figure 5. Later a third or thoracic segment is developed and carries four bundles of stiff barbed setæ, figure 6. The cephalic and caudal lobes are densely ciliated. During the subsequent cephalula period, two eyes, then two others appear in Cistella, and at the same time the dorsal and ventral sides of the thoracic segment become extended over the caudal, and are progressively defined as two lobes, figures 5–9, 24, 25.

Terebratulina has a tuft of bristles on the top of the cephalic segment. In Lacazella, the bundles of setæ are absent, and the head is more distinctly differentiated from the anterior segment than in Cistella. The closing cephalula stage in Cistella has an umbrella-like expansion of the cephalic border, and the organism becomes a free swimming larva, figures 7–9.

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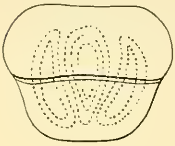

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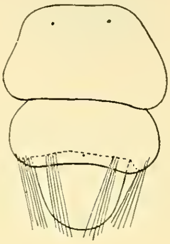

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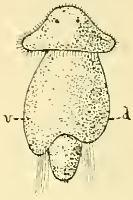

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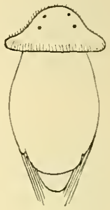

Cistella neapolitana Scacchi.

FIGURE 5.—Neoembryo. Embryo of two segments.
FIGURE 6.—Neoembryo. Cephalula, ventral side; showing cephalic, thoracic, and caudal segments, eye spots, and bundles of setæ. (5, 6, after Kovalevski.)
FIGURE 7.—Neoembryo. Lateral view of completed cephalula stage; showing extent of dorsal (*d*) and ventral (*v*) mantle lobes, and umbrella-like cephalic segment.
FIGURE 8.—Neoembryo. Same stage; ventral view. (7, 8, after Shipley.)

Larval stages.

The *Typembryo* is the larval stage at which some distinctive features make their appearance, but before the special characters of the class are to be found, figure 10. It is analogous to the molluscan embryo in which a shell gland and plate-like initial shell are developed. There is, however, no homology of parts or organs between the typembryonic mollusk and brachiopod.

In Cistella and Terebratulina the development of the typembryo has been observed, and consists of the folding upwards of the lobes which have been developed from the thoracic segment to form the mantle, so that they gradually enclose the anterior end, figures 24–27. The surfaces of the mantle which were exterior in the cephalula have now become inner and the bundles of setæ have revolved 180°, changing their direction from posterior to anterior. This leaves the lower part of the thoracic and the whole of the caudal segment exposed. The outer surface of the mantle is invested with a hard integument, which, upon completion, and before the growth of the true shell forms the protegulum. The pedicle at this stage is also defined, being a modification of the caudal segment. It may serve to attach the larva to foreign objects, as in Cistella, figure 10, and Terebratulina, or it may remain undeveloped for a time as in Glottidia and Discinisca. A rudimentary digestive tract is present.

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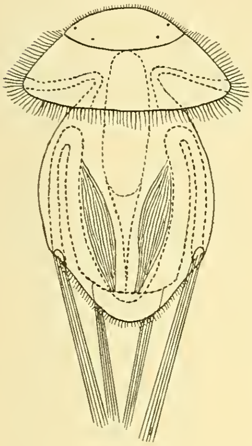

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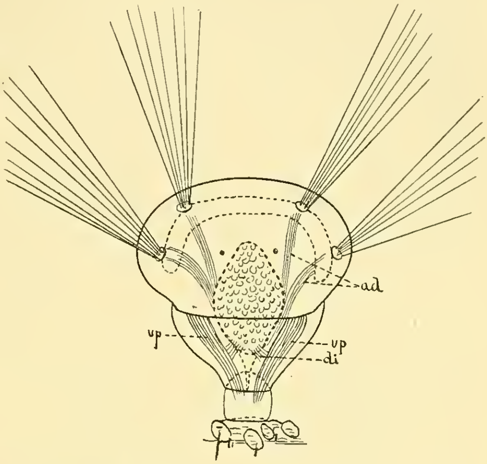


Cistella neapolitana Scacchi.

FIGURE 9.—Neoembryo. Completed cephalula stage.

FIGURE 10.—Typembryo. Transformed larva resulting from folding upwards of mantle lobes over cephalic segment: *ad*, muscles from bundles of setæ to sides of body cavity; *di*, muscles from dorsal to ventral sides of body; *vp*, muscles from ventral side of body to caudal segment or pedicle. (9, 10, after Kovalevski.)

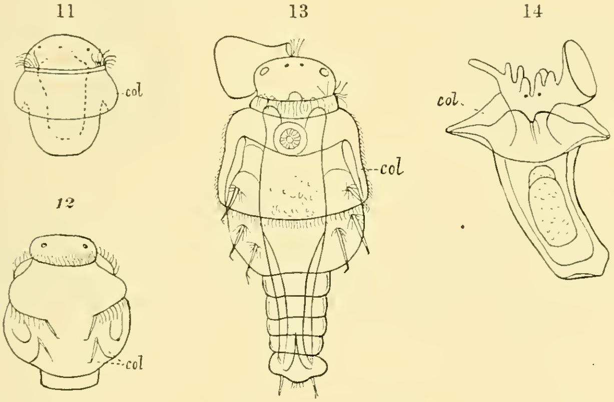
The body muscles which have been developed thus far consist of four distinct pairs. Two pairs lie close to the sides of the body cavity, and extend to the points of insertion of the bundles of bristles, figure 10, *ad*. They become after transformation the four adductor muscles of the valves. The third pair extends from the ventral side of the body to the caudal segment, and is converted into the ventral pedicle muscles, figures 10, 15, 16, *vp*. The fourth pair is situated posterior to the digestive tract, and extends from the dorsal to the ventral wall of the body, figure 10, *di*. They form the divaricator muscles in the mature brachiopod, figure 16, *di*, and are divided into or duplicated by a pair of dorsal and a pair of ventral divaricators. There is also a pair of dorsal pedicle muscles in the larva of Liothyrina and Terebratulina.

The folding upwards of the mantle lobes forms the first hinge line of the future valves, *hl*, figures 26, 27. Thus its origin is not, as in pelecypods, a line produced by the bending of a single plate (Jackson), but is the line along which the two mantle lobes are bent against the body. Between them projects posteriorly nearly half the body of the animal, and the whole opening corresponds to the pedicle opening of later stages of growth. The hinge of brachiopods, therefore, is not primarily a line of articulation of the valves, but the limiting borders between the body and the attached edges of the mantle. Secondarily, and during later growth, the extension of the valves along a line of apposition forms a true hinge line.

The first points of contact of the valves to form the true hinge lie adjacent to the right and left sides of the body of the animal, at the cardinal extremities, figure 15, *t*. Here naturally the first hinge teeth are formed, and their position corresponds to that in adult individuals; namely, on each side of the cardinal opening. The enlarging of the cardinal opening by shell growth results in the gradual divergence or separation of the teeth as in Terebratulina. In species with extended hinge lines, as in many forms of Spirifer, Orthis, and Strophomena, the teeth still lie in their original position on each side of the cardinal opening, and the elongation of the hinge has come not only from the enlargement of the opening by growth, but by additions at the hinge extremities, so that the teeth are situated on each side of the central area, below the beak, and not at the cardinal angles. The young of these genera, however, all have the hinge teeth at the extremities of the hinge, as the cardinal opening then occupies the whole posterior area of the shell.

Adult specimens of Kutorgina (*K. cingulata* Billings) have a deltidium as in Strophomena. The cardinal opening including the deltidium occupies the whole posterior end of the shell, and according to a statement made to the writer by Mr. Charles Schuchert, there are rudimentary teeth at the cardinal extremities. Therefore, this genus represents a nepionic condition of later forms, and, on account of these and other characters, it is believed to be related to Orthisina and Strophomena, of which it is the ancestral type. It consequently belongs to the articulate brachiopods.

The embryonic stages up to this point have frequently been compared to similar stages in other organisms, especially in the Annelida and Polyzoa. Without repeating these comparisons, which may be consulted elsewhere, [4, 12, 15, 16-19, 21] attention is called to the similarity of development of the brachiopod typembryo to the larval stages of Spirorbis. There are, however, important structural differences. An article by J. W. Fewkes, "On the Larval Forms of *Spirorbis borealis* Daudin,"[7] contains a nearly complete and very interesting account of the development of this chætopod. There is a striking resemblance in the characters of the cephalula stages in both organisms, as may be seen on comparison, figures 11, 12. Spirorbis develops a posteriorly directed extension from the middle segment, called a collar, which in later stages is reflexed anteriorly so as to cover more or less the cephalic portion, thus agreeing with the growth and change in position of the mantle in Cistella. The ventral lobe is also the larger in both. Many other comparisons and homologies have been made by Morse,[19] and the one here described is even more marked than his reference to the lobation of the cephalic collar in Sabella. Four figures are introduced illustrating the principal changes in Spirorbis. They may be compared with the development of Cistella shown in figures 6–10.



Spirorbis borealis Daudin.

FIGURE 11.—Cephalula, developing lobe from the body (*col.*).
FIGURE 12.—More advanced stage.
FIGURE 13.—Larval form before transformation; showing posteriorly directed expansion (*col*) from thoracic segment.
FIGURE 14.—Transformed Spirorbis; showing folding upwards of collar partially enclosing head. (11–14, after Fewkes.)

It is not intended by this to indicate a close relationship with the chætopods, for the writer is inclined to accept the opinion of Joubin,[12] that the brachiopods constitute a distinct and independent class.

The *Phylembryo*, figure 15, differs from the Typembryo in (*a*) the completion of the embryonic shell, or protegulum; (*b*) the first appearance of the tentacular lobes of the lophophore, or arms; (*c*) the usual dehiscence of the four bundles of setæ; (*d*) the obsolescence of the eyes; (*e*) the definition of the œsophagus and stomach; and (*f*) the agreement of the muscular system with that in adult forms. These features, with the pedicle which appeared in a preceding stage, represent the brachiopod phylum, and are properly referred to the phylembryonic period of Jackson. Although the molluscan stage called the prodissoconch in pelecypods, the protoconch in cephalopods and gastropods, and the periconch in scaphopods, represents the completed phylembryo of these groups, as the protegulum represents a like period in the developing brachiopod, yet there is no homology of distinctive organs.

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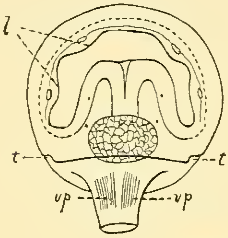

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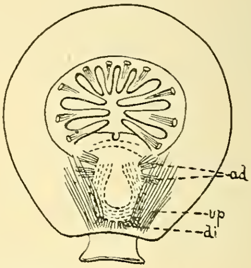

Cistella neapolitana Scacchi.

FIGURE 15.—Phylembryo., Brachiopod; showing shell (protegulum), beginning of tentacles of lophophore (*l*), obsolescence of eye spots, and formation of œsophagus. *t*, hinge teeth; *vp*, ventral pedicle muscles

FIGURE 16.—Nepionic brachiopod; showing distinct tentacles of lophophore, mouth and stomach, and transformation of muscles from typembryo, figure 10; *ad*, adductors; *di*, divaricators; *vp*, ventral pedicle muscles. (15, 16, after Kovalevski.)

The mantle of mollusks is first formed on the posterior dorsal side, and is in the shape of a disc, which gradually envelops the animal to a greater or less extent, and may become distinctly lobed. As has been shown, this organ in the brachiopods develops simultaneously from the dorsal and ventral side of the thoracic segment of the cephalula, and is primarily bilobed.

The initial shell of brachiopods is not produced from a distinct shell gland, as in the mollusca, but is an integument of the surface of the mantle lobes, and intimately connected with them. The position of the valves is dorsal and ventral. The pedicle has no organic similarity with either a foot or a byssus.

The mouth of mollusks (and annelids) is formed below the base of the cephalic lobe of the cephalula, and may be the blastopore, while in the brachiopods it is near the anterior pole within the cephalic segment. Notwithstanding these differences, so many parts are functional equivalents, that their growth and development may be discussed and interpreted in the same terms.

Before passing to later stages of growth which become more and more divergent from a common simple type, some points previously omitted, relating to Thecidium (Lacazella), Lingula (Glottidia), and Discinisca, should be here noted. As Lacazella is a form in which the ventral valve in the nealogic and ephebolic stages is cemented to foreign objects by calcareous fixation, it bears about the same relation to other brachiopods that Ostrea bears to Avicula, among the pelecypods, and a corresponding early absence, or modification, of many features present in adult individuals should be looked for. From what is known of the geological history of Thecidium, and if the interpretations of its phylogeny by the writer are correct, it is derived from an ancestry which had a similar condition of fixation as early as the Upper Silurian. Thecidium is apparently not a terebratuloid genus. Its structural affinities are evidently with the strophomenoids, especially such forms as Plectambonites, Leptænisca, etc. Briefly the reasons for this statement are (*a*) the presence of a deltidium of one plate; (*b*) the absence of a true loop supporting the arms (the internal calcification or spiculization is confined wholly to the mantle, and does not extend to the arms[16]); (*c*) a concave place in the cavity of the ventral beak, bearing the divaricator muscles; (*d*) the attached ventral valve, and (*e*) the cardinal processes in the dorsal valve.* The first character is of prime importance, because all the strophomenoids and none of the terebratuloids have a deltidium of one plate.

It would appear, therefore, that the early, free swimming, larval state, and the later pediculate stage have become lost by acceleration, thus accounting for the very unequal development of the mantle lobes in the cephalula stage, and the non-active and early sedentary larvæ as described by Kovalevski and Lacaze-Duthiers.

The young Lingula (Glottidia) described by Brooks,[4] and the Discinisca by Müller,[20] both representing the phylembryonic stage, were active and free swimming animals, with rudimentary pedicles. Terebratulina becomes attached or rests on the caudal segment during the cephalula stage (Morse), while at the end of this period in Cistella (Kovalevski and Shipley), there is an active, swimming, ciliated organism, which later attaches itself by the pedicle in the typembryonic period.

* Dall in 1870 (Am. Jour. Conchology) made a clear statement of the characters of Thecidium and of many of its radical points of difference with the Terebratulidæ, showing that it was entitled to rank as the type of a distinct family.

From the facts, that young individuals of paleozoic species belonging to such genera as Zygospira, Spirifer, Orthis, Rhynchonella, and Scenidium, have been observed by the writer to retain their original relations to the objects of support, and that casts of the pedicles of fossil Lingulæ and Eichwaldia have been described (Davidson,[5] Walcott[23]), it cannot be assumed that the free swimming condition was ever present in nealogic or ephebolic individuals. Evidently it has always been a larval character.

Origin of the deltidium and deltidial plates.

The origin and significance of the deltidium* (="pseudo-deltidium") are made apparent in the development of Thecidium, and it may be well in this place to make a few observations on the genesis of this important character, and its relations to the deltidial plates of other genera, as Rhynchonella and Terebratula. It has been already noted (Part I), that the deltidium in all species possessing it (the Protremata) is an embryological, or nepionic feature, which may or may not continue to the ephebolic period; while the deltidial plates in other brachiopods (the Telotremata) appear later during the nealogic and ephebolic periods, or may never be developed. The detailed researches of Kovalevski on Cistella and Thecidium, together with other observations now first made, furnish data for a clear understanding of these differences.†

Figure 18 represents a dorso-ventral section of a ripe cephalula just before the transformation, and shows the unequal lobes of the mantle, *v* being the ventral lobe, and *d* the dorsal; *h* is the head, and *p* the caudal segment developing into a pedicle. A deposit of integument representing the shell has formed on the inner side of the dorsal mantle lobe (*ds*), and also on the adjacent dorsal side of the body lobe (*del*). A larva somewhat more advanced is represented in figure 17, as viewed from the dorsal side. The mantle lobe is still directed posteriorly, as in the preceding figure, and the underlying shell plate is shown

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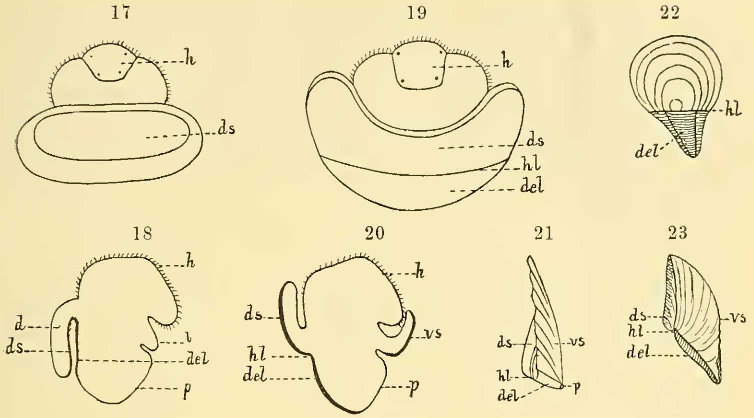
*The single plate or covering to the triangular opening beneath the ventral beak should be termed the *deltidium*, as it was thus extensively used by Davidson. When it consists of two plates they may be called *deltidial plates*. These names have been loosely used. In Part I of this paper the deltidium proper is referred to as pedicle covering, pedicle sheath, and pseudo-deltidium. Hall and Clarke have proposed to call the triangular opening in the beaks of brachiopods, the *detlhyrium*, and the concave plate in the ventral beak of Pentamerus, Orthisina, etc, they have termed the *spondylium*. There yet remains a term for the convex plate covering the opening below the beak of the dorsal valve, and resembling the deltidium of the opposite valve. For this feature the name *chilidium* (*χειλος*) is here proposed.

† Kovalevski.[15] For Thecidium consult the explanation of Pl. IV, figs. 15–26. For Cistella, Pl. I, figs. 13–15; Pl. II, figs. 17, 19–21.



Thecidium (*Lacazella*) *mediterraneum* Risso.

FIGURE 17.—Cephalula; dorsal side. *ds*, dorsal shell plate; *h*, head. (After Kovalevski.)

FIGURE 18.—Dorso-ventral longitudinal section of cephalula of about same age as preceding. *h*, head; *d*, dorsal mantle lobe; *v*, ventral mantle lobe; *ds*, beginning of dorsal valve; *del*, shell plate forming on dorsal side of body; *p*, pedicle. (After Kovalevski.)

FIGURE 19.—Typembryo. Larva transformed from folding upwards of mantle lobes. *h*, head; *ds*, dorsal valve; *hl*, hinge line of dorsal valve; *del*, shell plate on body and pedicle posterior to hinge line of dorsal valve. (After Kovalevski)

FIGURE 20.—Dorso-ventral longitudinal section of preceding. References as in figure 19. *vs*, ventral valve.

FIGURE 21.—Profile view of nealogic *Leptœna rhomboidalis*. The features of the shell are placed and lettered as in figure 20. *ds*, dorsal valve; *hl*, hinge line; *del*, deltidium; *p*, pedicle opening; *vs*, ventral valve.

FIGURE 22.—Adult *Thecidium* (*Lacazella*) *mediterraneum;* dorsal side; showing ventral area and deltidium.

FIGURE 23.—Profile of same. References as in figures 20 and 21.

at *ds*. In the process of transformation (figs. 19, 20), the mantle lobe is turned forwards in the usual manner, bringing the shell on the outside of the animal, so that both dorsal plates are now exposed, *ds* being the dorsal valve, and *del* the shell developed on the dorsal side of the walls of the body and caudal segments. As this plate (*del*) is below or posterior to the hinge line (*hl*), and extends down over the pedicle, it is evidently the beginning of the deltidium. At the same time, there is an extension of the edges of the mantle and pedicle on the ventral, or lower side, and shelly matter is deposited, forming the ventral valve (*vs*), figure 20. At this stage the hinge line, figures 19, 20, *hl*, is the line between the dorsal mantle shell (*ds*) and the dorsal body shell plate (*del*). The beak of the ventral valve is separated from the dorsal beak by the pedicle and the shell covering to the pedicle and body lobe, or the deltidium. The valves afterwards meet at their peripheries, the hinge is extended beyond the deltidium, forming the true hinge of articulate brachiopods. As there is no motion between the ventral valve and deltidium, the two become ankylosed. Figures 22, 23, showing an adult Thecidium, are lettered in the same manner as the preceding, and express the same relation of parts.

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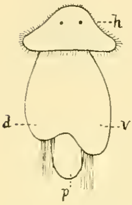

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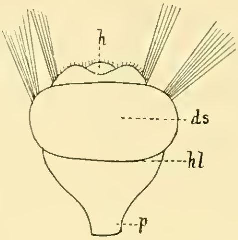

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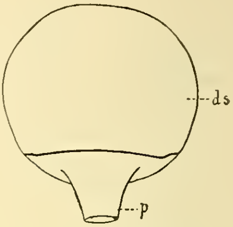

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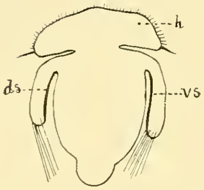

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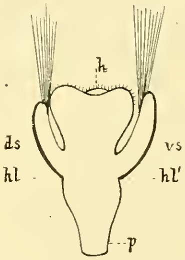

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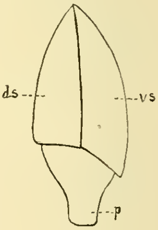

Cistella neapolitana Scacchi.

FIGURE 24.—Lateral view of completed cephalula stage. *d*, dorsal lobe of mantle; *v*, ventral lobe. (After Shipley.)

FIGURE 25.—Dorso-ventral longitudinal section of same: showing posteriorly extended mantle lobes. *ds* and *vs*, inner surfaces of mantle lobes which are to form dorsal and ventral valves. (After Shipley.)

FIGURE 26.—Typembryo. Dorsal view of larva after transformation. *h*, head; *ds*, dorsal valve; *hl*, hinge line of dorsal valve; *p*, pedicle. (After Kovalevski.)

FIGURE 27.—Dorso-ventral longitudinal section based on preceding; showing mantle lobes directed forwards, bringing interior shell-secreting surfaces, *ds* and *vs* of figure 25, on the exterior. *h*, head; *ds*, dorsal valve; *hl*, dorsal hinge; *vs*, ventral valve; *hl′*, ventral hinge; *p*, pedicle.

FIGURE 28.—Dorsal view of early nepionic shell, showing large posterior opening between valves. (After Kovalevski.)

FIGURE 29.—Profile of same. *ds*, dorsal valve; *vs*, ventral valve; *p*, pedicle.

The deltidium is not, therefore, primarily, on account of its manner of origin, an integrant part of the ventral valve, but is a shell growth from the dorsal side of the body, which afterwards becomes attached to the ventral valve, and is then considered as belonging to it.

The further growth of the deltidium around the body and pedicle, and its consequent extension into the cavity of the ventral umbo, may explain the origin of the spondylium.

Kovalevski[15] believed the ventral valve in Thecidium was secreted by the expanded edges of the pedicle and the body walls, whether or not this is so does not affect the interpretation of the origin of the deltidium. From the observations of Lacaze-Duthiers,[16] it seems, however, as though the ventral mantle lobe must have formed the shell in the usual way. This appears all the more probable from the fact, that the lower or ventral valve is punctate, and, so far as known, the mantle contains all the cæcal prolongations, which alone could produce the punctate structure. Careful microscopic examination has failed to detect punctæ in the deltidia of Thecidium, Strophomena, Leptæna, and other punctate genera belonging to the Protremata.

It is true that Aulosteges has spines on the deltidium, but spines even when tubular are not equivalent to punctæ, as shown in Productus, Strophalosia, and some species of Spirifer. Aulosteges is a geratalogous genus, which has become excessively spinose, and has also reverted to ancestral characters in its high hinge area and conspicuous deltidium. It is well known that even the spires of Spiriferina and the loop of Macandrevia are spinose.

Turning now to Cistella as a representative of the Telotremata, a different process obtains.

Figure 24 represents the fully developed, free swimming cephalula of Cistella, and shows the extent of the folds of the mantle and their posterior direction. Figure 25 represents the same in section. The inner sides of the mantle lobes are to form the future valves, the dorsal *ds*, and the ventral *vs*. The transformed larva or typembryo is represented in figure 26 and in section in figure 27. It is seen that the transformation consists in the folding forwards of the mantle lobes over the head segment *h*. Now the shell-secreting layers of the mantle are exterior, and the two valves begin to form, the dorsal shell *ds*, and the ventral *vs*. The pedicle and posterior portion of the body come out freely between the valves and mantle lobes and limit the hinge areas of both, *hl* anp *hl'*.

The further process of growth increases the distance between the initial dorsal and ventral hinges, for while the original dorsal beak is usually maintained at the hinge line, the ventral beak is progressively removed and the ventral hinge travels from its first position at the beak, along the edges of the umbo leaving an open triangular area or delthyrium in the ventral valve occupied by the pedicle. This condition represents the extent of the development of these parts in *Meristina rectirostra* Hall or *Gwynia capsula* Jeffreys, which lack deltidial plates in the adult shell. The young of other telotremate species, as *Magellania flavescens* or *Terebratulina septentrionalis*, agree in the same respect.

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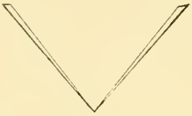

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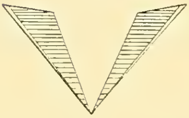

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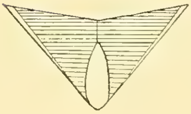

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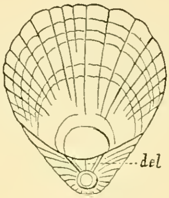

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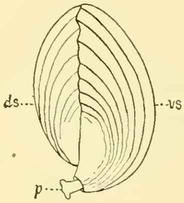

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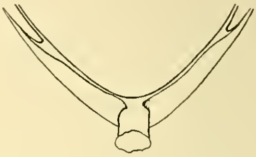

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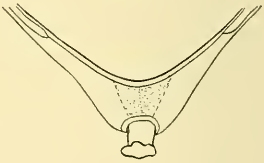

FIGURE 30.—Delthyrium of young Rhynchonella, without deltidial plates.

FIGURE 31.—The same at a later stage, with two triangular deltidial plates.

FIGURE 32.—The same after completed growth; showing joining of deltidial plates, and limitation of pedicle opening to ventral beak.

FIGURE 33.—Dorsal view of *Magellania flavescens;* showing completed deltidial plates, *del.*

FIGURE 34.—The same; profile. *ds*, dorsal valve; *vs*, ventral valve; *p*, pedicle.

FIGURE 35.—Dorsal view of umbonal portion of adult *Terebratulina septentrionalis*, with shell removed by acid; showing slight secondary extension of ventral mantle around pedicle (consequently small deltidial plates are secreted in this species). Mantle areas secreting deltidial plates are shaded.

FIGURE 36.—Dorsal view of umbonal portion of *Magellania flavescens*, with the shell removed by acid; showing the complete envelopment of base of pedicle by secondary expansions from ventral mantle, and consequent production of deltidial plates filling delthyrium except at pedicle opening. See figure 33.

An examination of the animal at this stage shows that the mantle lobes line only the interior of the valves proper. The exposed edges of the mantle are around the peripheries of the valves and also that portion of the ventral mantle border limiting the deltidial opening and passing along the sides of the pedicle at its base. The ventral mantle gradually extends from each side as two prolongations partially covering the opening and enveloping the proximal portion of the pedicle.

As this is an extension of the shell-secreting surface of the mantle, there naturally results the formation of two plates within the deltidial area. Their structure is commonly punctate whenever the valves are punctate.

These outgrowths or extensions of the mantle into the deltidial area finally touch and coalesce until, as in *M. flavescens*, the pedicle emerges through an opening in the ventral mantle, and *pari passu* the deltidial plates unite and limit the pedicle opening to the beak of the ventral valve. The latter process has been carefully described by Deslongchamps,[6] Clarke and the writer[3] and need not be dwelt on here. Figures 35 and 36 of the beaks of *T. septentrionalis* and *M. flavescens* with the shell removed show the relations of the ventral mantle to the pedicle, and the portions which secrete the deltidial plates.

The deltidium and delthyrium are often simulated in the growth of the *dorsal* valve in genera having a high cardinal area in this valve. Orthis, Leptæna, Clitambonites, Spirifer, and Stricklandinia, may be cited as examples. They cannot properly be correlated with similar parts in the ventral valve, for their origin is quite different. Primarily, a deltidial opening is for the extrusion of the pedicle and this belongs properly to the ventral valve. The dorsal fissure is the space between the diverging teeth sockets, and may be filled by the cardinal process, as in Leptæna and Orthis, or it may have in addition a convex plate or chilidium covering it, as in Clitambonites. In Spirifer and Stricklandinia, the opening remains unclosed.

The true deltidial plates are formed on the side of the pedicle adjacent to the hinge by extensions of the ventral mantle lobe, and begin as two plates. They are likewise expressive of maturity, and are of secondary development, while the deltidium begins as a single plate in the median line, and is eminently a primitive character in the Protremata.

From present knowledge of the group, it is difficult to offer an explanation for the presence of an anal opening in the Inarticulata and its absence in the recent Articulata, as the solution of the question depends upon whether the class is to be considered as progressive or degraded. The dorsal beaks of Amphigenia, Athyris, Cleiothyris, Atrypa, and Rhynchonella, are usually notched or perforate. The perforation comes from the union of the crural plates above the floor of the beak leaving a passage through to the apex. A similar opening occurs between the cardinal processes in Strophomena, Stropheodonta, and allied genera, and the chilidium may also be furrowed, as in *Leptæna* (=*Strophomena*) *rhomboidalis*. This character is evidently in no way connected with the pedicle opening, but points to the existence, in the early articulate genera, of an anal opening dorsal to the axial line, as in the recent Crania. This dorsal foramen was described and figured by King[13] in 1850, Hall[8] in 1860 and by several authors since, and has commonly been termed a visceral foramen.

Œhlert[21] suggests that it was probably occupied by the terminal portion of the intestine. The persistence of the foramen seems to indicate an anal opening. In reference to this character and the obsolescence of the eyes the class must be viewed as retrogressive since paleozoic time. Other features, however, are manifestly progressive; namely, the gradual shortening, through time, of the posterior elements of the animal, as the pedicle, visceral portions, and internal shell structures, and the expansion of the anterior parts, as the shell and brachia.

A further advance in specialization is shown in the limitation of the pedicle opening wholly to the ventral valve in the higher rhynchonelloids, athyroids, spiriferoids, and terebratuloids. The absence of punctæ in all the early radicles and their subsequent development in the derived types may also have a similar bearing.

The features and importance of the protegulum have previously been discussed.[1] It is merely noticed here as the embryonic shell of the completed phylembryonic period, for it is the first stage which can be observed among the fossil species, and is the initial point for the discussions of the relations and affinities of recent and fossil forms. Of the protegulum and later stages, there is abundant material available in nearly every family of brachiopods, ranging through their entire geological history.

Post-embryonic stages.

In discussing the post-embryonic stages of growth two aspects of development must be clearly differentiated; (*a*) the ontogenetical, and (*b*) the phylogenetical. The ontogeny of a form like Schizocrania may be conveniently divided into the nepionic, nealogic, and ephebolic periods, and such stages may be clearly defined. The ephebolic stage of Schizocrania, however, is like a nealogic stage of Orbiculoidea. In other words, Orbiculoidea, in its development, passes through a Schizocrania-like stage before reaching maturity.* These facts must be viewed from a phylogenetic standpoint. Moreover, in the geological history of a group, certain ephebolic characters of

* Attention was called to this fact in a publication preliminary to vol. viii of the Palæontology of New York, pp. 131, 132, issued February, 1890. Also the development of the pedicle opening in Orbiculoidea was fully described.

early species may become accelerated, and pass into the nealogic period of later forms, while other characters remain ephebolic. Discinisca offers an illustration of this. Its nealogic characters agree with Orbiculoidea in the form of the valves and in the pedicle notch, but the circular or elliptical form of the dorsal valve in adult and nealogic Orbiculoidea appears so early in Discinisca, that it marks all the nepionic stages. The interpretation of these facts is, of course, very evident, and will be subsequently given in detail. Attention is here called to the statement, that while nepionic, nealogic, and ephebolic stages represent equal intervals in the life of each individual, they do not represent conditions of growth, or the possession of characters which always agree stage for stage in the species of one family or of different families.

Other distinctions to be made whenever possible are (*a*) whether certain characters (natural or acquired) belong to a species by inheritance, or (*b*) are mere adaptations to special conditions of environment arising at any time in its history. A clear understanding of the first will lead to the true phylogeny of a species or genus, but to reach this the characters of the second category must be excluded. Thus in the series of Schizocrania, Orbiculoidea, and Discinisca, already cited, there is an apparent genetic connection in the facts as stated. The contrary must be the case with a shell like *Lingula complanata* Williams, and *L. riciniformis* Hall which initiate a holoperipheral* mode of growth in the ephebolic period, for this agreement in the method of concrescence with adult Orbiculoidea here appears in the mature stages of this species, and being absent in the early members of the genus cannot therefore be an ancestral character. It is a morphological equivalent, which may or may not be continued in the later species of the series.

Whenever features are present which can be referred to an ancestral origin, their elimination can take place only by the process of acceleration of development. On the other hand, there may be secondary characters of dynamical or homoplastic origin which appear simultaneously or independently in different groups belonging to diverse genetic lines, as the deltidial plates of the Rhynchonellidæ, Terebratulidæ, and Spiriferidæ. Further, many such secondary features may occur anywhere in the geological history of the group, as the high hinge area of Orthisina, Spirifer, Syringothyris, and Thecidium. These statements are in full accord with what Hyatt has determined in the Cephalopoda, and the application of such ideas affords a fertile field of research.

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* *ὅλὸς*, whole; *περιφε̃ρεια*, circumference.

Preliminary to a study of the stages of growth observed in the different orders, a simple characteristic example of each will be taken to show the limitations of the post-embryonic periods.

Nepionic period.—In brachiopods, as in pelecypods, this period represents the growth of the true shell immediately succeeding the embryonic shell or protegulum, and before the appearance of definite specific characters. In general, the nepionic shells of all groups are marked only by fine concentric lines of growth, and are therefore nearly smooth. Sometimes, however, a few radiating striæ or other ornaments may appear over the nepionic portion, but this is not the prevailing rule. *Obolus pulcher* Matthew shows a cancellated nepionic stage and is one of the most striking exceptional examples.

Plate I, figure 1, represents the nepionic stage of *Glottidia albida*, drawn from the beak of a well-preserved adult. The shell at this period had a short straight hinge (originally the hinge of the protegulum), with lines representing anterior and lateral growth, making the outline broadly ovate. It is divided from the succeeding growth of later stages by a strong varix. The form is suggestive of Obolella, and as this is the early form of growth of many of the Lingulidæ and allied families, it is here called the *Obolella-stage.* It is not known that otherwise the characters agree with those of Obolella, but as it is characteristic as well as descriptive the name is used to designate this form of nepionic growth whenever present.

The nepionic stage of *Orbiculoidea minuta*, figure 4, shows a continuance of the straight hinged condition after the completion of the embryonic shell, with nearly equal incremental lines. As this agrees with the shell of Paterina it is called the *Paterina-stage.* The pedicle emerged freely between the cardinal margins of the valves. It will be shown that both this and the Obolella-stage are represented in the nepionic periods of many genera belonging to the Atremata. They may succeed each other in a single species or one alone may be present. In case both appear, the Paterina stage is always the first one to be developed.

The nepionic stage of *Leptæna* (=*Strophomena*) *rhomboidalis*, fig. 7, Pl. I, is represented by a shell without radii, having a comparatively large pedicle opening in the ventral valve and a large deltidium. The hinge is not well defined and the shell is discinoid in form. This term is not used to suggest any special affinities with true discinoid genera, as Orbiculoidea or Discinisca. The proper name for this stage is not yet apparent to the writer. The external characters as expressed by both valves are manifestly nearer to Kutorgina than to any telotremate genus. Until the early forms belonging to the articulate brachiopods, especially to the orthoid and strophomenoid groups, have been thoroughly studied, the interpretation of the nepionic *Leptæna rhomboidalis* may be uncertain. It should be noted, however, that the young of Chonetes, Productus, Stropheodonta, Orthothetes, Leptæna, Plectambonites, and Strophomena, all have little or no indication of a straight hinge line, and that the extension of this member takes place during later nealogic and ephebolic growth. This in itself is significant, but is more marked when taken with the growth stages shown by some species of Strophomena which have after the protegulum, a Paterina-like stage, with straight hinge in dorsal valve, succeeded by holoperipheral, discinoid, nepionic growth, and finally a renewal of a straight hinged condition. Thus it has an early straight hinged form, which is lost during the next stage of growth, and again appears, and is progressively elongated during nealogic and ephebolic growth.

The nepionic stages of *Terebratulina septentrionalis*, fig. 10, Pl. I, represent a decreasing extension of the cardinal line from the protegulum, an open delthyrium, the absence of radii, and the introduction of the shell punctæ. The crura at this stage, as shown by Morse, are short and stout, and the loop is undeveloped.

Nealogic period.—During the progress of this period all the features which reach their complete growth in the adult organism are introduced and progressively developed. Usually they appear in succession, and gradually assume mature conditions. Thus in many species with radiate plications or striæ, a few radii appear in early nealogic growth, and are added to until the full number is present. Species with deltidial plates develop them in this period. The early stages may offer many points for comparison with the adult, but later stages usually differ little except in size. Figures 2, 5, 8, 11, Plate I, represent a nealogic stage in each of the four species taken as examples. Others from the same species could be given, but these suffice to show that one or more characteristic adult features have made their appearance.

Ephebolic period.—The period of complete normal growth, or the maximum of individual perfection. This corresponds to the adult, or mature organism, and is so well understood that no further explanation is necessary. For the sake of completing the series, the ephebolic shells of the species given are represented in figures 3, 6, 9, 12, Plate I.

Geratologic period.—The variations due to old age may be numerous and complex. As shown by Clarke and the writer,[3] the valves generally become thickened, and, as a consequence, the margins are truncate or varicose, the vertical diameter of the shell is increased, the beaks involuted, and the margins of the valves often lose the ornamentation characteristic of the species. The deltidial plates or deltidium may be resorbed as well as the beaks of the valves. Usually the ephebolic characters disappear in inverse order to their introduction. This is called the *clinologic stage* of geratology by Hyatt. Thus in a normal adult brachiopod having a plicate shell and deltidial plates, which characters were introduced during the nealogic period, the expression of old age will be found in the absorption of the deltidial plates and in the obsolescence of the plications. Large specimens of *Terebratella transversa* Sow. often furnish examples of this clinologic stage.

The geratologic development of Bilobites[2] consists in the obsolescence, in *B. varicus* Con., of the bilobed form of the shell, thus reverting to an early nealogic condition equally characteristic of *B. bilobus* and *B. Verneuilianus.*

Another aspect of growth and decline is manifest when the size of individuals and the chronological history of groups are taken into consideration. Each genus and family began with small representatives, and rapidly developed the more radical varieties of structure. Then came the culmination and final reduction in size, with abundance of geratologous and pathologic forms. The oldest known shell with calcareous spires, Zygospira, is a comparatively minute form. Nearly all the types of the suborder to which this genus belongs (Helicopegmata) appear in the Upper Silurian. Species presenting the maximum size belong to the Devonian and Carboniferous. Before the extinction of the suborder in the Trias, the individuals are small, and such abnormal genera as Thecospira, Koninckina, and Amphiclina, abound. Productus begins with small species (Productella) in the Lower Devonian, and in the Carboniferous attains the largest dimensions of any known brachiopod (*P. giganteus*). During the Permian, the species have dwindled in size, and the geratologous Strophalosia and Aulosteges are the chief representatives.

The culmination of geratologous growth results in the reversion of the animal to its own nepionic period, and is called the *nostologic stage.* As this is an extreme condition, it can be found only in certain genera and species which have been developed by a process of accelerated geratologous heredity. If Gwynia* is accepted as a valid genus, it belongs to a pronounced nostologic type. The shell has a small internal plate on each side of the dorsal umbo, evidently the bases of crural

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*Some authors have been disposed to consider this form as the young of a species not yet determined. It has also been referred to *Macandrevia cranium, Cistella cistellula,* and *C. neapolitana.* This question cannot at present be determined, although some characters of the shell indicate a mature organism.

plates. King,[14] the author of the genus, states that the labial appendages are attached directly to the shell, and not to a loop, as in other genera of the family. Cistella may be taken as a representative of nostologic development among the terebratuloids. The species are smooth, or pauciplicate, and small; deltidial plates obsolescent, loop more or less undeveloped. In *C. neapolitana*, the lamellæ of the loop are nearly obsolete and are free only near the crura, while the anterior portions are confluent with the valve (Shipley). A slight progression of these reversions would naturally result in a degenerate form like Gwynia, which is without a calcareous loop; with no surface ornamentation; deltidial plates absent, punctæ few and large, all of which features are strictly nepionic. Besides Cistella and Gwynia, other loop-bearing genera present nostologic features of importance in a natural classification. These consist mainly in their small size; the absence of surface ornaments; the obsolescence of deltidial plates, and the loss of a complete loop supporting the arms. In the Terebratulidæ, Kraussina and Platydia may be mentioned as belonging to geratologous types with a nostologic tendency. Likewise, in other groups, Atretia in the Rhynchonellidæ, and Strophalosia and Aulosteges in the Productidæ, are examples of nostologic types.

Cistella and Gwynia among the genera of brachiopods, therefore, bear the same relation to the terebratuloids that Baculites among the cephalopods bears to the ammonoids.

Synopsis.

Protembryo.—Ovum and segmented stages before formation of blastula cavity.

Mesembryo.—Blastosphere.

Metembryo.—Gastrula.

Neoembryo.—Trochosphere and cephalula, with posteriorly directed mantle lobes, and bundles of setæ from body segment.

Typembryo.—Larva with mantle lobes folded anteriorly over head segment.

Phylembryo.—Brachiopod covered by protegulum, tentacles of arms developed, bundles of setæ dehisced, definition of stomach and œsophagus, direct transformation of larval muscles into those corresponding to muscles of adult animal.

Deltidium.—A single plate developed at an early period by the body and pedicle of animal posterior to dorsal hinge, and later ankylosed to ventral valve.

Deltidial plates.—A nealogic and adult feature produced by the extensions of the ventral mantle lobe into the delthyrium.

Brachiopoda.—Retrogressive in loss of anal opening and eyes, progressive in concentration of posterior elements, expansion of anterior elements, and limitation of pedicle opening to one valve.

Nepionic period.—Young shells before the appearance of distinctive specific characters.

Nealogic period.—Progressive development of the specific features which reach their complete growth in the adult.

Ephebolic period.—Normal adult condition.

Geratologic period.—Special manifestations of old age in ontogeny and in phylogeny.

Nostologic types.—Extremes of geratology represented by Cistella, Gwynia, and Atretia.

Yale Museum, New Haven, Conn., May 31, 1892.

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EXPLANATION OF PLATE.

Glottidia albida Hinds.

FIGURE 1.—Nepionic shell; Obolella stage. ×36.
FIGURE 2.—Nealogic stage; showing anterior growth producing Lingula-like form. ×16.
FIGURE 3.—Ephebolic stage. × $\frac{3}{2}$.

Orbiculoidea minuta Hall.

FIGURE 4.—Nepionic shell; Paterina stage. ×36.
FIGURE 5.—Nealogic stage; first holoperipheral growth. ×16.
FIGURE 6.—Ephebolic stage. ×10.

Leptæna rhomboidalis Wilck.

FIGURE 7.—Nepionic stages, with short hinge. ×36.
FIGURE 8.—Early nealogic stage, with radiating striæ. ×10.
FIGURE 9.—Ephebolic stage. × $\frac{2}{3}$.

Terebratulina septentrionalis Couth.

FIGURE 10.—Nepionic stage, with open delthyrium. ×26.
FIGURE 11.—Early nealogic stage, with radiating striae. ×16. (After Morse.)
FIGURE 12.—Ephebolic stage. × $\frac{2}{3}$. (After Davidson.)

ART. XX.—*On some Double Halides of Silver and the Alkali-metals;* by H. L. WELLS and H. L. WHEELER. *With their Crystallography;* by S. L. PENFIELD.

DURING a systematic search for well crystallized salts of the type $M'Hl . AgHl$,* which we were anxious to obtain on account of their probable isomorphism with the alkaline trihalides, three well defined compounds of another type, $2M'Hl . AgHl$, were obtained. Our experience indicates that these 2 : 1 salts are more easily prepared and crystallize better than the 1 : 1 compounds.

The bodies to be described are $2CsCl . AgCl$, $2RbI . AgI$ and $2KI . AgI$. Two of these are believed to be new salts; the other, $2KI . AgI$ has been described by Boullay.† We have not obtained a complete series of these compounds, for good crystals could not be made of the other members, and, under the circumstances, no products were analyzed except such as could be measured.

The compounds are interesting from the fact that they do not conform to Remsen's law concerning the composition of double halides,‡ for, contrary to this, they contain a number of alkali-metal atoms which is greater than the number of halogen atoms belonging to the silver. In his latest contribution to the

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* This Journal, III, xliii, 30 and 485.
† Ann. Chim. Phys., II, xxiv, 377.
‡ Am. Chem. Jour., xi, 291.

subject,* Remsen states that the exceptions to his law are "not more than three or four out of over four hundred." The work here described confirms the result of Boullay, adds two more exceptions to the law and points to the existence of a greater number of compounds of the same type. It may be mentioned that a considerable number of other exceptions to this law have recently been established in this laboratory and will soon be described.

Preparation and properties.—The salts are made by saturating a very concentrated, hot solution of an alkaline halide with the corresponding silver halide, filtering, cooling to crystallization and, if necessary, evaporating the mother-liquor at ordinary temperatures. If the solutions are too dilute, in some cases at least, the 1 : 1 salts are formed. The compounds have little tendency to crystallize well and many trials are usually necessary in order to obtain satisfactory products. The salts are all white. They are readily decomposed by water.

Method of analysis.—The products analyzed were in the form of crystals of such size that it was certain that they were not mixed with other substances. In preparing them for analysis the mother liquor was removed rapidly and completely by pressing them between smooth filter-papers and great care was taken to avoid any evaporation of the liquid which adhered to them. The analyses were made by treating them with a sufficient amount of water acidified with nitric acid and weighing the silver halide thus separated. The filtrate from this was used for determining the remaining halogen or the alkali-metal.

ANALYSES.

	Found.	Calculated for $2CsCl . AgCl$.
Cæsium	----	55·38
Silver	24·85	22·47
Chlorine	----	22·15

	Found.	Calculated for $2RbI . AgI$.
Rubidium	25·05	25·91
Silver	17·32	16·36
Iodine	57·53	57·73
	99·90	100·00

	Found.	Calculated for $2KI . AgI$.
Potassium	----	13·79
Silver	18·73	19·04
Iodine	----	67·17

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* Am. Chem. Jour., xiv, 87.

Crystallography.—The three salts are isomorphous and crystallize in the orthorhombic system. The forms which were observed are:

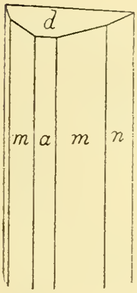
a, 100, i-$\bar{i}$	m, 110, I	d, 101, 1-$\bar{i}$
b, 010, i-$\breve{i}$	n, 120, i-$\breve{2}$	x, 301, 3-$\bar{i}$

The axial ratios and some of the prominent angles are given in the following tables, the fundamental measurements being marked by an asterisk. The crystals did not yield very accurate measurements.

	$\breve{a}$: $\bar{b}$: $\dot{c}$
$2CsCl \, . \, AgCl$	0·971 : 1 : 0·244
$2RbI \, . \, AgI$	0·977 : 1 : 0·236
$2KI \, . \, AgI$	0·977 : 1 : 0·234

	$m \wedge m$, $110 \wedge 1\bar{1}0$	$n \wedge n$, $120 \wedge \bar{1}20$	$d \wedge d$, $101 \wedge \bar{1}01$
$2CsCl \, . \, AgCl$	88° 18′	*54° 29′	*28′ 11′
$2RbI \, . \, AgI$	*88 40	54 12	*27 12
$2KI \, . \, AgI$	*88 40	54 12	*27 0

1.



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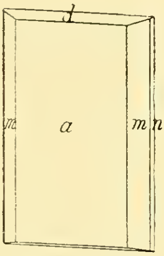

2 CsCl . AgCl was made in minute prisms, less than a millimeter in diameter, having the habit shown in fig. 1. The measurements are only approximately correct.

Two crops of 2RbI . AgI were examined. One was like fig. 1 in habit, the other in plates, fig. 2. The crystals were nearly 10mm in length. On this salt a cleavage, parallel to *a*, was observed; also, as small faces, the forms *b* and *x*, which are not shown in the figures. In convergent polarized light an obtuse bisectrix was seen, normal to *a*, the axial plane being the brachy-pinacoid.

2KI . AgI was made in prismatic crystals, over 10mm in length and having the habit and forms shown in fig. 1.

Sheffield Scientific School, April, 1892.

Art. XXI.—*On the Cæsium and Rubidium Chloraurates and Bromaurates;* by H. L. Wells and H. L. Wheeler. *With their Crystallography;* by S. L. Penfield.

A study of the compounds to be described was undertaken in the hope that some crystallographic analogy would exist between them and the alkaline pentahalides described in a previous article.* No such analogy has been found in spite of

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* This Journal, xliv, 42.

the similarity of such formulæ as $CsCl . Cl_3I$ and $CsCl . Cl_3Au$, but since some of these gold salts have never been described and as they show some interesting relations among themselves, our results are deemed worthy of publication.*

Th. Rosenbladt,† in an article on the solubility of the chloraurates, states that the cæsium and rubidium salts lose their water of crystallization almost completely when dried over sulphuric acid. He gives no statement of the amount of water, but refers to his dissertation of 1872 which is inaccessible to us. He mentions, however, that the crystals of both salts belong to the monoclinic system, so that it is probable that the compounds he obtained were the ones that we have found to be anhydrous.

The compounds that have been prepared are $CsAuCl_4$, $2CsAuCl_4 . H_2O$, $CsAuBr_4$, $RbAuCl_4$ and $RbAuBr_4$. We have attempted in each case to obtain bodies containing more cæsium and rubidium, but no evidence of their existence has been found.

An investigation of the corresponding iodine compounds was also undertaken, but, on account of the instability of auric iodide, we did not obtain any pure or well crystallized products.

Preparation:—The salts are so insoluble that they form precipitates when moderately concentrated solutions of the component salts are mixed, and the products are readily recrystallized from water or from the mother liquors. It is usually immaterial whether the solutions are neutral or acid or whether the gold or alkaline halide is in excess, but the salt $2CsAuCl_4 . H_2O$ requires special conditions for its preparation, for it is apparently formed only when a large excess of gold chloride is present and when the solution does not contain much free acid. We have used four atoms of gold to one of cæsium in making this salt, but it usually requires repeated trials under these conditions before it is obtained free from the anhydrous compound. The two salts are however so distinct in form that there is no difficulty in distinguishing them.

Properties:—The color of $CsAuCl_4$ and of $2CsAuCl_4 . H_2O$ is golden-yellow; $RbAuCl_4$ is yellowish-red; the two bromides are black, but give a dark red powder.

All the salts are sparingly soluble in water, especially when cold, and the cæsium compounds are less soluble than the rubidium. All of them are only slightly soluble in alcohol and insoluble in ether.

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* The announcement by Professor Remsen (Am. Chem. Jour., xiv, 89), that he and Mr. H. C. Jones proposed to examine the gold-rubidium halides, was not made until after the work described in this article had been completed.

† Berichte, xix, 2535.

Methods of analysis:—The crystals were prepared for analysis by quickly pressing them between smooth filter-papers and finally allowing them to become air-dry. The hydrous cæsium chloraurate, however, loses its water and becomes opaque on exposure. It was therefore dried as rapidly and thoroughly as possible on paper and was put into a weighing-tube as soon as some of the fragments began to lose their transparency.

Gold was determined by precipitation with ammonium oxalate or with sulphurous acid. The filtrate from the metallic gold was used either to determine the alkali-metal as normal sulphate or the halogen by the usual gravimetric method. Water was determined by the method used in the combustion of organic compounds, the halogens being held back by a mixture of lead chromate and lead oxide. The absence of water in the anhydrous compounds was established by the use of the same process.

ANALYSES.

	Found.	Calculated for $CsAuCl_4$
Cæsium	28·11	28·16
Gold	41·61	41·77
Chlorine	29·91	30·06
	99·63	

	Found.			Calculated for $2CsAuCl_4 . H_2O$
Cæsium	27·23	----	----	27·63
Gold	40·23	----	----	40·99
Chlorine	29·07	----	----	29·50
Water	2·32	2·37*	2·20*	1·87
	98·86			

	Found.		Calculated for $CsAuBr_4$
Caesium	20·73	----	20·45
Gold	30·32	30·26	30·34
Bromine	49·31	----	49·21
	100·36		

	Found.	Calculated for $RbAuCl_4$
Rubidium	----	20·14
Gold	45·53	46·46
Chlorine	32·98	33·40

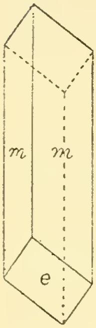
* From a separate product.

	Found.	Calculated for $RbAuBr_4$
Rubidium	----	14·18
Gold	32·54	32·73
Bromine	----	53·08

Crystallography:—The crystallization of $CsAuCl_4$, $CsAuBr_4$, $RbAuCl_4$ and $RbAuBr_4$ is monoclinic. The four salts form an isomorphous group and are identical in crystalline habit. The forms which have been observed on them are:

c, 001, O	*d*, 021, 2-$\grave{i}$	*p*, $\bar{1}11$, 1
m, 110, I	*e*, $\bar{2}01$, 2-$\bar{i}$	

1.



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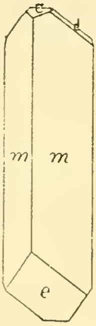

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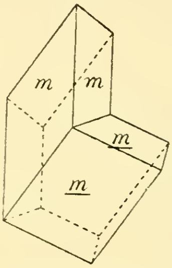

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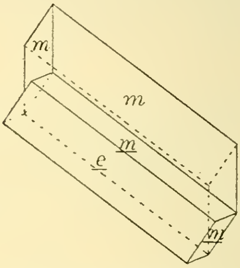

The crystals are prismatic and are usually terminated by *e*, fig. 1. When other faces are present they are always small, as represented in fig. 2. The pyramid *p*, which is not shown in the figure, frequently occurs as a small face, replacing the edge between *d* and *e*. Among the crystals of $CsAuBr_4$ several twins were observed, having *p*, $11\bar{1}$ as the twinning plane, fig. 3, while fig. 4 represents a crystal of $RbAuBr_4$ twinned about *e*, $20\bar{1}$. The letters belonging to the parts in twin position are underlined. Both kinds of twins are abnormally developed as represented in the figures. In all four compounds the cleavage is perfect parallel to the base.

The rubidium salts, being the most soluble, form readily in large crystals, several centimeters in length. The chloride, especially, yielded magnificent crystals, which frequently were only limited in length by the size of the vessel and volume of the solution containing them. The cæsium salts are less soluble and were made in small prisms, seldom over 5^{mm} in length. The crystals were frequently hollow or cavernous at the extremities, this was especially true of the two bromides. The faces, for the most part, gave excellent reflections of the signal on the goniometer.

The axial ratios are as follows:

$CsAuCl_4$
$\grave{a}:\bar{b}:\dot{c} = 1{\cdot}1255:1:0{\cdot}7228$
$\beta = 71^\circ\ 36'$
$RbAuCl_4$
$\grave{a}:\bar{b}:\dot{c} = 1{\cdot}1954:1:0{\cdot}7385$
$\beta = 75^\circ\ 32'$

$CsAuBr_4$
$\grave{a}:\bar{b}:\dot{c} = 1{\cdot}1359:1:0{\cdot}7411$
$\beta = 70^\circ\ 24\frac{1}{2}'$
$RbAuBr_4$
$\grave{a}:\bar{b}\ \dot{c}: = 1{\cdot}1951:1:0{\cdot}7256$
$\beta = 76^\circ\ 53\frac{1}{2}'$

In the following tables the angles which were chosen as fundamental are marked by an asterisk.

		$CsAuCl_4$		$CsAuBr_4$	
		Measured.	Calculated.	Measured.	Calculated.
$m \wedge m,$	$110 \wedge 1\bar{1}0 =$	*93° 46′		*93° 53′	
$m \wedge c,$	$110 \wedge 001 =$	77 36	77° 32′	*76 46	
$m \wedge d,$	$110 \wedge 021 =$	44 6	44 7	43 23,	43° 20′
$d \wedge p,$	$021 \wedge \bar{1}11 =$			32 23	32 40½
$d \wedge e,$	$021 \wedge \bar{2}01 =$	*75 17		75 31	75 59
$m \wedge e,$	$\bar{1}\bar{1}0 \wedge \bar{2}01 =$	*60 36		*60 41	
$c \wedge e,$	$001 \wedge \bar{2}01 =$	64 20,	64 18		
$m \wedge m,$	Reëntrant angle of twin,			27 58	27 58

		$RbAuCl_4$		$RbAuBr_4$	
		Measured.	Calculated.	Measured.	Calculated.
$m \wedge m;$	$110 \wedge 1\bar{1}0 =$	*98° 21′		*98° 40′	
$m \wedge c,$	$110 \wedge 001 =$	*80 36		*81 30	
$m \wedge d,$	$110 \wedge 021 =$			44 57	45 12½
$d \wedge p,$	$021 \wedge \bar{1}11 =$			31 26	31 35½
$d \wedge e,$	$021 \wedge \bar{2}01 =$			72 28	72 26
$m \wedge e,$	$\bar{1}\bar{1}0 \wedge \bar{2}01 =$	*62 12		62 9	62 21½
$c \wedge e,$	$001 \wedge \bar{2}01 =$	60 4	59° 59′		
$d \wedge d,$	$021 \wedge 0\bar{2}1 =$	110 20	110 4½	*109 26	
$m \wedge m,$	Reëntrant angle of twin,			55 42	55 17

In their axial ratios the two cæsium salts are very similar, as are also the two rubidium salts, while the rubidium compounds differ considerably from those of cæsium, especially in the relation of $\grave{a}$ to the other axes and in the angles β. It is therefore evident that the replacement of one metal by another in these salts has a considerable influence upon their form, whereas, as we have shown, such a replacement in the cæsium and rubidium trihalides has little or no effect. There seems to be no regularity in the influence of the replacement of chlorine by bromine in these gold salts, for in the cæsium compounds the chloride has a slightly shorter axis $\dot{c}$ and a greater angle β than the bromide, while in the rubidium salts exactly the reverse is true in both cases. This unexpected relation between the chlorides and bromides has been confirmed by repeating the measurements, especially of the angle $m \wedge c$, using both crystal and cleavage faces. It is certain that this angle is about a degree greater with the chloride than with the bromide in the cæsium salts, while in the rubidium compounds it is about a degree less.

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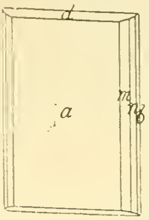


The crystallization of $2CsAuCl_4 . H_2O$ is orthorhombic. This salt was repeatedly made but only one crop of crystals was obtained which was suitable for measurement. These were thin plates, having the habit shown in fig. 5. They were not over 5^{mm} in length and were only a fraction of a millimeter thick. On removal from the mother liquor, or from a moist atmosphere, the transparent plates rapidly became opaque and the faces lost their luster so that only approximate measurements could be obtained.

The forms which were observed are:

a, 100, *i*-ī
b, 010, *i*-ĭ
m, 110, I
n, 120, *i*-2̆
d, 101, 1-ī

The axial ratio is as follows:

$$\breve{a} : \bar{b} : \acute{c} = 0·625 : 1 : 0·24$$

The following measurements were made.

$a \wedge m$, $100 \wedge 110$ = about 32°
$a \wedge n$, $100 \wedge 120$ = " 51°
$a \wedge b$, $100 \wedge 010$ = about 90°
$d \wedge d$, $101 \wedge \bar{1}01$ = " 42°

Under the polarizing microscope the crystals show parallel extinction and, in convergent light, an acute bisectrix normal to *a*, 100. The plane of the optical axes is the base. The divergence of the axes is large, the hyperbolæ opening out beyond the field of the microscope. The axes of elasticity are:

$$\breve{a} = \mathfrak{c}, \qquad \bar{b} = \mathfrak{a}, \qquad \acute{c} = \mathfrak{b}.$$

The double refraction is therefore positive.

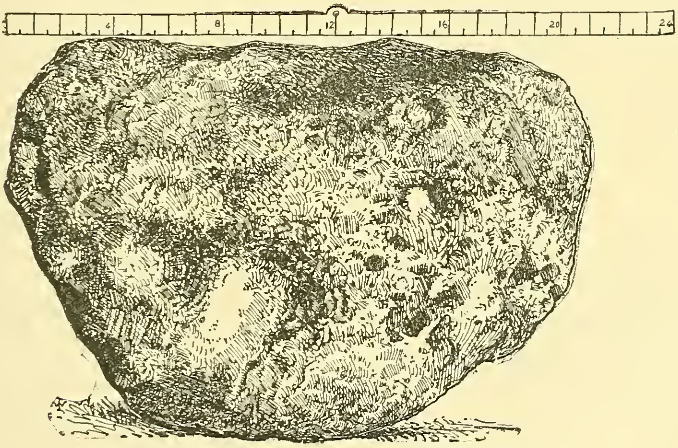
The change which the crystals undergo when exposed to dry air is a molecular rearrangement, accompanied by loss of water and, probably a change to the anhydrous salt which was described above. This rearrangement is a beautiful sight when studied with the microscope in polarized light. The change commences a few minutes after the crystals are removed from the mother liquor, and in less than ten minutes has usually advanced to such an extent that the crystals are no longer transparent. The crystals at first show a uniform action on polarized light, then from different parts of the surface the rearrangement, which is marked by aggregate polarization, commences. It advances, shooting out in various directions in a manner resembling the growth of ammonium chloride crystals under the microscope, until the whole field is covered and light is finally no longer transmitted.

Sheffield Scientific School, April, 1892.

ART. XXII.—*Preliminary Note of a New Meteorite from Kenton County, Kentucky*; by H. L. PRESTON.

[Read before the Rochester Academy of Science, June 27th, 1892.]

ON May 15th, Prof. Henry A. Ward received a letter from Mr. R. H. Fitzhugh, Bryson City, N. C., telling of a meteorite he had identified in Kenton County, Kentucky. In Prof. Ward's absence Mr. Frank A. Ward sent me off the same night to look up the meteorite. I arrived at Bracht station on the Cincinnati Southern R. R., Friday morning and drove as far as the roads would permit toward Mr. Geo. W. Cornelius's farm. He being away from home his wife showed me the "metal" as they called it. It proved to be a beautiful meteorite of the Siderite variety, 533×356×203 millimeters (21×14×8 inches) in its greatest diameters, and 163·0665 kilograms (359½ pounds) in weight.



Kenton Co. Meteorite, one-seventh natural size.

In form in certain directions it very much resembles a nautilus. It has numerous but mostly shallow pittings; a few deep pittings occur however on the side shown in the accompanying cut which gives a good idea of its general outline. This meteorite is entirely free from crust.

I saw Mr. Cornelius on the evening of the next day and obtained from him the following facts in relation to the meteorite.

About the middle of August, 1889, while cleaning out a spring situated at the head of a gully some three-quarters of a mile from his present home in Kenton County, eight miles south of Independence, the county seat, he struck with his hoe something that had a metallic ring; obtaining assistance he took the mass out, finding that it was interlocked in the roots of an ash tree from thirteen to fourteen inches in diameter and was between three and four feet below the normal surface.

He let the mass lie by the spring until August, 1890, when he removed it to his woodshed where it has lain until purchased by me for the Ward collection of meteorites. It is now at our establishment in Rochester, N. Y.

For the following analysis of this meteorite I am indebted to Mr. John M. Davison, of the Reynolds Laboratory, University of Rochester.

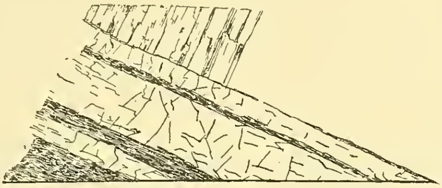
Fe	91·59
Ni	7·65
Co	0·84
Cu	trace.
C	0·12
S	trace.
P	trace.
	100·20

In the course of a conversation with Mr. S. J. Cornelius, a brother of the gentlemen of whom I purchased the meteorite, he mentioned the fact, that about three o'clock on the seventh of July, 1873, while returning from a picnic in this locality, and when within half a mile of where the meteorite was subsequently found, he heard a great rumbling in the heavens, which appeared to last three or four minutes and was followed by a quivering of the earth. As the day was clear he could not account for this phenomenon. I met at least seven other people who distinctly remembered the picnic and the "rumbling in the heavens," and some one or two "the quiver of the earth."

Is there any connection between this date and the fall of the meteor?

ART. XXIII.—*Additional observations on the Jura-Trias trap of the New Haven Region;* by JAMES D. DANA.

IN connection with my description of the south front of West Rock, the annexed figure of the eastern part of the exposed sandstone with a portion of the base of the overlying sheet of trap is introduced.* It is repeated here in order to mark from it the localities of two new observations of interest.



I. The exposure of sandstone represented in the above figure owes about eight feet of its height to the removal of overlying trap by the quarrymen. The trap quarry (see Plate VII of my former paper) extends from the point E eastward for nearly 140 yards. At a spot about 100 yards east of this point and 16 feet below it in level, the removal of the debris from the floor of the quarry has exposed the top of another ledge of upturned sandstone. The escape of the trap from the dike, therefore, was not along the sloping surface of the upper layer exposed at E, but along another about one hundred yards farther east.

II. About 90 feet west of the point E in the preceding figure, and 40 to 50 feet above the quarry-road, the talus with the partly concealed sandstone is crossed by a *five-inch dike of trap*. It was first observed last autumn by Professor W. O. Crosby. It looks from the quarry-road like a slight break in the steep surface. (On the phototype, Plate VII, referred to above, it is very faintly indicated across the bed of sandstone, just one inch from the sandstone point E.)

The little dike is a branch from the underside of the main sheet of trap. It makes a sinuous line of outcrops extending westward along the talus for about 40 feet, and then disappears under the debris. In this distance the dip of the outcrop is about 18 feet; but the true dip of the sheet is northwestward about 20° to 25°, as nearly as could be ascertained. Toward its junction with the main mass of the West Rock trap, it is reduced, for nearly a yard of its length, to two strands hardly

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* This Journal, xlii, 102, 1891.

an inch thick by an intervening mass of sandstone; but this is only an irregularity of outflow due to the way the sandstone has of breaking, like that in the Mill Rock dike described and figured on page 88 of the paper above mentioned.

This branch dike has several points of interest.

1. It affords new proof that the West Rock outflow took place under a heavy cover of sandstone and therefore was laccolithic. This conclusion was sustained, in my former paper (p. 103), on the ground (1) that the outflow continued to be an ascending one for the 500 yards of its westward flow—which could not have been true unless it were under a resisting cover; and (2) the outflow retains a thickness of 250 feet quite to its extreme western limit, which it could not have done if it had been a subaerial, or, using a much needed new word, a *surficial*, flow.*

But (3) under *laccolithic* conditions, the opening of a fissure in the underlying sandstone for a discharge from the lower part of the mass of trap or else from the dike, would be a natural result. The liquid trap that was being forced up and onward under the repressing sandstone formation, might readily have made the fracture, especially when, after the lava had attained nearly its full thickness, a new start in its movement was given. Had it been a surficial stream it would have had no fracturing power.

2. Other points of interest in the dike are connected with its constitution. (1) While the rock of West Rock is a compact, rather coarsely crystalline doleryte, and has a light blue-gray color owing to the abundance of labradorite with the pyroxene, and is darker and finer but still gray at its junction with the sandstone, the trap of the dike is black, without luster, and aphanitic. Moreover, (2) it is amygdaloidal or vesicular; some of the cavities are over an inch in diameter and contain a lining of quartz crystals with a filling often of laumontite, while others are minute and filled with quartz. The rock is besides irregularly jointed, and much rifted and deeply altered along the rifts by weathering.

Examined microscopically in thin slices, the rock is found to have other peculiarities. (3) Magnetite is unusually abundant in very minute grains, much more so than in the trap of West Rock. (4) The labradorite of the rock is in crystals of the usual form, but they are extremely small. (5) The gray pyroxenic material about the labradorite is also in minute grains and seldom shows color in polarized light. Further, (6) *greenish olivine* is present in crystals and groups of crystals—a mineral not yet observed in the West Rock trap.†

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* The word *superficial* is too various in its significations for the place. *Surficial* is like surface in having its prefix the French abbreviation *sur* in place of *super*.

† A full petrological description of the rock will be published later by another.

From the facts we are safe in concluding that the liquid rock of the little fissure had at its outflow the maximum temperature of the main mass; for it was from its lower portion. Evidence of high heat is indicated by the presence of olivine. For in the experiments of Fouqué and Michel Lévy, basalt on cooling after being for 48 hours at *white-red* fusion, "a temperature above the melting point of pyroxene and labradorite," afforded "crystals of olivine in a brownish vitreous magma;" but on cooling from *cherry-red* fusion sustained for 48 hours, afforded numerous microlites of labradorite and augite with magnetite.[*]

The olivine of the dike was made at the expense evidently of the pyroxene; and as ordinary olivine contains 8 to 10 per cent of iron protoxide and 41·5 of silica, and the pyroxene of West Rock trap, according to the analysis of Hawes,[†] 15·3 per cent of the former to 50·7 of the latter, some iron protoxide may have been set free in the process to add to the magnetite, besides silica to form the quartz-crystals and silicates in cavities or fissures.

The aphanitic texture of the trap indicates rapid cooling, and its vesicular character, cooling where there was much moisture. The temperature of the liquid trap was evidently too high to make chlorite from the constituents of the pyroxene. Moreover, the feldspar is not much altered notwithstanding the moisture at hand.

This dike, from the underside of the West Rock trap-mass, suggests an hypothesis with regard to the origin of the low and narrow belt of amygdaloidal trap that runs parallel with the high and wide belt of compact and nearly anhydrous trap of the Mt. Tom Ridge, from western Meriden northward, keeping in close parallelism with it and bending with it eastward at its southern extremity in the Meriden region. On Percival's map, Plate XVI in vol. xlii, of this Journal, the belt is that of the series of narrow dikes lettered A 1, situated just west of the areas 3, 4, 5, 6, 7, 8, 9, which mark the main trap range. It follows the curves and variations in height of the main range.

The hypothesis of Prof. Wm. M. Davis supposes that this low amygdaloidal belt is the outcrop of an inferior sheet of

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[*] Synthèse des Minéraux et des Roches, 1882, p. 62.

[†] This Journal, III, ix, 187. G. W. Hawes obtained for the composition of the trap (doleryte) of West Rock (mean of two analyses): Silica 51·78, alumina 14·20, iron protoxide 8·25, iron sesquioxide 3·59, manganese protoxide 0·44, magnesia 7·63, lime 10·70, soda 2·14, potash 0·39, phosphoric acid 0·14, ignition 0·63=99·89; and for that of its pyroxene: Silica 50·71, alumina 3·55, iron protoxide 15·30, manganese protoxide 0·81, magnesia 13 63, lime 13·35, ignition 1·17, [alkalies and loss, 1·48]=100.

trap, parallel with that of the Mt. Tom Ridge; and that the two were raised together from their original horizontality along with the sandstone formation in which they were intercalated, into a monoclinal of 20° to 25°. The apparent satisfactoriness of this explanation is the strongest point in Mr. Davis's hypothesis.

The parallel courses of the two *unlike* belts has always seemed to me difficult to understand. But supposing the Mt. Tom ridge to be of laccolithic origin, like West Rock, the view I still believe to be most probable for reasons I have stated, the new facts from West Rock suggest an explanation: that this subordinate amygdaloidal belt of trap was produced by a lateral discharge from the dike of the laccolithic Mt. Tom belt, when the laccolithic discharge was nearing completion. This would account for the close relation of the two in position. Moreover the trap of such a dike would be sure to be amygdaloidal; for the north and south line of dikes of the Mt. Tom Ridge, situated along the western side of the Connecticut valley trough, would have been, from the commencement of the outflow, a barrier to the eastward or southeastward flow of subterranean waters descending from the north and west, so that the accumulated subterranean stream would have been large. To the eastward, the subterranean waters of the valley would have been divided up by the parallel trap dikes, for the hydration and vesiculation of other such branch dikes.

The value of the two hypotheses as to the origin of the trap belts—the dike or intrusive and the monocline—can be tested in two ways. One I have already referred to: the removal of the trap debris making the long east-and-west talus of the Mt. Tom ridge, near Meriden, exposing the sandstone, as done for the east-and-west talus along the similar south front of West Rock near New Haven. The sandstone may be, as it is at New Haven, *upturned* beneath the trap-mass, without conformability between the two rocks. If this were found to be the case, there would be no further ground for doubt as to the upturning before the outflow.

The other method is by boring. A boring carried down through the sandstone at points a short distance to the west of the Mt. Tom ridge would pass through, if the monocline hypothesis is the true one, at no great depth—probably within 1000 to 2000 feet of the surface—a layer of compact trap 200 to 300 feet thick, and then, after a little more sandstone, a layer of amygdaloidal trap; and not so, if the dike theory is correct. This test, repeated in other parts of the Connecticut valley in Connecticut and Massachusetts, would give conclusive facts.

The conformability of beds in monoclines is usually proved to be a fact by the study of *transverse* sections. But in the case of the trap and sandstone of the Jura-Trias area of Eastern America, no transverse section exhibiting such conformability between the trap and sandstone has yet been made known by any observer.

III. An emergence of the sandstone placing it more or less above the sea-level is necessary to render the method of hydration above appealed to possible. There is other evidence of such emergence.

The existence of dikes of amygdaloidal trap in East Haven, and of others of compact anhydrous trap in New Haven localities, two to five miles apart, is evidence, as explained in my Geology, of the hydration of the liquid rock in the former region while on the way to the surface; for the lava at its source must have been all alike. This must have taken place during its ascent through the sandstone; for, as shown by E. S. Dana, the trap of the related dikes that intersect the metamorphic rocks is unusually anhydrous. The New Haven dikes are situated along the western slope of the Connecticut valley trough, and those of East Haven toward or at its center, where the subterranean waters would have flowed. Hence the difference. But if the sandstone were wholly under the sea-level, the amount of subterranean water could not have thus differed, in the two regions; and consequently, there was some emergence.

If the sandstone formation was thus early emerged another conclusion follows. The trap of the Lake Saltonstall and Hartford Range (its more southern part marked EI, EII, EIII on Percival's map)—which I have shown to have originated, in all probability from fissure-ejections subsequently to the upturning of the sandstone—would have made, as I long since explained, a barrier to the Connecticut River waters, that would have cut off their flow southward and determined sooner or later their discharge by the present Middletown-Saybrook outlet. (See Percival's map.) These facts therefore bear on Prof. Davis's hypothesis, and on his deductions from it as to denudation over the region of the Connecticut valley.

SCIENTIFIC INTELLIGENCE.

I. Miscellaneous Scientific Intelligence.

1. *Natural Science: A monthly review of Scientific Progress.* Each no. 80 pp. 8vo. (Macmillan & Co., London and New York; 14s., post free.)—The first number of this new monthly appeared on the 1st of March. The four numbers thus far issued show that it is to be a Journal of great value to all interested in the progress of natural science. Its contributors are men of high scientific standing. The June number contains papers by P. L. Sclater on the Antelopes of Somali-Land, with figures; R. Lydekker on Recent Researches in Fossil Birds; A. Vaughan Jennings, on the Cave Men of Mentone, giving the results of recent researches and a plate; G. H. Carpenter, Facts and theories in the development of Insects; and others by Prof. Teall, Prof. C. Loyd Morgan, besides various shorter notices of recent discoveries.

2. *Catalogue of Scientific Papers* (1874–1883).—Completed by the Royal Society of London, vol. ix, 1016 pp. London, 1891. —This large volume is the first of the three which will form the third series of the Royal Society's Catalogue of Scientific Papers, embracing titles of papers published or read during the decade, 1874–1883. The titles are arranged under the names of the authors and are given with great thoroughness and accuracy; this first volume contains the names from Abadie to Gissler. The work, like its predecessors, is invaluable to all concerned with the literature of science.

3. *Experiments with alternate currents of high potential and high frequency, by Nikola Tesla.* A Lecture delivered before the Institution of Electrical Engineers, London. With a portrait and biographical sketch of the author. 146 pp. 12mo. New York, 1892 (The W. J. Johnston Company).—Mr. Tesla's lectures delivered, in February last, before the Institution of Electrical Engineers in London have been republished in book form from the pages of the Electrical World. The author's name is already identified with some very important advances in connection with dynamos giving alternating currents. These lectures give the results of his experiments with very rapidly alternating currents of high potential, obtained from an induction coil operated either by the extremely rapid oscillations of a disruptive discharge from a condenser, or, in other cases, by a specially constructed alternator, giving many thousand reversals per second. The luminous phenomena obtained are not only novel and highly interesting, but very suggestive as to a possibly more efficient means of illumination than that now in use. The volume is well illustrated and serves to bring the substance of these remarkable lectures before a much larger audience than that which had the privilege of hearing them delivered.

APPENDIX.

Art. XXIV. — *Notes on Mesozoic Vertebrate Fossils;* by O. C. Marsh. (With Plates II–V.)

The extensive collections of vertebrate fossils from the Laramie now under investigation by the writer contain, besides those already described, many specimens of much interest, and some of these are briefly noticed and figured in the present article. The *Dinosauria* of this formation are of special importance, particularly in their relations to allied forms in the Jurassic, and hence some of the latter, also, are figured for comparison.

Claosaurus, Marsh, 1890.

Next in importance to the *Ceratopsidæ* of the Laramie are the Dinosaurs allied to *Hadrosaurus*, and, as but little is really known of the skeleton in this group, some of the important parts are here described, and figured in Plates II and III. These are mainly from a single specimen which is in remarkable preservation; but the remains of a second individual, likewise in good condition, and in some respects more perfect, have also been used in the investigation. The species is *Claosaurus annectens*, already briefly described by the writer.*

The skull will be described in a later communication. The number of vertebræ between the skull and sacrum is thirty, and all were found in position. There are nine vertebræ in the sacrum, thoroughly coössified with each other. The anterior forty-five vertebræ of the tail were found in position, and in good preservation.

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* This Journal, vol. xliii, p. 453. May, 1892.

The fore limbs are unusually small in comparison with the posterior, and the relative size of the two is shown on Plate II. The scapular arch presents many points of interest. The scapula is large, and so much curved that the axis of its shaft is nearly parallel to the articular faces of its lower extremity, (Plate II, figure 1, *s*). On the anterior margin, above the articulation for the coracoid, is a strong protuberance, with a well-defined facet, adapted to the support of the clavicle, if such a bone were present. The coracoid is very small, and is perforated by a large foramen (Plate II, figure 1, *c*). The two peculiar bones now generally regarded as belonging to the sternum were separate, as shown in Plate III, figure 1.

The humerus is comparatively short, and has a prominent radial crest. The radius and ulna are much elongated, the latter being longer than the humerus, and the radius about the same length. The ulna has a prominent olecranon process, and is a stouter bone than the radius. The carpal bones were quite short, and appear to have been only imperfectly ossified. The fore foot, or manus, was very long, and contained three functional digits only. The first digit was rudimentary, the second and third were nearly equal in length, the fourth was shorter and less developed, and the fifth entirely wanting, as shown in Plate II, figure 1.

In the functional digits (II, III, IV), the phalanges are elongate, thus materially lengthening the fore foot. The terminal phalanges of these digits are broad and flat, showing that they were covered with hoofs, and not with claws. The limb as a whole was thus adapted to locomotion or support, and not at all for prehension, although this might have been expected from its small size and position.

The elongation of the fore-arm and manus is a peculiar feature, especially when taken in connection with the ungulate phalanges. It may, perhaps, be explained by supposing that the animal gradually assumed a more erect position until it became essentially a biped, while the fore limbs retained in a measure their primitive function, and did not become prehensile, which was the case in some allied forms.

The pelvis is shown in Plate II, figures 2 and 3, and has already been described by the writer. Its most notable features are seen in the pubis and ischium, the former having a very large expanded prepubis, with the postpubis rudimentary, while the shaft of the ischium is greatly elongated.

The femur is long, and the shaft nearly straight. The great trochanter is well developed, while the third trochanter is large and near the middle of the shaft, as shown in Plate II, figure 2. The external condyle of the distal end is projected well backward, indicating great freedom of motion at the knee.

The tibia is shorter than the femur, and has a prominent cnemial crest. The distal end is much flattened, and the astragalus is closely adapted to it. The fibula is very straight, with its lower end flattened and closely applied to the front of the tibia. The calcaneum is large, with its concave upper surface closely fitted to the end of the fibula. Of the second row of tarsals, only a single one appears to be ossified, and that is very small and thin, and placed between the calcaneum and the fourth metatarsal, nearly or quite out of sight.

The hind foot, or pes, had but three digits, the second, third, and fourth, all well developed and massive. The terminal phalanges were covered with broad hoofs. The first and fifth digits were entirely wanting.

A comparison of the limbs and feet of *Claosaurus*, as here described and figured, with those of three allied forms from the Jurassic, *Stegosaurus*, *Laosaurus*, and *Camptosaurus*, as shown on Plates IV and V, is especially instructive. These three genera have already been quite fully described and figured by the writer, but new points of interest have been made out by the recent investigation of more perfect material. The present figures will show more accurately some of the mutual relations of these early herbivorous Dinosaurs to each other, as well as to their successors in Cretaceous time. The gradual changes that can be traced from one to the other will be discussed in a later communication.

Palæoscincus, Leidy, 1856.

A new reptilian genus and species, *Palæoscincus costatus*, was proposed by Dr. Leidy in 1856 for a single tooth found by Dr. Hayden in the Judith Basin. This tooth was more fully described and figured by Leidy in 1859.* The specimen showed well-marked characters, and many similar teeth have since been found, both in the Judith Basin and in various other localities of the Laramie.

A smaller species, apparently of the same genus, is not uncommon in the Ceratops beds of Wyoming, and a characteristic tooth is shown on Plate III, figure 3. This may be taken as the type specimen, and the species it represents may be called *Palæoscincus latus*. The crown of the tooth in this species is broader and the apex more pointed than in the first species described, and this is clearly shown in comparing the present figures on Plate III with those given by Leidy.

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* Proc. Acad. Nat. Sci. Philadelphia, p. 72, 1856; and Trans. Amer. Phil. Soc., p. 146, pl. ix, figs. 49–52, 1859.

The tooth from the Laramie described by Cope in 1882 as a mammalian premolar and as the type of the generic name *Meniscoëssus* evidently belongs to the above or an allied genus, and all three are unquestionably the teeth of Dinosaurian reptiles pertaining to the order *Stegosauria.* On Plate IV, figure 1, a very small but typical tooth of *Stegosaurus* from the Jurassic is represented. The allied genus *Diracodon*, also Jurassic, has similar teeth.

Aublysodon, Leidy, 1868.

In the same publications above cited, Dr. Leidy also described and figured, under the name *Deinodon*, a number of teeth which he regarded as pertaining to carnivorous Dinosaurs, but later, in 1868, he made a new genus, *Aublysodon*, for some of these teeth which differed materially in form from those known to belong to such Dinosaurs.* The teeth regarded by Leidy as characteristic of *Aublysodon* are represented in figures 35–45, Plate IX, of the Transactions above quoted, and the best preserved tooth of this series, which Leidy suspected to be an incisor, is shown in figures 41–45. The latter figures are carefully reproduced on Plate III, figure 4, of the present article, and two other similar teeth are represented on the same plate. They all have the same characteristic chisel-shaped crowns, covered with a thin coat of enamel, and show indications of wear.

The teeth referred by Leidy to the genus *Aublysodon* and many others of the same general character since discovered may be divided into the four following groups, all the specimens of which appear to be somewhat curved either to the right or left:

(1) Large teeth (Leidy's figures 37–40) having both edges crenulated, and the posterior ridge between them broad. The wear of the apex is apparently posterior.

(2) Somewhat smaller teeth, but still large, one of which is represented in Plate III, figure 5. Faint crenulations may be detected on the edges. The wear of the apex is on front and back, and also on the side, probably the outside. The posterior central ridge is narrow. This tooth represents a distinct species which may be called *Aublysodon amplus.*

(3) Smaller teeth with no crenulations, and the posterior ridge with a groove (Leidy's figures 41–45). The wear of the apex is in front. These may be regarded as typical of *Aublysodon mirandus*, Leidy.

(4) The most abundant teeth are much smaller, with no crenulations, and the posterior ridge sharp and not grooved.

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* Proc. Acad. Nat. Sci. Philadelphia, p. 198, 1868.

The wear is in front of the apex, and on one side, sometimes on both sides, as in figure 6, Plate III. This tooth may be taken as the type of a new species, *Aublysodon cristatus*.

The fact that these peculiar teeth are apparently in pairs, and are in themselves more like the teeth of mammals than of reptiles, has long been considered by the writer an argument for the mammalian character of the smaller forms at least. The large crenulated teeth described by Leidy strongly resemble those of carnivorous Dinosaurs, as he considered them, but no Dinosaur teeth of this form have been found in position in the jaws. The next smaller size, with very faint crenulations, one of which is figured in Plate III, figure 5, is too large for any mammal yet known from the Laramie, and this is true, also, of those figured by Leidy.

Many of the smaller teeth of this type, if considered apart from the others, would naturally be regarded as mammalian incisors, especially from the lower jaw, and the wear of the summits would in itself tend to strengthen this reference, if some of these teeth alone were considered. A number have been found, however, that show wear not only on the summit and on one side near the summit, but also on the other edge. This would imply, if these teeth are really lower incisors, either that the rami of the lower jaw were so loosely united at the symphysis that motion between them was possible, so that the incisors could thus rub against each other, or that these teeth were separated so as to admit the upper opposing teeth between them.

That some of these teeth are mammalian incisors there can be but little doubt, and this doubt can only be removed entirely by the fortunate discovery of a tooth in position in the jaw.

Cimolopteryx, Marsh, 1889.

The only bird hitherto known from the Laramie deposits is *Cimolopteryx rarus*, the type specimen of which is represented on Plate III, figure 2. Another species, about twice the size of the first, is indicated by various remains, among them the coracoid. This bone lacks the strong inner process near the pit for the scapula, which is characteristic of the smaller form. The present species, which may be called *Cimolopteryx retusus*, is also from Wyoming.

The new Laramie fossils here described and figured were collected by Mr. J. B. Hatcher and party, in the Ceratops beds of Montana and Wyoming. They will all be discussed more fully in another communication.

New Haven, Conn., July 18, 1892.

EXPLANATION OF PLATES.

PLATE II.

FIGURE 1.—Left fore leg of *Claosaurus annectens*, Marsh; outside view. *c*, coracoid; *h*, humerus; *r*, radius; *s*, scapula; *u*, ulna; I. first digit; IV. fourth digit.

FIGURE 2.—Left hind leg of the same individual; outside view. *a*, astragalus; *c*, calcaneum; *f*, femur; *f′*, fibula; *il*, ilium; *is*, ischium; *p*, pubis; *p′*, postpubis; *t*, tibia. Figures 1 and 2 are one-twentieth natural size.

FIGURE 3.—Pelvis of the same individual; seen from the left. One-sixteenth natural size. *a*, acetabulum; other letters as in figure 2.

PLATE III.

FIGURE 1.—Sternal bone of *Claosaurus annectens*. One-eighth natural size. *a*, seen from above; *b*, seen from below.

FIGURE 2.—Left coracoid of *Cimolopteryx rarus*, Marsh. Natural size. *a*, front view; *b*, inner view; *c*, back view; *d*, lower end.

FIGURE 3.—Tooth of *Palæoscincus latus*, Marsh. *a*, natural size; *b*, *c*, *d*, twice natural size.

FIGURE 4.—Tooth of *Aublysodon mirandus*, Leidy. Natural size. *a*, front view, with sections; *b*, side view. (After Leidy.)

FIGURE 5.—Tooth of *Aublysodon amplus*, Marsh. Natural size. *a*, side view; *b*, back view; *c*, front view.

FIGURE 6.—Tooth of *Aublysodon cristatus*, Marsh. Twice natural size. *a*, side view; *b*, back view; *c*, front view.

PLATE IV.

FIGURE 1.—Tooth of *Stegosaurus ungulatus*, Marsh. *a*, natural size; *b*, *c*, *d*, twice natural size.

FIGURE 2.—Left fore leg of the same species.

FIGURE 3.—Left hind leg of the same species. Figures 2 and 3 are one-sixteenth natural size. Letters as in Plate II.

PLATE V.

FIGURE 1.—Left hind leg of *Laosaurus altus*, Marsh; outside view. One-eighth natural size.

FIGURE 2.—Left hind leg of *Camptosaurus dispar*, Marsh; outside view. One-twelfth natural size.

FIGURE 3.—Pelvis of the same individual; seen from the left. One-twelfth natural size. Letters as in the preceding plates.

SELENITE CRYSTAL, 3 FT. LONG.

This immense crystal has recently been found in Utah and is probably the largest ever seen in New York. It is 2 ft., 10 in. long, 8 inches thick, weighs 60 pounds, and is beautifully formed, the planes being smooth and the angles sharp. It is very perfect, remarkably so for such a large crystal. It is a splendid museum specimen.

TWIN CALCITE GROUP.

Another magnificent museum specimen recently received is a group of **Phantom Twin Crystals of Calcite** from the famous locality at Egremont, England. It is the finest group ever found.

PYRITE ON BARITE.

A novelty from the same locality in England is **Barite** sifted over with small bright crystals of **Pyrite**, some of it being iridescent. The specimens average in size 3 × 4 to 5 × 6 inches ; prices $1.00 to $3.50.

ENGLISH CALCITES.

In the same shipment from England were many of the always beautiful **Calcites** from Bigrigg and Stank Mines.

WULFENITES.

We have just received a new lot of beautiful orange color **Wulfenite** from New Mexico ; it presents some rare forms which look like cubes and like flattened square prisms. Cabinet specimens, good quality, 50c. to $3.50 ; several large groups, $10.00 to $15.00. This is the finest lot of **Wulfenite** seen in New York for several years.

RUBELLITE IN LEPIDOLITE.

This beautiful mineral from San Diego Co., Cal., is exceedingly attractive and everyone wants a specimen for his collection ; 25c. to $3.00 for good cabinet specimens ; smaller specimens 10c. to 20c.

OTHER RECENT ADDITIONS.

Endialyte, from Arkansas, one specimen at $5.00, the best we have ever had.

Diaspore, Chester, Mass., fine large masses $3.50 to $5.00.

Chlorophane, from Virginia, showing beautiful iridescence when heated, 25c. to 50c.

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. XXV.—*The Gulf of Mexico as a Measure of Isostasy*; by W. J. McGee.

I.

The now venerable James Hall was one of the first geologists to observe that areas of rapid deposition are areas of subsidence. When Powell extended his early surveys into western America he observed the converse relation, namely, that areas of degradation are areas of elevation. As the geodetic surveys of Great Britain, India and the European continent yielded data for determining the distribution of density in the earth, Pratt and afterward Fisher and others observed that the sea bottoms are heavy, the continents lighter, the mountain ranges lightest of all. Meantime and subsequently the original observations were repeated and extended in different lands until the observed relations were found to be general; meantime also the relation of coexistence was inferred to be one of sequence, and thus it came to be recognized that mountains are high because they are light, that sea bottoms are low because they are heavy, that areas of degradation rise because of unloading, and that areas of deposition subside because of loading—i. e. it came to be recognized that the entire terrestrial crust is in a condition analogous to that of hydrostatic equilibrium. This subject has been profoundly studied by Dutton, who invented the term *isostasy* to denote such condition of static balance in the external portion of the earth.

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The earlier and most of the later data upon which the doctrine of isostasy depends were *indirect*, i. e., they were inferences from the characters and relations of formations laid down, or terranes lifted and degraded, during long past eons; yet there is no dearth of *direct* data—i. e., data derived immediately from observation—sustaining the doctrine.

One class of such data is found in the relation between tracts of deposition and earthquakes: If the earthquakes recorded in history are separated into three categories of association, viz: (1) earthquakes associated with volcanoes, (2) earthquakes associated with hot springs, and lines or zones of active orogeny, and (3) great earthquakes apparently not connected with vulcanism or orogeny—it will be found that the greater part of the third category have affected tracts of rapid deposition, and commonly that after the tremor the land stood lower than before. Thus, the Charleston earthquake of 1886, felt over an area of nearly a million square miles, affected the Atlantic coastal plain of the United States, a tract of remarkable simplicity and uniformity of movement during later geologic times yet one of rapid and long continued deposition; the New Madrid earthquake of 1811–13, felt over an area of certainly a million and a half square miles in central and eastern United States, affected a tract of exceptionally gentle movement and uniform geologic history, though the unloading ground of the great river of the continent, and the land was spasmodically depressed over thousands of square miles; the great Lisbon earthquake of 1755 originated in and affected most disastrously the tract upon which the Tagus drops the detritus gathered from a sixth part of the Iberian peninsula; the Kach earthquakes of 1819 and later dates devastated the delta of the mountain-born Indus and left the land some feet or yards lower than before, thus extending the vast watery waste known as the Rann of Kach; the Cachar earthquake of 1869 similarly affected the deposition-tract of the powerful Ganges and Brahma-putra; the deposition-tract of the mud-stained Hwang-ho and the torrential Yang-tse-Kiang are notoriously earthquake ridden—in short, nearly all if not all of the extensive non-volcanic earthquakes recorded in history centered in tracts of rapid deposition. In some cases the data derived from this relation are equivocal; yet they are sometimes apparently trustworthy.

A second class of direct data sustaining the doctrine of isostasy is found in the relation between tracts of deposition and measured subsidence of the land or encroachment of the waters. If the tracts of rapid deposition are separated into three categories of association, viz: (1) deposition tracts within or near the areas of Pleistocene glaciation, (2) deposition tracts in or near zones of active vulcanism or orogeny, and (3) deposition tracts in generally stable regions far removed from Pleistocene glaciation, vulcanism and orogeny—it will be found that the greater part of the third category are also tracts of rapid subsidence or of rapid encroachment of the waters. The data derived from this relation, which also are sometimes equivocal though often unmistakable, are of two kinds, which may be called respectively *quantitative* and *qualitative;* the first being actual measures, and the second inferences from analogous measured examples and from known geologic processes.

A good example of the first of these kinds of data is the southeastern shore of North sea, which is burdened beneath detritus dropped from the Rhine, Maas and Scheldt, the Weser and the Elbe, and which has been sinking since the beginning of local history; the island of Batavia, inhabited in the days of Tacitus is drowned; Zuydee Zee was formed by an invasion of the waters about the end of the 13th century; again and again towns and villages have been inundated and swept from the face of the earth; broad slices of ill-fated Heligoland are annually devoured by the sea; the Netherland polders (or dike-protected lands) are maintained by artificial embankments which require raising from generation to generation until now cultivated fields lie 7 to 10 meters below tide level; and the artificial embankments could not withstand the force of the waves were they not themselves protected by much larger natural embankments called dunes (analogues of the "keys" of the American coast). The measured rate of sinking along the Netherland coast ranges from 0·09 meter to 0·75 meter per century; since 1732 the mean rate, according to Girard, has been about 0·26 meter per century.* The rate of sea encroachment on the lowlands cannot accurately be determined, by reason of the artificial intervention which permits cultivation of lands lying far below tide level; the rate of encroachment on the higher lands is measured by the destruction of Heligoland, which was 190 or 200 kilometers in circuit in the year 800, 72 kilometers in 1300, only 6·5 kilometers in 1649,† and is decimated annually. Another example is the tract centering about New York bay though extending from Long Island sound to Chesapeake bay, into which is poured nearly all the sediment gathered from a many times larger semi-ellipse in eastern United States, and in which also the sinking is known to be rapid. According to the conservative estimates of the late Dr. George H. Cook, the direct subsidence reaches and probably exceeds two feet per century.

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* Recherches sur l'Instabilité des Continents, 1886, p. 168.

† Ibid, p. 31.

The encroachment of the bays and of the adjacent Atlantic is proportionately rapid; within the last fifty years it has reached half a mile in some localities, averaging a furlong or more, and has destroyed property amounting to millions of dollars. Both of these deposition tracts lie near and possibly within the influence of Pleistocene glaciation; yet they are especially significant in that the quantitative data derived from them are connected with and give value to data of the qualitative kind.

Through the association of the two kinds of data on the Netherland and New Jersey coasts, as well as through inference from geologic process, it is found that the most trustworthy physiographic indications of subsidence are: (1) encroachment of the sea; (2) wave-built breakwaters along lowland coasts (the "dunes" of Holland, the "keys" of America); (3) precipitous and talus-free or undercut cliffs along highland coasts; (4) estuaries at the mouths of sediment-bearing rivers; and (5) natural levées along the lower courses of rivers, leaving low-lying and periodically flooded marshes or salines on either hand. These physiographic indications express rates, though only in a qualitative way: Thus, the rate of encroachment is a function of the subsidence, but is affected by the seaward inclination, by the obduracy of the terrane, by the force of the waves and currents, etc. The building of natural breakwaters is characteristic only of coasts skirted by submerged terraces or shelves; for when coasts are so conditioned the waves come in with ever increasing impetus over the subsiding sea bottom, constantly casting up sand to strengthen the barrier, and if the contiguous land is low a lagoon or "sound" is formed behind the barrier and widens more rapidly than the barrier, is driven inland until both are finally overflowed and converted into open sea, when the process is repeated on new-made shores; and thus in a general way the strength of wave-built breakwaters and the width of the lagoons separating them from the mainland give rude measures of subsidence. Talus-free cliffs are indeed an indication of the ever increasing force of the waves on subsiding coasts; yet, while the cliff configuration of subsiding tracts like Chesapeake bay and of rising tracts like Puget sound are markedly distinct, so many other conditions affect sea-washed rock faces that they are useful only in exceptional cases. Again, estuaries may be inherited from earlier eons, and at the best only indicate that subsidence outruns sedimentation, thus giving minimum rather than mean measures of movement. Levée-building, on the other hand, may represent merely diminution in declivity resulting from the pushing out of deltas, and on the whole tends to give excessive or at most maximum measures of subsidence.

The qualitative kind of direct data are well exemplified at the head of the Bay of Bengal with the adjacent Sanderbands, the depositing ground of two of the most potent rivers of the globe (Ganges and Brahmaputra), where the rate of subsidence —shown by the Indian geologists to have reached over 400 feet in recent geologic times—has not been measured, yet is proved to be rapid by the coastal configuration, by the estuaries through which the rivers embouch, and by the immense natural levées flanking the rivers and their distributaries and bounding broad intervening flats, or "jhils"; they are exemplified again at the mouths of the Amazon and la Plata, which together carry the degradation products of the greater part of the South American continent, and which embouch into vast estuaries after dividing into networks of levée-flanked distributaries insulating extensive marshes; they are exemplified also about the mouth of the Indus, once supposed to be an area of uplift but now known to be subsiding, where the larger distributaries are estuarine and where the interstream flats are vast salines annually flooded and silt-mantled by fresh waters, yet always so delicately adjusted to tide level as to be flooded and salt-mantled by sea waters during each annual monsoon; they are apparently well exemplified again about the northern end of Caspian sea and in the delta plains of the Volga and Ural, as well as about Aral sea and in the broader delta plains of its far-reaching affluents; they are exemplified also on the northern and western shores of Black sea, and still more notably about the Sea of Azof, which together receive the drainage of a third of Europe; they are exemplified, particularly the estuaries and anastomosing levée-flanked distributaries, on the western shore of Hwang-hai (China sea or Yellow sea) about the mouths of the muddy rivers draining the eastern Himalayas and the loess-mantled plateaus of eastern Thibet and western China; they are strikingly exemplified at the northwestern extremity of Adriatic sea about the mouth of the levée-lifted Po, perhaps the most energetic river of the world in proportion to its size; and they are exemplified more notably than elsewhere on the globe about the shores of the Gulf of Mexico, the depositing ground of rivers degrading a fourth of the North American continent. These and other notable examples are summarized in the accompanying table, which is graphically depicted in figure 1 (p. 183).

On reviewing these examples yielding direct yet only qualitative data concerning the relation between deposition and subsidence, it appears that the data are of unlike value: The most extensive degradation tract on the globe is that of the Amazon, but the Amazonian detritus is partly spread over a vast flood plain lying at base-level, partly dropped in an extensive estuary, and partly cast into the sea to be widely distributed by exceptionally powerful oceanic currents; and, moreover, this vast river is comparatively little affected by seasonal freshets such as multiply the efficiency of extra-tropical streams.

Principal Degradation Tracts of the World (exclusive of Africa, Australia and Northern Lands) with the Correlative Deposition Tracts.

No.	Degradation Tracts.			Deposition Tracts.		Ratio.
	Rivers.		Areas.	Water Bodies.	Approximate Areas.	
		sq. m.	*sq. m.*		*sq. m.*	
1	Amazon		2,010,000*	Atlantic	?	?
2	Mississippi, Rio Grande, *et al.*		1,804,737†	Gulf of Mexico (N. half)	277,592‡	6½ : 1
3	Yang-tse-Kiang Hwang-ho	730,000 715,000	1,445,000*	Hwang-hai (W. pt.)	? 200,000§	7¼ : 1
4	La Plata		1,175,000*	Atlantic	?	?
5	Danube Don Dnieper Dniester Other rivers	312,000 225,000 225,000 30,000 200,000	992,000*	Black sea Azof	172,500‖	5⅔ : 1
6	Volga Ural	530,000 110,000	640,000*	Caspian (N. half)	90,000‖	7 : 1
7	Syr Daria Amu Daria	316,000 260,000	576,000*	Aral	24,000¶	24 : 1
8	Ganges Brahmaputra		575,000*	Bay of Bengal (N. part)	? 100,000§	5¾ : 1
9	Indus		415,000*	Arabian gulf (E. part)	? 80,000§	5 : 1
10	St. Lawrence		395,000*	Gulf of St. Lawrence	? 50,000§	8 : 1
11	Rhine Elbe Weser Other rivers	87,000 56,000 17,000 10,000	170,000*	North sea	? 15,000§	11⅓ : 1
12	Connecticut Hudson Delaware Susquehanna, *et al.*		83,000†	Long Island sound New York bay Raritan bay Delaware bay Chesapeake bay, *et al.*	?5,000†	16½ : 1
13	Po Adige, *et al.*	40,000 30,000	70,000*	Adriatic (N. part)	? 7,000§	10 : 1

The second degradation area in extent is that of the Mississippi, the Rio Grande, and their weaker neighbors, whose deposits not only fall into the nearly enclosed Gulf of Mexico but, by reason of the prevailing currents, are confined to its northern fraction. A portion of this degradation area is indeed subarid and only a small portion is mountainous; yet in general degradation is rapid—toward the Rocky Mountains because of

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* Reduced to statute miles from A. Keith Johnson's "Physical Atlas of Natural Phenomena," 1856, pls. 16, 17.

† Computed by means of the planimeter from the United States Geological Survey "9-sheet" base map of the United States, by John B. Torbert.

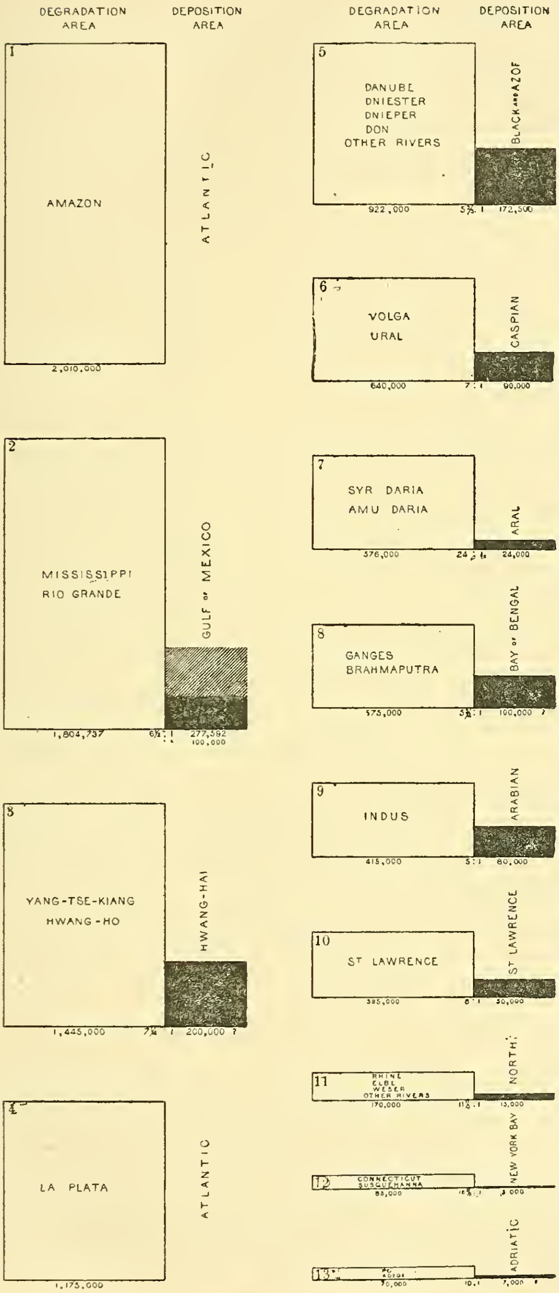
‡ Computed by John B. Torbert.

§ Estimated.

‖ Encyclopedia Brittanica, 9th edition.

¶ Appleton's American Encyclopedia.

1.



high declivity, over the Plains by reason of late Tertiary elevation, in the northern interior because of the easily eroded late Pleistocene drift, in the Cumberland plateau and the western Appalachians by reason of a late Tertiary elevation to which the streams are not yet adjusted, in nearly all parts by reason of seasonal storms or vernal snow-melting; indeed by far the greater part of the area stands so high above base-level that the activity of degradation is fairly comparable with that of the other great tracts of the globe. In the third degradation tract in extent (that of the Hwang-ho and Yang-tse-Kiang) unloading is unquestionably proceeding rapidly, but the correlative area of loading is so ill-defined as hardly to be susceptible of estimate; while in the fourth area (that of la Plata), where degradation is probably more sluggish, the deposition area is still more indefinite. The fifth in extent of the degradation tracts concentrates its detritus in the well defined area of Black and Azof seas; yet so little is known of the coastal configuration of these seas and of the possible influence of Pleistocene glaciation and contiguous orogeny that the data afforded by this example are of little service. The deposits of the sixth degradation tract are in like manner concentrated upon a limited area which may be assumed to equal the northern half of Caspian sea, and in the seventh tract the concentration is still greater, the degradation tract tributary to the Aral being no less than twenty-four times that of deposition; but both examples are enclosed basins in which the record of isostatic subsidence is complicated by the direct displacement of the water and also by the variations in water-volume depending on climatal conditions, and accordingly the data in these cases are unworthy of trust. The eighth degradation tract (Ganges and Brahmaputra) is especially noteworthy by reason of the activity of the rivers and the vast volume of detritus annually discharged; but the correlative deposition area is so ill defined that, apart from the incomplete measurements of the Indian survey. the relative value of the data afforded by this example is not easily ascertained; and this is true in still stronger measure of the ninth tract, or that of the notably active Indus. The tenth degradation tract in extent (St. Lawrence) is useless as a measure of isostatic subsidence, (1) because it is wholly within the area of Pleistocene glaciation, (2) because the correlative deposition tract is ill-defined, and (3) because its course is interrupted by several settling basins. The eleventh tract (that of the Rhine and its neighbors) is one of activity in both degradation and deposition, and one moreover in which the combined effect of tides and currents probably tends to confine deposition to the comparatively narrow zone along which subsidence is best marked, if not chiefly to Zuyder Zee and the riparian estuaries; yet it is possible if not probable that this area is within the influence of Pleistocene glaciation, and hence of an extraneous disturbance of equilibrium not yet completely restored. The twelfth tract, too (New York and neighboring bays), lies partly within the area of glaciation, and is moreover affected by a modern displacement; but it acquires value from the connection with rude yet useful rate measurements. The smallest of the degradation tracts (that of the Po, the Adige, the Piave, and several smaller streams, all of great activity), concentrates its products in a presumptively limited portion of Adriatic Sea; yet the value of this example is diminished by reason of the vulcanism and orogeny of contiguous territory. For similar reasons and because of its irregularity of outline and inequality of loading in different parts, the Mediterranean may be excluded from the list of noteworthy deposition tracts of the globe. The African and Australian degradation tracts may also be neglected, partly because the areas are ill determined, partly because deposition is seldom concentrated in measureable tracts.

Weighing the various considerations affecting the value of the data yielded by each of the tabulated deposition tracts, they appear to fall into the following order: (1) Gulf of Mexico, (2) North sea, (3) New York bay, (4) Bay of Bengal, (5) Adriatic sea, (6) Hwang-hai, (7) Black and Azof seas, (8) Arabian Gulf, (9) the Amazon estuary, (10) la Plata estuary, (11) Caspian sea, (12) the Aral, and (13) Gulf of St. Lawrence. On reviewing the data yielded by the several examples in view of this weighing, in view of the ratios between areas of degradation and areas of deposition, and in view of the relative activity of the several rivers, the influence of tides and currents, etc., it appears that all are consistent—that every considerable deposition tract beyond the reach of Pleistocene glaciation, vulcanism, and orogeny is subsiding; that, other things equal and so far as the data are available and trustworthy, the rate of subsidence is proportional to the relative areas of degradation and deposition; and that, other things equal and so far as the data are available and trustworthy, the subsidence is proportional to the activity of the rivers in the correlative degradation tracts.

So the indirect data concerning isostasy, derived through inferences from formations deposited or terranes degraded during long past eons, are supplemented by a trustworthy body of direct data derived from the physiography of the earth in its present condition; and the direct data are superior to most* of the indirect in that they are susceptible of relative, and in some cases absolute, evaluation.

II.

Even on casual inspection it is apparent that the Gulf of Mexico is one of the most fortunately situated deposition tracts of the globe for the measurement of isostatic subsidence; for it is a land-rimmed basin of considerable area, connected with open sea through relatively narrow straits, and fed by drainage

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* In one case the indirect data have been evaluated. This is Gilbert's classic study of the strength of the earth's crust as indicated by the deformed shore lines of the extinct Lake Bonneville (Bull. Geol. Soc. Am., vol. i, 1889. pp. 23-27; Monograph I, U. S. Geol. Survey, "Lake Bonneville," 1890. p. 387, et seq.).

from a many times larger degradation tract (figure 2). On closer inspection the first impression is strengthened: The northern half of the Gulf with the adjacent lands (of which alone the geologic history has been clearly read) is a province of simple structure, of limited and uniform continental movements since the middle Cretaceous; furthermore, it is this northern half of the Gulf which receives the drainage from the second largest degradation tract of the globe; moreover, one of the strongest oceanic currents of the globe—the main Atlantic equatorial current—enters the Gulf through Yucatan channel and sweeps through the basin in such fashion as to concentrate the sediments upon a narrow zone skirting the northern border of the basin; and finally the influence of sedimentation is not confined to a single delta but is so distributed that the rate of deposition is variable in different parts of the littoral zone, though in simple and easily ascertained fashion.

2.

Unfortunately the Gulf coast has only recently been surveyed with precision, and the surveys have not yet been repeated in such manner as to give quantitatively exact measurements of land-subsidence or sea-encroachment; but the physiographic indications of land-subsidence are numerous, consistent, and unmistakeable. Thus, island after island along the Louisiana coast has been submerged bodily or devoured by slices, and many historic plantations on the shores of Mississippi sound and the open Gulf have melted into the waters within the present century; thus, too, the coasts (with one or two most significant exceptions) are skirted by wave-built breakwaters separated from the mainland by long narrow bays (the "keys" and "sounds" of the vernacular) from the Rio Grande to Florida strait; again, wherever the generally low coastward lands rise a dozen feet or yards above tide, they are carved into precipitous talus-free cliffs; half of the rivers, too, albeit heavily detritus-charged, embouch into estuaries; and, moreover, each principal river, whether estuarine or delta-building toward its mouth, divides into distributaries (or "bayous") in its lower reaches, and the anastomosing channels are flanked by natural levées separating periodically-inundated flats, which are lakes, marshes, salines, or "black prairies" according to local conditions. In addition to these physiographic data there are found buried forests, old causeways now overflowed at low tide, aboriginal shell heaps nearly or quite submerged, savanna pine forests once luxuriant but now poisoned by salt water, and various other indications of changing relation between land and sea; and it is to be observed that while these indications vary in strength they are all consistent in direction—all point to subsiding land, none point to rising or even stationary land.

On comparing the physiographic data about the shores of the Gulf with the like data yielded by measured examples of New Jersey and the Netherlands, it would appear, (1) that the average rate of sea-encroachment about the Gulf is nearly or quite as high as on the New Jersey coast and higher than on the Netherland coast, at least since the building of the dikes; (2) that on the average the wave-built breakwaters are higher and more distant from the mainland than in New Jersey, and more extensive than, though scarcely so high and distant as in the Netherlands; (3) that the talus-free cliffs are even more characteristic than in New Jersey or (probably) the Netherlands; (4) that on the average the estuaries are nearly as broad and deep as in New Jersey and more extensive than in Holland; and (5) that the natural levées are relatively higher and broader than in New Jersey and, so far as comparison is possible, about as high and broad as in the Netherlands. The value of the physiographic indications of subsidence of course depends largely on a number of local and general conditions, such as volumes of rivers, height of tides, strength of oceanic currents, direction of prevailing winds, the material, height, and general configuration of shores, the breadth and depth of the water-body in which the waves are generated, etc.; yet howsoever these conditions affecting the comparison are weighed, the Gulf phenomena appear to record an average subsidence fully as rapid as that of the Netherlands or New Jersey; or (the vertical movement in the carefully measured case amounting to 0·26 meter and in the more roughly measured example reaching two feet per century) of at least a foot in a hundred years.

On comparing this value with the rates of degradation and correlative deposition, a relation is obtained which, although lacking in precision, is nevertheless useful: The area of degradation is 1,800,000 square miles; the maximum assignable area of deposition is less than 300,000 square miles, and since the direction and force of currents and the configuration of the Gulf bottom alike indicate that appreciable sedimentation must be confined to a relatively narrow zone skirting the coast, it may be placed at a third of that area or 100,000 square miles, which is one-eighteenth that of degradation. Now, the commonly accepted rate of degradation of the earth's surface, based on the surveys of the Mississippi by Humphreys and Abbot, is a foot in 6000 years; and this corresponds to deposition within the Gulf reaching one foot in 333 years. So it would appear that the average rate of subsidence deduced from comparisons with New Jersey and the Netherlands is three times higher than would be required for isostatic adjustment; and although the various factors are so uncertain (probably Humphrey's and Abbot's value and the deduced rate of subsidence are too low and the assumed deposition area too high) that the estimate is subject to a "probable error" perhaps large enough to explain the discrepancy, the discrepancy nevertheless suggests that a part of the subsidence may be due to some other cause. This suggestion derives strength from the indications of general subsidence along the contiguous Atlantic coast of the United States.

On comparing the local physiographic indications of subsidence at various points on the Gulf coast, a noteworthy diversity is found. Thus, the most decisive historical records of encroachment come from the Louisiana and Mississippi coasts, and there, too, talus-free cliffs are most characteristic. Again the strength of keys and the width of sounds varies widely; along the Florida coast, despite the long sweep of storm winds and trades, the keys are weak, the sounds narrow and shoal; toward the Appalachicola and Mobile bay the keys strengthen and the sounds widen, save where dammed by deltas; west of Mobile bay the keys are huge but half submerged banks rising in a line of islands separated from the mainland by the broad Mississippi sound; west of the great delta the corresponding keys are completely submerged and reduced to a series of banks and shoals separated from the mainland by a trough even broader than Mississippi sound, and new keys and sounds are forming along the present coast; southwest of Galveston bay the keys are of unparalleled strength and continuity, while the sounds are broad and scores or even hundreds of miles in length. Moreover, some rivers are estuarine while others are delta-builders, and this difference in habit is evidently independent in large measure of stream-volume and of sediment. Yet on careful examination, the apparent discordance falls into harmony: The strength of keys and width of sounds is least in the eastern part of the embayment where the sediment-bearing rivers are relatively short and feeble, greater in the northwest where the rivers are longer and more potent, and greatest about the depositing ground of the chief river of the continent. So, too, all the large rivers of the western and eastern coasts are delta-builders; while all of the extra-Mississippi streams within a hundred or a hundred and fifty miles of the great river (and presumptively within reach of its isostatic influence) embouche into estuaries.* This harmony is suggestive, if not precisely indicative, of a quantitative relation between local deposition and local subsidence.

Summarily, the Gulf of Mexico, considered as a unit, is one of the most fortunately situated deposition-tracts of the world for yielding a measure of isostatic subsidence; considered again as a unit, its shores appear to be subsiding quite as rapidly as isostasy demands; and considered as an assemblage of deposition sub-tracts, the varying rates of subsidence appear to be delicately adjusted to the local rates of deposition.

So the data relating to the condition of the earth's crust derived from the modern Gulf of Mexico indicate that throughout the vast geologic province of southeastern North America, isostasy is probably perfect, i. e., that land and sea bottom are here in a state of hydrostatic equilibrium so delicately adjusted that any transfer of load produces a quantitatively equivalent deformation.†

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* These features are set forth at some length in a paper on the Lafayette formation, 12th Ann. Rep. U. S. Geol. Survey. 1892, pp. 347–521, pls. xxxii–xli.

† Thomson and other physicists concluded some years ago, after a study of the tides, precession, etc., that the earth as a whole must be as rigid at least as steel. Newcomb has quite recently concluded, after discussing new data (including Chandler's brilliant coördination of the recorded variations in latitude in connection with Oppolzer's computations), that "the earth yields slightly less . . . than it would if it had the rigidity of steel, and that it is consequently slightly more rigid than steel" (Monthly Notices of the Royal Astronomical Society, vol. lii, no. 5 (1892), p. 339); so that while Thomson's result gives a minimum value, that of Newcomb gives a maximum value for the rigidity of the earth as determined from cosmic relations. Now, without analysis of the differences in defini-

III.

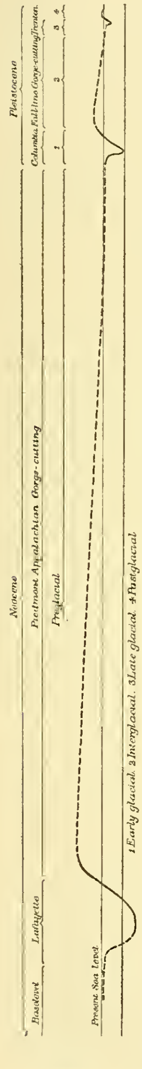
The measure of isostasy found in the modern Gulf of Mexico might be tested by comparison with the measures yielded by other gulfs and bays, were the data concerning the several fortunately situated deposition-tracts sufficiently precise; but in the dearth of surveys and bench-marks it must suffice to repeat that the physiographic data afforded by the Bay of Bengal, the Adriatic, Hwang-hai, Black and Azof seas, the Arabian gulf, the mouths of the Amazon and la Plata, etc., are harmonious therewith. The measure cannot well be tested by comparison with the indirect data derived from study of ancient formations or terranes in other geologic provinces, since most of such data are isolated and, by reason of ignorance concerning the absolute or relative areas of the tracts of degradation and deposition respectively only rudely qualitative, and since in the single case in which the indirect measure is quantitative—Gilbert's ancient Lake Bonneville—the problem is so complex as to permit only the statement that the results are in a general way harmonious with the data yielded by the modern Gulf. The measure may, however, be checked by comparison with past records of the geologic province represented by the Gulf and adjacent lands.

The later geologic history of the Gulf of Mexico is now fairly well known. The uppermost structural unit of the contiguous land area is the early Pleistocene Columbia formation; the next in age is the late Neocene (probably Pliocene) Lafayette (Appomattox) formation. Now the history recorded in these formations and in the unconformities by which they are bounded may be thus interpreted: Before the Lafayette period the configuration of the southeastern quarter of the continent was much the same as to-day, save that the land lay somewhat lower and flatter; then came the Lafayette inundation, 300 to 900 feet in depth and extending from 100 to 500 miles inland; this was followed by a high level period during which the land was tilted seaward from the Appalachian axis but lifted 300 to 1000 feet higher than before (or now), and during which half of the volume of the Lafayette formation was degraded, while the rivers carved broad and deep canyons forming the estuaries yet indenting the Atlantic and Gulf coasts; next the land gradually subsided to its previous (and about the present) mean

tion of terms to which are due the apparent discordance between the current doctrine of physics and that of geology, it may be pointed out that these remarkable and admirable inductions of physics have no more to do with the deformation dealt with by geologists than laboratory experiments on the rigidity and brittleness of ice have to do with the movements of glaciers; and the mobility of the terrestrial crust through a range reaching thousands of feet and even miles is now quite as well established as is the mobility of glacier ice.

altitude, though the relative lifting of the Appalachian axis persisted; then came the Columbia inundation, which was coeval with the first known ice-invasion, during which the Atlantic and Gulf again united and flowed inland 20 to 500 miles, rising 100 to 700 feet above their present level; finally the land rose so high as to permit the excavation of the submarine channels of the Hudson, the Delaware, the Susquehanna, the Potomac and the Mississippi, but soon subsided; and this last subsidence of the southern land seems to have been little affected by the later ice invasions, and is perhaps, even probably, yet in progress. These oscillations are represented graphically in the accompanying diagram (figure 3) in which the ordinates represent time, the abscissas continental altitude.*

3.



On comparing, or rather contrasting, these great continental oscillations with the gentle modern movement along the shores of the Gulf, they are found to differ widely: The modern subsidence appears to be a gentle warping in such direction as to deepen the basin and gradually submerge its perimeter; the old oscillations were widespread and involved both sea bottom and continent. The modern movement is slight and commensurate with the simple and uniform processes of degradation and sedimentation; the old movements were cataclysmic, and utterly transcended the influence of rain and rivers—they were indeed of greater amplitude than any other continent movements of southeastern North America since the close of the Cretaceous.

Now the modern movements not only yield a quantitative measure of isostacy (with a "probable error" whose value is indeterminate) but give a rude measure of the efficiency of degradational transfer of matter on the surface of the earth's crust in producing deformation; while the movements recorded in the Columbia and Lafayette formations were of so much greater amplitude that they may not be referred to a similar cause. In this province as in others, therefore, it becomes necessary to discriminate the two classes of earth movements elsewhere called,

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* They are represented physiographically in a series of tectonic maps illustrating a paper on the Lafayette formation now in press as a part of the 12th Ann. Rep. U. S. Geol. Survey (pls. xxxix–xli).

respectively, *antecedent* and *consequent*—the first including those grand initial movements of debatable cause by which continents are lifted and sometimes deformed or drowned, and the second including the more restricted movements due to loading and unloading.

So the modern province measures the competence of isostasy, the ancient province its incompetence; the modern Gulf illustrates the magnitude, the ancient Gulf the minitude, of isostatic deformation as a means in continent making.

IV.

Recurring now to the direct and indirect measures of isostasy afforded by the Gulf of Mexico in its present condition and past history, it may confidently be concluded: (1) that the direct data of modern times indicate that deposition and isostatic subsidence are not only related sequentially but that under favorable conditions they are quantitatively equal or sub-equal; (2) that this measure of isostasy is consistent with the direct data, both quantitative and qualitative, yielded by other noteworthy deposition tracts of the globe; and (3) that the indirect data afforded by the Gulf indicate that isostatic (or consequent) movement alone is incompetent to explain the general continental oscillations recorded in the Neozoic deposits. Thus the Gulf of Mexico yields both maximum and minimum measures of isostasy.

ART. XXVI.—*Persistence of Vision*; by ERVIN S. FERRY.

[Contributions from the Physical Laboratory of Cornell University, No. 10.]

EVER since the time of Aristotle, it has been known that when the eye is impressed by light, the sensation persists even after the exciting cause has ceased to act. In his work on dreams, Aristotle describes duration of impressions in the retina and then deduces as the cause of dreams a similar persistence of impression on the sensorium of things experienced when awake. The ancients noticed and correctly explained many optical illusions by persistence of vision; but it was not till twenty centuries after Aristotle that anyone attempted to measure the duration of visual impression. Segner* measured the duration of the light impression from a spark of a rotating stick and adopted 0·1 second as the probable value. D'Arcy,†

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* De raritate luminis (Göttingen, 1740, pp. 5–8).

† Mémoire sur la durée de la sensation de la vue (1768).

Cavallo,* and Parrott† have since fully substantiated this value by accurate measurements. Plateau,‡ in 1829, found that when discs divided into sectors alternately black and of some special color were rotated, different speeds were required to produce uniformity of tint, depending upon the color of the pigment used to paint the alternate sectors. By noting the angular size of the black and the colored sectors and the speed just necessary to produce uniformity of tint, he was enabled to determine the absolute duration of the maximum impression for the different colors experimented upon. By using the different discs painted in sectors, each having black alternating with some one color, Plateau obtained the following values for the duration of impression for these particular colors:—

White	0·191 secs.
Yellow	0·199 "
Red	0·232 "
Blue	0·295 "

One great difficulty with this method is that since no pigment gives a pure color and since pigments vary so widely in tint, the results obtained hold only for the particular specimens experimented upon. To overcome this difficulty, Dr. E. L. Nichols§ employed a revolving disc having sectors cut out, in front of the slit of the spectroscope, and defined his colors by their wave-lengths. In this manner by suitably choosing the wave-lengths used for observation, a curve was drawn showing the relation between the duration of impression and the color corresponding to any wave-length.

From the results obtained by Plateau, Emsmann,‖ Nichols and others, it was reasoned that the duration of retinal impressions depends upon the intensity of the light-giving source and upon the color of the light entering the eye. To test the validity of this latter proposition, and to determine the principal factors producing persistence of vision has been the object of the series of experiments now to be described.

Apparatus and Method of Observation.

The plan of the investigation was to obtain curves showing the relation between duration of the retinal impression of the normal eye and wave-length of light observed for spectra of

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* The elements of natural or experimental philosophy (London, 1803), vol. iii, p. 135.

† Entretiéns sur la physique (Dorpat, 1819), vol. iii, p. 235.

‡ Dissertation sur quelques propriétés des impressions produites par la lumière sur l'organs de la vue. (Liege, 1829).

§ On the Duration of Color Impressions upon the Retina, this Journal, vol. xxviii, p. 243.

‖ Ueber die Dauer des Lichteindrucks, Pogg. Ann., xci (1854), p. 611.

different intensities; to compare these curves with another showing the distribution of luminosity in the spectrum used; and finally to compare similar curves obtained from dichroic eyes.

The apparatus for the measurement of the retinal impression consisted of a diffraction-grating spectrometer; a sectored disc that could be revolved by an electric motor, interposed between the lamp and collimator; and a chronograph to register accurately the number of revolutions of the disc. The source of light was a hundred-volt Edison incandescent lamp supplied by a secondary battery, and it was kept at constant candle power by varying the resistance in circuit so that a volt-meter would always indicate one hundred volts. In front of the lamp was mounted a large condensing lens for the purpose of projecting upon the collimator slit an enlarged image of the filament. In this way a uniform distribution of light was obtained in all parts of the field of the spectrometer. At the focus of the eye-piece of the telescope was placed a diaphragm so as to isolate from the spectrum the single color it was desired to observe. The disc had a ninety-degree sector cut out from each end of a diameter so that when the disc revolved there would be seen in the telescope equal periods of illumination and of darkness. The speed of the disc was controlled by means of a friction-brake managed by the observer. On the shaft of the disc was mounted a contact device by means of which an electric circuit was made for an instant on each revolution of the disc. This current was conducted to the primary of an induction coil having the secondary so connected to a chronograph cylinder that a spark would puncture a blackened paper on the cylinder every time the sectored disc revolved. Pressing against the chronograph cylinder was a stylus electrically connected to the escapement of a standard clock. By this device the number of revolutions of the sectored disc in a second could be very accurately determined.

When taking an observation, the experimenter sits at the telescope of the spectrometer with one hand on the brake regulating the speed of the sectored disc. The disc is first made to revolve so slowly that the field of view in the telescope flickers, and then the speed is gradually increased till the point is reached when the field just becomes quiet; then a key is pressed and an assistant rotates the chronograph cylinder for five seconds and takes the record of the speed of the sectored disc. This gives the duration of the maximum impression on the retina. Such a short time of observation as here used has many manifest advantages. Even when the disc is steadied by a heavy fly-wheel as was done in these experiments, and rotated by a powerful motor, the speed can be kept constant for only a short time. Other experimenters have taken one-minute observations or longer, and found their separate observations differing by a large per cent from the mean. With this apparatus a difference of more than three per cent between two observations of the same region in a spectrum of ordinary brightness is rare. The observations at regions of low brightness are more difficult.

The eye was subjected to the intermittent light for as short a time as possible so as to avoid the secondary colors described by Signor Cintolesi.* After each observation on colored light the eye was rested by looking at white light and the succeeding observation was invariably made on a different color. Thus the disproportionate increase of sensitiveness of the eye for more refrangible rays due to adaptation, as noticed by M. H. Parinaud,† was guarded against. These observations were made in a room with blackened walls and every attempt was made to exclude extraneous light. It was also soon found that precautions were necessary to eliminate the slight tremor produced by the motor and the disc, because a vibration of the lamp or of the diffraction-grating produces a flicker in the field of view that cannot be distinguished from the appearance produced by a too slow rotation of the sectored disc.

Duration of Light Impressions on the Normal Retina.

To represent the normal eye, three persons were selected of about the same age, whose eyes were free from Daltonism, astigmatism, near- and far-sightedness and from such abnormal color sensations as have been recently observed by Captain Abney‡ in confirmed users of narcotics and stimulants. How very closely the duration of retinal impression for each part of the spectrum agreed for these cases is shown in the following table:

TABLE I.

Wave-length.	Duration of retinal impression in seconds.		
λ	E. S. F.	G. W. B.	E. F. N.
·435	·0357	·0357	·0333
·480	·0250	·0263	
·510	·0200	·0186	·0200
·540	·0156	·0152	
·570	·0139	·0139	·0139
·589	·0132	·0128	·0128
·615	·0141	·0142	
·645	·0156	·0152	
·684	·0192	·0179	·0192

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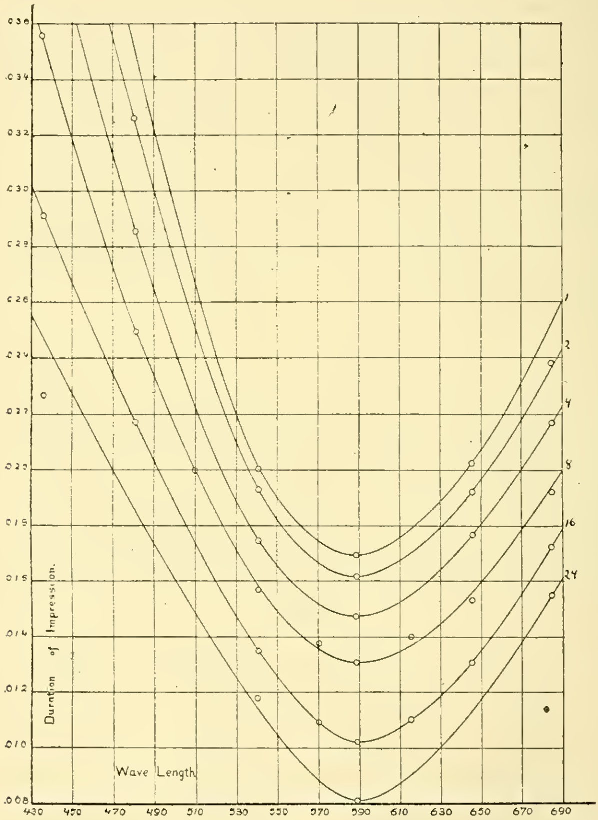
* Ann. di Optalmol. II and III, 1879.

† De l'intensité lumineuse des couleurs spectrales, Comptes Rendus, xcix, p. 937.

‡ On the Examination for Color of cases of Tobacco Scotoma, and of Abnormal Color-blindness, Roy. Soc. Proc., xlix (1891), p. 491.

The values given in this table as well as in all the succeeding tables are not averages of a number of observations, but are the values of a single set of readings. The third and fourth columns are the values obtained by two observers who had only used the apparatus for about an hour, and are hence less reliable than the values in the second column which have been many times repeated. The curve platted from the values in the second column is shown in fig. 1, curve 8.

1.



Duration of Impression of normal eye for different colors and different intensities.

The fact was noticed with some surprise that on different days the observations were nearly identical, if the eyes had not been strained or made more than normally sensitive by remaining for a long time in a dark room. And it was also found that the sensitiveness of the eye might have changed by several per cent without producing any noticeable difference in the duration of the retinal impression. This shows two things: first, that the personal equation, or more properly the personal error, in this sort of investigation is less formidable than ordinarily supposed; and secondly that a comparatively large change of sensitiveness of the eye is required to produce a marked change in the duration of the retinal impression.

An examination of this curve (8, fig. 1) shows that the retinal persistence is very different for different parts of the spectrum. As in the curves published by Dr. Nichols, in the paper already cited, the minimum duration is near the D line, and from this point the duration steadily increases toward each end of the spectrum. The observations were carried relatively farther into the blue than in the red, which largely accounts for the apparent unsymmetrical form of the curve. The curve is of the general form of a parabola with its apex approximately at the D line and the two branches becoming parallel to the ordinates of the ends of the spectrum.

Duration of Retinal Impression for light of different Intensities.

In the early part of this century Plateau* noticed that there was an intimate connection between duration of retinal impressions and the intensity of the light producing them. One of the principal objects of this investigation was to determine the law connecting these quantities. To do this, values of duration of retinal impression were obtained for monochromatic light of different intensities. The light intensity was varied by changing the width of the collimator slit according to Vierordt's method. The plan followed was to obtain a spectrum of a certain brightness, and measure the duration of retinal impression at sufficient points in it to be able to plat a curve showing the relation between the retinal persistence and wave-length. Then changing the width of the collimator slit by a definite amount, so as to obtain a spectrum of a brightness in known proportion to that of the preceding spectrum, to determine the duration of impression for the same points as before. In this way the following values were obtained for the duration of retinal impression of monochromatic light of different color and different intensity.

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* Dissertation sur quelque propriétés des impressions produites par la lumière sur l'organs de la vue. (Liege 1829.)

TABLE II.

Duration of retinal impressions for monochromatic light of different wave-length, of relative brightness from 1 to 24.

Wave-length.	Duration of retinal impressions in seconds.					
	1.	2.	4.	8.	16.	24.
·435				·0357	·0294	·0227
·480		·0328	·0286	·0250	·0217	
·510				·0200		
·540	·0200	·0192	·0172	·0156	·0133	·0119
·570				·0139	·0109	
·589	·0170	·0161	·0147	·0132	·0102	·0081
·615				·0141	·0111	
·645	·0204	·0192	·0179	·0156	·0130	
·684		·0238	·0217	·0192	·0172	·0156

These values are platted in the curves shown in fig. 1. The numbers affixed to the curves indicate the relative brightness of the spectra.

These curves show that with increased brightness the values of retinal presistence do not shift their positions relative to wave-length; that as the brightness of the spectrum increases, the duration becomes less in such a manner that each point in the curve is shifted downward by a nearly constant amount; and that the distance separating the different curves has a definite relation to the difference of the light intensity of the spectra from which the curves were obtained.

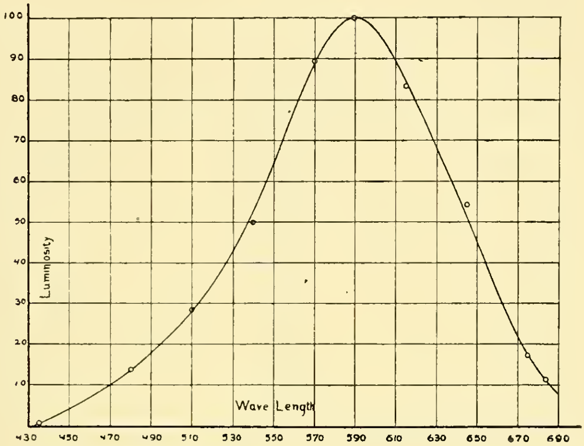
If the values be noticed for the duration of impression of all the curves, corresponding to any single wave-length, it will be perceived that the following statement is approximately true: as the intensity of light increases in geometrical ratio, the duration of the corresponding retinal impression decreases in arithmetical ratio. This statement can be concisely expressed in the form of the approximate empirical law—the difference of the duration of two retinal impressions produced by two lights of the same color, is inversely proportional to the logarithm of the quotient of the respective luminous intensities.

The value obtained for the ends of the spectrum deviate from this law, but this is probably due to the uncertainty of the observations in these faintly illuminated regions. The relation between duration and light intensity, thus far deals simply with lights of the same color. The next object of the experiment was to test the generality of this law, by determining if it would hold for lights of different color.

Relation between Luminosity and Duration of Retinal Impression.

By luminosity is meant the physiological effect of light upon the eye by means of which vision is accomplished. The measure of luminosity is the amount of light necessary to enable one to clearly distinguish objects. The spectra of various light sources are so very different in the distribution of luminosity, that it was considered necessary to determine these values for the particular lamp used in these experiments.

2.



Distribution of Luminosity in 16-candle power, 100-volt Edison Incandescent Lamp

The method employed was to insert an object into the eye piece of the spectrometer and to reduce the aperture of the objective of the observing telescope by means of a fine micrometer slit till the object was just visible. The reciprocals of the micrometer slit areas gave the relative luminosities of the different parts of the spectrum. This method is less convenient and possibly less accurate than the Rumford photometer method used by Abney and Festing* but it gave a probable error of only about five per cent.

Table III.

Distribution of Luminosity in normal spectrum of a 16 C. P. 100 volt Edison Incandescent lamp—Platted in Fig. 2.

Wave-length.	Relative luminosity.	Wave-length.	Relative luminosity.
·435	1·86	·589	100·00
·455	3·06	·615	83·25
·480	13·89	·645	54·37
·510	28·28	·675	17·12
·540	50·00	·684	11·16
·570	89·25		

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* Colour Photometry, Trans. Roy. Soc. Lond., 1888, p. 547.

The form of this curve suggested the possibility of luminosity bearing a reciprocal relation to duration of impression. This idea was tested in two ways. First, one particular region in the spectrum was chosen and its luminosity varied so as to be equal to the luminosity of different parts of the normal spectrum as given in Table III; the duration of retinal impression was then measured for these luminosities and gave the following values:

TABLE IV.

Duration of impression for a single color having its luminosity varied so as to equal the luminosities of different parts of the normal spectrum.

Relative luminosity.	Corresponding to wave-length.	Given duration of impression in seconds.
1·86	·435	·0333
13·89	·480	·0227
28·28	·510	·0200
50·00	·540	·0161
89·25	·570	·0143
100·00	·589	·0138
83·25	·615	·0143
54·37	·645	·0161
11·16	·684	·0192

The luminosities taken in this table are the same as in the normal spectrum that gave the values in the fifth column, Table II. A comparison of the third column, Table IV, and the fifth column, Table II, indicates that luminosity is the important factor in persistence of vision. To farther test this deduction, observations were made on the duration of impression for different colors of the normal spectrum, when each color was brought to the same luminosity. If the above deduction is valid, then if each color is brought to the same absolute luminosity, the retinal persistence of each color will give the same value. The values obtained are given below.

TABLE V.

Duration of impression when each spectral color is brought to the same luminosity.

Wave-length.	Duration in seconds.
·510	·0151
·540	·0147
·570	·0149
·589	·0147
·615	·0147
·645	·0147

Duration of Light Impressions on Color-Blind Eyes.

As a still farther test of the theory that retinal persistence is practically independent of color but depends principally upon luminosity, duration of impression curves were obtained from dichroic eyes. It is well known that a color-blind person not only lacks one of the fundamental color sensations but also that he perceives other colors differently from the normal. For instance, according to Holmgren,* in the spectrum as seen by red-blind persons yellow begins at about line C and extends an orange, yellow and yellowish green and ends near F. At this neutral zone the blue begins and extends to the end of the normal spectrum. If now duration of retinal impression does depend in any way upon color, one would expect that the curves obtained from color-blind persons would differ from those of the normal in a way that could not be explained by considerations of luminosity alone. An examination of about two hundred members of a large class in physics, by Holmgren's worsted method furnished eight cases of color-blindness, one being red-blind, the remainder being green-blind. The proportion of color-blind in even this limited number was about the same as found by Dr. Jeffries† from the examination of 175,000 persons.

These color-blind students were examined for the neutral point by the method of A. Koenig‡ which consists in determining the color that they will match with white or gray. A prism having one face coated with magnesium white was so mounted in the Helmholtz color-mixing spectroscope, that a ray of light from the collimator passing through the prism would be dispersed into a spectrum, while a ray from a second source falling on the white surface would be reflected directly into the telescope. If now the eye-piece of the telescope be removed, one-half the field of view will be filled with color and the other half with pure white or gray. With this arrangement a color-blind person will very accurately set the instrument to the exact point where the two halves of the field of view appear of exactly the same color to him.

After their neutral points had been found in this manner, these gentlemen very kindly offered to spend the time necessary to obtain curves for their retinal persistence.

Mr. W. C. W. is a marked case of inherited blindness to red. His father, uncles and brothers are similarly affected. The red end of his spectrum ends at about $\cdot 688\ \lambda$, and his neutral point is at $\cdot 510\ \lambda$. His eyes are otherwise normal.

Mr. H. S. has inherited green-blindness from his *maternal* relatives. Daltonism is so very rare among women that his case was studied with great interest. He is making a specialty

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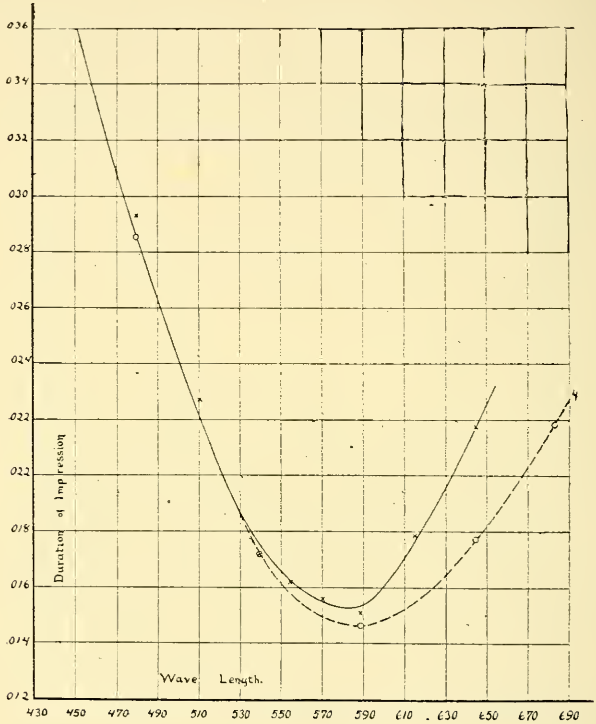
* How do the color-blind see the different colors? Proc. Roy. Soc. Lond., xxxi (1880), p. 302.

† 3·95 per cent among males. "Color Blindness: its dangers and detection." (Boston: 1879.)

‡ Zur Kentniss dichromatischer Farbensysteme. Wied. Ann, xxii (1884), p. 567.

of botany and finds no great inconvenience in any of his studies except chemistry. This subject he was obliged to discontinue as he could not distinguish the characteristic colors of the reactions. His neutral point was sharply located at ·516 λ. This gentleman wore glasses for near-sightedness.

3.



Duration of Impression for different colors of red-blind Eye.

The other observers were not aware of any similar cases in their families. The neutral point of Mr. G. A. W. was located at ·517 λ; Mr. W. M. at ·5165 λ; Mr. L. M. W. at ·518 λ; Mr. H. C. H. at ·516 λ. They are all green-blind and their eyes appear to be otherwise perfect with the exception of Mr. W. M., who is near-sighted. Their values of duration of impression are given in the annexed table.

The values of Mr. W. C. W. are platted in the full curve fig. 3; the broken curve being the curve of the normal eye for the same brightness of spectrum. The values obtained by Messrs. W. M., H. C. H., and L. M. W. are platted in the curves in fig. 4. The normal curves are drawn in as before to show the relation between the normal and color-blind eyes for persistence of vision.

TABLE VI.

Duration of Retinal Impression for Dichroic Eyes.

(The numbers at the head of each column indicate the brightness of the spectrum.)

Wave-length.	Duration of Impression in Seconds.					
	Red Blind.	Green Blind.				
	Mr. W. C. W.	Mr. H. S.	Mr. G. A. W.	Mr. W. M.	Mr. H. C. H.	Mr. L. M. W.
λ.	4.	8.	4.	2.	4.	8.
·435	----	----	----	·0357	----	·0357
·480	·0294	·0357	·0278	·0333	·0294	·0250
·510	·0227	·0227	·0227	·0263	·0217	·0192
·525	----	·0208	·0200	·0238	·0208	·0185
·540	·0172	·0200	·0185	·0222	·0200	·0172
·555	·0161	·0175	·0179	·0208	·0193	·0156
·570	·0156	·0161	·0161	·0192	·0166	·0143
·589	·0152	·0143	·0152	·0159	·0151	·0125
·615	0179	·0154	·0156	·0175	·0161	·0143
·645	·0217	·0175	·0167	·0192	·0172	·0156
·684	----	·0210	·0227	·0238	·0217	·0179

These curves show that light impressions of red last much longer on the retina of red-blind persons than on the normal, yellow somewhat longer than normal and the other colors about the same as normal. With green-blind persons, however, green impressions persist much longer than normal, red a little less than normal and the other colors the same as normal.

An explanation of the difference between the duration curves of dichroic and normal eyes was found in the difference in the sensitiveness for different colors of the dichroic from the normal eye. Messrs. Macé and Nicati* from the examination of a number of dichroic eyes obtained luminosity values which indicate, first, that red-blind people perceive red weakly, yellow nearly normal, green better than normal; second, that the green blind have better perception than normal for red, green feeble, yellow and blue normal. A later determination by Abney and Festing† confirmed their conclusions. In this experiment luminosity values were also obtained from Mr. W. C. W. which agree with the two determinations just cited. This shows that if account be taken of the difference between the sensitiveness of the normal and the dichroic eye for different

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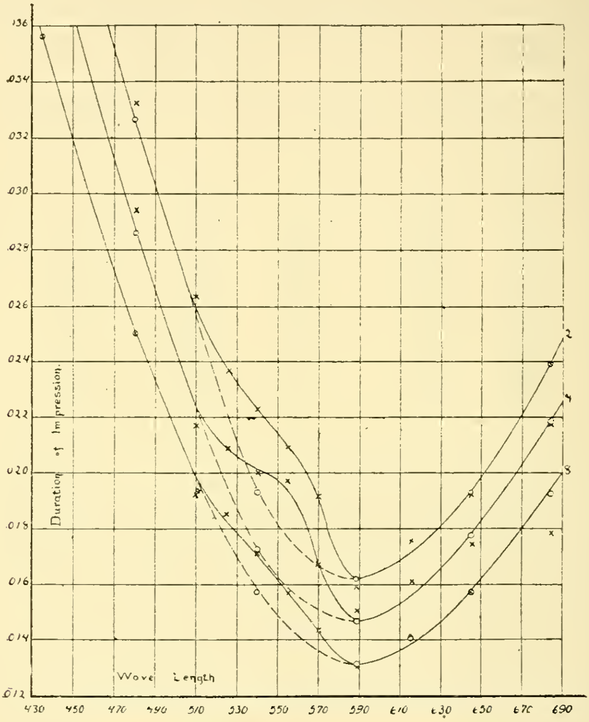
* De la distribution de la lumière dans le spectre solaire (spectre des Daltoniens). Comptes Rendus, xci, p. 1078.

† Colour Photometry. Trans. Roy. Soc. Lond., 1888, p. 547.

regions of the spectrum, that the curves of retinal persistence of the dichroic and the normal eye will be of the same form.

This appears to make the evidence conclusive that color is at most a slight factor in retinal persistence, and that luminosity is the all-important function.

4.



Duration of Impression of Green-blind Eye.

The law previously derived connecting duration of impression and luminosity of lights of the same color can now be made general and independent of color. This approximate empirical law can now be expressed in the concise form—*duration of retinal impression is inversely proportional to the logarithm of the luminosity*, or in the form of the equation

$$D = \frac{1}{k \cdot \log l}.$$

It is interesting to note the similarity of this with Fechner's law* connecting the intensity of stimulus and the sensation

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* Revision der Hauptpunkte der Psychophysik (Leipsig), p. 184.

produced. Fechner's law was also empirically deduced and has since been confirmed, for mean values, by Dalbouf's memoir to the Belgian Academy. It can be expressed in the form

$$s = k_{,} \cdot \log x$$

where s denotes intensity of sensation and x intensity of stimulus. In this particular case the stimulus is luminosity, hence we have

$$D = \frac{1}{k_{,,} \cdot s}$$

which means simply that retinal persistence varies inversely as the intensity of the sensation producing it. This seems to agree with ordinary experience and thus to confirm the validity of the law connecting retinal persistence and luminosity.

Effect of Age upon Retinal Persistence.

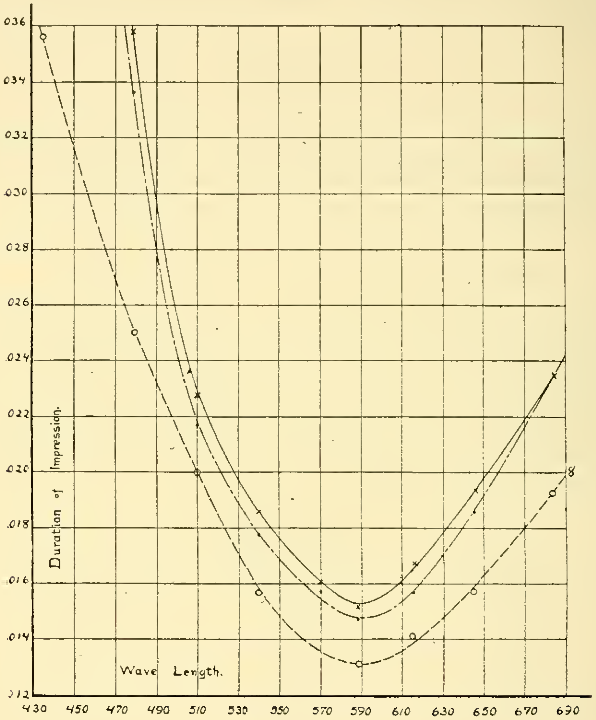
It was thought that possibly as a person advanced in years, the retina might become selective in its sensitiveness for different colors and that therefore the curve of duration of retinal impression might be different from that of a younger person. Two professors in the University kindly permitted their eyes to be tested for retinal persistence and the values obtained are given in the annexed table.

TABLE VII.

Wave-length. λ	Duration of retinal impression in seconds. Prof. S. G. W.	Prof. E. L. N.
·435	·0417	·0417
·480	·0333	·0357
·510	·0217	·0227
·540	·0179	·0185
·570	·0156	·0161
·589	·0147	·0155
·615	·0156	·0166
·645	·0185	·0192
·684	·0227	·0227

These values platted in fig. 5 seem to indicate that for both Dr. Nichols and Prof. Williams the more refrangible part of the spectrum is proportionately less luminous than to the eyes assumed to be normal. But the violet end of the spectrum is so feeble that observations in it are very difficult, and certainty cannot be obtained without more extended observations. If anything can be deduced from so few observations, these curves show to a high degree of probability that age increases retinal persistence to a considerable amount and that the increase is nearly uniform for all wave-lengths. This fact would be naturally expected, for it is well known that age decreases retinal sensitiveness ; and as the sensitiveness decreases the action of the retina would be less quick either to receive an impression or to dismiss one.

5



Summary of Results.

I. The duration of retinal impression is very different for different regions in the spectrum, being at a minimum value at the region of maximum luminosity and gradually increasing to maximum values at the ends of the spectrum.

II. If the luminosity of any region in the spectrum be so changed that the values vary in geometrical ratio, the corresponding values of duration of impression will approximately vary in arithmetical ratio for regions of ordinary brightness.

III. Color has, at most, very slight influence upon retinal persistence. Luminosity,—including the brightness of the light and the retinal sensitiveness—is the all-important factor.

IV. For ordinary values the following empirical law is approximately true—*Retinal persistence varies inversely as the logarithm of the luminosity.*

V. The values of retinal persistence in dichroic eyes is very different than in normal eyes. For instance, light impressions of red last much longer on the retina of red-blind persons than on the normal, yellow somewhat longer than normal and the other colors about the same as normal. With green-blind persons, green impressions persist much longer than normal, red a little less than normal and the other colors the same as normal.

VI. The very marked departure from the normal values of retinal persistence in dichroic eyes for the region of their lacking color sensation, affords a precise and convenient method of determining color-blindness.

VII. Within the range of these experiments, it seems probable to a high degree that age increases the duration of retinal impressions to a nearly equal amount in all regions of the spectrum.

In conclusion I wish to express my obligation to Mr. E. Gordon Merritt for his very valuable assistance in taking observations in these experiments.

Physical Laboratory of Cornell University, June, 1892.

ART. XXVII.—*Kilauea in April*, 1892; by Rev. SERENO E. BISHOP.

[Communication to J. D. Dana, dated Honolulu, April, 30, 1892.]

ON a visit, a little over a fortnight since to the volcano of Kilauea, the condition of Halemaumau crater was found to be greatly changed from that in 1887, as described in your "Characteristics of Volcanoes," and which I had the satisfaction of observing in your company. It also differs so greatly from what has been hitherto put upon record, that I venture to send you the particulars, with some illustrations for such use as you may choose.

At the collapse of the crater on March 5, 1891, precisely five years after the previous collapse in 1886, a deep open pit was left as before. The great mound* had entirely disappeared into the volcanic depths. The lava speedily reappeared without apparent obstruction, and has since then risen to within about 300 feet of the upper rim of Halemaumau, where it formed a floor of remarkable smoothness. Perhaps two months

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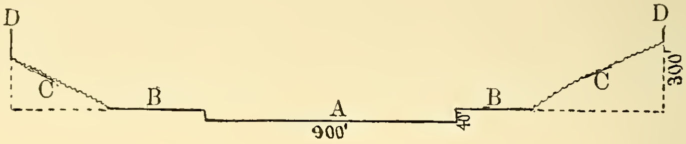
*The mound referred to is the "debris-cone" which occupied the interior of Halemaumau, the pit in the southwest part of Kilauea.

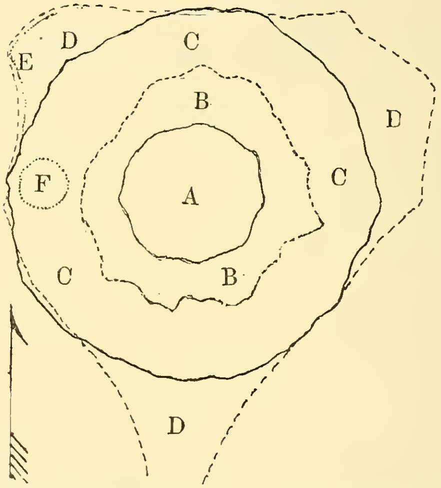
ago it began to subside, and when I last saw it, it was 40 feet below the level of the floor, having sunk about ten feet during five days. The diameter of the molten lake is just about 900 feet, and that of the floor around it averages 1500 feet.

1.



Vertical Section of Halemaumau, April 13, 1892.

2.



Ground-plan of Halemaumau in the southwest part of Kilauea.

Fig. 1 is a ground plan of Halemaumau, and 2, a section of it, as it existed April 13, 1892. In each, A is the Fire-lake of that date 900 feet in diameter; BB, the level floor of blackish lava around the lake, about 40 feet above the surface of the lake, and 1500 feet in diameter; CC, the talus-slope making the chief part of the sides of the pit; D, section of the outer rim of Halemaumau. In the ground-plan, fig. 2, the outer dotted line, is the outline of 1886, as given in Dodge's map; DDD, depressed areas of the pit of that date, filled up by overflows of 1889, 1890, 40 feet above the former level; E, section of former margin of the pit still visible above recent overflows; F, former position of Dana Lake.

The activity of the lake, relatively to its area, is somewhat less than that of Dana Lake as you witnessed it, although actually several times as great, and exhibiting larger single areas of violent activity. It differs materially from Dana Lake in the distribution of its action. The general movement of the thin crust is steadily from the periphery toward the center, where there is the greatest action. Long seams (fiery cracks) open near the outer edge, and draw inward, crinkling up as they progress, until they become interlaced. An open area of perhaps two acres at the center is occupied by a strong current pouring westward, filled with fragments of crust and exhibiting sparkles of fire with a multitude of small jets and sprays. This current disappears under the crust that extends out from the west side. Near the eastern edge of this central area there is a powerful fountain which did not intermit its action a single minute during several visits from the 8th to the 13th. Its movement was pulsating; about every twenty seconds it welled up in a round billow varying in diameter from 30 to 50 feet, and from 20 to 35 feet high. There was no explosive action, or spray, except what was caused by the falling back of the upheaved fluid.

A similar but smaller fountain played nearer the bank at the south. This, however, at my last visit, had exchanged its action for a more violent but intermittent one. Occasionally, and once for twenty minutes continuously, an area of 150×40 feet was occupied by a violently tossing mass of surges, from 15 to 25 feet high, the entire summit of which was feathery with spray. A similar but smaller area was several times in like action northwest of the center.

The great regurgitating and explosive fountains under the little cliffs, which made the chief displays in Dana Lake, were scarcely to be found here. A slight occasional action of that sort was noticed at two points at the northwest edge.

The remarkable fact is here to be noted, that *no vapor* could be distinguished without careful scrutiny. From the Volcano House, a column of very faint blue haze could be observed ascending, having the diameter of the lake. In the night, this column of vapor, illuminated by the fires, was more discernible. But from the edge of the crater, close at hand, it could barely be distinguished, even by night. I spent many hours on different sides of the crater, once walking around it, but never even perceived any odor of fumes when at the edge, although at some distance from it and all over the floor of Kilauea many crevices were emitting sulphurous fumes. At the present time, the lava seems to have no contact with old rocks near the surface, while the ducts below are doubtless heavily glazed, like those we saw at the bottom of "New Lake" in '87.

The top of Halemaumau crater has been found by aneroid measurement to be from 30 to 50 feet higher than in 1886.

There is every appearance that extensive overflows have taken place over every part of the rim since you were there, and there can be no doubt of a great accumulation of material. The "New Lake" and the intervening depression are totally obliterated. The high promontory west of "New Lake" is lost beneath the flood. The great depression at the south is also filled, though not quite to the general level. The conical form of Halemaumau has become very distinct, and is strongly appreciated in the ascent to it on nearly every side.

The volcano will soon be very accessible for tourists. The Hilo road is perfectly graded and rolled, and will probably be completed in a few months, when the drive to Kilauea will be one wholly of pleasure. The new hotel is a superior one, with lodgings for 70 guests. Plans are in progress for improving the walk over the lava. The whole is now in the hands of an active and enterprising corporation.

Art. XXVIII.—*The Devonian System of Eastern Pennsylvania;* by Charles S. Prosser.

[Published by permission of the Director of the U. S. Geological Survey.]

During the summers of 1884 and 1890 personal field work in southeastern New York, taken in connection with an opportunity to carefully study the Devonian exposures of this section and those of eastern Pennsylvania in the summer of 1891, is believed to have furnished important data toward the proper correlation of this system with the typical Devonian section of central New York. Numerous sections crossing this series of rocks, with quite a collection of fossils, have been made in the region between the Lehigh river in Pennsylvania and the northern part of Green county, New York. A single section across the Devonian terranes of this district will be briefly described in order to make this work available for use in the construction of the Appalachian geological maps and for the purposes of general correlation. The section along the line of the Delaware, Lackawanna & Western Railroad, crossing Monroe county, Pennsylvania, is considered a typical section and it has been selected for the subject of the present paper. It is no more than just to state that the geologic structure of this region, some of which is decidedly complicated, and the stratigraphic position of the formations have been worked out and mapped by Professors J. P. Lesley* and I. C. White† in an ad-

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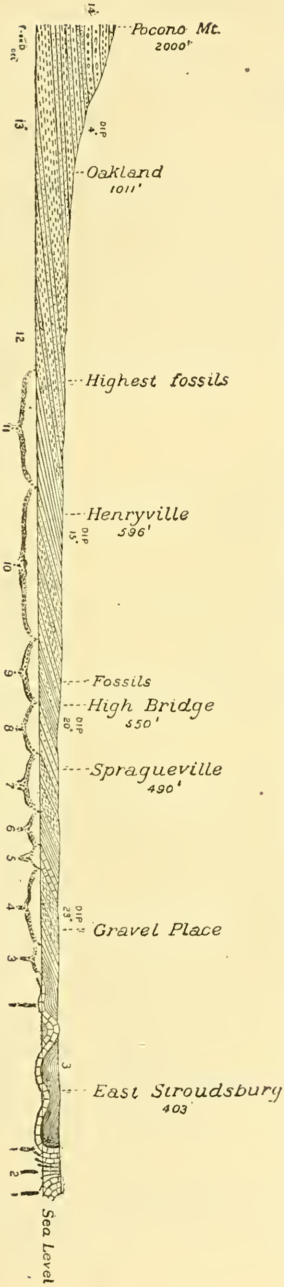
* The Geology of Pennsylvania, vol. i, 1858, pp. 270–289. For a statement of Prof. Lesley's work in eastern Pennsylvania, see 2d Geol. Surv. Penn., A, p. 102 and *ibid.*, G^6, pp. xiv, xx foot-note.

† *Ibid*, G^6, The Geology of Pike and Monroe counties, 1882



SECTION ALONG THE DELAWARE, LACKAWANNA & WESTERN RAILROAD FROM EAST STROUDSBURG TO MT. POCONO, PENN.

Horizontal scale 2¼ miles to the inch. Vertical scale 500 feet to the inch.

1. Upper Helderberg (Corniferous limestone). 2. Cauda-galli grit. 3. Marcellus shales. 4. Hamilton. 5. Tully limestone of Professor White. 6. Genesee shale of Professor White. 7. Chemung and Portage of Professor White. 8. Starucca sandstone (Upper Chemung of White). 9. New Milford red shale. 10. Delaware river flags. 11. Montrose red shale. 12. Honesdale sandstone. 13. Upper Catskill. (9 to 13 Catskill). 14. (?) Mt. Pleasant Conglomerate (Pocono).

mirable manner, the accuracy of which has been personally tested in many localities.

The base of the section is the Upper Helderberg limestone (Corniferous), which is well exposed in the D. L. & W. R. R. cut one mile south of the East Stroudsburg station. The railroad cut is through an anticlinal fold and near the center the Cauda-galli grit is exposed, the limestone at the northern end of the cut being overturned. The Marcellus shales succeed the limestone, one exposure being in the railroad cut a short distance south of the station, and another along McMichaels creek, opposite Elizabeth street, Stroudsburg. Fossils are not generally common, but at the northeastern end of the small ridge north of Scott street, Stroudsburg, is a bluish-black shale in which they are quite abundant.* The following species have been identified from this outcrop. (U. S. Geol. Surv., No. 1475 B^1).

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* This locality was mentioned by Prof. White; see 2d Geol. Surv. Penn., G^6, pp. 115, 116.

1.	*Leiorhynchus limitaris* (Van.) Hall	(*aa*)*
2.	*Chonetes mucronata* Hall	(*aa*)
3.	*Leiopteria lævis* Hall	(*c*)
4.	*Styliola fissurella* Hall	(*c*)
5.	*Orthoceras subulatum* Hall (?)	(*r*)
6.	*Pterinopecten dignatus* Hall	(*rr*)
7.	*? Goniatites* sp.	(*rr*)

About half a mile north of East Stroudsburg, another anticlinal fold brings to the surface the Corniferous limestone and then there are no more noticeable exposures of rocks along the railroad until a point is reached a short distance north of Gravel Place. At this locality, about two and one-half miles from Stroudsburg, are exposures of rather coarse arenaceous shales on the northeast side of the railroad. The fossils are quite abundant, especially *Vitulina pustulosa* Hall. The following species were found at this place (No. 1475 C^2 and C^3).

1.	*Vitulina pustulosa* Hall	(*aa*) 50 specimens.
2.	*Ambocœlia umbonata* (Con.) Hall	(*c*)
3.	*Phacops rana* (Green) Hall	(*r*)
4.	*Spirifera mucronata* (Con.) Bill.	(*r*)
5.	*Chonetes deflecta* Hall	(*r*)
6.	*Spirifera granulifera* Hall	(*rr*)
7.	*Modiomorpha subalta* (Con.) Hall	(*rr*)
8.	*Modiomorpha concentrica* (Con.) Hall (?)	(*rr*)
9.	*Pterinea flabellata* (Con.) Hall	(*rr*)
10.	*Palæoneilo constricta* (Con.) Hall	(*rr*)
11.	*Leiorhynchus multicosta* Hall	(*rr*)
12.	*Pleurotomaria* sp.	(*rr*)
13.	Crinoid, calyx	(*rr*)

It will be noticed that the above list is a typical Hamilton fauna and these arenaceous shales and thin sandstones make an outcrop nearly one mile in width.

Near the top of the above zone is an arenaceous, slightly calcareous shale which in places, especially where not weathered, forms a massive stratum of very compact rock. There is a good exposure of this zone by the side of the Stroudsburg and Spragueville highway, on the western side of Brodhead creek about one and one-half miles below Spragueville and a short distance south of Mr. E. Bonynge's house.† Fossils are very abundant at this exposure, especially corals and crinoid stems; but there are also numerous specimens of brachiopods.

Fauna of No. 1475 C^5.

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* The relative abundance of the species is indicated as follows:
aa = very abundant, *a* = abundant, *cc* = very common, *c* = common, *r* = rare, *rr* = very rare.

† This locality is described by Prof. White in G^6, pp. 109, 271 under the heading of the "Tully Limestone horizon."

1.	*Spirifera sculptilis* Hall	(*a*)
2.	*Spirifera fimbriata* (Con.) Hall*	(*a*)
3.	*Spirifera mucronata* (Con.) Bill	(*c*)
4.	*Orthis Vanuxemi* Hall	(*c*)
5.	*Nucleospira concinna* Hall	(*c*)
6.	*Athyris spiriferoides* (Eaton) Hall	(*c*)
7.	*Phacops rana* (Green) Hall	(*c*)
8.	*Cypricardinia indenta* (Con.) Hall	(*c*)
9.	*Atrypa reticularis* (Linn.) Dal.	(*c*)
10.	*Cyrtina hamiltonensis* Hall	(*r*)
11.	*Tropidoleptus carinatus* (Con.) Hall	(*rr*)
12.	*Chonetes coronata* (Con.) Hall	(*rr*)
13.	*Strophodonta perplana* (Con.) Hall (?)	(*rr*)
14.	*Leiorhynchus multicosta* Hall (?)	(*rr*)
15.	*Actinopteria decussata* Hall (?)	(*r*)
16.	*Mytelarca* (*Plithomytilus*) *oviformis* (Con.) Hall	(*rr*)
17.	*Conocardium* sp.	(*rr*)
18.	*Platyceras* sp.	(*rr*)
	Corals and Bryozoa.	

This horizon is especially important since Professor White considered it to be at the summit of the Hamilton stage and to represent the Tully limestone of New York. After describing the locality from which the above species were collected, the Professor stated "There can be little doubt that this stratum represents the *Tully limestone horizon* of the New York Reports, and it thus becomes a valuable guide in correlating and classifying the rocks of the district."† However, when this zone is studied carefully it will be noticed that it is usually a calcareous shale or sandstone, instead of a massive limestone and does not lithologically resemble the Tully limestone of central New York. But, far more important than the lithologic character of the zone, is the fact that the fauna therein contained is composed of Hamilton species, while those which are especially characteristic of the Tully limestone are absent.‡ This zone appears to the writer to correspond with the calcareous layers that occur in the midst of the regular Hamilton shales of central New York rather than with the Tully limestone.

While considering the correlation of this zone it is impor-

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* *Spirifer fimbriatus* Morton was proposed in 1836, this Jour , vol. xxix. p. 150, pl. II, fig. 1; while Conrad's *Delthyris fimbriatus* was named in 1842, Jour. Acad. Nat. Sci., Philadelphia, vol viii. p. 263. S. A. Miller in 1883, 2d ed. Am. Pal. Foss. named Conrad's species *Spirifera Conradana;* but in this paper the name by which the New York species is generally known has been retained.

† G^6, p. 109.

‡ For a list of the New York Tully fauna with a discussion of the species having a diagnostic value. see a paper by Prof. H. S. Williams on "The Cuboides zone and its fauna; a discussion of methods of correlation," Bull. Geol. Soc. Am., vol. i, pp. 490–494.

tant to recall the known limit of the eastern extension of the Tully limestone of central New York, which formation was found by Vanuxem in Chenango county " at the northwestern part of Smyrna, on the road to DeRuyter village, where the road crosses the west branch of the Chenango [river]."* In the summer of 1886 the writer studied this region, and near Upperville in Smyrna township reported limestone layers separated by calcareous shales, twenty-five feet in thickness.† Farther east in the Unadilla valley no representative of the zone was found.

One fourth mile farther north than the outcrop of the calcareous, coral zone, the highway crosses Brodhead creek and under the bridge and along the banks of the stream are exposures of rather finely arenaceous, bluish shales which are moderately fossiliferous. This zone is easily traced in the field on account of its being composed of thin, dark-colored shales which succeed the coarse arenaceous shales of the middle and lower Hamilton. One of the best localities for collecting fossils in this zone is in the gorge of the Sawkill creek, above Milford, Pike county, and the fauna of that station will be given for this horizon. (See fauna of No. 14767^2.)

The outcrop from which this fauna was obtained is one of the typical exposures of this zone, which was referred by Professor White to the Genesee shale. The fossils came from the upper part of the zone as exposed in the gorge of the Sawkill, which "rapidly excavates a long narrow cañon out of the *Genesee shale*."‡ While under the description of the geological formations, Professor White says that " the top of the *Hamilton* is marked off everywhere in this district by the appearance of a dark sandy fossil slate or shale, which seems to be identical with the *Genesee black slate* of the New York Reports."§

A geologist familiar with the Genesee shale of central and western New York will find some difficulty in correlating this zone with the New York Genesee. These shales have

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* Geol. New York, Pt. III, 1842, p. 292. Also, see p. 164.

† Proc. Am. Assoc. Adv. Sci., vol. xxxvi, 1887, p. 210.

‡ G^6, p. 199.

§ *Ibid.*, p. 107. Professor Lesley called these shales Genesee in the explanation of the geological structure of Monroe Co., Report X, 1885. p. lxxx.

Mr. Arthur Winslow in his work along the Lehigh river named the continuation of these shales Genesee, and mentioned them particularly at Weissport (Ann Rept. Geol. Surv. Penn., 1886. Pt. IV, pp. 1365, 1367, 1371). Also, see Winslow's map and section from exposures along the Lehigh river, sheet No. 3. In the continuation of the Lehigh section down the river by Mr. Frank A. Hill, similar shales are called Genesee (*Ibid*. pp. 1373. 1374). A considerable collection of fossils was made from near the Weissport station of the Central Railroad of New Jersey, and from the R. R. cut above Bowmans; the lithologic character of the shale and the fauna is about the same as in the exposures of the same zone farther northeast in Monroe and Pike counties.

Fauna of No. 1476 F²; with table of Geologic Range.

Number of Species.	List of Species.	Abundance.	Geologic Stage.*									
			Oriskany.	Schoharie grit.	Upper Helderberg.	Marcellus shale.	Hamilton.	Tully limestone.	Genesee shale.	Portage.	Ithaca.	Chemung.
1	*Nucula corbuliformis* Hall	*a*	--	--	--	--	×	--	--	--	?	--
2	*Tellinopsis subemarginata* (Con.) Hall	*a*	--	--	--	--	×	--	--	--	--	--
3	*Palæoneilo constricta* (Con.) Hall	*c*	--	--	--	--	×	--	--	×	×	--
4	*Nuculites triqueter* Con.	*c*	--	--	--	?	×	--	--	--	--	--
5	*Modiomorpha mytiloides* (Con.) Hall	*c*	--	--	--	--	×	--	--	--	--	--
6	*Phacops rana* (Green) Hall	*c*	--	--	?	×	×	×	--	--	--	×
7	*Chonetes mucronata* Hall	*c*	--	--	×	×	×	--	--	--	--	--
8	*Hyolithes aclis* Hall	*c*	--	--	--	--	×	--	--	×	--	--
9	*Pleurotomaria Itys* Hall	*c*	--	--	--	--	×	--	--	--	--	--
10	*Nuculites oblongatus* Con.	*r*	--	--	--	--	×	--	--	×	--	--
11	*Spirifera fimbriata* (Con.) Bill.	*r*	×	×	×	--	×	×	--	--	×	×
12	*Palæoneilo muta* Hall	*rr*	--	--	--	--	×	--	--	--	--	--
13	*Leda diversa* Hall	*rr*	--	--	--	--	×	--	--	--	--	--
14	*Leda rostellata* (Con.) Hall	*rr*	--	--	--	--	×	--	--	×	--	--
15	*Orthonota carinata* Con.	*rr*	--	--	--	--	×	--	--	--	--	--
16	*Prothyris lanceolata* Hall	*rr*	--	--	--	--	×	--	--	×	--	--
17	*Pholadella radiata* (Con.) Hall	*rr*	--	--	--	--	×	--	--	--	×	--
18	*Goniophora carinata* (Con.) Hall (?)	*rr*	--	--	--	--	--	--	--	×	--	--
19	*Modiella pygmæa* (Con) Hall	*rr*	--	--	--	--	×	--	--	--	--	--
20	*Orthonota* (?) *parvula* Hall	*rr*	--	--	--	--	×	--	--	--	--	--
21	*Athyris spiriferoides* (Eaton) Hall	*rr*	--	--	×	--	×	--	--	--	--	--
22	*Tropidoleptus carinatus* (Con.) Hall	*rr*	--	--	--	--	×	--	--	×	--	×
23	*Ambocœlia umbonata* (Con.) Hall	*rr*	--	--	--	×	×	×	×	--	×	?
24	*Coleolus tenuicinctum* Hall	*rr*	--	--	--	--	×	--	--	--	--	--
25	*Loxonema delphicola* Hall (?)	*rr*	--	--	--	--	×	--	--	--	--	--
26	*Bellerophon leda* Hall	*rr*	--	--	--	--	×	--	--	--	--	--
27	*Dalmanites* (*Cryphæus*) *Boothi* (Green) Hall, possibly the var. *calliteles* Green	*rr*	--	--	×	×	×	×	--	--	--	--
28	*Orthoceras* sp. fragments	*rr*	--	--	--	--	--	--	--	--	--	--
29	*Spirifera granulifera* Hall (?)	*rr*	--	--	--	--	×	--	--	--	--	--
30	*Grammysia lirata* Hall ?)	*rr*	--	--	--	--	×	--	--	--	--	--
31	*Cyclonema hamiltoniæ* Hall (?)	*rr*	--	--	--	--	×	--	--	--	--	--
32	*Bellerophon brevilineatus* Con. (?)	*rr*	--	--	--	--	×	--	--	--	--	--

* The data used in showing the geologic range of the species in the above list are derived principally from the various works of Professors Hall, H. S. Williams, and Clarke, and the distribution is confined mainly to New York. The reported occurrence of certain species farther south along the line of the Appalachians is intentionally left out of consideration, until further investigation shall enable us to compare their stratigraphic position and faunas more carefully with the New York series. Consequently the range of each species is based upon references concerning the reliability of which there is believed to be no question, or upon data that are personally known to be accurate This is a principle that is frequently ignored in the preparation of large tables of distribution and range of species.

very little lithologic resemblance to the Genesee and the list of fossils given above shows that the fauna is not that of the Genesee, but rather one of the Upper Hamilton stage. Only one species of the list identified from the upper shale of the Sawkill cañon has been reported from the Genesee shale of New York, viz: *Ambocœlia umbonata* (Con.) Hall.*

In central New York the Genesee shale does not extend much farther east than the Tully limestone. Near Smyrna the writer found black, argillaceous shales some twenty feet in thickness† and Vanuxem reported it farther east at North New Berlin,‡ now New Berlin. In 1883 the exposures along the valley of the Unadilla river to New Berlin and then across the hills to Oneonta were carefully studied; but no evidence was found of the Genesee black shale or its fauna.

The rather fissile Genesee (?) shales are succeeded by coarser, arenaceous shales alternating with sandstones of moderate thickness. The sandstones are slightly greenish-gray in color, quite micaceous and in lithologic appearance decidedly different from the darker and more argillaceous shales below. Fossils are not common in this zone, but occasionally occur abundantly in thin layers. In the ledges along the hill-sides east of the highway, and by the side of the county road, just above the D. L. & W. R. R. crossing, about one-half mile south of Spragueville, are exposures of these arenaceous shales containing fossils.

The fauna of No. 1475 $C^{6, 7, \text{ and } 8}$ is as follows:

1. *Palæoneilo plana* Hall .... (*a*)
2. *Nuculites oblongatus* Con. .... (*a*)
3. *Palæoneilo emarginata* (Con.) Hall (?) var. .... (*c*)
5. *Spirifera mesastrialis* Hall .... (*c*)
6. (*?*) *Actinopteria* cf. *Boydi* Hall .... (*c*)
7. *Nuculites* cf. *cuneiformis* Con. .... (*c*)
8. *Prothyris lanceolata* Hall .... (*r*)
9. *Microdon* (*Cypricardella*) *gregarius* Hall .... (*r*)
10. *Spirifera mesacostalis* Hall .... (*r*)
11. *Orthonota* (*?*) *parvula* Hall (?) .... (*rr*)
12. *Nucula corbuliformis* Hall .... (*rr*)
13. *Tropidoleptus carinatus* (Con.) Hall .... (*rr*)
14. *Homalonotus De Kayi* (Green) Em. .... (*rr*)
15. *Leptodesma Rogersi* Hall (?) .... (*rr*)

The rocks from which the above fauna was obtained are a typical exposure of those which have been called Chemung by

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* Dr. J. M. Clarke in 1885 gave a list of fifty-five species that had been found in the Genesee shale of New York (Bull. U. S. Geol. Surv., No. 16, pp. 33, 69, 70). To this fauna he has since added additional species; see, Am. Geol., vol. viii, August 1891, pp. 88–91.

† Proc. Am. Assoc. Adv. Sci., vol. xxxvi, p. 210.

‡ Geol. New York, Pt. III, p. 292.

Professor I. C. White in eastern Pennsylvania. In describing this exposure Professor White said: "Along the county road, about one-half mile below Spragueville, the *Chemung rocks* are seen in cliffs of gray, fine-grained sandstone, quite *fossiliferous;*"[*] and in his account of the geologic formations he further stated that "It was impossible to identify any of the beds between the base of the *Catskill* and the top of the *Hamilton* with the *Portage series* of other portions of Pennsylvania, either on lithological or palæontological grounds, and hence I have applied the name *Chemung* to the entire interval, preferring to regard the *Portage series* as absent from this district."[†] Several reasons are given for this correlation, that of first importance being "The occurrence of characteristic *Chemung fossils* throughout the entire interval."[‡] Later, in describing the geology of the Susquehanna river region, Professor White stated that probably the beds in the lower part of the Chemung "are the equivalents of the *Portage beds* in New York;"[§] and in a letter dated February 22, 1892, emphasizes the fact that he wishes the above statement to apply to Monroe and Pike counties, and that the lower part of the terrane called Chemung in those counties corresponds to the Portage of New York.

The fauna of this formation is not characteristic of the Chemung stage of southern central and western New York, or even of the highest fossiliferous pre Carboniferous rocks of southern Pennsylvania and western Maryland. On the contrary it is a modified Hamilton fauna, similar to the faunas that occur in central and eastern New York in the Portage, especially after the Tully limestone and Genesee shale have disappeared. It hardly seems to be so late as the "Ithaca group," but rather approaches the earlier modified stages of the Hamilton fauna, as possibly the *Paracyclas lirata* stage of Professor H. S. Williams, which is found well developed above the horizon of the Genesee shale at Oneonta and Norwich in central New York.[‖]

It is true that *Spirifera disjuncta* Sow. is reported from this formation;[¶] and if the specimens were correctly identi-

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[*] G^6, p. 272. [†] *Ibid.*, p 104. [‡] *Ibid.*, p. 104.

[§] G^7. 1883, p. 68; and see pp. 70 and 228 for similar statements.

[‖] See Prof. H. S. Williams, Proc. Am. Assoc. Adv. Sci.. vol. xxxiv. p. 225 and chart; and Prosser. *ibid.*, vol. xxxvi, p. 210. This fauna characterized the Oneonta group of Conrad (not Vanuxem, who applied the same name to the overlying gray and red sandstones and shales) which was composed of bluish shales with some sandstones and abundantly fossiliferous. The zone is well exposed in the quarry at the foot of the hill west of Oneonta, at Norwich in the quarry near the reservoir, and in the lower part of the high hill west of the village. For Conrad's description of the "group" see Ann. Geol. Rept.. N. Y. 1841, pp. 30, 31, 50, 53.

[¶] G^6, p. 105.

fied that would be almost conclusive proof of its Chemung age. But the writer has failed to find this species on the eastern side of the Pocono and Catskill mountains and is inclined to think that *Spirifera mesastrialis* Hall, an allied species which is not uncommon, is the one reported for *S. disjuncta*, especially since the Cascade section of Susquehanna County, Penn., has been reported to contain "well-known Chemung shaly and flaggy strata full of *Spirifera disjuncta*."[*] When the section was examined in company with Professor H. S. Williams it was found that the common species was *S. mesastrialis*, which had evidently been mistaken for the *S. disjuncta*.[†]

After considerable field work in southeastern New York and northeastern Pennsylvania, the conclusion is reached that the marine faunas terminated either slightly in advance or soon after the appearance of the Chemung stage. In central and southern Pennsylvania and western Maryland, the conditions seem to have been more favorable and *Spirifera disjuncta* with other Chemung species occurs in rocks which are stratigraphically equivalent to the unfossiliferous beds farther toward the northeast. The geological collections of Johns Hopkins University contain a few specimens of *Spirifera disjuncta* from near Cumberland, Maryland,[‡] and Professors Claypole,[§] White,[‖] Stevenson,[¶] Ashburner,[**] and Meek[††] have reported the species from a number of localities in Pennsylvania and Virginia.

These shales and sandstones of the Chemung series, which contain the highest fossil shells seen by Professor White, are succeeded by greenish-gray, thick-bedded sandstones—the Starucca sandstone of Prof. White—which at that time he considered the base of the Catskill.[‡‡] Later, Professor White

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[*] G^5, p. 78.

[†] See the remarks on the Cascade section by Prof. Williams, who states: "When I examined the section I found no trace of several of the species cited, and only rare and imperfect specimens of *Spirifera disjuncta* and the last stage with *Rhynchonella contracta;* but all the mass of the fauna was *Spirifera mesastrialis* and its legitimate associates, which is a lower fauna belonging to the more eastern part of this general area. The difference between the two *Spiriferas* appears at first glance slight; but they are clearly distinct" (Proc. Am. Assoc. Adv. Sci., vol. xxxiv. p. 231)

[‡] See list of Chemung fossils from Maryland by Charles R. Keyes in Johns Hopkins Univ. Circulars, vol. xi, December, 1891, p. 29; which specimens through the courtesy of Dr. W. B. Clark have been personally examined.

[§] F^2, pp. 74, 77, 289, 291.

[‖] T^3, pp. 98, 183, 194.

[¶] T^2, pp. 76, 80, 133, 212, 214, 216, 225, 226; and Amer. Geol., vol. ix, pp. 10 26.

[**] F, pp. 221, 225.

[††] Bull. Phil. Soc., Washington, vol. ii, Appendix, Art. viii, p. 34.

[‡‡] G^6. pp. 102. 103. See G^5, 1881, pp. 59, 70, 73 and fig. 10 on p. 77 for the original description of this zone.

states "it seems probable that the 600′ of grayish green beds at the top of the *Chemung* in Pike and Monroe which in G^6 were referred to the *Catskill*, under the name of *Starucca beds*, may be the equivalent of a portion of the *Upper Chemung* of this district [Susquehanna river region], and therefore erroneously referred to the *Catskill* in G^6."* In the letter mentioned above Professor White writes that 600′ of sandstones which in G^6 were put in the Catskill should be added to the Chemung. Referring to the difficulty in separating the Chemung and Catskill the Professor says, "I think the only possible separation of Chemung and Catskill is that founded upon physical characteristics and in my opinion we should separate them at the horizon of the *lowest* red beds, for these seem to come in at about the same general zone everywhere, and it is the only possible means of separation." The Starucca sandstone is well exposed at Spragueville and in the first D. L. & W. R. R. cut north of the station.

The second railroad cut, just north of the Brodhead creek railroad bridge, is in the New Milford red shale, which is now regarded by Professor White as forming the base of the Catskill. The red shales alternate with gray shales and sandstones as far as the "High Bridge" over the West Branch of Brodhead creek where the Delaware river flags of White are reached.† At the southern end of the first railroad cut north of "High Bridge," in the lower part of the Delaware flags, a greenish-gray sandstone contains many impressions of *Orthonota* (?) *parvula* Hall,‡ a species that occurs in the upper Hamilton shales of Schoharie county, New York, as well as frequently in the argillaceous Hamilton shales of central and western New York. There is also a breccia which contains fragments of brachiopod shells and fish bones. At the northern end of the cut are coarse, grayish. arenaceous shales in which fern-stipes occur, and one poorly preserved frond of *Archæopteris minor* Lx. (?) was found.

The Delaware flags are succeeded by the Montrose red shale in the vicinity of Henryville,§ and overlying these shales are the Honesdale sandstones. Near the transition from

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*G^7, p. 73.

† See G^6, p. 100.

‡ Dr. Charles E. Beecher has seen these specimens and agrees with the above identification. Dr. J. M Clarke has kindly compared some of the specimens with the types in the New York State Museum at Albany, and writes: "I see no reason why the shells in question should not be regarded as *Orthonota* (?) *parvula* in accordance with your identification; I have compared them with the types of *O.* (?) *parvula* and can find no distinctive characters."

§ From the railroad cut in the red shale, just south of Henryville station, Prof. White reported *Archæopteris Jacksoni* Dn. (G^6, pp 103, 320). No specimens were found by the writer and the only fossils seen in the shale were fucoidal (?) fragments, which are frequently seen in the red shales of the Chemung and Catskill.

White's Montrose shale to the Honesdale sandstones, as exposed along the D. L. & W. R.R, occurs the highest fauna that has yet been found in Monroe and Pike counties. Above these shells no fossils were seen in the higher rocks, except undeterminable fragments of plants. The shells occur in some greenish, argillaceous shales, about one and one-half feet above red shales. at the northern end of the second railroad cut north of Henryville. Several good specimens of *Spirifera mesastrialis* Hall were found and one of *Leda diversa* Hall (?). *Spirifera mesastrialis* which is reported from the Hamilton of Schoharie county, New York,* is an abundant and well known species of the middle zone of the "Ithaca group" at Ithaca and is also found in the lower Chemung farther south in southern central New York† and northern Pennsylvania,‡ while *Leda diversa* is a Hamilton species of eastern and central New York. The fossils seem to indicate that these shales are hardly younger than the lower Chemung and they might be still older, since the specimens of *Spirifera mesastrialis* do not appear to be the variety which is found in the lower Chemung of southern New York; but on the contrary the form found in the older rocks of the Portage. The nearest correlation to the above is that of Professor Stevenson in his Vice-Presidential address before Section E of the American Association, in 1891, when he drew the line, separating the Catskill from the Chemung, between the Montrose sandstone above and the Montrose red shale below,§ which is at a part of the series not distant from the horizon in which the *Spiriferas* were collected above Henryville.

Above this horizon coarse, gray sandstones and shales alternate with reddish shales. A thick mass of the red shale is well exposed in the railroad cut just west of Oakland. The cut below Mt. Pocono shows coarse, gray sandstone with fragments of fossil plants, thin, bluish, argillaceous shales, breccia and red shales, while in places the coarse gray sandstone contains quartz pebbles and is probably near the horizon of Professsor White's Cherry Ridge conglomerate, about 500 feet below the top of the Catskill.‖ In general structure and lithologic appearance, these rocks are very similar to the typical Catskill of the Catskill Mountains.

On the summit of the Pocono plateau, about two and one-half miles north of Tobyhanna, is a massive conglomerate which is considered by Professor White as the Mt. Pleasant conglomerate at the base of the Pocono.¶

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* Geol. Surv N. Y., Palæontology. vol iv, Pt. I, p. 417.

† Bull. U S. Geol. Surv.. No 3, pp. 17. 22, 24.

‡ Proc. Am. Assoc. Adv. Science, vol. xxxiv, p. 231.

§ Am. Geol.. vol. ix. p. 14.

‖ G⁶, p. 78. foot note.

¶ G⁶, pp. 90, 329.

Conclusions.—As a result of this investigation no change is suggested for the Lower Devonian—the Canda-galli grit and Upper Helderberg (Corniferous limestone). In the Middle Devonian the Marcellus is generally clearly defined, except in the upper part where it changes rather gradually from the argillaceous to the more arenaceous shales of the overlying Hamilton stage. The Hamilton as mapped and defined consists mostly of rather coarse arenaceous shales and thin sandstones; but to these possibly should be added the calcareo-arenaceous zone (called Tully limestone) and the black, fossiliferous shales above (called Genesee). It is shown that the so-called Tully and Genesee stages do not agree with the New York formations in either lithologic or paleontologic characters. After the disappearance of the Tully limestone and Genesee black shale in central New York there is very little evidence of their reappearance in eastern New York. Therefore the correlation of the zones in Pennsylvania with these New York formations is considered as open to discussion. The Chemung series contains a modified Hamilton fauna similar to that in the lower Portage of central New York, after the disappearance of the Tully limestone and Genesee shale. Above this fauna are the Starucca sandstones, the New Milford red shales, the Delaware flags with *Orthonota* (?) *parvula*, and the Montrose shales in the upper part of which *Spirifera mesastrialis* and *Leda diversa* (?) occur. These fossils seem to indicate that up to this horizon this series of rocks may not be of later geologic age than the lower part of the Chemung stage. From the above statement the inability to indicate any sharp dividing line between the Catskill and Chemung series, or the Chemung and Portage stages, will be readily understood.

Acknowledgment is due to Mr. Charles D. Walcott, Chief Paleontologist of the U. S. Geological Survey, and to Professors H. S. Williams of Cornell University, I. C. White of West Virginia University, and Lester F. Ward of the U. S. Geological Survey for suggestions and advice in this work.

U. S. Geological Survey, May, 1892.

ART. XXIX.—*On the Cæsium-Mercuric Halides;* by H. L. WELLS.

It is to be expected that more complete series of double-halides can be made with cæsium than with the other alkali-metals, because it is the extreme member of the potassium group and the most electro-positive element known, and because cæsium double-salts in general are less soluble than the corresponding compounds of the other alkali-metals. A thorough study of these compounds seems desirable since very little work has been done in this direction, and therefore the present investigation of the cæsium-mercuric chlorides, bromides and iodides has been undertaken.

The following is a complete list of the previously described mercuric double-halides containing the alkali-metals and ammonium, as far as I have been able to find them:

Na_2HgCl_4
Rb_2HgCl_4
Cs_2HgCl_4
$(NH_4)_2HgBr_4$
K_2HgBr_4
Na_2HgI_4
K_2HgI_4
$(NH_4)_2HgCl_4 . H_2O$
$K_2HgCl_4 . H_2O$
$Rb_2HgCl_4 . 2H_2O$
$(NH_4)_2HgI_4 . 3H_2O$

NH_4HgCl_3
$RbHgCl_3$
$KHgBr_3$
$NH_4HgCl_3 . \frac{1}{2}H_2O$
$KHgCl_3 . H_2O$
$KHgBr_3 . H_2O$
$NaHgCl_3 . 1\frac{1}{2}H_2O$
$NH_4HgI_3 . 1\frac{1}{2}H_2O$
$KHgI_3 . 1\frac{1}{2}H_2O$

$RbHg_2Cl_5$
$KHg_2Cl_5 . 2H_2O$

$(NH_4)_2Hg_3Cl_8 . 4H_2O$

$(NH_4)_2Hg_9Cl_{20}$

The greater number of these arrange themselves into two types with varying water of crystallization or with none. There are two compounds of a third type, while the two remaining, more complicated salts, stand alone. The last two were described by Holmes.*

An effort has been made to make the examination of the cæsium-mercuric salts very complete, but it is not safe to say that every possible compound has been prepared, for negative results are uncertain. It will not be necessary to describe the unsuccessful experiments where mixtures or uncertain products were obtained. It is sufficient to say that other double-halides were repeatedly looked for in every direction, and every indication of a new salt was followed up until a homogeneous product was obtained and analyzed.

The following table gives a list of the salts that are to be described. One of them, Cs_2HgCl_4, has already been prepared by Godeffroy.†

I.	II.	III.
Cs_3HgCl_5	Cs_2HgCl_4	$CsHgCl_3$‡
Cs_3HgBr_5	Cs_2HgBr_4	$CsHgBr_3$‡
Cs_3HgI_5	Cs_2HgI_4	$CsHgI_3$
$Cs_3HgCl_3Br_2$	$Cs_2HgCl_2Br_2$	$CsHgClBr_2$‡
$Cs_3HgBr_3I_2$	$Cs_2HgBr_2I_2$‡	$CsHgBrI_2$
	$Cs_2HgCl_2I_2$	
IV.	V.	VI.
	$CsHg_2Cl_5$	$CsHg_5Cl_{11}$
	$CsHg_2Br_5$	
$Cs_2Hg_3I_8$	$CsHg_2I_5$	
	$CsHg_2ClBr_4$	$CsHg_5ClBr_{10}$

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* Chem. News, v, 351.

† Berichte, viii, 9.

‡ These compounds are dimorphous.

These salts confirm the composition of all the previously known alkaline-mercuric halides, as given in the preceding table, except the single compound $(NH_4)_2Hg_9Cl_{20}$. It is extremely probable, however, that the correct formula for this is $NH_4Hg_5Cl_{11}$, for Holmes obtained results slightly lower than his theory in his ammonium determinations, and it would be scarcely possible to distinguish between the two formulas by analysis, as will be seen from the following numbers:

	Calculated for $(NH_4)_2Hg_9Cl_{20}$.	Calculated for $NH_4Hg_5Cl_{11}$.	Differences.
Mercury	70·70	71·00	0·30
Ammonium	1·41	1·27	0·14

The differences between the amounts of mercury and cæsium for the corresponding formulas are 0·80 and 0·85, so that it is evident that the cæsium compound furnishes a far better means of determining the composition of the salts.

The first type, Cs_3HgHl_5, is a new one. These compounds are interesting as exceptions to Remsen's law concerning the composition of double-halides.*

The salt $Cs_2Hg_3I_8$, although standing alone among the cæsium compounds, is a very well characterized body, and the compound $(NH_4)_2Hg_3Cl_8 . 4H_2O$, made by Holmes, belongs to the same type.

The results of the work on the cæsium-mercuric salts fulfill the expectations concerning the value of cæsium as a means of studying alkaline double-halides, for all the previously discovered types have been made with this metal, and one besides that had never been discovered.

Preparation.

The compounds were made by dissolving mercuric halides in hot solutions of cæsium halides and cooling, or in some cases evaporating at ordinary temperatures, to crystallization. The relative amounts of the two halides and the dilution both have an important influence in determining the salt produced. In most cases dilution with water is equivalent to the addition of mercury, while concentration produces the same effect as the addition of a cæsium halide. It has been noticed, where more than one salt is deposited from a solution by cooling, that the salts with more mercuric halides are formed first. This shows that cooling a solution may be equivalent to the addition of cæsium.

There are only a few of the salts that can be recrystallized unchanged from water, most of them requiring the presence of an excess of cæsium halide, or in two or three cases mercuric

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* Am. Chem. Jour., xi, 296; xiv, 85.

halide, for their formation. Crystallization from water can therefore often be used for preparing one salt from another.

All the compounds were made with solutions of the normal salts without the use of acids. Some of them have been made with alcoholic solutions, but this solvent has not been found to possess any advantages except for preparing $CsHg_2I_5$.

Analytical Methods.

The salts were always carefully examined to be sure that they were not mixtures. Many mixed crops of crystals were obtained, but I am confident that the products analyzed were pure. The crystals for analysis were always quickly and thoroughly freed from the mother-liquor by pressing repeatedly between smooth filter-papers, and, at the same time, they were crushed to remove included liquid. During this drying process the substances were exposed to the air as little as possible to avoid any evaporation of the adhering liquid before its removal. After the products had been dried as thoroughly as possible in this way, they were usually exposed to the air for an hour or two to remove the last traces of moisture, but this was not done in a few cases where I wished to be certain that no easily-lost water of crystallization was present.

Portions of about one gram of substance were usually taken for analysis In no case was the analysis hampered from lack of material. The chlorides and bromides were readily dissolved in water, but it was necessary in analyzing the iodine compounds to dissolve them in water containing alcohol. Mercury was invariably determined as sulphide, the precipitate being collected, dried at 100° and weighed on an asbestos filter in a Gooch crucible. Cæsium was usually determined in the filtrate from the mercuric sulphide and was always weighed as sulphate. In this operation the excess of sulphuric acid was removed by ignition in a current of air containing ammonia, as suggested by Krüss for potassium sulphate. In some cases where cæsium alone was to be determined, the substance was weighed out directly into a platinum crucible, sulphuric acid was added, the excess of this and the mercury were removed by evaporation and heating and normal cæsium sulphate was weighed. The halogens were invariably determined in separate portions and were weighed as silver salts. In the cases where two were present, they were determined by heating the mixed silver halides to constant weight in chlorine.

The Double-chlorides.

These are all white in color and are permanent when exposed to the air. On recrystallizing from water all of them finally yield $CsHgCl_3$.

Cs_3HgCl_5 is made by dissolving a comparatively small quantity of mercuric chloride in a nearly saturated cæsium chloride solution. It is deposited on cooling, but the best crystals are obtained by spontaneous evaporation. If too much of the mercuric compound is added or if too much water is present, other double salts or mixed products will be obtained. On the other hand, if too little mercuric chloride is present, cæsium chloride crystallizes out. The limits of the conditions under which it is formed are narrow, but by repeated trials, with slight variations suggested by previous results, a pure product is readily obtained. It forms slender, radiating prisms which are easily distinguished from the compounds with which it is liable to be mixed.

The following analysis was made of a sample which was rapidly dried on paper, but not air-dried. The small amount of water found was probably simply moisture. It was determined by direct weighing in a calcium-chloride tube.

	Found.	Calculated for Cs_3HgCl_5.
Cæsium	51·15	51·38
Mercury	24·84	25·76
Chlorine	21·79	22·86
Water	1·69	0·00
	99·47	100·00

Cs_2HgCl_4 is produced, by cooling a hot solution, when a little more mercuric chloride or water is used than in the case of the last salt. The conditions for its formation are narrow. It forms large but usually very thin plates which are readily distinguished from the other double-chlorides. A sample was dried on paper for analysis.

	Found.	Calculated for Cs_2HgCl_4.
Cæsium	44·06	43·75
Mercury	----	32·90
Chlorine	22·87	23·35
Water	0·52	0·00
		100·00

$CsHgCl_3$ is dimorphous, forming, according to circumstances, cubic or orthorhombic crystals. The cubic form is produced, under widely varying conditions by cooling dilute aqueous solutions, when cæsium chloride is considerably in excess. The orthorhombic form is deposited when cæsium chloride is not in great excess and by one or more recrystallizations from water of all the double chlorides. This form can be recrystallized from water indefinitely.

The compound is practically insoluble in absolute alcohol, but it dissolves in alcohol diluted with about one-third of its volume of water, and it is remarkable that the *cubic form* is deposited from such a solution on cooling.

The cubes often form peculiar aggregates, apparently of a pyramidal shape. The orthorhombic crystals are very brilliant and highly modified, usually forming groups of spear-shaped individuals joined end to end.

Three samples were analyzed; A, cubes simply dried on paper; B, cubes from alcohol; C, orthorhombic crystals, air-dry.

	Found.			Calculated for $CsHgCl_3$
	A	B	C	
Cæsium	30·29	30·26	29·92	30·26
Mercury	44·80	....	45·63	45·51
Chlorine	23·40	....	24·03	24·23
Water	1.42	....	....	0·00
	99·91		99·58	100·00

Since the orthorhombic form of this compound is not decomposed by water its solubility could be determined. This was done by analyzing the mother-liquor from a third recrystallization at about 17°. Of this solution, 100 parts contained 0·4255 parts of cæsium, corresponding to 1·406 parts of $CsHgCl_3$.

$CsHg_2Cl_5$ was made by dissolving 24 g. of $CsHgCl_3$ and 16 g. of $HgCl_2$ (a little more than one molecule of the latter) in about 150 c. c. of hot water and cooling. A large crop of needles was obtained which were undoubtedly homogeneous.

	Analysis gave.	Calculated for $CsHg_2Cl_5$.
Cæsium	18·13	18·72
Mercury	56·32	56·30
Chlorine	24·68	24·98
	99·13	100·00

The salt is not very readily decomposed by water, but by repeated recrystallization the orthorhombic form of $CsHgCl_3$ is obtained.

$CsHg_5Cl_{11}$ was prepared by making a nearly saturated solution of 12·5 g. of $HgCsCl_3$ and 38·5 g. of $HgCl_2$ (about one molecule of CsCl to six of $HgCl_2$) in boiling water and cooling. The compound was obtained in prisms, so well formed

that there was no doubt about their homogeneity. Two crops were analyzed.

	Found.		Calculated for $CsHg_5Cl_{11}$.
Cæsium	8·68	8·51	8·73
Mercury	65·59	----	65·64
Chlorine	24·97	----	25.63
	99·24		100·00

A single recrystallization of this salt from water gave a mixed crop of crystals and this, on repeating the operation, gave $CsHg_2Cl_5$ still containing a little of the original compound. This last crop was analyzed.

	Found.	Calculated for $CsHg_2Cl_5$.
Cæsium	15·57	18·72

The Double Bromides.

All of these salts are white, or nearly so, except $CsHgBr_3$ which has a lemon-yellow color. This color is remarkable since CsBr and $HgBr_2$ are both pure white.

All of the double bromides yield $CsHg_2Br_5$ on recrystallizing them one or more times from water. It is to be noticed that this salt belongs to a different type from the double-chloride which is stable with water, but if alcohol is used for recrystallizing this bromide, the salt corresponding to the chloride just mentioned is deposited.

Cs_3HgBr_5.—The preparation of this salt is exactly analogous to that of the corresponding chloride, and it has the same appearance.

	Found.	Calculated for Cs_3HgBr_5.
Cæsium	39·83	39·94
Mercury	19·50	20.02
Bromine	39·60	40·04
	98·93	100·00

Cs_2HgBr_4 is prepared similarly to the chloride, but the limits of the conditions under which it is formed are much wider. Like the chloride it usually forms very thin plates, but they can sometimes be produced of sufficient thickness for measurement. Three separate crops, made under considerably different conditions were analyzed.

	Found			Calculated for Cs_2HgBr_4.
Cæsium	33·84	34·43	33·69	33.84
Mercury	25·68	25·11	25·45	25·45
Bromine	40·48	40·40	40·52	40.71
	100·00	99·94	99·66	100·00

$CsHgBr_3$.—This compound is dimorphous, but while one form is cubic, like one of the chlorides, the other is monoclinic and has no apparent relation to the orthorhombic chloride. Just as in the case of the chlorides, the cubic form is produced when an excess of the cæsium halide is present, while the second form is deposited when this excess is not as great. Unlike the corresponding chloride, the second form of the bromide is decomposed by recrystallization from water, the salt $CsHg_2Br_5$ being formed, but, as will be noticed beyond, the opposite transformation can be produced by recrystallizing the last mentioned salt from alcohol. The limits of formation of the cubic salt are wide, but it is difficult to produce the other form in a pure state, and it is possible that the monoclinic crystals analyzed were mixed with a small quantity of the cubes.

	Found		Calculated for
	Cubic.	Monoclinic.	$CsHgBr_9$.
Cæsium	23·18	22·89	23·21
Mercury	34·95	35·54	34.90
Bromine	41·70	41·63	41·89
	99·83	100·06	100·00

$CsHg_2Br_5$.—The recrystallization of any of the other double-bromides from water produces this salt, and it can be recrystallized indefinitely without decomposition. It forms very small, thin plates which have a very faint tinge of yellow. By spontaneous evaporation of a mother-liquor from a recrystallization of this salt somewhat larger crystals were formed. Three separate crops were analyzed.

	Found.			Calculated for $CsHg_2Br_5$.
Cæsium	14·60	14·69	13·24	14·26
Mercury	42·71	----	----	42·87
Bromine	42·55	----	----	42.87
	99·86			100.00

The mother-liquor from a third recrystallization from water at about 16° was found to contain 0·1151 per cent of cæsium, corresponding to solubility of 0·807 parts of $CsHg_2Br_5$ in 100 parts of the solution. The salt dissolves rather sparingly in hot, strong alcohol and, on cooling this solution, the compound $CsHgBr_3$ separates out.

	Found.	Calculated for $CsHgBr_3$.
Cæsium	22·68	23·21

The crystals thus obtained were not large enough to measure, but it was probable, from microscopic examination, that they were the monoclinic form of this compound. This is interesting from the fact that it is the cubic form of $CsHgCl_3$ which crystallizes from alcoholic solutions.

No satisfactory crops of crystals were obtained from solutions made with $CsHg_2Cl_5$ and $HgBr_2$ together.

The Double Iodides.

These salts are all yellow, $CsHg_2I_5$ and $Cs_2Hg_3I_8$ having a color nearly like that of normal potassium chromate, while the others become paler as the cæsium chloride increases. All of them are decomposed by water, forming compounds containing more mercuric iodide than the original salt, or, at last, mercuric iodide itself. It is therefore possible to take any one of these double-salts, and, by recrystallizing from water and evaporating the resulting solutions, to prepare the complete series of five double-iodides, as well as the component simple iodides, without the use of any new material. It is noticeable that the iodides differ from the chlorides and bromides in not including a salt that can be recrystallized continually from water. This peculiarity is doubtless due to the comparative insolubility of mercuric iodide. In most cases, the analyses of the salts containing iodine show an excess of mercury and a deficiency of the halogen (or halogens). It is not known whether this was due to some impurity in the salts or to analytical errors. It is not considered probable that inaccuracies in the analyses could have caused so much variation from theory, for the methods used were the same as for the chlorides and bromides, except that alcohol was used as a solvent, and, while halogens and mercury were always determined in separate portions, the summations of the analyses were usually satisfactory.

Cs_3HgI_5.—This salt, like the corresponding chloride and bromide, requires for its preparation a very concentrated solution of the cæsium halide containing a relatively small amount of the mercuric compound. It crystallizes well and may be obtained either by cooling or spontaneous evaporation. The crystals form peculiar, steep pyramids.

	Found.	Calculated for Cs_3HgI_5.
Cæsium	33·02	32·33
Mercury	16·33	16·21
Iodine	50·42	51·46
	99·77	100·00

Its specific gravity taken in benzol was found to be 4·605.

When this salt is dissolved in a small quantity of hot water the compound Cs_2HgI_4 crystallizes out on cooling, but with a larger quantity of water everything remains in solution.

Cs_2HgI_4.—This salt is produced under wide limits of conditions by cooling solutions of the component salts when cæsium iodide is in excess. The monoclinic crystals vary in habit, forming long prisms, nearly square plates or intermediate forms. They are often obtained of very large size, sometimes extending completely across the bottom of the vessel containing the solution and turning upwards at the ends besides.

	Found.		Calculated for Cs_2HgI_4.
Cæsium	27·32	27·39	27·31
Mercury	21·57	21·21	20·53
Iodine	51·41	51·49	52·16
	100·30	100·09	100·00

Two determinations of the specific gravity, taken in benzol, gave the numbers 4·799 and 4·812.

The salt is decomposed by water, giving, according to the quantity used, either one of the salts containing more mercuric iodide or mercuric iodide itself. It is not dissolved or decomposed by alcohol.

$CsHgI_3$ (. H_2O ?).—This salt is formed only within very narrow limits from solutions containing a little more mercuric iodide or water than those from which the preceding salt is obtained. These conditions are perhaps most easily reached by dissolving the last salt in a small amount of hot water and cooling. It often happens that the three salts $Cs_2Hg_3I_8$, $CsHgI_3$ and Cs_2HgI_4 are successively deposited as a solution cools, and it is consequently difficult to obtain the salt under consideration in a pure state, but this was accomplished after a great many trials with varying conditions. The compound forms very thin transparent plates which usually radiate from a point and are often of large size. By pressing on paper they rapidly become opaque. Whether this is caused by molecular re arrangement or loss of water of crystallization is not certain, for, on account of the extreme thinness of the crystals, it was impossible to decide whether a small amount of moisture or a molecule of very unstable water of crystallization was present. Two samples were analyzed. A was air-dried after pressing on paper; B was quickly dried on paper.

	Found. A.	Calculated for $CsHgI_3$.	Found. B.	Calculated for $CsHgI_3 . H_2O$.
Cæsium ----	18·81	18·63	18·25	18·17
Mercury ----	29·29	28·01	28·74	27·33
Iodine -----	51·50	53·36	50·98	52·05
Water -----	----	0·00	2.51*	2·45
	99·60	100·00	100·48	100·00

Like all the other iodides, this salt is decomposed by water.

$Cs_2Hg_3I_8$ is formed under widely different conditions. It is most convenient to prepare it by dissolving Cs_2HgI_4 in the proper amount of hot water and cooling. It is also formed, in a finely divided condition, by treating the same salt with not too much cold water. The crystals vary considerably in habit, but they can be readily distinguished from the other iodides. A characteristic form is a triangular plate, but plates of different shape and more or less elongated prisms often occur. The following analyses were made of separate crops. Sample C was made by treating Cs_2HgI_4 with cold water.

	Found.				Calculated for $Cs_2Hg_3I_8$.
	A.		B.	C.	
Cæsium ------	13·89	----	14·14	14·07	14·13
Mercury -----	33·76	----	...	33·83	31·88
Iodine -------	52·07	52·10	52·63	52·96	53·99
	99·72			100·86	100·00

Specific gravity, taken in benzol, 5·14. The salt dissolves in alcohol. It is decomposed by water with the separation of a part of the mercuric iodide. From the solution thus obtained, the salts containing less mercuric iodide can be prepared by evaporation.

$CsHg_2I_5$.—When a hot aqueous solution of cæsium iodide is saturated with mercuric iodide, this compound is formed on cooling, but, under these conditions, the substance is usually mixed with HgI_2 and often with $Cs_2Hg_3I_8$. When weak alcohol is used as a solvent, however, a pure product is obtained without difficulty. It forms slender yellow prisms which become red on standing in an aqueous mother-liquor. They are more permanent in the solution when it is alcoholic, but, on drying them by pressing on paper, they quickly assume the

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* By loss at 100°.

red color of of mercuric iodide without losing their form. It is probable that the spontaneous decomposition results in the formation of $Cs_3Hg_2I_8$ and HgI_2. It was necessary to analyze the material which had become red.

	Found.	Calculated for $CsHg_2I_5$.
Cæsium	11·47	11·39
Mercury	35·73	34·25
Iodine	52·93	54·36
	100·13	100·00

The Mixed Double-halides.

A great deal of labor has been devoted to a study of these compounds in order to find to what extent they could be prepared. The results show that cæsium chloride and mercuric bromide unite readily although there is a tendency towards an exchange of halogens and the formation of unmixed salts. It is also noteworthy that, while there is a double chloride as well as a double bromide which is not decomposed by recrystallization from water, all the chloro-bromides finally yield mercuric bromide when so treated.

The number of bromo-iodides is less than that of the unmixed salts, for, when attempts are made to prepare compounds containing the larger amounts of mercuric iodide, there is an exchange of halogens and almost pure double iodides are produced.

Only one compound of mercuric iodide with cæsium chloride could be prepared. This is $Cs_2HgCl_2I_2$, and the type to which it belongs may probably be considered, on this account, the most stable one of the cæsium-mercuric halides.

It is evident that the mixed salts are not as readily formed as the unmixed, and that the more dissimilar the two halogens are, the less tendency there is to form the mixed compounds.*

In preparing these salts, containing two different halogens, the halogen of higher atomic weight was always added in combination with the mercury. The methods of preparation are exactly analogous to those by which the unmixed salts are made, so that most of these details will be omitted in describing them.

The Chloro-bromides.

In form these all resemble the unmixed salts between which they are intermediate, and all of them are colorless except $CsHgClBr_2$, which is pale yellow.

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* This point is discussed in connection with the cæsium trihalides. (Wells and Penfield, this Journal, III, xliii, pp. 31 and 32.)

$Cs_3HgCl_3Br_2$.—

	Found.	Calculated for $Cs_3HgCl_3Br_2$.
Cæsium	48·12	46·10
Mercury	23·80	23·11
Chlorine	16·24	12·30
Bromine	11·82	18·49
	99 98	100·00

The product was made with a very large excess of cæsium chloride, and it contained a considerable amount of the double chloride. The analysis corresponds nearly to the formula $2Cs_3HgCl_3Br_2+Cs_3HgCl_5$.

$Cs_2HgCl_2Br_2$.—Two products, which were made under different conditions, were analyzed.

	Found.		Calculated for $Cs_2HgCl_2Br_2$.
Cæsium	40·34	38·86	38·16
Mercury	28·79	28·58	28·69
Chlorine	12·94	10·48	10·19
Bromine	17·43	22·07	22·96
	99·50	99·99	100 00

One of these crops corresponds very closely to the formula, while the other, made in the presence of a greater excess of cæsium chloride, contains a little Cs_2HgCl_4.

$CsHgClBr_2$.—This has been obtained, like the chloride and bromide, in dimorphous forms. One of these is cubic like the other salts, while the second form crystallizes like the chloride and not like the bromide. The color of both varieties is pale yellow.

	Found.				
		Orthorhombic form.			
	Cubic form.	Separate products.			Calculated for $CsHgClBr_2$.
Cæsium	26·50	26·97	26·74	26·01	25·17
Mercury	38·75	40·21	40·05	38·91	37·84
Chlorine	9·23	11·32	11·42	8·53	6·72
Bromine	25·21	21·63	21·94	26·65	30·27
	99·69	100·13	100·15	100·10	100·00

These products evidently contain some of the chloride. The analyses of the first two samples of the orthorhombic salt correspond closely to the formula, $2CsHgClBr_2+CsHgCl_3$.

$CsHg_2ClBr_4$.—Two separate products, made under different conditions, were analyzed.

	Found.		Calculated for $CsHg_2ClBr_4$.
Cæsium	15·48	15·23	14·97
Mercury	45·72	45·06	45·02
Chlorine	5·75	3·71	3·99
Bromine	32·30	36·06	36·02
	99·25	100·06	100·00

$CsHg_5ClBr_{10}$.—This compound was prepared by recrystallizing the preceding salt from water.

	Found.	Calculated for $CsHg_5ClBr_{10}$.
Cæsium	6·23	6·76
Mercury	52·77	50·80
Chlorine	2·85	1·80
Bromine	38·19	40·64
	100·04	100·00

There is a chloride corresponding to this compound, but no bromide was obtained of this type. It forms elongated crystals much smaller than the chloride. The final product, when this salt is recrystallized from water, is mercuric bromide.

The Bromo-iodides.

Only three of these compounds have been prepared. When attempts were made to obtain compounds containing larger amounts of mercuric iodide, there was an interchange of halogens and nearly pure double iodides were formed. Two such products were analyzed.

	Found.	Calculated for $Cs_2Hg_3I_8$.	Found.	Calculated for $CsHg_2I_5$.
Cæsium	14·69	14·13	11·62	11·39
Mercury	33·72	31·88	36·09	34·25
Bromine	2·19	0·00	2·43	0·00
Iodine	49·58	53·99	49·45	54·36
	100·18	100·00	99·59	100·00

$Cs_3HgBr_3I_2$.—This salt resembles the iodide, not the bromide, in form. Its color is a pale yellow, intermediate between the brighter iodide and the colorless bromide.

	Found.	Calculated for $Cs_3HgBr_3I_2$.
Cæsium	37·21	36·50
Mercury	19·39	18·30
Bromide	25·18	21·96
Iodine	18·24	23·24
	100·02	100·00

$Cs_2HgBr_2I_2$.—This compound has a very faint tinge of yellow. It is apparently dimorphous, although no other salt of this type has been made in more than one form. It occurs in very thin plates, like the chloride, bromide and chlorobromide, and in stout monoclinic crystals like the iodide. The limits of the conditions under which the plates are made are very narrow, and it is difficult to obtain them free from the dimorphous crystals. As the solution cools, however, the plates are deposited first, and, with the proper dilution, it is possible to remove them and get the mother-liquor pressed out with paper before the other crystals begin to form. There is no difficulty in preparing the other modification of the compound.

	Found.		Calculated for
	Thin plates.	Orthorhombic crystals.	$Cs_2HgBr_2I_2$.
Cæsium	30·71	30·20	30·23
Mercury	24·14	23·86	22·73
Bromine	21·05	17·91	18·18
Iodine	24·23	28·50	28·86
	100·13	100·47	100·00

It is noticable that the plates, which resemble the bromide in form, contain a small excess of bromine and a corresponding deficiency of iodine.

$CsHgBrI_2$.—Only one form of this compound has been prepared, although three other salts of this type are dimorphous. Its form is monoclinic, like one modification of the bromide, and it is pale yellow in color.

	Found.	Calculated for $CsHgBrI_2$.
Cæsium	20·26	19·94
Mercury	31·44	29·99
Bromine	13·35	11·99
Iodine	34·39	38·08
	99·44	100·00

The Chloro-iodide, $Cs_2Hg\,Cl_2I_2$.

This is the only combination of cæsium chloride and mercuric iodide that could be produced. It is formed only in very concentrated solutions containing a great excess of cæsium chloride. Its form is different from any other salt of the type, for it occurs in slender, radiating needles. It is snow-white in color, and when it is brought in contact with water it instantly becomes bright red from the formation of mercuric iodide. Two entirely separate crops were analyzed

	Found.		Calculated for $CsHgCl_2I_2$.
Cæsium	33·38	33·14	33·63
Mercury	26·71	----	25·28
Chlorine	8·87	9·01	8·98
Iodine	30·85	30·17	32·11
	99·81		100·00

When it was attempted to make a chloro-iodide containing more mercuric iodide than this, a nearly pure double-iodide was formed by exchange of halogens.

	Found.	Calculated for $Cs_2Hg_3I_8$.
Cæsium	13·76	14·13
Mercury	33·49	31·88
Chlorine	0·16	0·00
Iodine	50·74	53·99
	98·15	100·00

The investigation of double-halides will be continued in this laboratory, and it is hoped that a further study of the cæsium salts will lead to a better knowledge of this class of compounds in general than we now possess.

In conclusion, it gives me pleasure to express my gratitude to my colleague, Professor Penfield, for his hearty coöperation in undertaking the crystallographic examination of the compounds which have been described. His results have been freely used in the foregoing descriptions, and they will be given in detail in a future article.

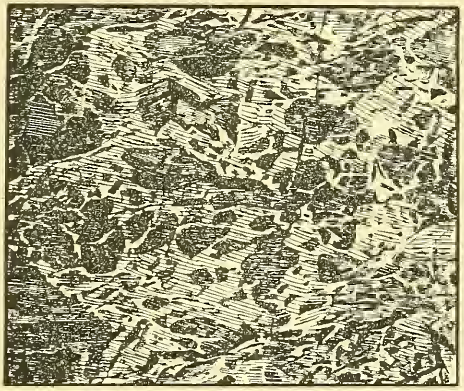
Sheffield Scientific School, New Haven,
Conn., May, 1892.

Art. XXX.—*On the relations of the Laurentian and Huronian on the North Side of Lake Huron*; by Alfred E. Barlow.

[Published by permission of Dr. Selwyn, Director, Geological Survey of Canada.]

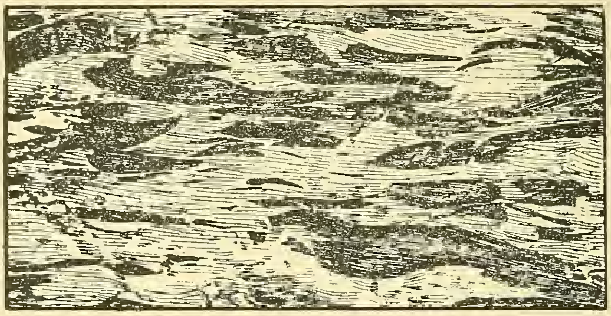
In this Journal for March, 1892, there appears an article on "The Structural Relations of the Huronian and Basement Complex on the North side of Lake Huron" by Messrs. Pumpelly and Van Hise. On page 228 they refer to an article by me "On the Contact between the Laurentian and Huronian north of Lake Huron" which was published in the American Geologist (vol. vi, 1890, pp. 19–32). The region to which my paper referred might better have been defined as north-east rather than north, as the descriptions related only to certain portions of the line of junction between Lakes Temiscaming and Panache, the latter locality being over one hundred miles east of Thessalon, near which Messrs. Pumpelly and Van Hise observed the contact. The endeavor to correlate two series of facts concerning rocks so far separated geographically after a brief and hurried visit and over a limited area has only led to more confusion and misunderstanding. Their description of the line of junction between the granite and crystalline schists is a feature very frequently observed in the Laurentian (or basement complex). These schists, however, do not in the least resemble the micaceous schists and quartzites described by me as Huronian in contact with the Laurentian gneiss, for those described by Pumpelly and Van Hise show no clastic structure whatever and seem always to belong to the basement complex (Laurentian) with which they are associated, while the fragmental origin of those described by me may readily be seen in the field or in thin slice under the microscope. Beautiful examples of the mode of occurrence of the Laurentian schists may be seen at the Murray Mine, on the main line of the Canadian Pacific Railway, three miles and a half northwest of Sudbury. Here the hornblende schists or amphibolites are seen embedded in a light colored gneissic granite, the pseudo-conglomeratic appearance thus produced being sometimes very marked. (See Fig. 1). In other cases the hornblende schists occur in lenticular patches lying parallel to one another. (See Fig. 2.) Prof. G. H. Williams (see Report Geological Survey of Canada, Part F, 1891, p. 73) classes these amphibolites among the undoubted eruptives and thus describes them: "A fine grained, very dark green or nearly black foliated rock containing a much coarser felspathic or granitic vein. This is a closely interwoven aggregate of

Fig. 1.



green hornblende and brown biotite. The foliation is produced by the approximate parallelism in the cleavage directions of the minerals. The only other constituents visible under the microscope are quartz and ilmenite surrounded by veins of sphene (leucoxene). Of the origin of this rock we can say nothing now with certainty. It may well have resulted from the extreme metamorphism of some basic eruptive, but from a small specimen like this it is unsafe to draw any such conclusion. The feldspathic vein is a much coarser aggregate of quartz, orthoclase and plagioclase with a little green hornblende. The feldspar has many minute hornblende needles secondarily developed in it, but otherwise the rock appears like a fresh granite."

Fig. 2.



The eruptive origin assigned to this rock by Prof. Williams would seem to agree with its relations in the field and on account of its intimate association with granitoid gneisses we have classed it with the Laurentian and so colored it on the recent maps issued by the Canadian Survey of the Sudbury Mining District. These gentlemen also make me state that I "drew the conclusion that nowhere on the north shore of Lake Huron are any detritals which are later than and rest unconformably upon the basement complex," when in the article is distinctly described (see p. 37, American Geölogist, Vol. VI, 1890) a thinly bedded slate conglomerate resting upon the upturned edges of the Laurentian gneiss on Annima-Nipissing Lake.

Briefly then, the Huronian System may be regarded as the oldest series of sedimentary strata of which we have at present any knowledge in this district, while the Laurentian gneiss or basement complex is the original crust of the earth or the firm floor on which the first sediments were laid down. The composition of this floor, judging from the overlying strata, would be closely analogous to granite and the laminated pebbles in the slate conglomerates indicates that this basement had in many places a foliated or gneissic structure. The immense pressure exerted by the overlying stratiform material, and the crumpling folding and fracturing of the comparatively thin and weak crust consequent on the earth's cooling would all tend to sink large portions of the Huronian below the line of fusion, the submergence of which would produce conditions of contact such as I have described to the north-east of Lake Huron and which subsequent upheaval and denudation have exposed.

At other places the basement complex may have remained undisturbed so that the overlying detritals though somewhat altered have not been intruded or pierced by the granitic mass beneath. The latter doubtless have been the conditions which obtained in the localities visited by Messrs. Pumpelly and Van Hise north of Lake Huron and by me on Annima-Nipissing Lake. The explorations of the past two seasons have served to confirm the opinions expressed in the paper published in the American Geologist and as the region then under examination has just been finished, I hope to move farther west during the coming summer and explore the district visited by these geologists.

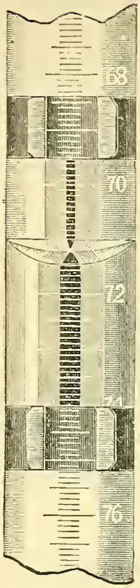
Before closing I would like to take exception to the various brief visits paid to certain so-called "typical localities," as the hurried examinations thus made must always lead to confusion. Had Messrs. Pumpelly and Van Hise written to me I would have been only too eager to accompany them to the many points of geological interest exhibited in this district. It is often so easy then to reconcile seemingly opposite views, whereas a letter in reply, no matter how written, only leads to endless and sometimes useless discussion.

ART. XXXI.—*Some Convenient Forms of Laboratory Apparatus;* by F. A. GOOCH.

[Contributions from the Kent Chemical Laboratory of Yale College—XVI.]

Burette Clip.—A simple and effective device to replace the Erdmann float (which has well-known disadvantages) in getting exact burette readings is made by cutting thin springy brass, or copper, or other metal to the form of a letter **H**, shaping it as shown in fig. 1 so that it will cling to a burette with the cross-bar vertical, and fastening to the cross-bar a fold of white paper ruled longitudinally with a heavy, sharply defined, dark line. The clip may be made to hold firmly to any burette, while capable of easy upward and downward motion, and is

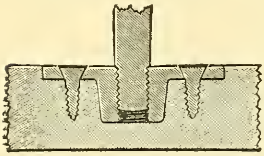
1.



readily removable and replaceable when it becomes necessary to pass the point of support of the burette. The refractive action of the meniscus upon the dark line upon the white background acts just as in the enamelled burettes which have recently come into use, and serves to define exactly the level of the liquid. Errors of parallax in observing are easily avoided by placing the eye in such position before reading that the front segment of the circle nearly completed by the edge of the upper ring falls into coincidence in perspective with the back segment as shown in the figure.

Apparatus support.—The simple device illustrated in fig. 2 and fig. 3 has been in use for several years in this laboratory wherever a rod support is desirable and has almost entirely replaced the movable stand which students usually find unwieldy and difficult to dispose of in limited space. The brass fitting into which is cut a strong screw thread, as shown in fig. 2, is set directly in the face of the work table with its upper surface flush with that of the table, and is held in place firmly by screws if the table-top is of wood, or by bolts and nuts if the table-top is of soapstone or other material which does not afford holding ground for ordinary screws. Iron rods of sizes and lengths suited to holding all sorts of apparatus, from the lighter forms used in elementary laboratory instruction to the heavier lecture apparatus, are cut with screws matching the thread of the brass fitting and may be set firmly in place as shown in the figures. The rods are of course interchangeable as occasion may require. When stripped of apparatus the rod takes up very little table space, but if a clear table is desired, it is easy to remove the rod by means of tongs kept at hand for the purpose in the laboratory tool-box. This device is neat, inexpensive, and easily made by any worker in brass and iron.

2



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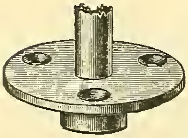
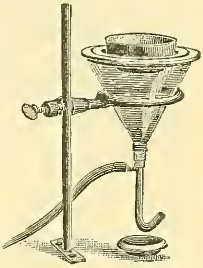


Steam evaporator.—A convenient, simple and inexpensive form of individual steam-bowl is easily constructed in the form shown in fig. 4 wherever steam connections are available. An ordinary glass funnel of suitable size is hung in an iron ring, for holding which the rod support previously described serves admirably. The stem of the funnel is cut off short and a T-tube is attached as shown, set in a short piece of rubber tubing, with the lower end of the vertical branch bent to make a water-trap, while the horizontal branch is connected with the steam supply. A pipe to convey away the condensed water which overflows from the trap is a convenience, but in the absence of a drip-pipe any suitable receptacle may serve a similar purpose. Ordinary water-bath rings adapt the funnel to vessels of various sizes, but the funnel itself serves efficiently in holding several different sizes of round-bottomed dishes. The transparency of the funnel makes it possible to regulate the steam supply so as to secure the maximum heating effect without saturating the surrounding atmosphere with waste steam. Of course, if it is desirable, several of these steam-baths may be hung to the same rod.

4.



Mercury washer.—Various forms of mercury-washing machines have been proposed and used with success. The particular form here described and shown in fig. 5, differs essentially from its predecessors only in the degree of fineness to which the impure mercury is reduced when it is brought into contact with the purifying medium. In this apparatus the impure mercury, liquid enough to flow readily, runs of its own weight from the uppermost funnel through the supply arm of a glass atomizer through the other arm of which compressed air is admitted in force sufficient to break the thin stream of mercury to fine dust. Thus thoroughly comminuted, and presenting the maximum surface to the liquid, the mercury falls into dilute nitric acid, from which it passes to distilled water, and thence to the dry receiver. Funnels fitted with outlet tubes set in rubber stoppers, as shown in the figure answer well for containing vessels, and the rod and socket device described above serves as a support for the apparatus. In the case of the particular apparatus which I have used

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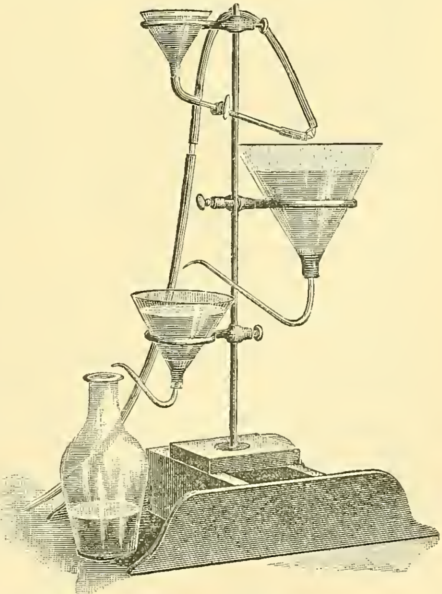

the air was admitted to the atomizer under a pressure of about one-third of an atmosphere above the ordinary.

Certain experiments made to determine whether ferric chloride or chromic acid might be used in the purifier instead of dilute nitric acid showed that the superficial effect of these reagents upon the extremely finely comminuted mercury prevents the reunion of the particles even when submitted to considerable pressure. When dilute nitric acid is employed no such difficulty arises.

ART. XXXII.—*Note on the change of electric conductivity observed in rock magmas of different composition on passing from liquid to solid;* by CARL BARUS and JOSEPH P. IDDINGS.

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§ 1. *Introduction.*—The chemical composition of rock magmas and the process and results of their crystallization and solidification have been studied with more or less thoroughness; but direct investigation of their physical properties has not been systematically undertaken until recently.

Conceptions of the physical nature of molten rock magmas, however, have been obtained by observing the phenomena of their crystallization, and by pointing out analogies between the latter and the behavior of aqueous solutions, and of metallic alloys.

Evidences that a chemico-physical differentiation of molten magmas was the cause of chemical differences in igneous rocks, which evidences have been reviewed by one of us in a paper on the origin of such rocks,* have led to the further analogy between this process of differentiation and the concentration and partial dissociation of salts in aqueous solution. They also suggested the possibility of testing the fact of dissociation by electrolytic investigation.

The method employed was the determination of the electric resistance encountered by a current in passing through fused rock magma, whose temperature was gradually lowered. The investigation, though of a preliminary character has been productive of such definite results that we have embodied them in the present paper in order that they may become known as early as possible.

§ 2. *Observations.*—The following table contains typical ex-

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*J. P. Iddings. The origin of igneous rocks, Bull. Phil. Soc. Washington, 8°. Washington, 1892, vol. xii, pp. 89–214.

amples of sixteen series of electric measurements made with three kinds of rock magmas, which cooled slowly in a furnace from the molten state. Temperatures* and resistances were noted simultaneously every two minutes during each series. The resistances were measured by Kohlrausch's method of intermittent currents. The data for mean temperatures are closely accordant, but at very high temperatures and at low temperature sharpness is lost, owing to polarization and to the immense range of electrolytic resistances encountered. These difficulties are largely unavoidable, although our method is capable of much improvement. Reductions to absolute values are approximate.

TABLE I.

Table 1. The specific electrolytic resistances of rock magmas, varying with temperature and composition.

1. Acid magma. 75·50 per cent SiO_2.			2. Intermediate magma. 61·5 per cent SiO_2.			3. Basic magma. 48·5 per cent SiO_2.		
Series.	Temperature.	Resistance.	Series.	Temperature.	Resistance.	Series.	Temperature.	Resistance.
xiv	°C	ohms × 10^6	xiii	°C	ohms × 10^6	viii	°C	ohms × 10^6
	1640	1·8		1430	1·8		1400	2·9
	1320	2·2		1260	2·5		1230	4·4
	1164	2·9		1114	4·2		1124	5·4
	1086	3·1		1034	6·3		1050	14·7
	1011	3·8		956	8·8		995	27·8
	948	4·7		894	13·4		939	54·7
	890	6·5		843	20·0		883	94·0
	827	8·0		754	46·4		834	152
	787	11·6		715	70·2		792	227
	746	15·3		680	105		754	321
	705	21·6		643	158		723	432
	665	29·5		608	239		692	602
	626	41·3		580	344		645	1000
	598	53·8		552	497		612	1400
	582	64·2		496	1140			
	560	82·2						
	533	114						
	504	166						
	467	281						
	444	417						
	425	584						
	395	1060						
	355	2540						
	320	5700						

The results of these observations have been plotted as in the diagram, fig. 1, the ordinates being specific resistances in

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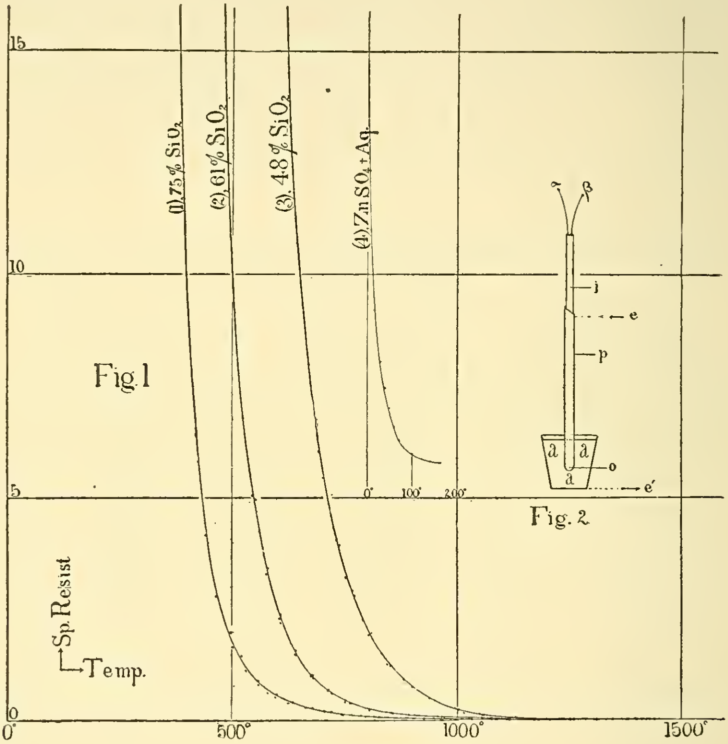
* Regarding temperature measurements see Phil. Mag., July, p. 1, 1892.

megohms, the abscissæ temperatures in °C. The curves (which, as shown, contain *all* our observations) are numbered (1), (2), (3), as in Table I, relatively to the magmas. Between 1000° and 1500° the points lie so near the axis, that a discrimination is no longer possible. This can be done, however, by expressing the variations of conductivity with temperature for the interval. It is here omitted because it leads to no novelties. The corresponding curve for a concentrated solution of



Legends.

Fig. 1. Chart showing the relation of the specific electrolytic resistance (megohms, *cc*) to Temperature (°C), in case of
(1) An acid magma,
(2) An intermediate magma,
(3) A basic magma.
(4) Zinc sulphate, concentrated aqueous solution. Resistance relative.

Fig. 2. Crucible and appurtenances with the furnace withdrawn:
aaa, rock magma in platinum crucible;
p, tubular platinum electrode;
i, insulator (fire clay) of the thermocouple;
αβ, thermocouple with its junction at *o*:
ee′, electrolytic current (intermittent).

zinc sulphate in water has been added for comparison. Here the ordinates are ratios in terms of the resistance of the solution at 100°. Points above 100° were obtained under pressure. Fig. 2 explains itself.

A series of observations with another basic magma gave corroborative evidence. The only electrical indication of fusion was found in the case of the basalt (3). It was somewhat above 1100°, but is not certain. The rhyolitic or acid magma (1) changes character suddenly below 500°, for reasons probably accidental which must be further examined. In this rock, which is very viscous even at 1600°, it is almost impossible to free the magma of gas bubbles. We have not been able to make allowance for volume expansion of the magma, and the residual errors are in keeping with this omission. Finally, without sacrificing accuracy of temperature measurement, it is difficult to make the electrodes sufficiently large in area to exclude polarization.

§ 3. *The magmas.*—The magmas investigated represent three phases of igneous rocks from the same region. The first is a rhyolite; the second, a crystalline andesite or porphyrite; and the third, a basalt. The chemical composition of the rocks is shown by the following analyses made by Mr. J. E. Whitfield.

	I.	II.	III.
SiO_2	75.50	61·50	48·49
TiO_2	none	none	2·19
Al_2O_3	13·25	17·42	18.35
Fe_2O_3	1·02	4·66	7·63
FeO	·91	1·09	1·21
MnO	none	tr.	none
CaO	·90	5·33	10·40
MgO	·07	1·26	6·72
Li_2O	·06	·03	·02
Na_2O	4·76	3·99	3·02
K_2O	2·85	1·29	·57
P_2O_5	none	·60	·20
SO_3	·32	·35	·52
H_2O	·41	2·44	·67
	100·05	99.96	99·99

The three magmas clearly form the middle and extremes of a chemical series.

When heated in a platinum crucible, the basalt melts at about 1250° to a fluid which at slightly higher temperatures becomes quite liquid, and upon solidification forms a black glass that is brown in the thinnest edges and is without gas bubbles.

The porphyrite when heated decrepitates, and afterward fuses in the neighborhood of 1400°, but does not become as liquid as the basalt for like temperatures. It solidifies as a dark brown glass with some gas bubbles.

The rhyolite melts at about 1500°, but remains quite viscid at 1700°, and solidifies as a gray glass filled with minute gas bubbles.

The amount of gas bubbles serves as an indication of the relative viscosity of the different magmas at the temperatures to which they were subjected.

§ 4. *Relation to temperature.*—In making the present deductions the outspoken parts of the data of Table I can alone be taken, viz: in case of the magma (1) between 900° and 500°; in case of (2) below 1034°, and in case of (3) between 1124° and 692°. Careful scrutiny of the relation of resistance to temperature then shows, that the ratio, dr/dt, of corresponding decrements of specific resistance, $-dr$, and of temperature, dt, is proportional to the corresponding resistance at the given temperature. In other words we have $-r' = a + bt$, whence

$$ln(a + br) = c - bt \qquad (1)$$

where a, b, c, are constants. Relative to Table I these values are approximately (r in megohms)

	(1)	(2)	(3)
a	−·10	−·05	+·05
b	·0134	·0125	·0091
c	7·59	8·78	7·96

It is probable that a merely reflects the errors of observation and that its real value is zero. The constant b, which is an index of the composition will be discussed in §§ 5, 6. The quantity c/b, which is a temperature, has no apparent meaning. These results are exceedingly interesting since a relation similar to equation (1) was found[*] for the thermal variation of the viscosity of a highly viscous body like pitch. Again the acid magmas at least, betray no evidences of circumflexure, or anything that would be an electrical index of polymerism or melting point. An aqueous solution of zinc sulphate carried under pressure through a large interval of temperature, shows changes of resistance[†] quite akin to the present. In both cases, therefore, we have similar solution phenomena, exhibiting a thoroughly regular change of the electrical character with temperature.

Moreover the nature of the law embodied in equation (1), for silicates, the enormous range of temperatures to which they

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[*] Proc. Am. Acad., xxvii, p. 13, 1892.

[†] This Journal, xlii, p. 135, 1891.

can be exposed, the extreme sensitiveness of the electrical indications, and the simplicity of the necessary apparatus, suggest a method of pyrometry specially available for temperature approaching the melting point of platinum. One would obviously select an exceedingly acid magma, both because of its relatively great infusibility, and because of the occurrence of the maximum of uniform electrical conduction, in such a case, as will be shown in the next paragraphs.

§ 5. *Relations to chemical composition.* — Endeavoring to interpret these results with reference to their chemical bearing by means of Kohlrausch's* law we are handicapped at the outset because the rates of procession of ions (Hittorf's "Überführungszahlen") in silicate solutions are not known. In other words the quantities expressing the velocity of either ion relative to the combined velocities of both are unknown. We cannot even state what the structure of the electrochemical equivalents may be. It makes a difference whether the cations travel singly or in groups, or whether the anions be $\frac{1}{2}SiO_3$, $\frac{1}{4}SiO_4$, etc., singly or combined. We could not therefore express more than a mere opinion relative to the velocities of the ions, even if the specific molecular conductivities were computed. Nevertheless, in the face of these difficulties we are able to deduce certain striking results insomuch as the method of this paper is one in which the cation is brought gradually, and as nearly as possible to vanish in amount. An index of acidity, independent of temperature, is given by the constant b of equation (1). We regard the anions, whatever their specific structure may be, as identical in the three magmas examined; and the cations, from the large number of elements contained in the magmas, as possessed of a common or average property.

Several general deductions, however, may be drawn from the work, incomplete as it is at present. In the first place, Table I shows strikingly that electric conduction increases with the degree of the acidity of the magma, that is, with the degree of dilution of the cation. And since fusibility decreases in a marked way as the composition of the magma approaches pure silica, it follows that *in a series of different magmas electric conduction at any given temperature increases in proportion as the viscosity increases.*

Thus the most acid of the rocks investigated, (1), is a stiff paste above 1500,° whereas the basalt, (3), can be poured at a temperature much below 1300°; and yet the rhyolite, in virtue of its acidity is a better conductor than basalt at any given temperature.

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* Kohlrausch, Wied. Ann., vi, pp. 145 et seq., 1879.

The table also shows that the conductivity of rock magmas at high temperatures is considerable even when they have passed from a liquid to a solid state, that is, when they exist as highly heated glasses.

In general, therefore, a thorough change of chemical structure through ionic diffusion, whether directed by an electrical field or otherwise, must be an easy possibility in a sufficiently temperatured but otherwise solid magma.

§ 6. The second point gained is more specific. Kohlrausch[*] has shown that the contribution of a single ion in promoting electrical conductivity decreases with the number of ions present. In other words in concentrated solutions the ions are stopped *en route* by what may be termed friction, but what is probably temporary intercombination with each other. Hence their mean velocity, and consequently the specific molecular conductivity of the solution falls short of the proportionate quantity. Moreover, it is perfectly well known[†] that many solutions (H_2SO_4, HCl, $ZnSO_4$ etc.) show maxima of electric conductivity for gradual changes of concentration. The case of an aqueous electrolyte decreasing in electric conductivity with increasing concentration is therefore given by many examples, and doubtless their number could be indefinitely increased by employing aqueous solutions at high temperatures under pressure.

Now this is exactly what we observe in our series of three silicate solutions. Conduction increases markedly from (3) to (1), that is, from basic to acid, and it seems altogether probable that the anticipative maximum will correspond to a degree of silicic dilution greater than 75 per cent of silica.

Tracing this inference further we come to the conclusion that pure silica is probably an insulator, or that it occupies a position in siliceous electrolysis very closely analogous to that of water in aqueous electrolysis. It is to be remarked that we here refer to the electrolytic solvent and leave the question of chemical solvent temporarily out of consideration. This is in accord with the observations of Warburg,[‡] who has elaborately investigated the insulation of a film of pure silica at about 300,° the film having been produced by the electrolysis of glass. The insulator was found to be so perfect that the capacity of the condenser was measureable. The insulation of quartz relative to glass has to some extent (as far as 224°) been tested by Warburg and Tegetmeier,[§] though the conditions were complicated in this instance both by crystalline structure and the impurity of the mineral.

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[*] Kohlrausch, l. c. p. 183.

[†] l. c. p. 43.

[‡] Warburg, Wied. Ann., xxi, p. 622, 1884.

[§] Warburg and Tegetmeier, Wied. Ann., xxxv, p. 463, 466, 1888.

§ 7. *Conclusion.*—Looking at our results as a whole we find them trenching in a novel way on the solution theories of Arrhenius, Ostwald and vant' Hoff. It is difficult to withhold one's assent from the proposition, that the ions of a molten magma are largely present in the dissociated state, and more especially so as we approach very acid magmas. Terms like *colloid* applied to these magmas are absolutely without relevancy so far as we can make out. To the extent of our enquiry, the behavior of molten rock magmas is in its nature quite identical with that of any aqueous or other solution, the difference being one of solvent.

The above paragraphs give a mere draft of a series of experiments which we propose to carry out with greater vigor. We desire, however, to express our conviction that electrolytic resistance is not only a valuable aid to petrological research, but that the definition of molecular structure is possibly within the reach of the method.

ART. XXXIII.—*Estimation and Dehydration of Silver Oxide;* by M. CAREY LEA.

IN some analytical determinations it became necessary to estimate silver oxide and the question arose at what temperature the moist oxide could be perfectly dried, and also at what temperature it began to lose oxygen. As no such data are to be found, they had to be determined, and the results obtained may possibly be of use to others.

Moist oxide precipitated by perfectly pure sodium hydrate obtained from metallic sodium, and thoroughly washed, was dried at 100° C. for 20 hours. Of this material 1·5528 grams was taken and heated again to 100° for 20 more hours, after which heating it weighed 1·5524, a loss of 0·0004 grams. It was next heated to 160°–165° C. for five hours and was then found to weigh 1·5389 grams, a loss of 0·0135 gram. It was then replaced in the oven and heated 5 more hours. No loss whatever of weight could be detected resulting from this second heating. The oxide was then ignited and gave 1·4358 grams of silver.

Taking the atomic weight of silver at 107·66 and O = 16 argentic oxide should contain 6·92 per cent of oxygen (more exactly 6·917).

From the foregoing it follows that moist silver oxide dried for 40 hours at 100° lost by ignition	7·51	per cent
The same oxide with 10 hours drying, at 160°–165° C. lost by ignition	6·70	"
Calculation for Ag_2O gives for O	6·92	"

It follows that after 40 hours drying at 100° the oxide has reached a constant weight and still retained 0·59 per cent of moisture. When heated to 160–165° till constant in weight it had lost 0·22 per cent of oxygen.

It was next attempted by a shorter second heating and a lower temperature to expel the water alone. Silver oxide was dried for 20 hours at 100° and was then heated for 2 hours to 130°–135° C. Of this oxide 1·8043 gram was ignited and left 1·6701 gram of silver, indicating a loss by ignition of 7·44 per cent. This was only ·07 less than when the heat was not raised above 100° C., showing that the oxide is not dehydrated by exposure to a temperature of 130°–135° C.

The conclusion to be drawn would apparently be that the point at which the last portions of water were driven off was very close to that at which oxygen began to be disengaged. It can be shown however that this is not so and that oxygen is lost long before the last portions of water escape. This can be proved by the delicate photochloride reaction which I described some years ago. If the silver oxide, dried as above described at 100° C till it reaches a constant weight, is moistened with dilute hydrochloric acid, a chloride is obtained of a deep lilac color. This color always denotes the presence of hemichloride due to the fact that a certain portion of the oxide had been reduced to hemioxide. The hemichloride combining with the white chloride forms a photochloride characterized by the coloration just mentioned.

A really accurate estimation of silver oxide is therefore impossible, as it loses oxygen too easily.

Silver oxide is not supposed to form a hydrate, nevertheless some portion of moisture remains united with it more strongly than some part of the oxygen with which it combines to form a strong base.

But it also appears that the loss of oxygen is very small and soon ceases even at 160°–165° C. For after 5 hours exposure to that temperature, the weight became constant.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Phenomena of Coal-dust Explosions.*—Thorpe has described a lecture experiment to illustrate the phenomena which are observed in explosions wherein light combustible solids like coal dust suspended in the air are the chief combustibles. In coal mines opinions are divided as to whether coal dust alone in the air can give rise to explosions, or whether it can do so only when

mixed with fire damp. The apparatus employed by Thorpe consists of a narrow box of wood 12 feet long and 5 inches square intersected at its middle point by a second similar box 6 ft. long. Both boxes are open at the ends and are provided with lids attached with strong hinges and hasps. They are made of inch oak and are put together with screws. At one end of the long box is a slide; and the end itself fits into a quadrangular box 9 inches square, furnished with a lid on top and a small hole for the introduction of a tube carrying gas. On delivering into the box such an amount of gas as will make an explosive mixture (best from a graduated bell-jar over water) and on strewing coal dust along the entire length of the boxes, a blank cartridge, fired from a pistol through the lid of the box to illustrate the effect of a blast, raised a dust cloud which ignited by the explosion, projects a flame several feet long from the farther end of the box. To illustrate a local explosion of fire damp, the slide at the end of the box is pushed in and an explosive mixture is made in the box beyond it. The slide is then withdrawn and a match applied. The explosion raises a cloud of dust and this by its violent ignition produces a continuous cloud along the whole length of the box which is driven out four or five feet from the remote end. Little heaps of gunpowder, or pieces of touch paper placed at intervals along the box, are rarely fired.—*J. Chem. Soc.*, lxi, 414, May, 1892. G. F. B.

2. *On certain New forms of Carbon.*—A new variety of carbon has been obtained by LUZI. When a piece of porcelain, such as a crucible or crucible-cover, is heated in a blast furnace to the highest attainable temperature, say to 1770° C., the fusing point of platinum, and then the access of air is cut off, the highly heated porcelain is surrounded by a smoky flame, which is allowed to act upon it for ten or fifteen minutes. On removing the piece of porcelain from the furnace, it is found to be covered with a peculiar deposit of carbon. If it was unglazed, the deposited carbon resembles graphite; but if glazed, the deposit is bright and silvery and has a metallic luster, resembling closely a silvered mirror. Portions of the deposit adhere so firmly that they can be polished with a cloth ; others separate in the form of mirror-like facets of high luster. Loose portions can be pulled off; and then they curl up into rolls like metal shavings. They are exceedingly light and stick to the fingers like silver leaf. This form of carbon is free from ash and does not contain hydrogen ; nor does it give the nitric acid reaction for graphite. Moreover it is absolutely opaque. The author has also examined 17 additional varieties of natural graphite by his nitric acid reaction. Nine of these give the reaction and are therefore graphite proper; eight do not and are therefore included in the second class which he calls graphitite. Of the 31 specimens thus far examined 16 were graphite and 15 graphitite. The blackish-gray substance into which diamond is converted on heating, and which resembles graphite, did not give the nitric acid reaction.—*Ber. Berl. Chem. Ges.* xxv, 214, February, 1892. G. F. B.

3. *On Quinite, the simplest Sugar of the Inosite group.*—Since Maquenne proved inosite to be a six-fold hydroxylized hexamethylene, it was to be expected that the hydroxyl derivatives of this substance which are poorer in oxygen would possess sugar-like properties. BAEYER has now succeeded in reducing the *p*-diketone of hexamethylene by means of sodium amalgam to the glycol of hexamethylene. To purify it, he converted it into the diacetyl derivative and this on saponification with barium hydrate gave the pure glycol, $C_6H_{12}O_2$. It is cistrans-paradioxyhexamethylene and resembles in appearance and behavior a sugar of the mannite group. It is permanent toward permanganate solution and Fehling's solution, tastes at first sweet and then bitter. It is easily soluble in water and alcohol, fuses at 143°–145°, and distils without decomposition. According to its formation it is a hexahydro-hydroquinone, and in that case would afford on heating with chromic acid quinone. Since it possesses sugar-like properties and is the simplest representative of the inosite group, the author proposes for it the name *quinite.* The preparation of this substance opens the way apparently for the production of other hydrobenzene compounds.—*Ber. Berl. Chem. Ges.*, xxv, 1037, March, 1892. G. F. B.

4. *On the Relation between the Color of Compounds and their Chemical Constitution.*—From an extended study of a large number of colored compounds both organic and inorganic, SCHÜTZE has obtained some results going to show a relation between the color of these substances and their chemical constitution. These results he sums up as follows: (1) A displacement of the absorption from the violet toward the red corresponds to the color-changes greenish-yellow, yellow, orange, red, reddish-violet, violet, blue-violet, blue, blue-green, etc.; this order of change being called "lowering the tint." A displacement from red to violet corresponds to an inverse color change, i. e., to a "raising of the tint." (2) Atoms and atomic groups on entering a molecule produce, for compounds of the same chromophore and for the same solvent, a characteristic lowering of color-tint (bathochromic groups) or a raising of the color tint (hypsochromic groups). (3) Hydrocarbon radicals act always bathochromic; so that in homologous series the shade deepens as the molecular mass rises. (4) The color-changing action of the elements of the same periodic group also increases with an increase in the atomic mass. (5) Addition of hydrogen is always accompanied by a raising of the tint. (6) The raising or lowering of the color-tint (displacement of the absorption toward the violet or the red) by the substitution of hypsochromic or bathochromic groups, or by the addition or removal of hydrogen, is the more decided the nearer the chemical change which takes place is to the chromophore. In general the distances of the atoms from one another given by structural formulas correspond to their actual distances; in some cases, however, it appears that as in the di-derivatives of benzene, the substituents in the para position are nearer to each

other than are those in the meta position. (7) These rules hold good only for "monochromophoric" compounds and for such "dichromophoric" ones as have equal color-groups influenced in the same way by the neighboring atoms. The color of an unsymmetrical diazo-compound of the type Y–A–X–A–Z is approximately the same as that of a mixture of the two symmetrical compounds Y–A–X–A–Y and Z–A–X–A–Z.—*Zeitschr. physikal. Chem.*, ix, 109, February, 1892. G. F. B.

5. *On Free Hydroxylamine.*—The assumption that hydroxylamine is not capable of existing free, arose apparently from the presence of water in the process employed. LOBRY DE BRUYNE has now succeeded in isolating it by acting on hydroxylamine hydrochloride dissolved in absolute methyl alcohol, with nearly the theoretical quantity of a concentrated solution of sodium methoxide, at a gentle heat. The sodium chloride produced was filtered off and the filtrate was distilled under a pressure of 160–200^{mm}; since at this reduced pressure the alcohol carried off less hydroxylamine. When most of the alcohol had been thus removed, dry ether was added. This separated the liquid into two layers, the upper containing 5·5 per cent hydroxylamine, the lower 53·5 per cent. The lower layer again distilled under a pressure of 165^{mm} until the temperature rose to 86° gave a solution containing 70 per cent of hydroxylamine. Finally, all the solutions were mixed and distilled under a pressure of 60^{mm}. The residue, containing 80 per cent of hydroxylamine, was fractionated in three portions, the last of which solidified in long needles in the cold receiver. This after pressing between filter paper, contained 99·4 per cent hydroxylamine. In this form it is a hard crystalline mass, very hygroscopic and fusing at about 27·5°. Sodium chloride readily dissolves in it and potassium nitrate liquefies it, so that it resembles water. Sodium attacks it strongly. It is inodorous and somewhat denser than water. When heated rapidly on platinum foil it explodes with a clear yellow flame. It is scarcely soluble in chloroform, benzene, ether, ethyl acetate or carbon disulphide. Exposed to the air it first liquefies and then evaporates. It appears to be stable alone as well as in solution. —*Rec. trav. Chim.*, x, 100; *J. Chem. Soc.*, lxii, 402, April, 1892. G. F. B.

7. *Physical and chemical phenomena under the influence of very low temperatures.*—M. RAOUL PICTET states that heat-waves corresponding to low temperatures traverse all bodies with hardly any resistance. A test tube filled with chloroform was placed in a nitrous oxide refrigerator at −120°. A thermometer in the tube showed a gradual fall to −68°·5, when crystallization commenced. On removing the test tube to a refrigerator at −80°, the temperature indicated by the thermometer fell rapidly from −68°·5 to −80, while the crystals formed on the walls of the test tube fused and disappeared. On replacing it in the −120° refrigerator, the temperature rose to −68°·5, and the crystals reappeared. M. Pictet explains these phenomena by supposing his

thermometers to have acted as thermo-dynamometers rather than thermoscopes. While the crystals were forming in the first refrigerator, the radiation from the bulb was neutralized by the latent heat given out by the chloroform in crystallizing, whereas in the warmer refrigerator the crystals did not form, and radiation alone was active. Alcohol and sulphuric ether thermometers were used, which were checked by thermometers containing dry hydrogen at four different pressures.—*Comptes Rendus,* May 30, *Nature,* June 9, 1892. J. T.

8. *New method of determining the specific inductive capacity of a dielectric.*—F. T. Trouton and W. E. Lilly point out that the comparison between the energy of a condenser charged with a certain quantity of electricity, first as an air condenser and secondly with a dielectric sheet between the plates, shows that the energy in the first case is greater than in the second, and therefore the dielectric sheet will be drawn in between the plates; for the electric energy of the system being less after the introduction of the dielectric than before, work must have been done by the electric forces during the operation. The amount of this force depends on the specific inductive capacity of the dielectric, and by observing this force the specific inductive capacity may be determined for any given substance. The authors describe a method of measurement, and show its applicability.—*Phil. Mag.*, June, 1892, pp. 529–532. J. T.

9. *Action of the Electric discharge on Gases and Vapors.*—C. Ludeking has made a number of experiments to determine whether electrolysis takes place in the action of the electric discharge on gases and vapors. He concludes that "some of the phenomena noted were in part due to true electrolysis. Others seem to be 'thermolysis,' that is the compounds are simply dissociated by the heat of the discharge. The predilection of the atoms, thus liberated, for electricity of different kinds would make them, like pith balls, fly to the pole having the charge opposite their own, and thus give the entire phenomenon the appearance in all respects of a true electrolysis, while in reality there is the greatest possible difference."—*Phil. Mag.*, June, 1892, pp. 521–528. J. T.

10. *Ratio between the Electromagnetic and Electrostatic Units.*—A new determination has been made by M. H. Abraham of the value of v. The method employed was that of measuring the capacity of a plane condenser with guard ring in both systems. The value obtained was $v = 299{\cdot}2 \times 10^8$.—*Comptes Rendus,* June 7, 1892. J. T.

11. *Influence of Electrification on Cloud Condensation.*—Mr. John Aitken has studied this subject, using a steam jet—and finds that the mere presence of an electrified body has no influence on the steam jet. In order to produce the increased density the water particles in the jet must be electrified either by direct discharge, or by an inductive discharge, effected either by means of a point or a flame. The increased density produced by electri-

fication is due to an increase in the number of water particles in the jet, by the electrification presenting the small drops coming in contact by their mutual repulsions, in the same manner as the water drops in Lord Rayleigh's experiments with water jets, which scatter more when electrified than when not electrified. The coalescence of the drops in water jets takes place only under the disturbance produced by the presence of an electrified body, while such a disturbance produces no effect on steam jets. The action of electricity does not seem to be positive, as it has no effect on a mixture of hot moist air and cold air. It seems rather to prevent something which takes place in the jet under ordinary conditions. The jet on becoming dense emits a peculiar sound which is the same whatever be the cause of the increased density. But when electrified, along with this sound there is another, due to the discharge of the electricity, which causes the electrified jet to appear to make a louder noise.—*Royal Society*, April 28, 1892; *Nature*, May 26, 1892. J. T.

12. *The thermal variation of viscosity and of electrolytic resistance;* by Carl Barus.—Experiments made on the effect of temperature (θ) on the viscosity (η) of a very viscous substance like marine glue showed that $\log \eta_{p,\,\theta} = \log \eta_{p0} - B\,\theta$ very fully reproduced the results. The subscripts give the quantities constant and variable; p denotes pressure, and B is constant. For napierian logarithms, absolute measure, ° C., and marine glue, $\eta_{00} = 10^{12}$ and $B = {\cdot}379$. In other words the rate at which viscosity decreases with temperature at $\theta°$, is proportional to the viscosity at $\theta°$.

Experiments made on the effect of temperature on the electrolytic resistance, r, of a silicate (diabase) within 1500° C., showed that $\log\,(a+br) = \log\,(a+br_0) - b\theta$, very fully reproduced the results. Here a and b are constant and a merely reflects the observational errors. For diabase, megohms and °C., $a = {\cdot}05$, $b = {\cdot}009$, $r_0 = 318\times10^6$, napierian logarithms being taken. If a be eliminated, $b = {\cdot}010$. In any case, however, the rate at which electrolytic resistance decreases with temperature, at the temperature $\theta°$, is proportional to the resistance at $\theta°$. Hence viscosity and electrolytic resistance conform with the same law, and I infer that a common kinetic principle underlies both. This may be stated thus: The rate at which either configurational or molecular instability increases at the temperature θ, is proportional to the instabilities present in the given volume at that temperature—supposing that the number of unstable configurations, or of unstable molecules, respectively, is at all times small relative to the total number of configurations or molecules. (Cf. this Journal, xlii, p. 135, § 12, 1892.) The thermoelectric equivalent, $d\,e = A\,e\,d\,\theta$, I will soon develop.—*Communicated by the Author.*

13. *Outlines of Theoretical Chemistry*, by Lothar Meyer, translated by P. Phillips Bedson and W. Carleton Williams. With a preface by the author. 220 pp. 8vo. London and New York (Longmans, Green & Co.).—The name of the author and

the character of his well known larger work upon Modern Theories of Chemistry are sufficient guarantee of the excellence of this new volume. Although there are a number of admirable books at hand upon the philosophy of modern chemistry, each one may be said to occupy a place and have a peculiar value of its own, and this is particularly true of this work by Professor Meyer. It gives a clear, well balanced discussion of the various topics embraced under the head of theoretical chemistry, and would be read with profit by students in this department of science.

14. *Theoretical Mechanics:* A class book for the elementary stage of the Science and Art Department, by J. SPENCER. 243 pp. 12mo. London, 1892 (Percival and Co.).—This little book, by an author who has had much experience in this line, fills well the place for which it is specially prepared. The principles are clearly stated and liberally illustrated by numerical examples. If the solutions by geometrical methods seem awkward, their use must be ascribed to the fact that the author is not at liberty to assume that his readers have a knowledge of trigonometry.

15. *Die Negativ-Retouche nach Kunst- und Naturgesetzen.* Mit besonderer Berücksichtigung der Operation (Beleuchtung, Entwicklung, Exposition) und des photogr. Publikums. Ein Lehrbuch der künstlerischen Retouche für Berufsphotographen und Retoucheure von HANS ARNOLD 480 pp. Vienna, Pest, Leipzig, 1891 (A. Hartleben).—This is a readable volume in an interesting branch of photography, discussing the several topics with much fullness; the scope of the work is given in the title quoted above in full.

II. GEOLOGY AND MINERALOGY.

1. *Upraised Coral Islands off New Guinea.*—In the course of a journey through British New Guinea, in January last, the indefatigable Administrator, Sir William Macgregor, examined and described several remarkable islands, which he shows to be almost certainly ancient atolls that have been elevated by steady horizontal uplift. The island generally known as Kitava (but called Nowau by the natives) has an area of about five or six square miles. It appears to be surrounded by a fringing reef. Nearly all round the island there is a low and slightly sloping margin covered with trees, and about a quarter of a mile wide. This terminates inland in a steep coral wall, which rises abruptly to the height of 300 or 400 feet, and is covered with forest. Shells in the coral point to a comparatively recent upheaval. From the crest of this wall the land dips gently to a plateau from 50 to 100 feet lower, which occupies the center of the island. The plateau is undulating, has a rich chocolate soil, and being protected from wind by the raised rim, whilst subject to a copious rainfall, it is very fertile. All the people live in the

hollow, so that from the sea the island seems to be uninhabited. The central hollow is drained by filtration through the cracked and porous coral rock. Kwaiawata Island, which is from one and a half to two miles in diameter, showed precisely the same form and structure, and in Gawa Island there is a still more perfect instance of a raised atoll. The coral wall in the last instance rises so abruptly to the height of about 400 feet that part of it has to be climbed by ladders, and the plateau representing the old lagoon is nearly 100 feet below the level of the edge. Iwa, another adjacent island about a mile in diameter is of the same kind, only the gently sloping border has been worn away, and the coral cliff meets the sea nearly all round.—*Proc. Roy. Geograph. Soc.*, June, 1892.

2. *The Origin of Igneous Rocks.*—Mr. J. P. Iddings, in a paper read before the Philosophical Society of Washington in June last (Bull., vol. xii), has made a very important contribution to science on the Origin of Igneous Rocks. After mentioning at length the opinions that have been presented on the subject, he considers the intimate relations of the various igneous rocks in mineralogical constitution, and especially in chemical composition, illustrating the subject with a large array of facts and tables of analyses. Further, the associations or groupings of the different kinds of rocks in various regions of eruption and the order of succession in origin or outflow in each region are reviewed. After a careful and judicious survey of these subjects in their various relations, the author presents the following conclusions.

The differences in kinds of igneous rocks are not due to the existence of two or more subterranean zones of unlike magmas, or of zones of unlike rock-material which under physical changes might become such magmas; but they arise from the local differentiation of a common magma; and the series, in any region of eruption, usually commences with a kind having the mean composition of the series and ends with rocks of one or both extremes. Mr. Iddings remarks that this law, while it has its exceptions, holds for all the localities that he had personally studied, and for the order of eruption described by Prof. Judd for the lavas of the Lipari Island, "which began with rocks of intermediate composition and has reached the stage where rhyolite and basalt are being thrown out." Other conclusions are: that the variation in the composition of the rocks of a series of eruptions at any volcanic center is the result of the chemical differentiation of a magma of mean or intermediate composition; that molten magmas are essentially solutions, as put forth by Bunsen—a point illustrated in the experiments by Barus and Iddings described on a preceding page; that in each case those portions of the magma which were the later to crystallize may be considered as having been a solvent for the other portions—a solvent not for the silicates necessarily but for their constituents; that the differentiation in any case is due chiefly to differences in temperature, the temperature varying with the condition of the source of the magma, its relations to the enclosing material, and other causes.

The views presented by Mr. Iddings tend to simplify greatly the subject of rocks, as the author states in his concluding paragraph: "The confusion which has overtaken the classification of igneous rocks and the burden which is being heaped up by the present tendency to multiply its terminology by creating names for each modification of rock, will find their remedy in a more logical conception of the true nature of the differences and relations of rocks."

3. *Bulletin of the Philosophical Society of Washington*, vol. xi, 618 pp., 8vo. Washington, 1892.—This volume, covering the years 1888 to 1891, inclusive, contains valuable papers by Prof. Langley, Capt. C. E. Dutton, J. P. Iddings, E. D. Preston, F. W. Clarke, J. R. Eastman, Everett Hayden, W. J. McGee, G. H. Eldridge, Whitman Cross, and H. W. Turner.

Captain Dutton's paper "*On the greater problems of Physical Geography*," relates to the earth's form, changes of level, and mountain-making. In it he proposes (on p. 53), the term *isostasy* for "the condition of equilibrium of figure to which gravitation tends to reduce a planetary body irrespective of whether it be homogeneous or not," and discusses "How nearly does the earth's figure approach to isostasy?" He speaks of the theory he presents as a modified form of the theory of Herschel and Babbage. The effects of denudation and transportation in determining movement of material under the law of isostasy are also considered, and concluded to be such along coasts as would shove the material of the sea bottoms landward. Mr. Dutton argues also that they might produce systematic plications like those of the Appalachians, stating as an "important fact that these systematic flexures were mainly formed at the times the sediments were deposited," and that "this is a fact of geologic observation." Whose "observation" is not mentioned.

Mr. Dutton remarks that isostasy offers no explanation of the great permanent changes of level; that its very idea means the conservation of profiles against lowering by denudation on the land and by deposition on the sea-bottom; that the cause of permanent changes in the profiles of the land and sea-bottom, or the real nature of the uplifting force, is an independent one, and to him "an entire mystery." "But," he adds, "I think we may discern one of its attributes, and that is a gradual expansion, or a diminution of density, of the subterranean magmas. If the isostatic force is operative at all, this expansion is a vigorous consequence; for whenever a rise of the land has taken place one of two things has happened: the region affected has either gained an accession of mass, or a mere increase of volume without increase of mass." The former supposes a raising of the plateau against its own rigidity and its statical weight; the latter no overcoming of resistance; and hence, Mr. Dutton infers that the cause of elevation, whatever it may be, involves the expansion of the underlying magmas and the cause of depression, their shrinkage.

4. *Siliceous bed consisting of Diatoms, Radiolarians and Sponge-spicules, in the Eocene of New Zealand.*—This siliceous bed of organisms, occurring on the east coast of the South Island of New Zealand at Oamaru, whose Sponge-spicules are described by Dr. G. J. Hinde and W. M. Holmes (in the J. Linn. Soc., 1892), is regarded as probably a deep-sea deposit, "comparable with the Diatom ooze which now forms a belt of varying width surrounding the South Polar Regions, between the Antarctic Circle and the 40th parallel," at "a depth of 600 to 1975 fathoms, and an average of 1477 fathoms. A bluish siliceous deposit now found off the same east coast at depths of 700 to 1100 fathoms is very different in consisting chiefly of material from the land with few siliceous organisms.

5. *A Preliminary Catalogue of the systematic Collections in Economic Geology and Metallurgy in the U. S. National Museum*, by FREDERIC P. DEWEY. 256 pp. 8vo. Washington, 1891 (Bulletin of the United States National Museum, No. 42).—This bulletin gives not only a full description of the National Museum collections, but also a valuable account of mining and metallurgical processes in the different parts of the country, illustrated by many admirable plates.

6. *The Palæontology of the Cretaceous formation on Staten Island;* by ARTHUR HOLLICK. Reprint from Trans. N. Y. Acad. Sci., vol. xi, 1892.—Dr. Hollick gives in this paper a brief summary of the various discoveries that have been made by himself and others of animal and vegetable remains on Staten Island. They consist altogether of eight species of mollusks and a dozen or more of plants, many of them in a bad state of preservation. They were found at Kreischerville, Tottenville, Eltingville, Prince's Bay, Arrochar and Clifton, in more or less ferruginous and concretionary matter underneath the bowlder drift or somewhat mingled with it and bearing evidence of considerable disturbance. Only at Kreischerville are the Cretaceous clays found in place. The shells are of marine Cretaceous type and the plants are characteristic forms of the Amboy clays of New Jersey across the Kill and the Raritan, most of which, however, were originally described by Heer from the Cretaceous of Greenland, or by Lesquereux from the Dakota formation. The plants were all found at Tottenville and Prince's Bay, and Dr. Hollick shows that their occurrence can be accounted for on the theory of glacial transportation from the well-known plant-beds of the Woodbridge district, but he thinks the marine shells of Arrochar, sheltered on the west by the Archæan ridge, do not admit of this explanation and must be regarded as in place. The paper is illustrated by four plates, three of which are devoted to the plants. The figures are remarkably clear and instructive.

L. F. W.

7. *Untersuchungen über fossile Hölzer Schwedens;* von H. Conwentz. Kongl. svenska Vetenskaps-Akademiens. Bandet 24, No. 13.—The vegetable remains described in this important memoir all come from the southern extremity of Sweden, sometimes called Scania, in which so many horizons are exposed that yield fossil plants, especially the Rhetic and the Pleistocene. Nilsson, as long ago as 1831, proved that there was a Tertiary plant bed at Köpinge, and now we have evidence of an Upper Cretaceous (Senonian) deposit, called the Holma sandstone, which contains coniferous remains consisting of silicified trunks in place and also lesser twigs and even well-preserved pine cones. Most of these belong to two species, both of which are regarded as new to science, which Dr. Conwentz here fully describes and illustrates in his thorough manner, both in their external characters and their internal structure, and names respectively, *Pinus Nathorsti* and *Cedroxylon Ryedalense.* The Holma Sandstone occurs on both sides of the Ryssberge north of the 56th parallel of north latitude.

Besides these remains in place the present memoir also describes a large amount of drift wood (Geschiebehölzer) from the extreme southern peninsula, much of which had long lain in the museums at Stockholm and elsewhere awaiting identification. Most of these proved to be coniferous, but wholly unlike the Holma Sandstone flora, having the Sequoia type of structure which is referred to Cupressinoxylon, or if roots, to Rhizocupressinoxylon. One piece, however, turned out to be a palm stem and was intrusted to Dr. Stenzel who is so great an authority on such forms. He describes it as *Palmacites filigranum,* a new species of fossil palm.

As regards the original source of those blocks of silicified wood, their systematic character is sufficient proof that they cannot be in place in the comparatively modern drift (Diluvian) in which they chiefly occur. They differ too widely from the forms found in the Holma Sandstone to make it at all probable that they belong to that age. The author concludes that they were originally derived from a formerly wide-spread Tertiary formation, the softer parts of which have been long since eroded away leaving only these heavy undestructible blocks of silicified wood which now lie buried under the superficial deposits.

L. F. W.

8. *On Penfieldite, a new species;* by F. A. Genth. (Communicated by the author.)—While examining a lot of minerals, formed by the action of sea water on ancient slags which Mr. Geo. L. English collected at Laurion, Greece, I noticed a *very few* hexagonal crystals which proved to be a new species, for which I propose the name: Penfieldite, in honor to Prof. Sam'l L. Penfield the indefatigable worker in mineralogy and crystallography.

Hexagonal; generally in prisms with basal plane; the first pyramid is indicated by striation of the prismatic planes; a second obtuse pyramid appears on some of the crystals in small triangular planes. Some of the crystals are tapering at the ends and the basal plane is thus obliterated. The crystals with basal plane are generally dull, being coated with an opaque film, suggesting incipient alteration. Cleavage indistinct, basal. The tapering crystals from 0·5–1^{mm} thick and up to 5^{mm} long, the opaque from 0·5–2^{mm} thick and 2–3^{mm} long. Color white; luster vitreous, inclining to greasy. B.B. in a closed tube, gives *no water*, decrepitates and gives an abundance of sublimed lead chloride, soluble in water, leaving a yellowish white oxychloride. Easily soluble in dilute nitric acid.

$$\text{Composition} = PbO\ .\ 2PbCl_2.$$

The analyses gave:

	1. Tapering crystals.	2. Opaque crystals.	Calculated
Cl =	18·55	17·94	18·21
Pb =	78·25	lost.	79·73
O =	----	----	2·06
			100·00

Associated with the Penfieldite is a mineral in long (up to 10^{mm}) silky needles, which largely volatilizes on heating, and *may* be another form of Penfieldite, or a new mineral; the other associates are anglesite and small quantities of laurionite.

Philadelphia, July 26th, 1892.

9. *Brief notices of some recently described minerals.*—MASRITE is a fibrous kind of alum found in Upper Egypt and described by H. DROOP RICHMOND and HUSSEIN OFF. It contains a small amount of cobalt and, as believed by the authors, a minute quantity of a new element for which the name *masrium* is proposed, after the Arabic name for Egypt. Assuming that masrium is a bivalent element, its atomic weight is calculated as 228, and it is regarded as belonging in the beryllium-calcium group in which group there is a place in the periodic system for an element with an atomic weight of 225. The analysis of masrite gave:

SO_3	Al_2O_3	Fe_2O_3	X[a]	MnO	CoO	FeO	H_2O	Insol.	
36·78	10·62	1·63	0·20	2·56	1·02	4·23	40·35	2·61	= 100

[a] X=Masrium oxide.—*Proceedings Chem. Soc.*, April 21, 1892; *Nature*, May 26.

BASILIITE is a hydrous manganese antimonate described by IGELSTRÖM from the Sjö mine, Grythytte parish, Sweden. It occurs in steel-blue bladed forms with metallic luster, which it loses upon exposure; it is not magnetic. An analysis gave:

Sb_2O_5	Mn_2O_3	Fe_2O_3	H_2O	
13·09	70·01	1·91	15·00	= 100·01

For this the formula $11Mn_2O_3 . Sb_2O_5 . 21H_2O$ is calculated.—*Geol. För. Förh.*, vol. xiv, 307, 1892.

Sjögruvfite is a manganese arsenate, also described by **Igelström**, from the same locality. It occurs in crystalline granules or seams in jacobsite. The color is light yellow, resembling some garnet, but its hardness is less. An analysis gave:

As_2O_5	Fe_2O_3	MnO	CaO	PbO	H_2O	
49·46	11·29	27·26	3·61	1·74	6·81	= 100·17

It is not far from other manganese arsenates actually described, and it needs further examination to prove that it is a distinct mineral.—*Ibid.*

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Transactions of the Wisconsin Academy of Sciences, Arts and Letters,* vol. viii, 1888–1891, 448 pp. 8vo. Madison, Wisc., 1892.—This volume contains besides other papers, the following on Physical, Geological, and Natural Science: Chamberlin, Additional evidences bearing on the Interval between the Glacial Epochs; W. M. Wheeler, On the Appendages of the first abdominal segment of embryo Insects (54 pages with 3 plates); C. D. Marsh, on the deep-water Crustacea of Green Lake; H. B. Loomis, on the effect of changes of temperature on the distribution of magnetism; E. Kremers, on the Limonene group of Terpenes (63 pp.); E. A. Birge, List of Crustacea Cladocera from Madison, Wisconsin, with a plate; besides papers by C. R. Van Hise and F. Leverett that have appeared in this Journal.

2. *A Dictionary of Altitudes in the United States*, Second Edition. Compiled by **Henry Gannett**, Chief Topographer. 393 pp. 8vo. Washington, 1891 (Bulletin No. 76, U. S. Geol. Survey).—In the new edition of this useful work considerable additional matter has been added, and the arrangement is changed, the places being in alphabetical order throughout instead of being grouped under the several States.

Through Mr. Gannett the Survey has recently issued an excellent colored contour-map of the United States.

Journal of American Ethnology and Archæology, edited by J. Walter Fewkes. Vol. ii, 194 pp. with several illustrations. This volume contains papers by the editor on a few Summer Ceremonials of the Tusayan Pueblos; Natal ceremonies of the Hopi Indians; Report on the present condition of a ruin in Arizona called Casa Grande.

The Humming Birds, by Robert Ridgeway. This work of 150 pages, with 46 plates, is from the Report of the National Museum for 1890, pp. 253–383.

Silk Dyeing, Printing and Finishing, by G. H. Hurst, F.C.S., 226 pp. 12mo, with 11 plates of samples of colored silks. London, 1892.—George Bell & Sons, London and New York.

Principles of the Algebra of Physics, by A. Macfarlane, Fellow of the Roy. Soc. of Edinburgh, Prof. Phys. Univ. Texas. 117 pp. 8vo. Salem, Mass.—Salem Press Publishing and Printing Co.

The Optical Indicatrix and the Transmission of Light in Crystals, by L. Fletcher, M.A., F.R.S. 112 pp. 8vo., with 21 wood cuts. London, 1892.—Henry Frowde; Macmillan & Co., New York.

Annuaire Géologique Universel: Revue de Géologie et Paléontologie, by Dr. L. Carez et H. Douvillé, Année 1890, Tome vii, 42 Fascicule. pp. 817 to 1158. Paris.—Comptoir Géol. de Paris.

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AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XXXIV.—*On a Color System*; by O. N. ROOD, Professor of Physics in Columbia College.

[Read before the National Academy of Sciences, Nov. 12th, 1891.]

IT is possible to combine by rotation a circular disc of cardboard painted with vermilion, with a similar disc covered with a bluish-green pigment exactly complementary to the red, and to ascertain whether by mixture a gray is produced when the two colored areas are equal. If such should be the case, in a certain sense we could say that these two colors were equal, in spite of differences of luminosity or amounts of white light mingled with them. If it were found that to make the mixture neutral, more or less red were required, we could assign to the vermilion disc a coefficient of 1, and to the blue-green disc its proper coefficient whatever that might be. Supposing for the sake of simplicity that the coefficient of the blue-green disc was also equal to unity, we then could mark the positions of the two colors at the extremities of a straight line and at its middle point locate white (gray), and we would then have a line containing, so to speak, all possible mixtures of these two colors, and by simple processes could indicate on it the positions, and consequently coefficients, of any red or blue-green surfaces having hues of the same character; for example, a red surface reflecting half the amount of red light of our standard disc, would be located half way between the positions of the standard red and of white, while another red disc might even find its position on the same line outside of our standard. In all these cases the vermilion disc would be the material standard to which a great number of reds and blue-greens, more or less pale or intense, could be quantitatively referred. But it might be possible to go farther, and to be able to say that our standard vermilion disc reflected the same amount of red light that is furnished by white card-board under the same illumination, or that at all events it reflected a known fractional part of it. All the colors just spoken of would then be virtually referred to white card-board, or to some other white reflecting surface as might be determined on, and the standard red disc could at will be reproduced at any time or in any part of the world. To the reproduction of standard red discs I have not devoted much time, as before they can be made valuable a much more difficult problem must be solved.

For if we undertake to go farther than the proceeding just indicated, and build up a whole system of colors we are immediately confronted by the fact that we are quite unable to leave our line; or for example, to express the amount of orange colored light or of green light reflected by other discs in the same terms, or to bring them all into one system. As Helmholtz has remarked,* masses of colored light which when mixed with their complements furnish in pairs the same white, may be said to belong to the same system and may be located at equal distances from the same center. A set of ideal discs which when combined pair-wise all furnished the same white, would in this system find their positions on the circumference of a circle with white at the center. But it is not practicable to experiment directly in this way, as it is nearly impossible to measure directly the amounts of white light mingled with the colored in the case of painted surfaces.

I have employed a different proceeding and built up with it a reproducible system, which, as far as I can ascertain, is the one above indicated. Let us suppose that the positions of our standard red and its complement have been laid down at the extremities of a line with white at its center: we then combine with the red disc a green which is a little too blue to be strictly complementary, and obtain the best neutralization, the gray furnished having the least perceptible color, and we will suppose that this takes place when the areas of the two colored surfaces on the composite disc are equal; we shall then know that the new color also belongs on the circle not far from the complement of vermilion. One step has thus been taken, we have been able to leave our first line of mixtures. We can then with ease and certainty locate the complement of this new hue, which will be a little more orange than the vermilion; or better still, we may combine the new color with one that is

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* Handbuch der Physiologischen Optik, p. 287.

still more refrangible than its true complement, and locate a disc which is still more orange, advancing thus more rapidly in the work. In the same way this orange-red disc will enable us to add a still bluer green, until in this way all the colors of the chromatic circle have been provided for and all our colored discs have *received coefficents*, for of course it will rarely happen that the actual positions of the colored discs fall on the circle, mostly they will be well inside of it. The first part of the work then consists in assigning coefficients to a series of painted discs which are arranged so as to have only small progressive differences of color.

Mode of experimenting.—To compare together colors which are not strictly complementary a number of precautions must be taken. In the first place, the pairs of discs employed should always have as nearly as practicable about the same coefficients; consequently the selection of the colored papers offers very considerable difficulty, and in the majority of cases it has been necessary for me to prepare the paper specially for each case as it arose. Of course it is desirable to use papers with as high coefficients as possible, but cases occur where one is compelled to use lower coefficients (blues and cyan blues) and in these it is always necessary, so to speak, to take a fresh start, and to descend to the lower coefficient by a line passing through the center of the circle and not outside of it, that is by reaching the other side of the circle by the aid of a *complementary* disc with a lower coefficient.

It is absolutely necessary that the eyes should be thoroughly rested after each individual observation, and they should be protected from side lights by a hood. Only the central portion of the retina should be used; that is, the colors should be observed through a small aperture in blackened card-board held at arms length. It is an advantage and a saving of time, to protect the eyes with quite dark neutral spectacles while engaged in the manipulations not involving observation of the colors.

As a source of illumination, sunlight falling on a stretched sheet of bleached cotton cloth was employed, and only the hours near noon were utilized. The frame with the white cloth was outside of the window, inclined at a suitable angle, and consequently was behind the observer as well as placed symmetrically to the colored discs. Extraneous light from buildings and blue sky was screened off and the room suitably darkened. If light from a uniformly overcast sky is employed a different set of coefficients will be obtained, and there is reason to believe that they vary somewhat with the nature of the sky on such days.

In some observations it was found advisable, for the sake of using high coefficients, to employ paper which was slightly fugitive, but by properly arranging the process the evil effects of this were obviated.

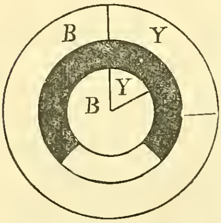
The coefficients of two strictly complementary discs are as their distances from the center or from white, and this distance is of course measured along the two radii that make up the diameter, but in the method used by me for colors not strictly complementary, the cosine of a small angle is necessarily employed and treated as if it were a radius. The angles used however were quite small, from 1°·5 to 3°, and consequently the error in any individual case was insignificant, but it is cumulative and finally becomes comparable with those of observation. After the uncorrected results have been plotted in a Newton's diagram, the angular distances of the colors will be known, very nearly, and the small errors from this geometrical source can be corrected and a fresh diagram constructed.

As above stated, it was not found advisable to employ angles larger than about 3°, since with larger angles the results were more uncertain, while with the angle above indicated the manipulation was hardly more difficult than in the case of truly complementary discs.

Mode of ascertaining the most neutral mixture.

Let us suppose that we wish to obtain the most neutral mixture that can be furnished by yellow and blue discs that are not complementary; the best method of procedure according to my experience is the following: a pair of large blue and yellow discs are combined as shown in figure 1, and on the same axis comes a black and white disc destined to furnish the comparison grays, and again on this, smaller yellow and blue discs cut from the same papers. Of course these three compound discs can be varied independently of each other. We start now with an amount of yellow on the larger disc which is far too small for approximate neutralization, and on the smaller disc with still much less yellow, and call the difference between the sectors the interval. This interval in any given case is always to be kept roughly constant, and the more nearly complementary the discs are, the smaller it may be made. There is however no gain whatever in trying unduly to diminish it, and such attempts tend only to defeat their object, it being far better and safer to have the interval too large than too small. The arrangement in figure 1 indicates

1.



about the first position for discs that have nearly the same coefficient, but are quite removed from being complementary. As soon as the compound disc is set in rotation it will be noticed that the mixture-tint furnished by the larger disc is the least colored of the two, and the amount of yellow in it is to be increased, the smaller disc following with the same interval, and this proceeding is to be pushed forward till the observer is unable to decide whether the larger or the smaller disc is the paler, the least colored. Both will differ sensibly from the pure gray mixture, and the two pale mixtures will differ from each other in hue, still after some practice the observer will learn to decide with promptitude that they differ about equally from gray. This is a much more certain and easy process when in general only a little color is present, than when the hues presented are at all decided, and this is the reason that in building up the system the advances were made by small steps. The first half of an observation being now made and the mean noted, the yellow element is made from the start to preponderate considerably, the interval is preserved, and with a reversed approach the best neutrality obtained. The two readings constitute one complete observation, and if the maximum reliability is demanded, not more than five complete observations in any one case should be made on the same day, it being more profitable to devote the remaining time to other determinations.

As an example of the results to be attained I give three sets of determinations for five discs with rather low coefficients, each number being the mean of only three complete observations made on the same day:

CB9*a*	·585	·575	·585
Y6⅓	·506	·480	·486
CB8	·466	·442	·452
Y6½	·432	·421	·428
B28	·394	·384	·398

When it is remembered that in photometric observations involving light of the same color the error in any one observation may easily be two per cent and more it will be seen that these results are satisfactory so far as uniformity goes.

By the methods above indicated I obtained the coefficients of a series of slightly differing discs ranging in color from orange-yellow through red into purple, and on the other hand from a somewhat yellowish green through cyan-blue to blue. Then, instead of extending the process all around the circle, a Newton's diagram was constructed using the standard vermilion disc, the extreme green attained and the blue. The angular positions of these colors were not arbitrarily assumed, but determined from the mixture equation and the ascertained coefficients. With the aid of this triangle and color equations experimentally obtained, I plotted in the usual way the positions of five of the discs used in the building up process, and calculated their coefficients with the following result:

	Direct coef.	Calculated.
G1	1·119	1·109
O1	1·221	1·231
P12	1·229	1·257
G18	·867	·892
P1	·571	·566
GY5	·806	·795

GY5, a greenish yellow, was quite beyond the limits of the triangle.

This agreement shows that the zig-zag process employed by me is homogeneous with that ordinarily used in Newton's diagram, and from this it follows that it is not necessary to determine by my method coefficients for a greater number of discs than will furnish a properly shaped triangle, and that the remainder of the work can be done by the older method. It may here be remarked that in obtaining the fundamental equation for the construction of the diagram and those for locating the colors, it is necessary to exercise far more suspicious care than is the case in the direct determinations of the coefficients. Although a pure gray is always attainable, theoretically, yet it seldom is obtained quite to the satisfaction of the observer; the best way is to employ on the same axis duplicate sets of discs separated by the comparison gray, to vary the manipulation and multiply the observations. The work having progressed thus far it becomes possible to ascertain the coefficient of any colored surface and to assign it a position in the diagram.

It may be remarked that the angular positions assigned to colors by the method just described agree in their main features with those given by me in a diagram on page 250 of "Modern Chromatics," which is founded on contrast observations, the main differences being in the angular positions assigned in the diagram to violet and blue-violet; these would have to be moved about 15° to the right, i. e., nearer to the other blues to make them coincide with positions furnished by this system.

I give here some of the coefficients obtained: the vermilion with a coefficient of 1 had only a moderate brilliancy, being made of English vermilion applied to card-board as a paste: since then I have found in the shops a red, supposed to be vermilion, with a coefficient as high as 1·174.

Chrome yellow (paste)	·846
" "	·933
"Pale" " "	·991
Emerald green "	1·119
Prussian blue (wash)	·354
" " "	·392
Cobalt blue (paste)	·562
Artificial Ult. blue (paste)	·506
Crimson lake (wash)	1·23

The system which is here proposed can be built up by experimenters and ought to be practically identical in all cases if made by normal eyes, provided the same standard vermilion is used, or the coefficient of it is known, or in general if the starting point is made from any disc of bright color the coefficient of which is known. As before stated it may be possible hereafter to refer the coefficient of the vermilion disc to white card-board, which indeed has been done in the case of my own disc with some approximation to correctness. The system may then be considered a fairly reproducible one, but the question still remains as to its nature. The thought that in it we have one where complementary colors having a determined coefficient of unity furnish the same gray, naturally suggests itself and is rendered probable by the following considerations. The standard red and its true complement when mixed furnish a certain gray, and it is evident that other pairs situated at small angular distances from them, such as 10° on either side, will sensibly do the same. This furnishes two sectors of 20° on either side of white; but the coefficients of the colors situated within them are reproducible with the aid of the triangle, which would hardly be the case unless the colors situated at its angles obeyed the same law, viz: furnished the same white when mixed with their true complements; this again applies to the reversed triangle and the two provide for about two opposite quadrants of the circle, and what holds good of these ought, it would appear, to apply to the remaining quadrants.

The question whether in this system, all the colors located on the circumference furnish by mixture the same white when treated in pairs, is quite difficult to answer by actual experiment, as in the case of most of the discs it is very hard to ascertain the relative amounts of colored and white light reflected, owing to the well known fact that in most cases portions of the colored light mix, and produce what amounts to an indeterminate amount of white light. Some attempts, with the aid of the spectroscope, of colored glasses and of gray discs were made to measure the actual amount of standard white (gray) furnished by the mixture of the *pure* fundamental red and its pure complement; a number was obtained expressed in terms of the luminosity of white card-board, and the same operation was performed for complementary yellow-green and purple as well as for yellow and blue discs. Without laying much stress on the results obtained, it can at least be said that they did not render improbable the idea that these pairs all furnished equal grays when united. To settle this problem experimentally would of course require a considerable amount of elaborate work, if indeed it is at present capable of such solution.

I shall be glad to furnish without cost samples of colored paper with coefficients to those who are particularly interested in these matters.

ART. XXXV.—*An Ottrelite-bearing Phase of a Metamorphic Conglomerate in the Green Mountains;* by CHARLES LIVY WHITTLE.

[Published with permission of G. K. Gilbert, Chief Geologist, U. S. Geological Survey.]

THE geological position of the limestone and quartzite of the Rutland valley has lately been definitely determined, the limestone paleontologically and the quartzite stratigraphically.* Occurring next below the limestone the quartzite is the northern continuation of the Clarksburg-mountain quartzite in Massachusetts in which Walcott has found the Olenellus fauna characteristic of the Lower-Cambrian horizon. About one mile north of Rutland village, in Vermont, Dr. Wolff and Dr. Foerste were fortunate enough to find Lower-Cambrian fossils in a siliceous limestone that lies superjacent to the quartzite. Northeast of Rutland the quartzite is found associated with a sandy, phyllitic schist that belongs to a series of metamorphosed clastics having a vitreous quartzite or conglomerate at its base. This whole series, barring the Lower Cambrian quartzite and limestone, has been subjected to the most intense dynamic action. The sequence of the different members of the series is in many regions hopelessly obliterated and confused by the mountain-building forces that have produced new structural planes and a new mineral composition; and have additionally complicated the geological order of succession by sharp folding, as a rule too much

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* On the Lower Cambrian Age of the Stockbridge Limestone. Bulletin Geol. Society of America, vol. ii, pp. 331–338.

involved for decipherment. These phenomena are particularly true of the conglomerate horizon and its many phases, and it is in this rock that I wish to describe some of the evidences and effects of metamorphism shown by the destruction of old clastic minerals and in the production of new ones.

Occurrence of ottrelite schist.—One of the most conspicuous phases of the conglomerate is due to the development of ottrelite in great abundance so that it is not uncommon to find fully twenty-five per cent of the rock made up of this mineral. The ottrelite is commonly most abundantly developed where the rock has now a well-marked schistose character that is due either to an original fine-grained deposit, or is a result of the shearing and crushing action of dynamic forces. It is often found, however, occurring in the groundmass of the coarsest conglomerate or along planes of shearing in a blue, hyaline quartzite. Still another phase is more nearly massive, fully forty per cent being ottrelite, the rock at first sight simulating in appearance some porphyritic hornblende dike. The rock is a very variable one, but, considered as a whole it forms one of the most important stratigraphical horizons found in the more crystalline areas of the Green Mountains. In lateral extension it has been traced with unimportant breaks all the way across the Green-mountain anticlinal axis, as mapped by Hitchcock,* from Mendon, Vt., to North Sherburne, Vt. In vertical extension it has considerable thickness although accurate determination is very difficult owing to the obliteration of planes of bedding in many instances and the complexity of the flexures; but it seems safe to assume a thickness of several hundred feet, at least in several localities that have been most carefully studied, viz: a spur extending south from Mount Carmel, in the town of Chittenden, and the east and west crest forming the southern portion of the mountain, somewhat inappropriately named "Old Aunt Sal," in the town of Mendon. The phases studied thus far in the laboratory are from this latter locality and from the western part of the "Rabbit Ledge" just south of Mendon "City."

Physical and microscopical characters.—In the hand specimen the ottrelite of the most massive occurrence of the ottrelite-bearing rock appears either as isolated areas generally with rudely circular outlines, or groups of these in a background of fine-grained, pinkish-brown to dark purple quartz, in places constituting nearly pure ottrelite. These areas possess an approximate common diameter of about three-sixteenths of an inch. In structure they are made up of tabular areas of radiating imbricated plates generally arranged in essentially one plane for any single area; but the positions of the

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* See fig. 4, Section VI, Hitchcock's "Green Mountain gneiss," Geol. of Vt., vol. ii, 1861.

different areas seem in the main to be accidental, although locally they may be arranged parallel, as shown by a tendency in the rocks to cleave into rude slabs,—a tendency augmented by thin folia of sericite. A well-marked spherocrystalline habit characterizes all the ottrelite areas; in some this radiated growth seems to be perfect.

Microscopically the radiated structure is much more evident; composite and fan-shaped areas, penetrating one another irregularly coexist with isolated prisms and beautiful spherocrystalline aggregates yielding imperfect crosses in polarized light. Only sections cut parallel to the bundles of plates (basal sections) show well the radiated structure; all other sections show this character less and less, dependant upon the plane of the section until it is transverse when the mineral appears prismatic. The areas of the spherocrystals are not infrequently bounded by overlapping six-sided plates of which three are usually free; the others are intergrown and confounded in the central portion of the aggregate.

The extreme mobility of the ottrelite-bearing solution is indicated by the manner the ottrelite needles have insinuated themselves into included feldspar grains along no visible lines of fissuring.

As in all described occurrences of this mineral an abundance of inclusions exists. It is noticeable that while quartz and occasionally feldspar are included, sericite, which is the principal micaceous constituent of the rock, is seldom enclosed by the growing ottrelite, but may be wholly or in part the nucleus about which an aggregate formed. Such nuclei seem to have governed the growth of the ottrelite. There is a tendency as the mineral formed for the plates to orient themselves parallel to the sericite nucleus so that when such a nucleus is surrounded by basal ottrelite it is apt to be basal also. By far the most abundant interpositions are a multitude of extremely minute black to brown dots and aggregates. These with a No. 7 objective are resolved, in the main into rutile occurring in knee-shaped and heart-shaped twins but generally in rounded forms in which twinning is not distinguishable. In other cases the highest objectives are incapable of individualizing the grains as is mentioned by Rénard in his "Researches Sur la Composition et La Structure Des Phyllades Ardennes."* In some crystals the rutile is grouped in reticulated lines conforming rather rudely to the planes of the two principal cleavages; but, as a rule grouped along irregular lines that traverse the ottrelite and the groundmass alike, and was arranged originally in structural lines, possibly depositional

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*Phyllade Ottrélitifère de Monthermée: Bulletin De Musée D'Hist. Nat. D Belgique, 3, 1884, '85, p. 252.

that afterwards were built into the ottrelite with total disregard to any observed relationship, in the same manner that quartz and feldspar droplets were built into albites in another phase of this rock. Other inclusions are graphite (determined by deflagration) and little coffee-brown ilmenite plates (titaneisenglimmer). A powerful current from an electromagnet applied to the rock powdered and run through a 120-mesh sieve failed to attract but little, so that magnetite and probably ferrous oxide are absent. The usual test for titanium gave a positive reaction.

As in biotite and chlorite, pleochroic zones about crystals of zircon are very common in the ottrelite and the characteristic dependence of maximum pleochroism upon maximum pleochroism of enclosing mineral is observable. While zircon usually occupies the centers of these zones, others occur, having no perceptible associated inclusion, but are circular areas of a brownish color, not resolvable with the highest power, that are probably rutile grains.

1.

Ottrelite schist showing formation of ottrelite at many different points. Each small area is oriented with all the others, forming a large area having a general prismatic outline. The prism (A) has been developed transverse to the schistosity of the rock. The background (B) is largely gneissic quartz with some secondary feldspar. × 25.

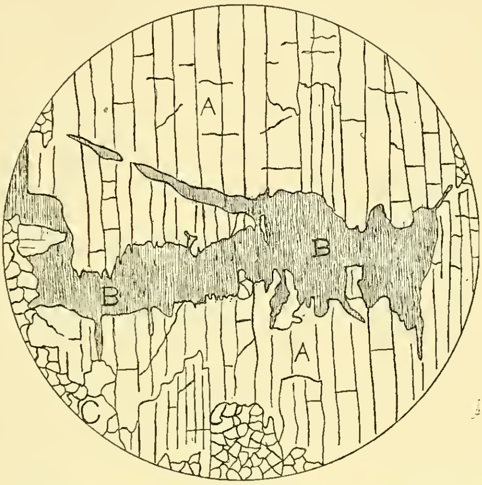
Although twinning with composition face parallel to O is not uncommon in the ottrelite a large part of what seems to be twinning is seen to be due to overlapping plates. As the stage is revolved the wavy extinction caused by this may be observed, — the usual spherulitic structure. Examples of crystal growth set up in several places at the same time occur in the rock, where each part is controlled by every other, resulting in an irregularly-outlined prism composed of many individuals. These parts are separated by areas of the groundmass and yet are all oriented together (see fig. 1). This phenomenon is unlike that of andalusite, which occurs so frequently grown into large individuals enwrapping all other minerals of the background; but is another example of independent parallel growth analogous to that of quartz in pegmatite. Such growths are commonly developed nearly at right angles to the layers of quartz and feldspar that make up the schistosity, and are usually freer from inclusions than the bundles. They occur between the main areas of ottrelite and may represent a second generation; they were necessarily formed after the groundmass was converted to a mosaic by granulation.

The same phenomenon is noticed in the rutile. Little yellowish-brown grains of this mineral developed in the interspaces of the minerals composing the background tend, although made up of separate and sometimes isolated grains, to orient themselves parallel to one another, forming groups having prismatic outlines. These groups are only sparingly developed, but when observed they are generally parallel to one another and to the schistosity of the rock and are restricted in their occurrence, like the ottrelite individuals just described, to the most quartzose parts of the rock which they enclose in the same manner as the ottrelite.

An interlamination of chlorite and ottrelite at first glance was mistaken for either the contemporaneous formation of these minerals or an infiltration of chlorite parallel to the basal cleavage of the ottrelite. Further investigation, however, showed that the chlorite as often traversed the ottrelite irregularly in bifurcating veins and enclosed parts of it (see fig. 2). A study of the nature of these veins convinced me that the chlorite is an alteration product of the ottrelite. The edges of the veins where they traverse the ottrelite transverse to the basal cleavage are jagged, the saw-like teeth projecting along the composition faces or basal cleavage. The chlorite in such cases is distinctly made up of little fibers which have arranged themselves parallel to one another and to one set of twinning lamellæ. Lines of inclusions once continuous in the ottrelite now stop short against interlaminated areas of chlorite showing the evident secondary nature of the latter mineral.

In other places the chlorite is developed along the basal cleavage, leaves this and follows one of the prismatic cleavages and then again follows the basal, making one continuous line, producing steps in much the same manner that garnet does when it undergoes this alteration. Cores of unaltered ottrelite remain in the chlorite and the pleochroic zones once in the parent are seen again in the secondary mineral, while the relationship of maximum pleochroism of these zones to the greatest pleochroism of the chlorite is handed down as well. This metasomatic phenomenon has not been observed in other phases of the ottrelite-bearing conglomerate thus far studied by me.

2.



Alteration of ottrelite to chlorite. A, overlapping plates of ottrelite. B, bifurcating vein of chlorite allomorphosed after ottrelite and including cores of unaltered mineral. C, quartz and feldspar mosaic.

The background of the rock is composed about equally of quartz and feldspar as principal constituents. The feldspar is fresh and glassy, untwinned and is probably albite; but it is hardly abundant enough in the ottrelite-bearing phases to make the rock a gneiss even in mineralogical composition; and, structurally, a gneissic habit has been nowhere observed where ottrelite exists to any extent. Sericite is also abundant and occurs in minute prisms between the interlocking quartz grains and enclosed by the albite generally, and rarely by the ottrelite. It also encloses lines of rutile dots arranged parallel to its cleavage planes, and, next to the ottrelite it is the last-formed mineral.

Associated with rutile in the groundmass are groups of stout and slender prisms and plates having a very high single and double refraction and a variable color from brownish-yellow to blue even in the same individual. These I identified as anatase and for verification I studied Diller's sections described in his contribution on "Anatas als Umwandlungsprodukt von Titanit im Biotitamphibolgranit der Troas."* Unlike the anatase

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*N. J. B., 1, 1883, pp. 187–193.

there described its occurrence in narrow prisms in this rock together with its multitude of rutile inclusions seem exceptional. The stouter prisms have terminal faces of an octahedron and range in size from $\frac{3}{50}$ to $\frac{1}{200}$ of a millimeter in length. As the stage is revolved the pleochroism seems only the intensification of the inherent color of the mineral: browns become browner and blues, bluer. The presence of rutile inclusions shows the anatase to have formed after that mineral and suggests the probability of its being a paramorphic product of the rutile inclusions.

Rutile dots and prisms exist in multitudes enclosed by all other minerals of a secondary nature. They are so extremely minute that even in a very thin section they focus in six or more different planes.

All traces of original clastic material in the rock have disappeared: feldspar detritus, if it once occurred, has been converted into a mosaic of quartz, sericite, biotite and probably albite, and the detrital quartz has been granulated. The existing feldspar is the characteristic untwinned glassy variety carrying quartz and sericite inclusions so common throughout this horizon, and was formed after the granulation of the rock, since granulation could not have taken place without straining or crushing it. Nearly all the quartz is sprinkled with rutile inclusions, but it is noticed the larger areas have less of them and may be cores that have escaped granulation. Their presence, however, in such abundance militates against the probability of any of the quartz being allothegenic and indicates, rather, its secondary nature. In the same way quartz may enclose plates of micaceous ilmenite but does not enclose sericite. There is evidence of two periods of dynamic action indicated by a faint wavy extinction in the feldspar, in some instances and by the bending and breaking of ottrelite prisms.

We have then in this rock three titanium-bearing minerals (ilmenite, rutile and anatase) ottrelite, chlorite, feldspar and quartz. What is their genetic order of development? This is a difficult question to answer without more data and is particularly difficult in the cases of the ottrelite and rutile. The relative position of the former mineral can be determined easily, but the source of the solution introducing it is not easily discovered. Ottrelite was formed after the rock had undergone metasomatic and dynamic changes that converted its clastic feldspar to its resulting minerals, after its detrital quartz was sugared and the rock had become a stable aggregation of minerals under the conditions of environment then existing. This environment changing, owing to one or more of the many factors affecting the character of a rock mass, ottrelite was introduced probably and seemingly necessarily from some extraneous source. The environment of the rock underwent a third change and this was probably an elevation which strained the albites, fissured the ottrelite and subjected the rock to normal surface weathering, during which the conversion of ottrelite to chlorite, was initiated. Prior to the granulation of the clastic constituents the titanium in some combination must have existed in the rock, but the mineralogical nature of this combination is obscure. The most likely source of rutile is from some titanium-bearing iron oxide the presence of which has not been made out definitely except in the case of micaceous ilmenite, itself manifestly of a secondary nature, occurring as it does in a clastic rock, and which yields no evidence of alteration. Ordinary granular ilmenite, such as occurs so abundantly in phyllites, which is prone to decomposition, was most likely the common source for all three minerals carrying titanium, the rutile being an intermediate stage in the formation of anatase. The micaceous ilmenite was developed before the formation of the gneissic quartz, since the latter encloses it; the anatase probably forming after the quartz, as it occurs in the interstices between the quartz grains.

If this be a correct interpretation, the order of crystallization of the existing minerals is essentially as follows: first, rutile and micaceous ilmenite followed by the formation of gneissic quartz enclosing them and coincidently the growth of sericite-enclosing rutile. The glassy feldspars were then formed enclosing all the previously formed minerals, and the anatase may have resulted as an alteration product of the rutile at about this stage in the rock's history. Then the ottrelite began its growth, including all the other minerals in the rock and finally the initial alteration of this mineral to chlorite closes its history up to the present time.

Cambridge, Mass., March, 1892.

ART. XXXVI.—*The Age-coating in Incandescent Lamps;* by EDWARD L. NICHOLS.

[Experimental work by Messrs. B. E. Moore and C. J. Ling.]

[Contributions from the Physical Laboratory of Cornell University, No. 11.]

WHEN an incandescent lamp is maintained at constant voltage, it invariably falls off in candle-power. The diminution in brightness is attended by an increase in the amount of energy consumed per candle-power of light; this change being specially marked in the earlier portion of the life of the lamp.

This phenomenon, which seems to take place in all incandescent lamps of the present day, was first studied exhaustively by Mr. W. H. Pierce, who read a paper entitled "The Relation between the Initial and Average Efficiency of Incandescent Electric Lamps," before the American Institute of Electrical Engineers, in 1889.* Mr. Pierce made a careful study of ninety-four lamps, including nearly all the types of glow-lamp then in use. He found no exception to the rule of progressive degeneration.†

These changes may be ascribed to at least three causes: loss of vacuum, increase of resistance, due to the disintegration of the filament, and finally, the deposition of the disintegrated carbon upon the inner surface of the lamp-bulb. It was the object of the experiments to be described in this paper, to make a study of this coating. We endeavored (1) to determine its character; that is to say, whether it is colorless, or is selective in the particular rays it absorbs; (2) to learn something about the rate and distribution of deposit; and (3) to determine how far the absorption of light by the coating is accountable for the diminution in the brilliancy of the lamp.

For the determinations under the first head, we made use of a form of polarizing spectro-photometer which has been more than once described in the pages of this Journal.‡ The standards of light were incandescent lamps. These were maintained at a candle-power considerably below the normal, that the changes taking place in them might be slow. Frequent comparisons of their spectra showed that the relative changes of brightness and quality of light were inappreciable.

The first step in our investigation consisted in the measurement of the absorption spectra of the bulbs of certain unused lamps, which had been selected for study. These lamps were then brought to degrees of incandescence, previously agreed upon, and were maintained in that condition by means of the current from a storage battery carefully kept constant, until they showed coatings of sufficient density to admit of ready measurement. They were then taken out of circuit and the absorption spectra of the blackened bulbs were determined. These readings gave the amount of light of each wave-length absorbed, and by repetition, the rate of deposition during different periods of the lamp's existence. The entire set of photometric observations were duplicated, but since the final results

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* Trans. Am. Inst. E. E., vol. vi, p. 293.

† Since the above was written an extended investigation upon this subject has appeared. It entirely confirms the results obtained by Mr. Pierce. (See "A life and efficiency test of incandescent lamps" by Prof. B. F. Thomas and Messrs. Martin and Hassler), Trans. Am. Inst. E. E., vol. ix, 1892.

‡ This Journal, vol. xxxvi, p. 332; also Phil. Mag., V, xxxii, p. 404.

obtained by the two independent observers (Moore and Ling), were in agreement, only the mean of the two sets is given in the following tables.

In order to ascertain precisely what part in the decadence of the lamp is attributable to the coating, it was necessary to keep careful watch of the continually shifting electrical and photometric conditions during its entire life; and in order to maintain in each lamp the precise conditions under which it had been determined that it should be burned, measurements of candle-power and voltage had to be made at short intervals, together with continual readjustments of the current.

Fourteen lamps in all were selected for the investigation. These were of two widely different types, representing the two great classes, viz: lamps with untreated and with treated filaments. Of these, some were maintained at the voltage indicated by the maker, or at predetermined, constant voltages other than this. Others were kept at constant candle-power throughout their entire life, the current being increased whenever the decrease in brightness due to increasing age had become appreciable.

From the data obtained in this way, the life curves of the various lamps were plotted, showing the variation in candle-power or voltage respectively, of resistance and of efficiency expressed in watts per candle, during its entire existence. Some of these curves have already been published.* As these results were quite in accordance with those obtained by Mr. Pierce, to which reference has already been made, it will be necessary to deal with them here only in so far as they bear upon the question of the influence of the age-coating upon the efficiency of the lamp.

I.

Color of the coating.

Measurements upon all fourteen of the lamps which were subjected to the spectro-photometric tests, showed the color of the coatings upon lamp-bulbs containing treated and untreated carbons, respectively, to be practically identical in character. The color of the coatings obtained in lamps of either type, under widely diverse conditions (as for example, by maintaining a sixteen candle-power lamp at sixty-four candles throughout its life), was the same as that produced under normal conditions of service. The color in question is very nearly neutral, the percentage of light transmitted being approximately the same for all parts of the visible spectrum. The effect of the

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* The Artificial Light of the Future: Electric Club Pamphlets, No. 24, New York, 1890; also Electrical World, 16, p. 387, Electrical Engineer, 10, p. 595.

"*age-coating*," as the deposit which we are considering may be called, is therefore to dim the lamp, without appreciably changing the quality of its light.

The most complete set of observations obtained with lamps of untreated carbon are those referring to a lamp designated in our list as No. 2.* This lamp was maintained at normal voltage for over eight hundred hours. Frequent readings of candle-power and current, during this time, afforded the means of tracing the progressive changes of light-giving power, efficiency and resistance. Measurements of the age-coating were made after 100, 200, 400 and 800 hours of life, readings being taken in ten regions of the spectrum. The results are given in Table I, together with data indicating the condition of the lamp at the above mentioned periods of its life. These are taken from a set of sixty-seven readings of voltage and current, distributed over the entire life of the lamp at nearly equal intervals. The variation in voltage during the entire eight hundred hours was never more than 0·3 volts above or below the initial value.

TABLE I.

Lamp No. 2 (untreated filament).

Initial Conditions.

Volts.	Amperes.	Ohms.	Candle-power.	Watts per candle.
101·8	0·474	214·8	16·00	3·015

Conditions after 100 hours.

Volts.	Amperes.	Ohms.	Candle-power.	Watts per candle.
101·9	0·453	225·3	12·50	3·697

Light transmitted by the coating, after 100 hours.

λ = ·750	88·9 per cent	λ = ·507	92·2 per cent
·713	90·2	·481	92·8
·635	91·8	·460	92·3
·658	91·5	·443	92·4
·538	91·9	·429	92.4

Conditions after 200 hours.

Volts.	Amperes.	Ohms.	Candle-power.	Watts per candle.
101·8	0·421	225·9	10·8	4·250

Light transmitted by the coating after 200 hours.

λ = ·750	83·5 per cent	λ = ·507	86·4 per cent
·713	84·5	·481	86·9
·635	85·6	·460	87·6
·580	85·4	·443	87·9
·538	85·9	·429	85·4

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* This and other numbers used refer to the records of these experiments as given in full in the thesis of Messrs. Moore and Ling, a manuscript deposited in the library of Cornell University. (The Life and Duration of Incandescent Lamps; with special Reference to the Light absorbed by the Coating within the Bulb, by B. E. Moore and C. J. Ling. 1890.)

Conditions after 400 hours.

Volts.	Amperes.	Ohms.	Candle-power.	Watts per candle.
101·8	0·428	237·7	9·67	4·510

Light transmitted by the coating after 400 hours.

λ = ·750	79·3 per cent	λ = ·507	83·5 per cent
·713	80·9	·481	83·6
·635	82·3	·460	84·0
·580	82·0	·443	84·3
·538	82·6	·429	82·1

Conditions after 800 hours.

Volts.	Amperes.	Ohms.	Candle-power.	Watts per candle.
101·9	0·415	245·6	7·20	5·880

Light transmitted by the coating after 800 hours.

λ = ·750	75·7 per cent	λ = ·507	78·7 per cent
·713	75·9	·481	79·4
·635	78·0	·460	79·9
·580	78·6	·443	80·5
·538	78·4	·429	77·3

Another typical case was that of lamp No. 10, which was a lamp with a treated filament. It was maintained at a very different degree of incandescence, being a lamp of low efficiency, which when set at the voltage indicated by the manufacturer, required an expenditure of 5·16 watts per candle. The age-coating of this lamp approached even more nearly to complete neutrality of shade than did most of those which we had occasion to measure. The results obtained at two hundred and nine hundred hours are given in Table II.

Table II.

Lamp No. 10 (treated filament).

Initial Conditions.

Volts.	Amperes.	Ohms.	Candle-power.	Watts per candle.
36·0	1·171	30·63	8·2	5·16

Conditions after 200 hours.

Volts.	Amperes.	Ohms.	Candle-power.	Watts per candle.
35·9	1·145	31·27	7·1	5·91

Light transmitted by the coating after 200 hours.

λ = ·750	91·9 per cent	λ = ·507	90·7 per cent
·713	90·4	·481	90·4
·635	89·5	·460	90·7
·580	90·5	·443	90·5
·538	90·5	·429	90·4

Conditions after 908 hours.

Volts.	Amperes.	Ohms.	Candle-power.	Watts per candle.
36·14	1·14	31·70	(unknown)*	

Light transmitted by the coating after 908 hours.

$\lambda =$ ·750	86·6 per cent	$\lambda =$ ·507	84·5 per cent
·713	85·2	·481	85·0
·635	83·1	·460	85·5
·580	83·6	·443	86·0
·538	84·5	·429	86·0

The normal life of a lamp starting at 5 watts per candle, is many thousands of hours. Lamp No. 10 was prematurely broken at 908 hours, at which time the coating had reached a density corresponding to that of a 3 watt lamp (No. 2) after 200 hours of life. A comparison of Tables I and II will show that while the coatings on these two lamp bulbs were not quite neutral nor precisely identical in tint, that they both transmit light with much greater uniformity than do such materials, for example as optical glass, calcite, etc.†

II.

The distribution of the age-coating within the bulb.

The distribution of the age-coating was determined indirectly, as follows: Two of the lamps under examination, were measured for horizontal candle-power according to the "Franklin Institute" method;‡ measurements being made in twelve meridians, 30° apart. The readings were repeated at frequent intervals throughout the life of the lamps. The results were plotted with polar coördinates. They show (figure 1), by the diminishing area of the successive curves, the progressive loss of brightness due to age, of which about one-half is ascribable to the coating. The similarity of the curves, from first to last, indicates that the coating is deposited uniformly within the bulb, or in uniform lateral zones, so that the density of the film, is symmetrical with reference to any given meridian. The case chosen for illustration is lamp No. 7. The results obtained with lamp 8, were in every essential respect the same as those shown in the diagram.

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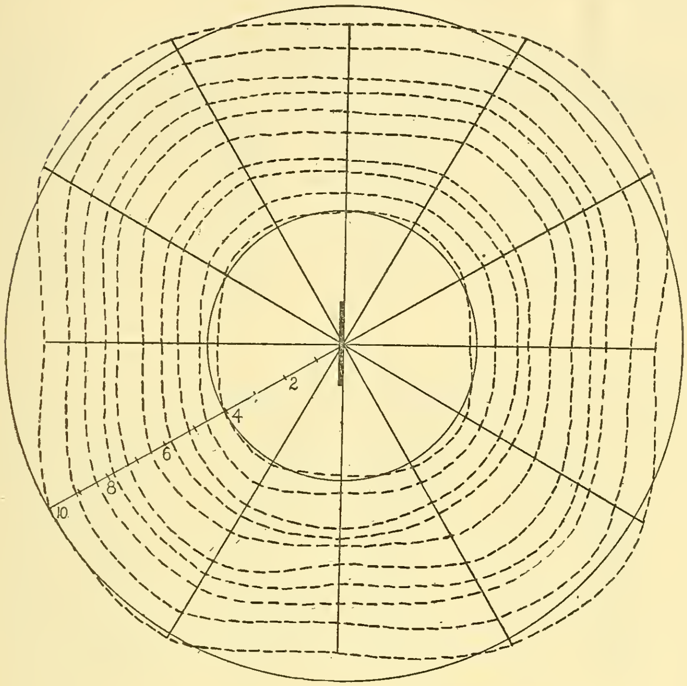
* The lamp was broken before the photometric measurements had been completed.

† See Kruess, Kolorimetrie, p. 243; also, Nichols and Snow, Phil. Mag., V, vol. xxxiii, p 379.

‡ See Franklin Institute Tests (International Electrical Exhibition, 1884), Philadelphia, 1885.

1.



III.

The age-coating considered as a factor in the diminishing efficiency of the lamp.

It may be seen from the Tables (I and II) that the absorbing power of the coating is in itself sufficient to account for a very considerable falling off in the candle-power, as the lamp, within the bulb of which it forms, grows old in service. By summation of the values in the tables, we may obtain the average absorbing power for the entire spectrum; and since selective absorption is almost entirely absent, these averages will give very closely indeed the loss in candle-power, which at the time in question was ascribable to the influence of the coating. From the data in Tables I and II, also, we may compute the efficiencies of the lamps at various stages in terms of their initial efficiency as unity; likewise their brightness from time to time, in terms of their initial candle-power, as unity. In Tables III and IV are given, for purpose of comparison, the relative brightness and efficiency of lamps 2 and 10, at various periods, also the average absorbing power of their coatings.

Table III.

Relative brightness, efficiency and transparency of lamp No. 2, at various periods (each expressed in terms of its initial value taken as one hundred).

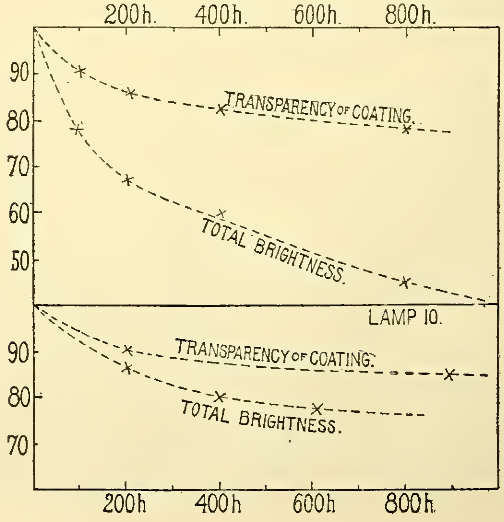
Time.		Relative brightness.	Relative efficiency.	Relative transparency of bulb.
000·	hours	100·	100·	100·
100	"	78·1	81·5	91·44
200	"	67·5	70·9	85·91
400	"	60·4	66·8	82·46
800	"	45·0	51·3	78·24

Table IV.

Relative brightness, efficiency and transparency of lamp 10, at various periods (each expressed in terms of its initial value, taken as 100).

Time.		Relative brightness.	Relative efficiency.	Relative transparency of bulb.
0·	hours.	100·	100·	100·
50·	"	92·6	92·6	----
109·	"	91·4	90·1	----
200·	"	86·6	87·3	90·5
400·	"	80·5	81·6	----
511·	"	78·7	80·0	----
600·	"	78·0	79·5	----
900·	"	----	----	85·0

2.



The curves in figure 2 are based upon these data. They show that the loss in candle-power and efficiency are only in part due to the opacity of the coatings. It is of some interest to compare lamps 2 and 10, since the former is a three watt lamp, whereas the other required 5·16 watts per candle at the beginning of the test. It is to be regretted that the tests did not extend over the normal life-time of such a lamp; the results obtained, however, suffice to show that the loss due to coating is a much larger portion of the total loss in the low efficiency lamp than in the other. Measurements with several lamps, maintained at abnormally high temperatures seemed to indicate that the higher the state of incandescence the less marked (relatively) is the influence of the age-coating upon the decadence of the lamp.

Summary of results.

1. The rate of deposit of the coating in incandescent lamp bulbs is greatest in the early part of the life of the lamp. For example, in the case of a lamp which lasted 800 hours, (see Table III) more than half of the coating was deposited during the first 200 hours.
2. The loss of brightness due to the absorbing power of the age-coating is a variable part of the total loss, being greatest in lamps of high initial efficiency.
3. The coating does not appreciably modify the character of the light which emanates from the lamp.
4. The distribution of the coating within the bulb is a nearly uniform one (see figure 1).
5. No marked difference between treated and untreated filaments appears to exist, as regards the density or quality of the coating produced from them.*

Physical Laboratory of Cornell University, July, 1892.

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*Since this article was written it has been pointed out by Professor B. F. Thomas (in the paper already cited), that in the case of lamps exhausted without the aid of mercury the age-coating is scarcely perceptible.

ART. XXXVII.—*Mica-peridotite from Kentucky;* by J. S. DILLER.

IN November, 1890, I received from Mr. E. O. Ulrich of the Geological Survey of Kentucky the information that a dike, called the Flanary dike, had been discovered in Crittenden County of that State. The specimens from the dike sent to me at that time for examination were laid aside awaiting the report upon the eruptive rocks of Arkansas by J. Francis Williams, and J. F. Kemp. It was expected that similar rocks would be found in Arkansas and this paper rendered unnecessary.

Mr. Ulrich has kindly furnished me the following information concerning the occurrence of the rock in the field.

The dike is in a fault striking N. 44 E. Although the peridotite has not yet been found all along the fault it is known to occur at four points on the line with a distance of 6 miles between the extremes. In Livingston county a little was seen in a shaft mixed with fluor spar and other vein matter. A mile and a half northeast of the county line and three miles from the locality just noted, a shallow opening exposes considerable decomposed peridotite of a light gray or ash color. Here again it is associated with vein matter chiefly fluor spar. At the Flanary shaft the dike is over 20 feet wide with no wall seen on either side. Crosscuts were made 6 feet on one side and 8 feet on the other without finding the walls. It may be that the shaft is at the intersection of several veins in a sort of "chimney." A quarter mile southeast on the Holly the vein matter is 6 feet solid and pure fluor spar. The dike break separates strata faulted no less than 800 feet with the St. Louis beds on the northwest and the upper Chester and coal-measure conglomerate on the southeast.

At least one other dike has been discovered in the county and Mr. Ulrich thinks its material is closely related to that of the Flanary dike. It occurs in a much tumbled region just south of the Columbia mines which he regards as the chief center of disturbance.

The specimens for my study were selected by Mr. Ulrich from among the material thrown out of the Flanary shaft. The shaft is 45 feet deep and the material exposed to surface weathering for nearly two years. The rock is dull greenish-gray. At first glance it has a granitic aspect but upon closer examination the resemblance disappears. It contains many small dark greenish spots besides brownish scales of mica. Upon comparing it with an altered specimen of the peridotite from Elliott county, Ky., one is led at once to suspect that the dark green spots are serpentine and represent original olivine. A thin section of the rock examined under the microscope confirms the conjecture.

The rock is composed essentially of biotite, serpentine, and perofskite with a smaller proportion of apatite, muscovite, magnetite, chlorite, calcite and other secondary products which cannot be definitely determined. It is possible that originally there may have been some pyroxene present. The biotite is somewhat in excess of the serpentine and together they form nearly 75 per cent of the whole rock, small crystals of perofskite are abundant but their total mass is less than that of the brownish-gray clouded material supposed to be of secondary origin. Opaque black grains of magnetite are rather common and a few clear crystals of apatite as well as scales of chlorite and muscovite and small veins of fibrous calcite are present. Judging from the chemical analysis there is probably considerable chromite present also.

If we consider only the relation of the large scales of biotite to one another as determining the structure of the rock it is granitoid for the biotite is allotriomorphic. This mineral is yellowish brown to almost colorless. It occurs in round or oblong patches averaging about 4^{mm} in diameter and forms the groundwork of the rock. Within these irregular scales are scattered the crystals and grains of serpentine in such a way as to render them pœcilitic on a cleavage face. The biotite here plays essentially the same role as the hornblende and augite in the picrites. Between the larger scales, scattered here a few, and there many, throughout the brownish-gray clouded matter are smaller scales of biotite. In sections of the biotite perpendicular to its basal cleavage, although its colors between crossed nicols are brilliant its absorption is very feeble even less than that of ordinary brown hornblende. Prof. Rosenbusch suggests that the absorption is too small and the bisectrix too oblique for normal biotite. The biotite is occasionally altered to chlorite.

The serpentine is distributed uniformly throughout the rock in irregular rounded or angular grains averaging about 1^{mm} in diameter. The characteristic sections with outlines like those of olivine parallel to the base and macropinacoid are sufficiently numerous and well defined to clearly indicate that the serpentine originated from the alteration of olivine. The large quantity of olivine originally present shows that the rock belongs to the peridotites.

The mineral regarded as perofskite is abundant and generally well crystallized. The diamond-shaped, square and triangular sections which are completely isotropic demonstrate that it is isometric. Its color is honey-yellow and only moderately transparent. The crystals vary in size from ·01^{mm} to ·1^{mm} in diameter and are almost always black-bordered. The chemical analysis of the rock shows that it contains 3·78 per cent TiO_2 with 9·46 per cent CaO. After taking out of the analysis the elements demanded for the other determined minerals there yet remains essentially the composition of perofskite. Titanic acid is frequently found in biotite and it is desirable that analyses be made of both biotite and perofskite in this case ; but as the minute crystals of perofskite are generally enveloped by the biotite it would be very difficult and perhaps impossible to satisfactorily separate them.

The muscovite, chlorite, magnetite, apatite and fibrous calcite have no features deserving special mention. The brownish gray clouded material which is next in abundance to the serpentine is scattered throughout the section generally between the scales of biotite, but often within them. It is without crystallographic outline or such physical features as definitely indicate its origin.

The following chemical analysis of the rock for which I am greatly indebted to Mr. W. F. Hillebrand was made in the chemical laboratory of the U. S. Geological Survey.

SiO_2	33·84
TiO_2	3·78
Al_2O_3	5·88
Cr_2O_3	0·18
Fe_2O_3	7·04
FeO	5·16
MnO	0·16
NiO	0·10
CoO	tr.
CaO	9·46
BaO	0·06
MgO	22·96
K_2O	2·04
Na_2O	0·33
H_2O	7·50
P_2O_5	0·89
Cl	0·05
Fl	?
CO_2	0·43
	99·86

In addition to the water given, the sample lost 0·68 per cent water at 100° C. The large percentage of H_2O and CO_2 shows the highly altered condition of the rock.

Among the peridotites already described Rosenbusch has recognized six forms. Considering only their essential constituents, the designations adopted by him are as follows:—*picrite* = olivine+augite, *amphibole picrite* = olivine+amphibole, *Wehrlite*=olivine+diallage, *Harzburgite*=olivine+rhombic pyroxene, *Lherzolite*=olivine+diallage+bronzite, *dunite*=olivine+chromite without pyroxene or amphibole.

Heretofore[*] no peridotitic rock has been recognized in which biotite[†] has played the rôle of an original essential constituent. While it is evident that the Flanary dike rock belongs to the peridotites, it is clearly excluded from any of the subdivisions above. In order that it may be conveniently distinguished from other peridotites I propose for it the name *mica-peridotite*, a name which I believe will at once suggest to all students of petrography its kinship.

More than half a decade ago Prof. A. R. Crandall[‡] discovered the peridotite of Elliott county, Kentucky, and to this Mr. Ulrich now adds one more of the same type of rocks from the western part of the State. Closely related rocks of the same group have been described by Drs. J. C. Branner[§] and R. N. Brackett from Pike Co., Ark., by Prof. G. H. Williams,[‖] from Syracuse, N. Y., and by Prof. J. F. Kemp,[¶] from Ithaca, N. Y.

A very fresh olivine mica rock closely related to the mica peridotite of Kentucky has been described by Dr. Max Koch,[**] who recognizes it as a new type. It occurs in the gabbro region of the Harz and contains augite and plagioclase as accessory minerals in small quantities. These minerals as well as the geologic relations of the rock indicate according to Dr. Koch, that it belongs to the gabbro group.

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

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[*] Excepting perhaps one described by Max Koch which will be noticed later.

[†] The peridotitic rock described by Judd (Quart. Jour. Geol. Soc., Aug., 1885, p. 401), as scyelite is rich in mica; but he regards it as secondary resulting from the alteration of augite. Furthermore, scyelite contains hornblende of which not a trace has been found in the rock from Flanary dike.

[‡] Geol. Survey of Ky., Report on the Geology of Elliott County, by A. R. Crandall, p. 17. See also articles by J. S. Diller, this Journal, Aug. 1886, and U. S. Geol. Survey, Bulletin No. 38.

[§] This Journal, vol. xxxviii, p. 50, 1889; also, Geol. Survey of Ark. Annual Rept. for 1890, vol. ii, p. 377.

[‖] Ibid., vol. xxxiv, pp. 140–142, 1887.

[¶] Ibid., vol. xlii, p. 410, 1891.

[**] Zeitschr. d. d. geolog. Gesell., xli, p. 163, 1889.

ART. XXXVIII.—*Glaciation in the Finger-Lake region of New York;* by D. F. LINCOLN, M.D., Geneva, N. Y.

THE Appalachian plateau, at the line between New York and Pennsylvania, is composed of Upper Devonian sandstone and sandy shale, dipping slightly to the south, with summits 2000–2500 feet above tide level. The valleys are rather deep (400–800 feet), and resemble in a general way those of central Pennsylvania, but without the N.E.–S.W. parallelism of the latter. The elevations do not take the form of ridges; they consist of broad, clumsy masses, diminishing in steepness as they ascend, and capped with irregular rolling plains.

The Susquehanna, with its tributary the Chemung, here forms an important depression, north of which the land rises to the height of 2000 feet, again sinking to form the basin of the Finger Lakes. The lakes therefore occupy a section of the northern slope of the Appalachian plateau, which may be defined as extending 100 miles E.–W., from the Genesee Valley to Cazenovia Lake, and about 70 miles N.–S., from Lake Ontario to the curved line of high land just south of the lakes.

This line of heights corresponds in position with the "Terminal Moraine of the Second Glacial Epoch" of Chamberlin,* and is defined as a water-parting by the following high points—Bristol, 2254 ft.; Urbana, 1940; Orange, 2033; Newfield, 2095; Dryden, 1888; Virgil, 2133; Solon, 1977; Fabius, 2015; Fenner, 1862.†

The height of land of which these are the summits is cut through by many deep straight valleys, which on the south communicate with the Chemung-Susquehanna valley, while on the north they converge toward a common imaginary center in Lake Ontario. The northerly discharge is intercepted by streams flowing eastward, which unite to form the Oswego River. Most of these north-south valleys are so blocked with drift as to form lakes.

The middle of the common basin is axially depressed, in a north–south direction; the depression is occupied by the two largest lakes, Seneca and Cayuga.

There is a considerable system of minor, preglacial valleys still traceable in the elevated tracts between the lakes. This system, however, has been so disturbed by glaciation that it no

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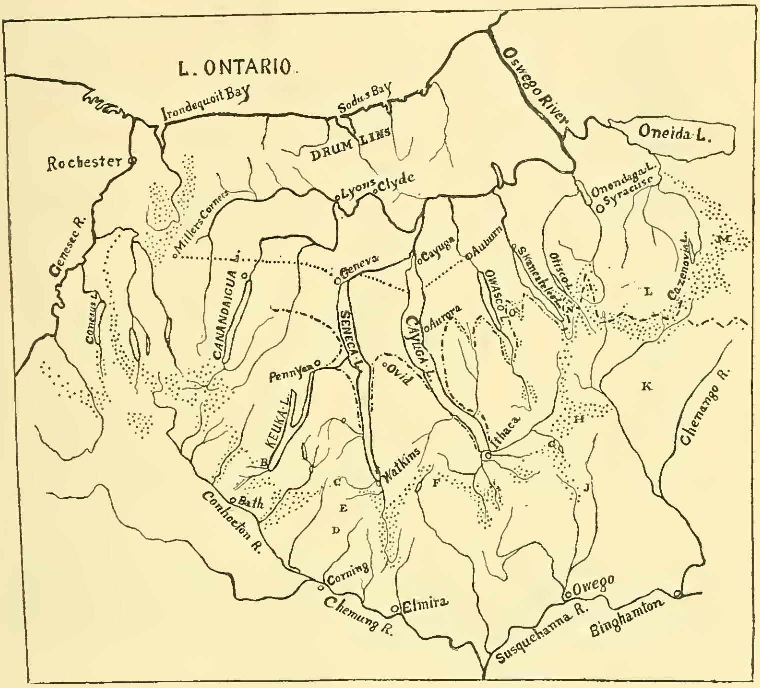
* U. S. Geol. Survey, Third Report.

† Triangulation of N. Y. State Survey, 1883, 1887.

longer furnishes in normal fashion a series of tributaries to the lakes. The greater part of the surface water enters the lakes through torrents, running from two to four miles in a straight course, at right angles to the lake-axis, through precipitous gorges, which they are still actively deepening. Some of the finest scenery in the State is found in these gorges. Watkins and Havana glens are examples; the highest waterfall in the State occurs in the Taughannock glen, near Ithaca; its perpendicular fall is 190 feet.



The Finger-lake region of New York.

Terminal moraine (from Chamberlain) is represented by dots.—Corniferous limestone, a line of dots.—Tully limestone (Prof. H. S. Williams) dots and dashes — . — .

A, Bristol;	B, Urbana;	C, Sugar Hill;	D, Hornby;
E, Orange;	F, Newfield;	G, Dryden;	H, Virgil;
J, Richford;	K, Solon;	L, Fabius;	M, Fenner.

Elevations above sea-level—Rochester, 508; Lyons, 407; Clyde, 396; Bath, 1105; Elmira, 863; Sugar Hill, 2091; Hornby, 2045; Richford, 1995.

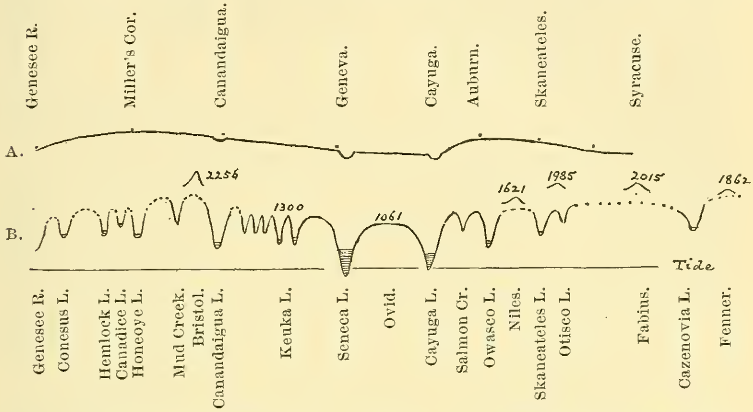
Altitudes and Depths of Lakes.

	Elevation above tide.		Greatest depth.
Erie	572·9	L	210 G
Chautauqua	1291	G	
Conesus	821	R	70 G
Hemlock	898	R	87 G
Canadice	1099	R	87 G
Honeoye	less than Hemlock		25 G
Canandaigua	668	G	
Keuka (Crooked)	718′ 10″	G	
Seneca	441	C	618 M
Cayuga	378	C	435 M
Owasco	670	G	
Skaneateles	860	G	
	864′ 12″		
	861	C	
Otisco	no data		
Cazenovia	900	G	
Schuyler	1200	G	
Otsego	1193	G	
Onondaga	361	G	
Oneida	369	G	
	367·71		
	368	C	
Ontario	246	L	738

L = U. S. Lake Survey. C = Resurvey of N. Y. Canals. R = Rochester Water Works Surveys. P = Penn. & N. Y. R. R. G = French's Gazetteer of N. Y., 1860 (comparatively poor authority.) M = Soundings given on map published by Engineering Department of Cornell University.

The entire basin may conveniently be divided into three regions or zones, nearly corresponding with certain geological formations. The northern zone (Silurian) is nearly *level*, with a heavy mantle of drift; it extends from the Ontario coast to the northerly escarpment of the Corniferous limestone, which is skirted by the line of railroad passing through Auburn, Geneva, Canandaigua, and Miller's Corners. The middle zone comprises the *moderate ascent* of the lower Devonian, extending south from 6 to 20 miles from the railroad. The southern zone, with *steep slopes* and deep valleys, comprises the Upper Devonian (Chemung and Portage rocks), including on the east the lower Devonian to Skaneateles. The zigzag dotted line of the Tully limestone partially indicates the demarcation between the two latter zones. The terminal moraine bounds the whole on the south.

The northern zone comprises the Medina, Clinton, Niagara, and Salina formations, dipping south at a low angle. The Clinton and Niagara limestones form escarpments facing north, which are inconspicuous in large part. It is traversed by the N. Y. Central R. R. and the Erie Canal at very easy grades. A portion along the southern edge of this belt is level and free from drift-hills: north of which the surface is diversified by an extraordinary series of drumlins, already described by Hall (New York State Geological Report for 4th Dist., 1842) and Johnson ("Parallel Drift Hills of Western New York;" Annals of N. Y. Acad. of Sci., Nov. 9, 1882). These are stated by Hall to be bounded northerly by the beach of the ancient Lake Iroquois—the "Ridge Road"—which runs a few miles from the shore of Lake Ontario.



A. Vertical section nearly E.-W. along N. Y. Central R. R., nearly on Corniferous outcrop.

B. Vertical section near the middle of each lake; dotted lines show deficiency of exact data, partially supplied by a few adjacent known points.

As compared with the drumlins of New England, these are of much greater length, are relatively much narrower, much sharper at their ridges and steeper in their side-slope. Their northern ends are very bluff, their southern ends gently inclined. Their axes lie nearly north and south, on the whole, with marked local differences.

The width of these hills at top is often sufficient to receive a country road without much leveling, but some would not (in their original state) admit the passage of a single cart along the ridge; while in exceptional cases there are flat tops some hundreds of feet in width.

The inclination to the south is often so gentle as to have no definite ending; thus many hills which begin northwardly with well-marked drumlin-outlines sink and broaden southwardly into plains of till. Some, however, are well-defined at both ends, and in length fall within one-half or two-thirds of a mile. Johnson states that the best developed ones run two or three miles, and reach the height of 100–200 feet above the plain; that they are highest and longest chiefly just south of the Niagara escarpment, though there are a few very high ones more to the south.

Measurements of a few of the steeper ones (kindly communicated by Mr. George H. Barton) show the inclination of the sides to be about 23°, and only exceptionally 25°.

The material of these hills is a till, possessing the usual characteristics—unless a tendency to the formation of very deep gullies (5–15 feet deep) on the sides be considered exceptional. Some are covered very thickly with good-sized traveled stones; some with sand or gravel of varying depth. In the neighborhood of Rochester are some of which the nucleus is sand, till forming the upper part. Considerable kame-deposits are associated with the drumlin-belt at some points, and near Rochester a portion of the moraine traverses it.

The writer's personal study of this region is limited to five localities, and the above statements are in part drawn from other sources. An excellent cursory view can be had from the car windows as the traveler passes east from Rochester on the main line of the N. Y. Central R. R. via Lyons and Clyde to Syracuse.

This belt of *large* drumlins practically comes to an end at the distance of twenty miles from Lake Ontario. Then come low lands, partly sandy, partly marshy. Still farther south, within the middle zone, the drumlin-formation is resumed, in ridges of much smaller height, but in considerable numbers. As this point has not met the writer's eye in print, attention is here called to it, and some special observations are offered.

Among the drumlins of the second range (in the middle belt) there are some which resemble the typical "lenticular hill" of New England. More, however, are of the ridge variety. And of the latter there are many grades, from the very well marked ridge with rather steep banks to very low ridges which are often so low and flat as to simulate terraces. The face of this part of the country is laid out in shallow grooves, often producing the strong impression of "fluting."

An instructive group of these ridges occurs in and around the town of Geneva. They are very nearly parallel, their axes lying between 10° and 15° west of north. The easternmost skirts the lake, and is somewhat eroded by the waters, displaying sections of till, with limited beds of blue clay and "quicksand." Its crest, on which Main street is built, reaches a height of 90 feet above the lake. The other ridges increase in absolute elevation, but not in size, having an apparent height of 20–50 feet above the ascending slope which they cover. At somewhat over a mile from the shore they attain a height of 300 feet above the surface of the lake, which corresponds with the verge of the higher levels of land. Similar ridges are found for several miles farther west; sometimes crossing the road at pretty regular intervals of $\frac{1}{4}$ to $\frac{1}{3}$ mile, with elevations of only a few feet; at other times forming hills with a rather bold northern descent.

A distinct termination north and south can generally be traced in the ridges of the Geneva group, although the ordinary observer is inclined to overlook the fact. Their general outline, their material, and their tendency to steepness at the north end, ally them with the drumlins of the northern belt. The long ridge running west from the end of the lake is of typical till, with some large bowlders, overlaid in part by stratified sandy clay.

In this locality, the till evidently forms a continuous sheet, of which the ridges are merely a surface irregularity.

The slope of the sides of the ridges is about from 2° to 10° at Geneva, and their crests are occasionally from 100 to 300 feet wide.

The direction of the ridges of till as a whole is probably similar to that of the glacial striations, that is, convergent to a northerly point. At Clyde and Lyons (on the central axis of the region) they run a degree or two west of north. Near Cayuga, about N. 8° W.; and still further east, about 20° west of north.

The till at Geneva is a firm "hard-pan," containing a great number of subangular striated stones of all sizes up to three feet in length. The greater part of the stones are from the Corniferous limestone, which is exposed just north of the village. Of those representing more northern formations, many are water-rolled. The limestone fragments give a bluish tint to the otherwise reddish brown mass.

About three feet of the upper part of this till appears thoroughly oxidized and leached. This portion is a red clay, distinctly contrasted with the gray-blue till, and rather well demarcated. It is of a deep shade, unstratified, very tenacious, nearly free from sand; at times flaky, at times tending to split when dry into rectangular forms. It cuts with a slight grittiness; the surface is dotted with occasional specks of material not fully decomposed, which may represent some of the myriads of little bits of limestone found in the till. The stones are few, chiefly such as resist oxidation (quartzites); these correspond in appearance and amount with a simliar ingredient of the till. Gneisses and schists are absent, or badly rotted. The forms are characteristic of till, and in some cases striation is observed. A part of the stones react feebly to HCl; the clay does not react.

Midway of the Cayuga lake shore, on the east side, there are fine till sections which give a similar result on analysis.

The same leaching of the upper part has been observed in stoneless sedimentary clay of Geneva. Absence of the lime-reaction is stated to be characteristic of the soil at the State Agricultural Station in the same town.

At many points on the surface of the lower-till (Drumlin) deposits just described, there is little or none of the englacial material defined by Upham.* But where the stones lie thickly in the fields it is necessary to suppose that they are chiefly of englacial origin; for the proportion of limestone fragments in such cases is quite too small to permit us to refer them to the lower-till. This is easily seen in the piles of stones which the farmers draw from the fields—sometimes 12–20 feet in diameter from a 100-acre lot—consisting mostly of gneissoids, schists, and quartzites, with perhaps one-fifth corniferous limestone, the lumps varying from 2 to 200 pounds in weight. The larger stones (bowlders) carry out this statement; they are almost all far traveled stones. Large bowlders are not very frequent. The largest within observation are one of labradorite (7×7 feet), and one of an argillaceous rock from the Salina beds (6×11) which is exceptional in having traveled only 5 or 6 miles.

Stratified deposits are not infrequent, however, upon the drumlin formation. Rolled gravel is not rare, and the kames and osars deserve a fuller description than can here be given.

On reaching the higher levels, west of Geneva or east of Aurora, we often find the surface sandy. The sand even takes the form of low hills and ridges. The deposit of tough lower-till, however, is still found beneath the light top-soil.

The thickness of the till-sheet at Geneva is reported at several points as 20–30 feet. Sand lies beneath this, and still lower, till again. At one well, there was 14 feet of sand, and 13 feet or more of the deeper till bed. Layers of vegetable matter, and blue clay, are also found.

In passing south from the soft shales of the Hamilton group to the sandy shales and hard fissile sandstones of the upper Devonian beds, we are informed of the change of bed-rock by the alteration in the character of the lower-till. The latter, in recent exposures, may be very tough, but is sandy rather than clayey. The enclosed stones are sandstone, rarely limestone. Fragments handsomely glaciated occur as large as three feet

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* Amer. Geologist, vol. viii, No. 6.

long. The field-stones in this region split, losing their likeness to till-stones. Hence the "flat gravel," characteristic of the soil of the hilly districts.

The deltas of the lake sides are among the most conspicuous accumulations of drift material. Rising at intervals along the sides of the lakes and the southern continuations of their valleys, they attain by a series of steps the height of (?) 400 feet above the lakes. Their strata contain many stones which still show half obliterated glacial striæ.

The remainder of this paper will be devoted to certain points of preglacial topography and drainage, and the associated questions of amount of glacial corrasion, and bulk of drift-deposit. The northern zone, except as specially designated, will be omitted from consideration.

The deposits of the terminal moraine are very heavy; for a description of this feature the reader is referred to the paper on this subject by Thomas C. Chamberlin.

From considerable examination of the country included between the four larger lakes, the writer has been led to set a moderate estimate upon the amount of drift, and a very high estimate upon the amount of erosion in certain parts.

The lakes are to a great extent bordered by vertical cliffs of rock, with little or no beach at their foot. Owing to the greater prevalence of westerly winds the cliffs are best developed on the east side. In the case of Cayuga Lake this natural facility is aided by the presence of a railroad at the water's edge, for which in many places the cliffs have had to be cut. From Aurora southward for nearly 20 miles the top of the cliff is visible most of the way, undulating in very moderate curves, occasionally rising 50 feet or more, and at several points sinking below the level of the lake for short distances. In the latter case the rock is exposed in brooks a few rods inland. Till overlies this rock, varying in thickness from 2 to 40 feet. The till deposits along the east shore of Seneca lake are apparently not much in excess of the above.

It is probable that the rock-sections thus displayed correctly represent the general surface of the region as it would appear if the drift were removed. In some tracts, at all events, this is demonstrably the case. In the northern reaches of the lakes, hills of rock with a very flat curve correspond with these cliffs. A few examples may be worth describing. At the foot of Seneca Lake on the east side there is a line of cliff (Marcellus shale), which rises gradually to a height of 25–30 feet and extends more than a mile. A hill-side rises directly from the brow of this cliff to the height of about 90 feet; mainly rock with 2–20 feet of till. Three miles to the southward is another long shore-cliff of rather greater height, the land behind which rises for 1½ miles eastward, reaching a height of 150 (?) feet, and forming a broad-backed N–S ridge of Hamilton shale covered with a couple of feet of drift. A third ridge 250 feet high, at a similar interval to the S.E., slopes very evenly to the lake (2½ miles distant) over rock covered with a very few feet of drift; in this case no cliff is formed, the rock not quite reaching the lake. The axis of this hill points N. 20°–30° W. On Cayuga lake, south of Aurora, there is a hill 300 feet in height, forming a cliff at the lake-side, two miles long and one mile across, with its long axis directed N.W.–S.E., composed of Hamilton shale. The top of this hill, for the length of a mile, forms a plateau. A smaller hill of Marcellus shale lies 4 miles to the north of this.

In the present state of the question it is admissible to suppose that these hills may be remnants of preglacial hills of bolder outline. The fact that they lie parallel to the lake need not militate against this view, since the old valleys of the region—farther south than the hills described—unite with the lakes and with each other at very acute angles.

The hills may constitute a very insignificant remnant of old hills; or may even have been carved out *de novo* from rock which occupied levels below the roots of their predecessors. In other words, the corrasion at the latitudes of Geneva and Auburn may have removed one hundred or several hundred feet. Definite evidence limiting these estimates is not before me. Apart, however, from the numerical estimate, it is interesting to note the parallelism between the axes of these hills and those of the drumlins which are found close by. Their material, a soft shale, yields readily to force applied horizontally, and it is not beyond the province of legitimate speculation to suggest that their forms may have been carved at the same time and in similar circumstances with the drumlins. Their bluffer northern sides, and their exceedingly gentle southern slopes, add much to the likeness.

A system of small valleys for local drainage, opening lakeward, doubtless existed before glaciation. We can point to no surviving representatives of these valleys at the lake level unless the slight depressions in the cliff line be taken as such. These descending curves run but a short distance below the lake level, and represent but slight inward bends of the rock-shore. If the lake were drained, the present mouths of the brooks flowing in these hollows would be a mile from the main stream which presumably occupied the axis of the valley. In going this mile they would fall from 300 to 600 feet. Such streams must have cut deep and wide gorges extending far inland. How deep some of these would have been at parts of the lake where the shores are bolder, may be estimated by considering that the land at the upper part of Seneca lake rises in six miles to upland pastures nearly 2000 feet above the bed of the lake.* The continuity of cliffs for 15 miles along the west coast near Watkins, and the frequency of rock exposures on the high lands, forbid the belief that such gorges exist.

The inference from these considerations is that the preglacial river which has been developed into Seneca lake must have occupied a level many hundreds of feet above the present bed of the lake.

Some drift-buried valleys certainly exist. One such, probably with a meridional course, seems to lie to the east of Aurora, where two E.–W. ravines appear to cut it, one of which exhibits a till-section 100 feet thick, with bottom not reached. However this be, there still exists a large system of valleys, with banks several hundred feet high, subsidiary to the lake valleys and in several places communicating with them. These valleys are rock-cut, and often show rocky bottoms; they run mainly parallel to the lakes, but occasionally branch in a transverse direction. They run straight through the line of terminal moraine. Their trough-like aspect north of the moraine points to probable widening and deepening, as in the case of their much bigger brothers, the lakes.

As an illustration, take the large valley, 20 miles long, entering Cayuga lake 6 miles north of Ithaca. It is cumbered with some drift, but its walls rise 400 feet above its bed, in full sight from the lake.

Perhaps the case of certain upland valleys will add confirmation to these views. East of Watkins there is a system of these at 400–600 feet above the lake. The main drainage of this system is at present southward, but it communicates with the Seneca valley by two wide gaps, allowing several short streams to enter the lake, which they do by a sudden plunge—one of them cutting the beautiful Havana glen in its descent. These streams must have fallen 1,000 feet in three miles in order to have reached the Seneca valley bottom at its present level. In like manner the stream which has excavated the celebrated Watkins Glen descends about 500 feet in its last mile through a canyon with vertical walls, while its upper five miles are mostly in an old valley with moderate grades.

Again, Dundee, situated three miles from the west shore and ten miles north of Watkins, stands 600 feet above Seneca lake. It occupies a site apparently near the mouth of an old valley, bounded by rock-hills from 300 to 400 feet high, and displaying a rocky bottom in the stream at Dundee. The valley has four or five branches, extending six miles above the

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*Seneca lake bottom is 177 feet below tide; high points W. of Watkins, near 2100 feet above tide.

village in several directions, with very moderate grades. In the direction of the lake the valley-sides become lower, and the valley itself disappears, debouching upon the lake side at an imaginary plane in mid-air. From this point the lake-side descends smoothly and rapidly, while the stream, with many cascades, falls 500 feet in two miles.

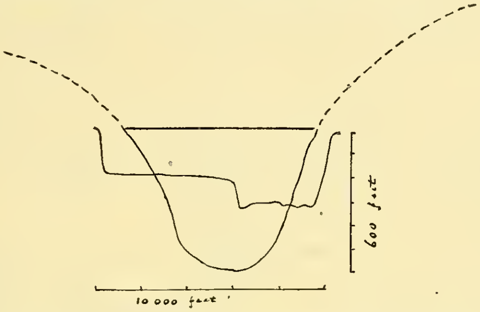
If these valleys, or any of them, had a preglacial existence, and a rational connection with the lake valley, it would seem necessary to suppose that the bed of the latter then stood at an elevation 800 (?) feet higher than at present. If they drained away from the lake, they would soon have been cut down by robber-streams falling into the Seneca valley. The present Chemung river valley, which would be the southerly exit, is 1200 feet higher than Seneca valley floor.

The trough of the present lake runs straight south from Watkins to the open valley about Elmira, 22 miles distant. The present bottom of the lake is 1,000 feet below the river at Elmira; a discrepancy which may be harmonized by either of two hypotheses,—glacial erosion of the lake bed, and filling of the valley at Elmira with overwash from the moraine. That the truth is a composite of both, seems very probable.

The belief that the lakes are deeply gouged by ice is consistent with the fact that their depth (in the case of the two largest) is much the greatest in the southern third. Considered relatively to the glacial movement, this is the downward part, and the fact agrees with Geikie's statements regarding the rock-cut lochs of western Scotland, which form basins, deepest toward their outlet. The section of Seneca lake along its axis is like that of an elongated tablespoon, pointed to the north. But until we know more about the depth of alluvial and drift deposit at the ends of the lakes, this consideration may be waived. It is nearly certain, however, that the lake bed is not more than 300 feet deep at Geneva where the apparent depth is 40 feet.

The direction of preglacial drainage may perhaps be inferred from the considerable and continuous slope of the land toward Lake Ontario. The height of land between this slope and that toward the Susquehanna system is near the south ends of the lakes, and it does not seem necessary to suppose that it was formerly placed much farther to the north. Such valleys as Seneca may have had their divide near the southern ends of the present lakes. A number of streams seem to have run southward across the divide; of which Keuka lake, and much of the distribution of the valleys about Canandaigua and Owasco lakes, offer strong suggestions.

Few borings have been made north of the lakes, and it is not advantageous to speculate upon a possible outlet for the north-flowing streams. The lowlands north of Cayuga lake (Montezuma marshes) offer a very slight barrier to such a discharge. It is worth noting that a boring made at Geneva, at the lake side, encountered obstacles from bowlders at about 100 feet, and struck no true rock until 240 feet below the water line. A valley three miles wide between existing rock-exposures, and 300 feet deeper than the present lake surface, apparently opening to the north, is indicated at Geneva: some of this depth may be ascribed to glacial action.



Section of Channel of Wisconsin River (Report of U. S. Geol. Sur., VI, p. 230) partially filled with river-gravel; compared with that of Seneca Lake at deepest point. The latter section is adapted to scale from that given on the map published by Cornell University; the dotted slope of bank is obtained from contour-lines of map. Ratio of vertical to horizontal scale nearly = 10 : 1.

The accompanying cut is given to show the contrast between the much-glaciated banks of Seneca Lake, with thin smooth gentle curve leading to the upland levels, and the unglaciated banks of the Wisconsin River, falling at a sharp angle from the level of the plain in which the valley is cut. The section is from one of the narrower parts of the river, in its course through the non-glaciated region. The river valley is filled to an unknown but considerable depth with material brought from glaciated territory. The lake valley, judging from the outline given, is free from heavy glacial or postglacial deposits for many miles; its ends, however, are deeply filled.

Art. XXXIX.—*On Certain Points in the Interaction of Potassium Permanganate and Sulphuric Acid*; by F. A. Gooch and E. W. Danner.

[Contributions from the Kent Chemical Laboratory of Yale College—XVII.]

In an article published some years ago by Mr. Francis Jones* upon the action of reducing agents upon potassium permanganate the statement is made that in the interaction of

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* Jour. Chem. Soc., xxxiii (1878), p. 95.

oxalic acid and the permanganate in whatever way the conditions were varied—whether there was excess of oxalic acid or of permanganate, whether the solutions were strong or dilute, whether acid was present or not—in every case oxygen was obtained as a product of the reaction. The action between the permanganate and ferrous salts, in presence or absence of acids, in dilute or strong solutions, was said to yield oxygen similarly. In the discussion which followed the reading of this paper before the Chemical Society (London) some adverse comment seems to have been developed.*

More recently,† in developing his excellent volumetric methods for the estimation of tellurium, Professor B. Brauner has noticed a similar effect in the action of potassium permanganate upon tellurous oxide dissolved in sulphuric acid, and has shown, further, that in this particular case the evolution of oxygen is proportional to the amount of sulphuric acid employed, and that in working with alkaline solutions little evidence of such action appears.

The production of permanganic acid, and secondarily of free oxygen and ozone, by the action of strong sulphuric acid upon a permanganate is one of the commonest of phenomena, and the formation of a precipitate consisting largely of hydrated manganese dioxide by the action of hot dilute sulphuric acid upon the permanganate in aqueous solution is likewise well-known. It seemed desirable to us, therefore, to study further the action of sulphuric acid of different strengths upon the permanganate in solution, with a view to determining how far such action may be responsible directly or indirectly for the liberation of free oxygen in oxidations brought about in the presence of the acid. In the first set of experiments directed to this end we determined the amount of potassium permanganate remaining after exposure to the action of sulphuric acid during different intervals of time and under varying conditions of strength and temperature. The permanganate was used in approximately decinormal solutions (3·16 grms. to the liter) the exact strength of which was determined relatively to an approximately decinormal solution of oxalic acid. In fixing the standard small portions (usually 10 cm^3) of the oxalic acid were diluted to a volume of 100 cm^3 by means of sulphuric acid of two per cent strength by volume, the solution was heated to 70° C. or 80° C., and the permanganate was added as usual until the first permanent blush of color appeared.

The general mode of proceeding in the test experiments was, in brief, to mix the solution of permanganate with the sul-

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* Ber. d. d. Chem. Gesell., 1878, p. 257.

† Jour. Chem. Soc., 1891, p. 238.

phuric acid (always previously diluted with an equal volume of water, and cooled) and, after the lapse of time indicated to add oxalic acid in quantity a little more than sufficient to bleach the entire amount of permanganate, warm to about 80° C., and titrate the residual oxalic acid by gradual addition of more permanganate. The difference between the amount of permanganate needed under the conditions to destroy the known amount of oxalic acid and that used in the determination of the standard should measure the oxygen lost by the permanganate under the action of the sulphuric acid. The results and details of these experiments are given below.

TABLE I.

H_2SO_4 [1 : 1] cm^3	Water. cm^3	$K_2Mn_2O_8$ in decinormal solution. cm^3	Percentage of H_2SO_4 [1 : 1] in solution during action.	Percentage of $K_2Mn_2O_8$ used as compared with that required by theory. cm^3
A. Treated immediately.				
2	8	10	10	100
4	6	10	20	100
6	4	10	30	101·5
8	2	10	40	101·6
10	--	10	50	101·9
B. Treated after standing eight hours at ordinary temperature.				
2	8	10	10	99·7
4	6	10	20	99·7
6	4	10	30	101·3
8	2	10	40	105·3
10	--	10	50	115·7
C. Treated after standing five days at ordinary temperature.				
2	8	10	10	104
4	6	10	20	121·6
6	4	10	30	149·7
8	2	10	40	155·9
10	--	10	50	156·4
D. Treated after standing one and one-half hours at 80°–90° C.				
2	8	10	10	101·3
4	6	10	20	143·8
6	4	10	30	135·9
8	2	10	40	149·1
10	--	10	50	155·3

It is manifest from an inspection of Table I that the decomposition of the permanganate increases directly in each series of experiments with the increase in the proportion of sulphuric acid, that the amount of decomposition is greater as the time of action is extended, and that increase of temperature heightens the change. We note in particular, for example, that the presence of ten per cent of [1 : 1] sulphuric acid induces at the ordinary temperature no immediate decomposition of the permanganate, none in eight hours, and a breaking down amounting to four per cent in five days; and that the presence of fifty per cent of acid of the same strength occasions the decomposition of about two per cent at once, fifteen per cent in eight hours, and more than half the entire amount of permanganate in the course of five days. It is evident also that twenty per cent of the [1 : 1] acid produces no appreciable effect at ordinary temperatures and under exposures of a few hours only. The effect of heating the mixture of acid and permanganate to 80° C. for an hour and a half is closely comparable with that brought about by the five days action at the ordinary temperature.

In another series of similar experiments, the detailed record of which we omit as unnecessary, the absolute amounts of liquid and acid were increased while the proportion of the latter to the whole volume of the former was preserved. The volume of the liquid containing the acid and permanganate was fixed at 100 cm^3 and the absolute amounts of acid were taken five times as great as those used at corresponding points of the preceding series. The amounts of decomposition observed in these experiments followed those of the first series so closely as to compel the conclusion that it is the proportion of acid present rather than the absolute amount which is chiefly influential in the decomposition of the permanganate under given conditions. In still another series of experiments which differed from the last in the single point that the amount of permanganate used was increased five-fold no appreciable differences in effect which might be traced to such extra use of permanganate were discoverable.

It is, of course, possible, and even probable, that some decomposition of the permanganate by the sulphuric acid might be brought about after the addition of the oxalic acid during the warming of the mixture up to the temperature at which the oxalic acid and permanganate interact. The experiments of Table II were therefore undertaken to test this point. In them oxalic acid was replaced by a solution of ferrous sulphate in order to secure the removal of the residual permanganate at ordinary temperatures. The greatest care was taken to guard against atmospheric oxidation during the course of the experiment. The solution of ferrous sulphate was standardized before and after making the test experiments and found to be unchanged during the period of work. In the first five experiments of series B the proportions of acid and liquid of series A were preserved while the absolute volumes were increased; in the last four experiments the range of variation in proportions was extended.

TABLE II.

H_2SO_4 [1 : 1] cm^3	Water. cm^3	$K_2Mn_2O_8$ in decinormal solution. cm^3	Percentage of H_2SO_4 [1 : 1] in solution during action.	Percentage of $K_2Mn_2O_8$ used as compared with that required by theory.
		A. Treated at once.		
2	8	10	10	100
4	6	10	20	100·2
6	4	10	30	100·1
8	2	10	40	100·1
10	--	10	50	100·3
		B. Treated at once.		
10	80	10	10	100·1
20	70	10	20	100·1
30	60	10	30	100·
40	50	10	40	100·5
50	40	10	50	101·3
60	30	10	60	103·
70	20	10	70	105·
80	10	10	80	103·3
90	--	10	90	108·1

The results of these experiments indicate, as was anticipated, that rather less decomposition of permanganate is caused by the sulphuric acid when the reduction of the residual permanganate is effected at ordinary temperatures. The increase in the amount of decomposition as the proportions of sulphuric acid [1 : 1] present are pushed beyond fifty per cent of the liquid is striking.

We have studied these same phenomena still further, varying, however, the mode of proceeding so as to observe and measure the gas evolved from the liquid as Jones* and Brauner* did in their individual investigations of the evolution of oxygen during oxidations. In these experiments tubes of suitable size and length, holding from 100 cm^3 to 200 cm^3, were sealed at one end, filled completely with the mixtures of acid and permanganate, inverted, and allowed to stand with the lower and open end submerged in liquid of the exact composition of that which filled them. The details and results of these experiments are recorded in Table III.

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* loc. cit.

TABLE III.

	A. $H_2SO_4[1:1]$ = 50 per cent.		B. $H_2SO_4[1:1]$ = 25 per cent.	
Time elapsed.	Gas from 100 cm³.	Appearance.	Gas from 100 cm³.	Appearance.
5 min.	0·1 cm³	No change.	Small bubble.	No change.
1 hour.	1·1 "	No change.		
1 day.	14· "	Red brown.		
3 days.	15·3 "	Light brown.	9·6 cm³	Reddish purple. Turbid.
4 "	15·6 "	" "		
7 "		Brown, turbid.	15·1 "	Reddish pink. Clearing by precipitation.
8 "	16 "	Clearing by precipitation.		
15 "	17·3 "	Clear, straw-colored.	18 "	Nearly clear.
17 "	17·4 "	" " "		
35 "	17·5 "	" " "	18·4 "	Clear and colorless.

	C. $H_2SO_4[1:1]$ = 12·5 per cent.		D. $H_2SO_4[1:1]$ = 6·25 per cent.	
1 hour.	Small bubble.	No change.	Small bubble.	No change.
1 day.	Bubble.	" "	Bubble.	" "
3 days.	Bubble larger.	" "	Bubble larger.	" "
14 "	7·1 cm³	Color lighter.	1 cm³	" "
37 "	11· "	" "	3 "	" "
44 "	12· "	" "	5 "	Little change.

The full amount of permanganate present in 100 cm³ of each mixture should, if reduced to the lowest condition of oxidation, be capable of liberating about 28·6 cm³ of oxygen, and every cubic centimeter of gas collected corresponds to 3·5 per cent of the entire quantity of available oxygen. In comparing the amount of gas liberated at once by 50 per cent sulphuric acid [1 : 1] (Table III, A) with the amount of reduction of the permanganate indicated under similar conditions (Table I, A) it appears that less than one-fifth (0·35 per cent) of the available oxygen of the permanganate which disappears in the action escapes solution and appears in free form. When, however, the comparison is made between the amount of gas liberated after four or five days (about 55 per cent of the total available oxygen) and the amount of reduction of the permanganate during a similar interval (Table I, C) the agreement is fairly close—within one or two per cent—the proportion of oxygen which goes to saturate the liquid being small relatively to the large absolute amount. It would seem to be evident that during this interval the breaking up of the permanganate resulted chiefly in its reduction to the lowest form of oxidation. After the seventh day in Exp. A, when a precipitate began to appear, comparatively little oxygen was set free; and on the thirty-fifth day, when the precipitation had ceased and the remaining liquid was straw-colored the amount of gas collected corresponded to about 61 per cent of the available oxygen of the permanganate. The remaining 39 per cent must have gone with the precipitated oxide or have remained in solution as a higher sulphate. That but little of the higher sulphate did remain, however, is shown by comparison of A with B, in which after thirty-five days the liquid was entirely bleached. The gas finally set free in B amounted to 64·4 per cent of the available oxygen of the permanganate, and the remainder, 35·6 per cent, would be enough to throw down about 90 per cent of the entire amount of manganese in the permanganate in the degree of oxidation of MnO_2. It is noteworthy that the stronger acid, 50 per cent [1 : 1], still held some of the higher oxide in solution until the end, and that the acid of 25 per cent [1 : 1] allowed the decomposition to pass to completion in thirty-five days, while the smaller amounts of acid, 12·5 per cent [1 : 1] and 6·25 per cent [1 : 1], brought about in forty-four days decomposition amounting respectively to 42 per cent and 17·5 per cent respectively.

Table IV.

Percentage of H_2SO_4 [1:1]	Time elapsed.					Percentage of $K_2Mn_2O_8$ decomposed.
	1 day,	2 days,	3 days,	4 days,	5 days.	
10	Color unchanged.	Color unchanged.	Color unchanged.	Color unchanged. Slight sediment.	Color unchanged. Slight sediment. Slight scum.	103·6
20	“ “	“ “	“ “	Color unchanged. Slight sediment.	Color unchanged. Slight sediment.	107·4
30	“ “	“ “	“ “	Reddish tinge. Slight sediment.	Reddish tinge.	106 9
40	“ “	“ “	Tinged with reddish brown.	Reddish brown.	Reddish brown.	139·2
50	“ “	“ “	Reddish brown.	Reddish brown.	Red brown.	157·4
60	Color redder.	Color redder.	Reddish brown.	Sherry brown.	Reddish olive.	158·9
70	“ “	“ “	Sherry brown.	Reddish olive.	Reddish olive.	161·1

It seemed to be desirable in this connection to make the experiments detailed in Table IV, in which note is made of changes in color and formation of precipitates in 100 cm^3 portions of liquid containing 10 cm^3 of decinormal permanganate and varying proportions of acid during five days' standing, the degree of decomposition of the permanganate being finally determined, as in the experiments of Tables I and II, by adding a small excess of oxalic acid to those mixtures contained in Erlenmeyer flasks, heating to about 80° C., and titrating with permanganate the residual oxalic acid.

In the first five experiments little change of tint was noted upon the addition of the oxalic acid to the cold solution, but in the last two experiments the reddish olive color became at once distinctly red—presumably because the higher sulphate of manganese was attacked in the cold by the oxalic acid (as Brauner has shown) and so the natural color of the permanganate was permitted to assert itself. The extreme decomposition—that which took place in the last experiment, in which 70 per cent of the [1 : 1] acid was present—corresponds nearly to the reduction of the entire amount of permanganate present to the condition of oxidation of MnO_2 which is known to exist in combination with sulphuric acid in the form of a higher manganic sulphate. It is to be noted that the separation of the insoluble higher oxide took place only when the percentage of acid was low.

It appears therefore, in brief, that when potassium permanganate and sulphuric acid are brought into solution together under the conditions which we have studied there is developed a tendency toward reduction on the part of the former which is the greater as the strength of the acid is increased, as the temperature is raised, and as the duration of action is extended. It appears further, at least when the acid is not present in proportion greater than 50 per cent of the [1 : 1] mixture, that in the early stages of the action the oxygen lost to the permanganate is liberated, and that later on the decomposition of the permanganate results in the precipitation of manganese in the form of a higher oxide or in the retention of the manganese in solution in the form of a higher sulphate. It is natural to suppose that the first effect of the mutual action of the acid and the permanganate is to set free permanganic acid, which, being unstable, breaks up with the results described.

The bearing of these observations and inferences upon the question of the action of potassium permanganate during oxidations carried on in the presence of sulphuric acid is obvious; for, if the aqueous acid is able to liberate permanganic acid in such proportions as to be spontaneously unstable, it is reasonable to presume that any reducing substance present at the time of such action may, by virtue of its attractive action upon the oxygen of many more molecules of the permanganic acid than would be necessary to supply the exact amount needed for perfect oxidation, tend to increase the general instability of the already unstable molecules and so set up a far-reaching decomposition. It seems to us that these considerations throw some light upon the phenomena observed by Brauner* in the oxidation of tellurous oxide in presence of sulphuric acid; and the fact that the liberation of free oxygen in this special case is more noticeable than in the oxidation of ferrous salts or oxalic acid, for example, is explicable in the light of Brauner's observation that the attraction of tellurous oxide for oxygen is greatly inferior to that of these substances —not sufficient, in fact, to break up so unstable a substance as manganic sulphate, which is at once reduced by ferrous salts or oxalic acid. The practical lesson to be drawn is the desirability of keeping the acid present in oxidations effected by the agency of permanganate at the lowest limit consistent with perfect oxidation.

In Table V are recorded the results of a comparison made between Brauner's two excellent methods for the determination of tellurous oxide by titration with potassium permanganate—the one in alkaline solution, the other in acid solution—in which the precaution suggested as to the restriction of the amount of acid which should be present was taken. The tellurous oxide used in these experiments was prepared for the so-called pure crystallized element by oxidation with nitric acid and the prepared and ignited oxide was dissolved in potassium hydroxide.

In series A the alkaline solution of the oxide was diluted to 100 cm^3, potassium permanganate was added in excess, sulphuric acid [1 : 1] was introduced to an amount not exceeding by more than 5 cm^3 that needed for neutralization, oxalic acid was added in excess of the amount needed to destroy the manganic oxide and permanganate, the liquid was warmed to about 80° C., and the surplus of oxalic acid was titrated by permanganate.

In series B the alkaline solution of the oxide was treated with sulphuric acid [1 : 1] until the precipitate first thrown down was just redissolved, and 1 cm^3 of the same acid was added in excess. Permanganate was added in excess and oxalic acid in excess of the permanganate, the liquid was warmed, and titration by permanganate to the final reaction was completed as usual. In the calculation of the results the atomic weight of tellurium used by Brauner in his work† was adopted and the figures obtained correspond fairly well (without the application of any correction) with theory based upon this assumption. Our purpose, however, was simply to test the agreement between titrations made in alkaline solution and those carried out in acid solution.

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* loc. cit.

† loc. cit., p. 240.

TABLE V.

A.

	TeO_2 taken.	TeO_2 found.	Error.		Mean error.
(1)	0·1200 grm.	0·1199 grm.	0·0001 grm.	−	0·0006 grm.+
(2)	0·0783 “	0·0783 “	0·0000 “		
(3)	0·0931 “	0·0938 “	0·0007 “	+	
(4)	0·1100 “	0·1116 “	0·0016 “	+	
(5)	0·0904 “	0·0907 “	0·0003 “	+	
(6)	0·1065 “	0·1077 “	0·0012 “	+	

B.

	TeO_2 taken.	TeO_2 found.	Error.		Mean error.
(1)	0·0910 grm.	0·0912 grm.	0·0002 grm.	+	0·0003 grm.+
(2)	0·0910 “	0·0908 “	0·0002 “	−	
(3)	0·0911 “	0·0922 “	0·0011 “	+	
(4)	0·0913 “	0·0913 “	0·0000 “		
(5)	0·0912 “	0·0913 “	0·0001 “	+	
(6)	0·0914 “	0·0921 “	0·0007 “	+	

The agreement between the indications of the two methods is evidently close, and it is suggestive that that error which is slightly the larger, and also in the direction indicative of larger expenditure of the permanganate in producing the effect sought, is found on the side of the determinations made in alkaline solution.

As to the correlative question of the liberation of oxygen during oxidations by potassium permanganate in alkaline solution we have made no experiments, but experience (not detailed in this paper) in the collection of the gas liberated in oxidations effected in presence of acid leads us to distrust the evidence of such experiments unless the amount of gas liberated is considerable. While, on the one hand, small quantities of liberated gas may be so completely absorbed as not to appear free at all it often transpires, on the other hand, that the simple admixture of unlike liquids—such, for example, as a solution of potassium permanganate with sulphuric of strength insufficient to liberate oxygen—may bring about a very appreciable liberation of dissolved gases. So far as appears, however, the affirmation of the liberation of oxygen in oxidations by potassium permanganate in alkaline solutions now rests upon evidence of that nature only.

ART. XL.—*On the Crystallography of the Cæsium-Mercuric Halides*; by S. L. PENFIELD.

THE salts to be described in this paper were prepared by Prof. H. L. Wells, and their chemical description has been given by him in the September number of this Journal.

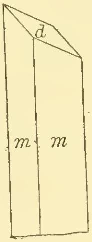
The crystals were all measured on a Fuess reflecting goniometer, model II, and great pains were taken to select the best measurements as fundamental. In a few cases, where the crystals were very small and the reflections of the signal, therefore, rather broad, the mean of a series of measurements was used. The axial ratios are given in tabular form at the beginning of each separate chemical type and the fundamental angles, from which these are derived, are marked by an asterisk in the table of angles accompanying each salt.

Type 3 : 1.

			$\breve{a} : \bar{b} : \overset{\shortmid}{c}$
Cs_3HgCl_5, Orthorhombic, monoclinic hemihedrism			0·7976 : 1 : 0·6605
$Cs_3HgCl_3Br_2$	"	" "	0 7882 : 1 : 0·6527
Cs_3HgBr_5	"	" "	0·7966 : 1 : 0·6656
Cs_3HgI_5, Orthorhombic, sphenoidal hemihedrism			0·5362 : 1 : 0·97975
	or $\frac{3}{2}\breve{a} : \bar{b} : \frac{2}{3}\overset{\shortmid}{c}$	=	0·8043 : 1 : 0·6532
$Cs_3HgBr_3I_2$	"	" "	approximately like Cs_3HgI_5

The first three salts have exactly the same habit and crystallize in slender prisms, attached at one end and terminated at the other by faces which are arranged with monoclinic symmetry, figs. 1, 2 and 3. The crystals were seldom over 1^{mm} in diameter, but the faces were perfect and admitted of accurate measurement. The forms and angles are:

1.



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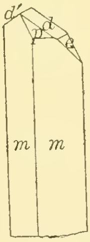

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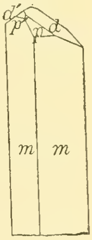


m, 110, *I*	*d'*, $0\bar{1}1$, '1-ĭ	*p*, 111, 1
d, 011, 1-ĭ	*e*, 021, 2-ĭ	*p'*, $1\bar{1}1$, '1

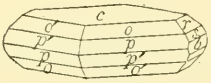
	Cs_3HgCl_5		$Cs_3HgCl_3Br_2$		Cs_3HgBr_5	
	Measured.	Calculated.	Measured.	Calculated.	Measured.	Calculated.
$m \wedge m$, $110 \wedge 1\bar{1}0$ =	*77° 9′		76° 33′	76° 30′	*77° 5′	
$m \wedge p$, $1\bar{1}0 \wedge 111$ =	*43 21		*43 29		*43 6½	
$m \wedge p$, $1\bar{1}0 \wedge 111$ =	80 41	80° 41½′			80 37	80° 36½′
$m \wedge d$, $110 \wedge 011$ =	69 55	69 54	70 14	70 13	69 49	69 48
$m \wedge e$, $110 \wedge 021$ =	60 8	60 11			60 10	60 7
$d \wedge e$, $011 \wedge 021$ =	19 29	19 26	19 28	19 25		
$d \wedge d'$ $011 \wedge 0\bar{1}1$ =	66 53	66 53½	*66 16		67 16	67 18
$d \wedge p$, $011 \wedge 111$ =	34 39	34 39	34 37	34 44	34 47	34 49

The crystals have orthorhombic optical properties. When lying on their prismatic faces all show in polarized light an extinction parallel to the vertical axis, and in convergent light a trace of the ring system can be seen, indicating that the plane of the optical axes is the base.

We have here an excellent illustration of monoclinic hemihedrism in the orthorhombic system. Among all of the crystals which were examined, there was not one which had a holohedral termination. The forms *d′* and *p′*, when present, were always smaller than the corresponding forms *d* and *p*, while *e* was only observed to the right above. Also the right handed vertical edge of the prism showed a tendency toward a skeleton-like growth, which was not observed to the left. In measuring the crystals great pains were taken to detect a monoclinic character by the angles, but none could be found. Of course the three salts may be regarded as monoclinic, with an angle β, differing so little from 90° that it can not be detected by the goniometer, but against such a supposition are the arguments, that the crystals have orthorhombic optical properties and, while there is a variation in the axial ratios of the series as bromine is substituted for chlorine, there is no change in the angle β, as would be expected if the salts were monoclinic. In this connection it is interesting to note that while the chloride and bromide are very similar in their axial ratios, the chemically intermediate chloro-bromide is not crystallographically intermediate.

At the present time there seems to be no other known compound which illustrates this hemihedrism. Different substances, which have been referred to this class, as datolite or wolframite, for example, have been shown by accurate measurement, or a study of their optical properties, to be truly monoclinic. Professor P. Groth, in the last edition of his Physikalische Krystallographie, has not mentioned this hemihedrism as a possibility in the orthorhombic system, although in the former edition of his work and in most treatises on crystallography it is recognized.

4.



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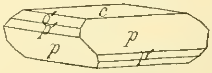

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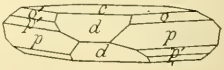

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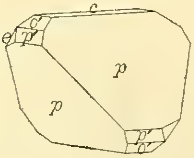

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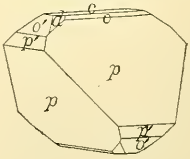

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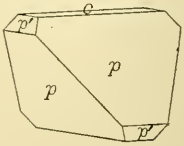


The different crops of Cs_3HgI_5 which were examined showed a great variety in habit, represented by figs. 4–8. The hemihedral development is not always strongly marked, and forms like figs. 5 and 6 are the commonest. The crystals sometimes measured over 5^{mm} in diameter and gave excellent reflections.

Only one crop of $Cs_3HgBr_3I_2$ was examined. The crystals were in the form of sphenoids, fig. 9, some of them over 10^{mm} in diameter, but the faces were curved and striated and only approximate measurements could be made.

The forms which were observed are:

b, 010, $i\text{-}\breve{\imath}$ d, 102, $\frac{1}{2}\text{-}\bar{\imath}$ s, 021, $2\text{-}\breve{\imath}$ p', $1\bar{1}1$, -1 o' $1\bar{1}2$, $-\frac{1}{2}$
c, 001, 0 r, 011, $1\text{-}\breve{\imath}$ p, 111, 1 o, 112, $\frac{1}{2}$ e, $1\bar{2}1$, $-2-\breve{2}$

The angles of Cs_3HgI_5 are:

	Measured.	Calculated.		Measured.	Calculated.
			$c \wedge o$, $001 \wedge 112$ =	46° 1′	46° 2′
$c \wedge p$, $001 \wedge 111$ =	*64° 15′		$o \wedge o'$, $112 \wedge 1\bar{1}2$ =	39 55	39 46
$p \wedge p'$, $111 \wedge 1\bar{1}1$ =	*50 23		$o \wedge o'$, $112 \wedge 11\bar{2}$ =	87 57	87 56
$c \wedge r$, $001 \wedge 011$ =	44 23	44° 25′	$o \wedge d$, $112 \wedge 102$ =	19 50	19 53
$c \wedge s$, $001 \wedge 021$ =	62 58	62 58	$p \wedge e$, $1\bar{1}1 \wedge 1\bar{2}1$ =	17 48	18 4

Both Cs_3HgI_5 and $Cs_3HgBr_3I_2$ cleave distinctly, parallel to the base, but the crystals are very brittle and usually break with a conchoidal fracture. Crystals of the former, which are tabular parallel to the base, show in convergent polarized light a bisectrix normal to c, 001; the plane of the optical axes is the macro-pinacoid and their divergence is large.

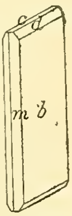
Type 2 : 1.

		$a : b : c$	
Cs_2HgCl_4	not measured.		
Cs_2HgBr_4	Orthorhombic	0·5706 : 1 : 1·4715	
$Cs_2HgCl_2Br_2$	"	0·567 : 1 : ----	
$Cs_2HgCl_2I_2$	"	not measured.	
Cs_2HgI_4	Monoclinic	1·3155 : 1 : 0·9260	$\beta = 69° 56'$
$Cs_2HgBr_2I_2$	"	Approximately like Cs_2HgI_4	

The crystals of Cs_2HgCl_4 were too thin to measure.

Both Cs_2HgBr_4 and $Cs_2HgCl_2Br_2$ crystallize in thin rectangular plates; those of the former were sometimes several centimeters long, but seldom over $\frac{1}{2}^{mm}$ thick, and had the habit shown in fig. 10. The crystals of the latter salt were very much thinner. The plates were often grouped, with the large pinacoid faces slightly divergent, and isolated crystals, suitable for exact measurement were only occasionally found.

10.



The forms which were observed on Cs_2HgBr_4 are:

b, 010, $i\text{-}\breve{\imath}$ c, 001, O m, 110, I d, 011, $1\text{-}\breve{\imath}$ p, 221, 2

and on $Cs_2HgCl_2Br_2$, b, m and a second prism 130, $i\text{-}\breve{3}$. The end faces could not be made out.

The angles of Cs_2HgBr_4 are:

	Measured.		Measured.	Calculated.
$m \wedge m$, $110 \wedge 1\bar{1}0$ =	*59° 25′	$m \wedge p$, $110 \wedge 221$ =	33° 58½′	33° 58′
$b \wedge d$, $010 \wedge 011$ =	*34 12			

On this salt the dome *d* is always small and frequently wanting. The pyramid *p* was only observed on a few crystals. In convergent polarized light a bisectrix may be seen normal to *b*, 010. The plane of the optical axes is the macro-pinacoid and their divergence is so large that they cannot be measured in air but in α-monobromnaphtaline the following values were obtained:

2H = 80° 12′ for yellow, Na flame.
2H = 85 23 for red, Li flame.

The dispersion is strong $\rho > v$. The acute bisectrix is axis of least elasticity, the double refraction is therefore positive.

The only angles on $Cs_2HgCl_2Br_2$ which were measured are:

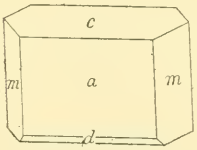
$m \wedge m$, $110 \wedge 1\bar{1}0$ = *59° 6′ and $110 \wedge 130$ = approx. 30° 53′, calculated 30° 59′

In convergent polarized light a bisectrix may be seen normal to *b*, 010. The plane of the optical axes is the macropinacoid, and their divergence is large. The axis of greatest elasticity is normal to *b*.

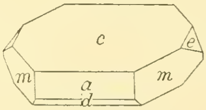
Only very fine needles of $Cs_2HgCl_2I_2$ were obtained, which were too small for measurement. These appeared under the microscope as striated prisms, with their obtuse edges rounded by oscillatory combinations. In polarized light they show a parallel extinction and in convergent light a biaxial interference figure, the plane of the optical axes being the vertical pinacoid. The acute bisectrix is axis of least elasticity.

The crystals of Cs_2HgI_4, which were frequently several centimeters in diameter, showed a variety of habits represented in figs. 11, 12 and 13. The crystals of the latter habit are usually attached at one end and taper toward the free extremity, owing to a tendency to develop vicinal pyramids in the zone *d*–*b*.

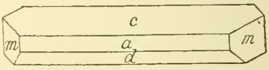
11.



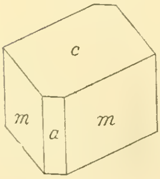
12.



13.



14.



The crystals of $Cs_2HgBr_2I_2$, which were examined, were about 2^{mm} in diameter and had the simple habit shown in fig. 14. The faces were rounded and uneven so that only approximate measurements could be made.

The forms and angles are :

a, 100, *i-ī*	*c*, 001, *O*	*d*, $\bar{2}01$, 2-*ī*
b, 010, *i-ì*	*m*, 110, *I*	*e*, 011, 1-*ì*

		Cs_2HgI_4 Measured.	Cs_2HgI_4 Calculated.	$Cs_2HgBr_2I_2$ Measured approximately.
$c \wedge a$,	001, 100 =	*69° 56′		66° 41′ to 66° 47′
$m \wedge m$,	$110 \wedge \bar{1}10$ =	*77 58		77 16 to 77 57
$a \wedge d$,	$\bar{1}00 \wedge \bar{2}01$ =	*41 25		
$c \wedge e$,	$001 \wedge 011$ =	40 55	41° 1′	

The cleavage of both salts is perfect parallel to the base, less so parallel to the clinopinacoid. With Cs_2HgI_4 the plane of the optical axes is at right angles to the symmetry plane and clinopinacoid cleavage sections show in convergent polarized light an obtuse bisectrix, which is axis of least elasticity. The axis of greatest elasticity makes an angle of about 50° with the vertical axis in the acute angle β.

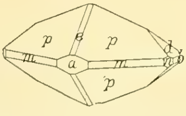
Type 1 : 1.

		a : *b* : *c*
$CsHgCl_3$	Isometric and Orthorhombic	0·57735 : 1 : 0·40884
$CsHgClBr_2$	“ “ “	approximately like the above.
$CsHgBr_3$	“ “ Monoclinic	1·0124 : 1 : 0·70715, β = 87° 7′
$CsHgBrI_2$	“	0·978 : 1 : 0·743 , β = 87° 3½′
$CsHgI_3$ not measured.		

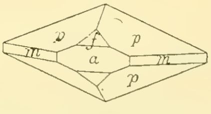
The first three compounds are dimorphous and, from solutions containing an excess of alkali halide, they all crystallize in cubes. These sometimes have their edges truncated by small dodecahedron faces, less often beveled by 210, *i*-2. The crystals show a slight action on polarized light and give an extinction parallel to the diagonals of the cube, but this anomaly is probably due to some internal tension, for when crushed the fragments are isotropic. No cleavage could be detected.

$CsHgCl_3$ was repeatedly recrystallized from water and always two types were observed. One of these was confined to those crystals which were attached to the sides of the beaker, while those which grew more in the interior had an entirely different habit. The crystals of the first type averaged about 2^{mm} in greatest diameter and had the habit shown in figs. 15 and 16. The forms and angles are as follows :

15.



16.



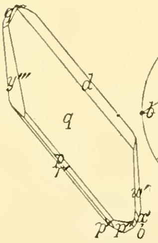
a, 100, $i\text{-}\bar{\imath}$
b, 010, $i\text{-}\breve{\imath}$
m, 110, I
n, 130, $i\text{-}\breve{3}$
e, 101, $1\text{-}\bar{\imath}$
f, 201, $2\text{-}\bar{\imath}$
d, 021, $2\text{-}\breve{\imath}$
p, 111, 1

	Measured.	Calculated.		Measured.	Calculated.
$m \wedge m$, $110 \wedge 1\bar{1}0 =$	*60° 0′		$a \wedge p$, $100 \wedge 111 =$	56° 45′	56° 45½′
$d \wedge d$, $021 \wedge 02\bar{1} =$	*101 27⅓		$m \wedge p$, $1\bar{1}0 \wedge 111 =$	71 33½	71 33
$p \wedge p$, $111 \wedge \bar{1}11 =$	66 28½	66° 29′	$p \wedge d$, $111 \wedge 021 =$	36 54	36 54
$p \wedge p$, $111 \wedge 1\bar{1}1 =$	36 54	36 54	$a \wedge e$, $100 \wedge 101 =$	54 42½	54 42
$m \wedge p$, $110 \wedge 111 =$	50 43½	50 43⅔	$a \wedge f$, $100 \wedge 201 =$	35 13	35 13½

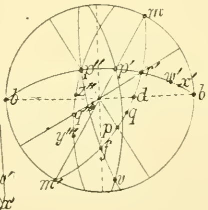
The crystals were brilliant and gave wonderful reflections. The prismatic angle was measured repeatedly and found to be 60° and the forms *could* be referred to the hexagonal system, making the m and b faces a prism of the first order, a and n a prism of the second order and p and d the unit pyramid. There was nothing, however, in the development of the faces to suggest hexagonal symmetry. Thin sections were prepared, hoping that the optical properties would throw some light upon the form, but they showed only a very weak double refraction, in fact they appeared almost like isotropic sections, so that no satisfactory conclusions could be drawn.

The crystals of the second type were spear-head shaped, fig. 17, and grew out into the center of the solution, either attached to one another by the acute solid angles, or to a slender, parallel growth of crystals, which served as a sort of stem. The crystals which are about 5^{mm} in length are complicated and perplexing, and the faces are developed with triclinic symmetry, although they can be referred to the axes of the first type. The most prominent faces are shown in the figure, while the distribution of all those which gave distinct reflections are given in the spherical projection, fig. 18. The forms which were observed are given as if they belonged to a triclinic crystal and are:

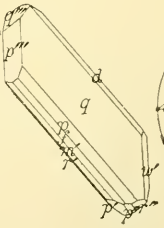
17.



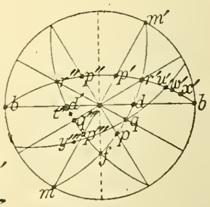
18.



19.



20.



b, 010, $i\text{-}\breve{\imath}$
m', $1\bar{1}0$, $'I$
f, 201, $'2\text{-}\bar{\imath}'$
d, 021, $2\text{-}\breve{\imath}'$
p, 111, $1'$
p', $\bar{1}11$, $_{,}1$
p'', $\bar{1}\bar{1}1$, $1_{,}$
q, 132, $\frac{3}{2}\text{-}\breve{3}'$
q''', $1\bar{3}2$, $'\frac{3}{2}\text{-}\breve{3}$
r', $\bar{1}31$, $_{,}3\text{-}\breve{3}$
w, $\bar{1}91$, $_{,}9\text{-}\underset{\smile}{9}$
x', $\bar{1}151$, $_{,}15\text{-}\underset{\smile}{15}$
y''', $7\bar{9}5$, $'\frac{9}{5}\text{-}\breve{\tfrac{9}{7}}$
z'', $\bar{1}\bar{9}7$, $\frac{9}{7}\text{-}\underset{\smile}{9}_{,}$
v, $\bar{1}131$, $11\overline{\tfrac{11}{3}}'$

The crystals gave excellent reflections and only occasionally a slight striation interfered with making accurate measurements. All of the forms were observed on two crystals and probably others could have been found by measuring a larger number.

The crystals of $CsHgClBr_2$ have a similar habit, fig. 19, and the distribution of all of the faces which gave distinct reflections is given in the spherical projection, fig. 20. This salt is more insoluble than the chloride and the crystals are consequently much smaller, not over $1\frac{1}{2}^{mm}$ in greatest diameter. All of the forms given above for the chloride were observed except *z* and *v*, and in addition:

d' $0\bar{2}1$, $'2\text{-}\breve{\imath}$ p''', $1\bar{1}1$, $'1$ r'', $\bar{1}\bar{3}1$, $3\text{-}\breve{3}_{,}$ u', $\bar{1}71$, $_{,}7\text{-}\breve{7}$ t, $2\bar{1}\bar{2}7$, $'\frac{12}{7}\text{-}\breve{6}$

The crystals gave very good reflections, considering their size, and the best measurements agreed so well with those of the chloride that no attempt was made to calculate a new axial ratio. The most marked difference in the two salts is the development of the zone p'' z'' q''' y''' in the chloride and r'' d' t''' q''' p''' f in the chlorobromide.

The measured and calculated angles are as follows:

		$CsHgCl_3$	$CsHgClBr_2$	Calculated.
$m' \wedge f$,	$1\bar{1}0 \wedge 201$	44° 45′	45° 6′	44° $58\frac{1}{3}$′
$f \wedge p$,	$201 \wedge 111$	26 35	26 27	26 $34\frac{1}{2}$
$p \wedge q$,	$111 \wedge 132$	18 27	18 34	18 27
$q \wedge d$,	$132 \wedge 021$	18 26	18 23	18 27
$d \wedge r$,	$021 \wedge \bar{1}31$	26 44	26 26	26 $34\frac{1}{2}$
$x \wedge r$,	$\bar{1}151 \wedge \bar{1}31$	33 40	33 20	33 $40\frac{1}{2}$
$w \wedge r$,	$\bar{1}91 \wedge \bar{1}31$	26 $36\frac{1}{2}$	26 27	26 33
$u \wedge r$,	$\bar{1}71 \wedge \bar{1}31$		21 35	21 $47\frac{1}{2}$
$r \wedge p'$,	$\bar{1}31 \wedge \bar{1}11$	26 33	26 37	26 $34\frac{1}{2}$
$p' \wedge p''$,	$\bar{1}11 \wedge \bar{1}\bar{1}1$	36 $52\frac{1}{2}$	36 37	36 54
$b \wedge r''$,	$0\bar{1}0 \wedge \bar{1}\bar{3}1$	44 44		44 58
$y''' \wedge q'''$,	$7\bar{9}5 \wedge 1\bar{3}2$	22 13		22 13
$z'' \wedge p''$,	$\bar{1}\bar{9}7 \wedge \bar{1}\bar{1}1$	28 38		28 35
$q''' \wedge p''$,	$1\bar{3}2 \wedge \bar{1}\bar{1}1$	50 54		50 49
$y''' \wedge q$,	$7\bar{9}5 \wedge 132$	62 $29\frac{1}{2}$	62 22	62 $28\frac{1}{2}$
$p'' \wedge v$,	$\bar{1}\bar{1}1 \wedge \bar{1}\bar{1}\bar{3}\bar{1}$	60 46		60 45
$p' \wedge v$,	$\bar{1}11 \wedge \bar{1}\bar{1}\bar{3}\bar{1}$	66 53		66 59
$f \wedge p'''$,	$201 \wedge 1\bar{1}1$		26 38	26 $34\frac{1}{2}$
$p''' \wedge q'''$,	$1\bar{1}1 \wedge 1\bar{3}2$		18 23	18 27
$q''' \wedge d'$,	$1\bar{3}2 \wedge 0\bar{2}1$		18 34	18 27
$t''' \wedge d'$,	$2\bar{1}\bar{2}7 \wedge 0\bar{2}1$		10 13	10 19
$q \wedge w$,	$132 \wedge \bar{1}91$	50 59	51 4	50 46
$q \wedge p'''$,	$132 \wedge 1\bar{1}1$		50 50	50 49
$q \wedge q'''$,	$132 \wedge 1\bar{3}2$	60 3		60 4

It will be seen from the spherical projection that the forms of $CsHgClBr_2$ lie mostly in three zones, suggestive of hexagonal rhombohedral symmetry, although there is nothing in the arrangement of the faces, and still less with $CsHgCl_3$, to indicate that this is correct. The crystals of $CsHgClBr_2$ have a slightly stronger action on polarized light than those of $CsHgCl_3$. When lying on the large q faces, both show an extinction parallel to the edges between p, q and d.

On a crystal of $CsHgCl_3$ the faces in the zone p, q, d, r made prisms, which served for the determination of the follow-indices of refraction.

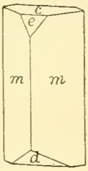
Prism of 36° 54′, $021 \wedge \bar{1}\bar{1}\bar{1}$, n_y, Na flame = 1·791 n_r, Li flame = 1·779
Prism of 63° 28½′, $\bar{1}31 \wedge \bar{1}\bar{1}\bar{1}$, n_y, " " = 1·792 n_r, " " = 1·779

The crystal was of course very small and the refracted rays were not very bright, but the latter were well defined and the double refraction was not strong enough to separate them into two distinct rays.

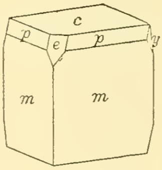
The author cannot give any satisfactory explanation of these curious forms. They seem to illustrate a tetartohedral development of the faces of an orthorhombic crystal, resulting in a figure with triclinic symmetry. The mathematical relations have been very carefully determined and the facts given. It is hoped that a further study will throw some light on the subject.

The different crops of $CsHgBr_3$ which were examined showed a variety of habits, represented by figs. 21, 22 and 23.

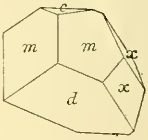
21.



22.



23.



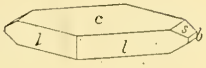
The forms and angles are as follows :

c, 001, 0	e, 201, $-2\text{-}\bar{\imath}$	o, $\bar{1}11$, 1	y, 261, $-6\text{-}\breve{3}$
m, 110, I	d, $\bar{1}01$, $1\text{-}\bar{\imath}$	p, 221, -2	x, $\bar{1}31$, $3\text{-}\breve{3}$

		Measured.	Calculated.			Measured.	Calculated.
$c \wedge m$,	$001 \wedge 110 =$	*87° 58½′		$m \wedge m$,	$110 \wedge 1\bar{1}0 =$	*90° 38′	
$c \wedge d$,	$001 \wedge \bar{1}01 =$	*35 52		$d \wedge x$,	$\bar{1}01 \wedge \bar{1}31 =$	60 41	60° 40′
$c \wedge e$,	$001 \wedge 201 =$	52 28½	52° 30½′	$e \wedge p$,	$201 \wedge 221 =$	38 46	38 46½
$c \wedge o$,	$001 \wedge \bar{1}11 =$	45 40	45 49	$e \wedge y$,	$201 \wedge 261 =$	67 21	67 28

The crystals are seldom over 5^{mm} in diameter and sometimes have a hemimorphic development, although this is not always apparent. In the prevailing type, fig. 22, there is perhaps a tendency for 221 to predominate over $\bar{2}21$ but this is not great. The pyramids x and y were observed only with hemimorphic development, fig. 23. The crystals were tested for pyro-electricity but no satisfactory results were obtained, which is perhaps owing to their small size. The crystals of $CsHgBrI_2$ were about 2^{mm} in diameter and had the habit shown in fig. 24, which is quite different from that of the bromide. The forms and angles are as follows:

24.



b, 010, *i-ì* *c*, 001, 0 *l*, 320, $i\text{-}\overline{\tfrac{3}{2}}$ *s*, 034, $\tfrac{3}{4}\text{-}\grave{i}$

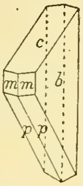
	Measured.		Measured.	Calculated.
$l \wedge l$, $320 \wedge 3\bar{2}0$ =	*66° 8′	$l \wedge s$, $320 \wedge 034$ =	*72° 22′	
$b \wedge s$, $010 \wedge 034$ =	*60 54	$l \wedge s$, $\bar{3}20 \wedge 034$ =	76 16	76° 50′

The basal planes were curved and uneven so that no satisfactory measurements could be made from them, and the other faces, although bright, did not give very satisfactory reflections. The crystals show in convergent polarized light an optical axis, almost normal to the base, the plane of the optical axes being the clinopinacoid.

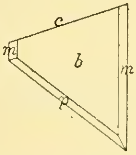
Type 2:3.

$Cs_2Hg_3I_8$. Monoclinic, hemihedral. $a : b : c$ = $0{\cdot}3438 : 1 : 0{\cdot}3544$, $\beta = 71° 55\tfrac{1}{2}'$

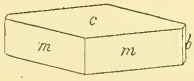
25.



26.



27.



The crystals of this salt have a curious development. Some of the most conspicuous forms are triangular plates, fig. 25, while fig. 26 is a projection of the same upon the clinopinacoid. These crystals are terminated above by a basal plane and below by pyramidal faces, which gives a curious hemimorphic development in the direction of the symmetry plane. A variety of habits was observed, long prismatic, skeleton forms and simple shapes like fig. 27, but in almost all of these the hemihedral character was prominent. The crystals frequently measured over 10^{mm} in greatest diameter. The faces were bright and gave excellent reflections. The forms and angles are as follows:

b, 010, *i-ì* *c*, 001, 0 *m*, 110, *I* *p*, $11\bar{1}$, 1

The pyramid was observed only with hemihedral development.

	Measured.		Measured.	Calculated.
$c \wedge m$, $001 \wedge 110$ =	*72° 51′	$m \wedge p$, $110 \wedge 11\bar{1}$ =	*50° 26′	
$m \wedge m$, $110 \wedge 1\bar{1}0$ =	*36 12	$b \wedge p$, $010 \wedge 11$ =	74 17	74° 14′

Two cleavages were observed, one perfect parallel to the clinopinacoid, a second less perfect parallel to the base. In polarized light clinopinacoid tables give an extinction, inclined about 23° to the vertical axis in the acute angle β. Basal plates show in convergent light an optical axis not far removed from the center of the field. The plane of the optical axes is the clinopinacoid.

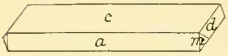
These crystals furnish an excellent illustration of inclined faced hemihedrism, as recently developed by Prof. Geo. H. Williams,* who has shown that it is of frequent occurrence on pyroxene.

Type 1 : 2.

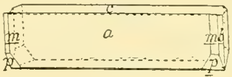
		$a : b : c$
$CsHg_2Cl_5$,	Monoclinic	$1{\cdot}6099 : 1 : 1{\cdot}3289$, $\beta = 78° 54'$
$CsHg_2ClBr_4$	Orthorhombic	$0{\cdot}586 : 1 :$ -----
$CsHg_2Br_5$	"	$0{\cdot}590 : 1 : 1{\cdot}15$
$CsHg_2I_5$. not measured.		

$CsHg_2Cl_5$ was made in slender lath-shaped crystals, over 10^{mm} long in the direction of the symmetry axis but not over $\frac{1}{2}^{mm}$ in diameter. Fig. 28 represents a simple, and 29 a twin crystal, with the orthopinacoid as twinning plane. The forms and angles are as follows:

28.



29.



a, 100, *i-ī*	*c*, 001, *O*	*d*, 011, 1-*ì*
b, 010, *i-ì*	*m*, 110, *I*	*p*, 111, −1

Two orthodomes were also identified, $\bar{1}01$ and $\bar{2}01$, but they were very small and yielded only approximate measurements.

		Measured.
$a \wedge c$.	$100 \wedge 001$ =	*78° 54′
$a \wedge m$,	$100 \wedge 110$ =	*57 40
$c \wedge d$,	$001 \wedge 011$ =	*52 31

		Measured.	Calculated.
$c \wedge m$,	$001 \wedge 110$ =	84° 5′	84° 5′
$m \wedge p$,	$110 \wedge 111$ =	31 12	31 8
$a \wedge p$,	$100 \wedge 111$ =	58 4	58 3
$b \wedge p$,	$010 \wedge 111$ =	47 19	47 19

The plane of the optical axes is at right angles to the symmetry plane and the obtuse bisectrix is nearly normal to the base.

30.

Both $CsHg_2ClBr_4$ and $CsHgBr_5$ were made in rectangular tablets, fig. 30, which were not over $1\frac{1}{2}^{mm}$ in greatest diameter and were very thin. Twins were common, with the unit prism as twinning plane, and the plates often penetrated at angles of about 60° and 120°, reminding one of little cerussite twins.

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* This Journal, xxxviii, p. 115, 1889.

The forms and angles are as follows:

$CsHg_2ClBr_4$	$CsHg_2Br_5$
b, 010, *i*-ĭ	*b*. 010, *i*-ĭ
m, 110, *I*	*n*, 120, *i*-2̆
d, 011, 1-ĭ	*d*, 011, *i*-ĭ
	e, 014, ¼-ĭ

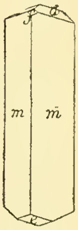
		Measured.	Calculated.
$m \wedge m$,	$110 \wedge 1\bar{1}0 =$	*60° 44′	
$b \wedge b$,	twin =	60 35	60° 44′

		Measured.	Calculated.
$b \wedge b$,	twin =	*61° 5′	
$b \wedge d$,	$010 \wedge 011 =$	*41 0	
$b \wedge n$,	$010 \wedge 120 =$	40 20	40° 17′
$b \wedge e$,	$010 \wedge 014 =$	73 25	73 57

Type 1:5.

		a : *b* : *c*	
$CsHg_5Cl_{11}$,	Monoclinic	0·7233 : 1 : 0·4675	$\beta = 85° 51' 40''$
$CsHg_5ClBr_{10}$	" "	0·7111 : 1 : 0·4561	$\beta = 85$ 29

31.



The chloride was made in prismatic crystals, fully 10^{mm} long, and having the habit shown in fig. 31. The forms and angles are as follows:

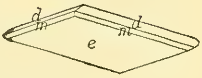
m, 110, *I* *d*, 011, 1-ì *e*, $\bar{1}01$, 1-ī *f*, 101, −1-ī

The dome *f* was usually wanting.

		Measured.	Calculated.
$m \wedge m$,	$110 \wedge 1\bar{1}0 =$	*71° 37′	
$d \wedge d$,	$011 \wedge 0\bar{1}1 =$	*50 0	
$m \wedge e$,	$\bar{1}\bar{1}0 \wedge \bar{1}01 =$	*66 8	
$d \wedge e$,	$011 \wedge \bar{1}01 =$	41 21	41° 20½′

		Measured.	Calculated.
$m \wedge d$,	$110 \wedge 011 =$	72° 31′	72° 31′½
$m \wedge d$,	$\bar{1}10 \wedge 011 =$	78 49	78 48
$d \wedge f$,	$011 \wedge 101 =$	39 30	39 29½
$e \wedge f$,	$\bar{1}01 \wedge 101 =$	65 43	65 42

32.



The chlorobromide $CsHg_5ClBr_{10}$ is much more insoluble than the chloride and was made in crystals, which were not over $\frac{1}{2}^{mm}$ in greatest diameter. The habit is shown in fig. 32 and is very different from that of the chloride. The forms and angles are as follows:

m, 110, *I* *d*, 011, 1-ì *e*, $\bar{1}01$, 1-ī

		Measured.
$m \wedge m$,	$110 \wedge 1\bar{1}0 =$	*70° 40′
$d \wedge d$,	$011 \wedge 0\bar{1}1 =$	*48 54

		Measured.	Calculated.
$d \wedge e$,	$011 \wedge \bar{1}01 =$	*40° 58′	
$m \wedge d$,	$110 \wedge 011 =$	72 40	72° 40′

The crystals are strongly double refracting and the little tables show in convergent polarized light a bisectrix nearly normal to *e*. The plane of the optical axes is the clinopinacoid and the optical axial angle is small. The interference phenomena are very interesting when observed through colored glasses. In the hyperbola position the figure is almost uniaxial when viewed through red glass, while with blue the hyperbolæ are separated, probably as much as 15°–20°.

Sheffield Scientific School, New Haven, June, 1891.

ART. XLI.—*On Silver Hemisulphate;* by M. CAREY LEA.

THE existence of those substances which I described some years ago under the name of photosalts of silver* necessarily implied the existence of the hemihaloids of silver also, as these latter entered into the composition of the photosalts. Similar inferences, though less definite, had long been drawn from the action of light on silver haloids. Two of these, the chloride and bromide, lost by the action of light their complete solubility in ammonia without becoming completely soluble in nitric acid. Evidently there was indicated an intermediate compound between the normal haloid and metallic silver. During the last ten or twelve years I have devoted much time to the attempt to isolate these lower compounds of silver and to gain some certain knowledge as to the hemioxide, whose existence seemed almost a necessary inference from that of the hemihaloids. Some eight years ago, I obtained a substance having all the properties which one would be disposed to ascribe to Ag_2Cl and a large number of analyses made seemed to confirm the view. I hesitated, however, to publish a description of it, not feeling entire certainty that it might not be a mixture, as to which a concordance of the proportions found of Ag and Cl with theory gives no sufficient information. Since then M. Guntz has described a subchloride obtained by acting on silver hemifluoride with phosphorus pentachloride and a hemioxide derived from it. Up to the present time no combination of silver hemioxide with an oxyacid has been known.

Such a combination I have been able to obtain as a double salt of hemisulphate and normal sulphate containing one molecule of each. The new salt has a light bright brown color, and exhibits a stability which in view of its composition, is something remarkable. It has no tendency either to oxidation or to reduction. Nitric acid, unless very strong, has but little action upon it. Acid of 1·42 poured over it in large excess and let stand for several days gradually dissolves it completely, but the same acid diluted with with two or three times its volume of water has so little action that it forms a convenient means of purification. On the other hand, ferrous sulphate which instantly reduces argentic sulphate has no action whatever on the new substance even with several days' contact. Hot strong sulphuric acid has no action. It might almost be expected that under its influence, the argentous salt would gradually take up oxygen and be converted into argentic sul-

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* This Journal, xxxiii, May and June, 1887.

phate. But a specimen which was covered with a large excess of undiluted sulphuric acid in a flask and was kept under boiling water for ten hours was not altered thereby. Another strong proof of its stability is found in its resistance to heat.

The application of heat produces a somewhat curious succession of colors. The terra cotta or warm brown shade of the moist substance changes by drying above 100° to pale lilac, at 165°–170° it becomes grayish, at a somewhat higher temperature, yellowish green. Considerably below red heat it acquires a fine ruby red color. In cooling, this red darkens almost to black, then becomes lighter again and when cold the color is light olive-green. The changes are repeated as often as the substance is heated and cooled. No sulphuric acid vapors are disengaged even at a low red heat.

It was mentioned in a previous paper that when silver nitrate is reduced by solutions of phosphorous or hypophosphorous acid or by acidified solutions of their alkaline salts, transient colorations were produced that seemed to suggest the presence of some form of allotropic silver. Since that paper was published this reaction has been taken up for further study. It soon appeared that when the silver salt was treated with a solution of alkaline hypophosphite, acidified with sulphuric acid, the result obtained was entirely different from that which presented itself under any other circumstances. It became clear that sulphuric acid did not act solely by setting free the hypophosphorous acid, but also acted on the silver with formation of a double sulphate.

A remarkable though limited analogy here presents itself between the substance just described and the photosalts of silver. The silver hemihaloids are very unstable substances, but acquire stability by uniting with the normal haloids. In the same way the hemisulphate, which is not known to be capable of separate existence, becomes perfectly stable by union with the normal sulphate. The limitation to this analogy lies in the fact that the last mentioned combination occurs in definite proportions, which does not seem to be the case with the halogen compounds.

The new substance then is formed by the joint action of sulphuric and hypophosphorous acid on a silver salt. Hypophosphorous acid has but little action on silver sulphate already precipitated, but it is different when the silver sulphate is formed in presence of hypophosphorous acid.

Several silver salts may be used. I have at different times employed the nitrate, phosphate and carbonate. The latter is perhaps the best, because the action with the nitrate is too rapid, and with the phosphate, too slow, and for other reasons.

A weighed quantity of silver nitrate is precipitated with an excess of alkaline carbonate and washed. The carbonate, as well as all the other reagents employed must be absolutely free from chlorides, otherwise the product becomes contaminated with silver chloride which cannot be removed. The silver carbonate is then treated with a solution of alkaline hypophosphite acidified with sulphuric acid. All the alkaline hypophosphite of commerce contains much more than a trace of chloride: this is best got rid of by adding to its solution a little solution of silver nitrate, stirring well at intervals, letting stand for twenty-four hours and filtering. This filtrate with addition of sulphuric acid is to be poured over the moist silver carbonate and constantly stirred. The reaction is complete in twenty or twenty-five minutes, when a bluish-black film of reduced silver begins to form on the surface. Further action is then cut short by neutralizing the liquid with alkaline carbonate. The precipitate is next to be washed several times by decantation. Very pure distilled water is, of course, needed throughout.

Convenient proportions are: 40 grams silver nitrate precipitated with excess of alkaline carbonate. Of sodium hypophosphite, 100 grams, dissolved in 650 c. c. of water are treated with a little silver nitrate, and after standing and filtering, 4 c. c. of sulphuric acid are to be added and the liquid poured over the silver carbonate. After a few minutes, 6 c. c. more of sulphuric acid, diluted with a little water, are added by degrees. With this second quantity of sulphuric acid the characteristic reddish-brown color of the substance first appears.

This process may be varied by precipitating with disodic phosphate (which must be perfectly free from chloride) instead of alkaline carbonate. The action is much slower, about 24 hours being needed. Silver nitrate itself may be used, but the action is too rapid and the product is less in quantity.

The crude product obtained in either way is to be purified with nitric acid. Acid of 1·42 is diluted with three times its volume of water, and of this dilute acid a quantity is taken about double in volume to that of the precipitate and of the water left after decanting closely. After a time some effervescence takes place, but the mixture does not become warm. After standing for three or four hours over the precipitate, it is to be poured off and the precipitate washed. This treatment with acid is applied three times: the first removes a good deal of silver, the second a little, the third a trace. Each time the acid is left three or four hours in contact. The product is then washed by pouring on it a large quantity of boiling water. This is repeated four or five times, each time (except the first) placing the vessel in a water bath kept at 100° C. for several hours.

The product is either dried in the air or (for analysis) at 100° C. It forms a bright brown substance, permanent in the air, changing to violet when kept for some time at 160° C. It has the peculiarity that when water is poured on it, it makes a sharp hissing noise. This takes place with the air-dried substance as well as that dried at higher temperatures and as much with the former as with the latter.

The substance after purification has about one-half the weight of the silver nitrate taken.

These proportions and this mode of operating are those that I have found to give the best result. But the substance is formed under a great variety of conditions. It seems impossible to bring a silver salt into contact with alkaline hypophosphite acidified with sulphuric acid without producing more or less of it. Its presence is often completely obscured by reduced silver. But a mass which looks perfectly black and might be supposed to contain nothing but metallic silver will leave, when treated with nitric acid, a bright brown residue of the double sulphate. We have here, as before, an analogy with the photosalts. For it will often happen that a blackish mass, containing metallic silver and mixed or combined silver chlorides will, when treated with nitric acid, resolve itself into bright purple or rose colored photochloride.

All the specimens of this new substance contain a little phosphoric acid which cannot be removed. Reckoned as phosphoric anhydride it amounts to a little over two per cent. Three determinations gave respectively, 2·30; 2·09; 2·18, mean 2·19.

It is apparently united with silver and this silver phosphate is united so firmly with the double sulphate that it cannot be detached. If it were not so united it would be dissolved in the nitric acid with which the substance is three times treated if it were normal phosphate, and if it were hemiphosphate it would be converted (if in a free state) to normal phosphate and dissolved.

Another attempt to remove this phosphate was made by heating the substance with sulphuric acid to 100° C. for ten hours, followed by copious treatment with boiling distilled water to wash out the sulphate which it was hoped would be formed at the expense of the phosphate. It seems difficult to believe that a silver phosphate could resist this treatment, but a quantitative determination showed that the proportion of phosphoric anhydride is not even diminished by it.

Other modes of formation than those described here were experimented on with the view of obtaining the substance free from phosphate, but without good result.

It is possible that the silver phosphate may be combined in definite proportions and the approach to uniformity of composition somewhat favors this idea. But such a view would require the assumption of a large, perhaps too large a molecule.

Analyses.

A. Material prepared from silver carbonate and dried at 100° C.

	(1)	(2)	Mean.
Ag	76·13	76·75	76·44
O	3·29	....	3·29
P_2O_5	2·30	2·09	2·19
SO_3	16·19	16·47	16·33
Water	1·78	....	1·78
	99·69		100·03

B. Material prepared by various other methods considered less reliable.

Determinations.

Ag per cent.	P_2O_5.	SO_3.	O.
78·59			3·93
78·45			3·69
77·16			3·61
75·43	2·18	15·61	3·29
75·46			3·25
75·35	1·77		
Mean 76·74			Mean 3·55

The determinations of phosphoric and of sulphuric anhydride are placed opposite the silver determinations to which they belong. The oxygen determinations are distinct.

The most reasonable interpretation of these results is that we have to do with a double sulphate of silver hemioxide and protoxide in which a portion of the sulphuric acid is replaced by phosphoric. The proportion of phosphoric acid seems to be nearly constant, three concordant analyses having given 2·09, 2·30, and 2·18, with a mean of 2·19. These proportions may be expressed by the formula

$$7(Ag_4SO_3Ag_2SO_3H_2O) + Ag_6PO_4Ag_3PO_4.$$

The comparison of this formula with results obtained is as follows:

	Calculated.	Found (Mean).
Ag	76·79	76·44
SO_3	15·67	16·33
P_2O_5	1·98	2·19
O	3·80	3·29
H_2O	1·76	1·78
	100·00	100·03

This large molecule results from the relatively small proportion of P_2O_5, and although the figures obtained for phosphoric anhydride are very concordant, it perhaps is better to consider the substance as a double sulphate in which part of the sulphuric acid is liable to be substituted by phosphoric. If the silver phosphate is taken as adventitious, the formula becomes simply Ag_4SO_4, Ag_2SO_4, H_2O.

Decompositions.—The action of alkaline hydroxides is confirmatory of the above conclusions, and also offers further proof of the great stability of the substance.

When the double salt is placed in contact with excess of dilute sodium hydroxide it blackens, being converted into a mixture of the hemioxide which is intensely black, and the normal oxide. This decomposition, however, takes place much more slowly than with the salts of the protoxide, so that (unless heat has been applied), if after ten or fifteen minutes the alkali is poured off and the oxides are dissolved with dilute nitric or sulphuric acid a considerable residue is found of the red-brown double salt which has escaped decomposition.

With continued treatment with sodium hydroxide (that obtained from metallic sodium was used as being absolutely free from chlorine, the decomposition is complete.

The oxide thus precipitated was thoroughly dried at 160°–170° C., weighed and ignited. Five determinations of oxygen from various specimens gave 4·73 ; 4·63, and again 4·24 ; 4·19 ; 4·17 per cent of oxygen respectively. A salt with the constitution already described should yield one molecule each of hemioxide and of normal oxide, and this mixed oxide should contain 4·68 per cent of oxygen. We have then:

	Mean of 5 determinations.	Calculated.
Oxygen per cent	4·39	4·68

The double salt is more readily decomposed by hydrochloric and hydrobromic acid or even by alkaline chlorides or bromides. Under their action it instantly blackens. That part of the silver that exists in the form of hemisulphate is converted into black hemichloride or hemibromide. The extreme instability of these hemihaloids causes them spontaneously to resolve themselves into metal and normal haloid. They rarely remain as hemihaloid for more than an hour or two, and often for much less time. The change is often quite sudden and is easily observed by the alteration of color, the black of the hemihaloid passing into the metallic gray color belonging to a mixture of normal haloid with metallic silver. The hemibromide seems to be a little less unstable than the hemichloride.

This instability does not render an analysis impossible since both the products of the change are insoluble; but renders it somewhat more difficult, as the freshly formed silver haloid tends to run through a filter. Sometimes indeed it seems as if traces of the silver chloride were for a few moments soluble in water with a yellow coloration. The appearance of this yellow color in the water is apt to be the first indication of the splitting up of the hemichloride.

Two analyses were made, one of material obtained by acting on the brown salt with dilute hydrochloric acid; this contained 81·79 per cent of silver. One by decomposing it with sodium chloride; this gave 81·93 per cent. A substance having the formula already given should, by conversion into chloride, give a mixture in which two-thirds of the silver should exist as hemichloride, and one-third as normal chloride. We have then—

	Found.			
	1.	2.	Mean.	Calculated.
Ag per cent	81·79	81·93	81·86	82·35

a result sufficiently close to afford a confirmation of the constitution assigned.

When the brown salt is decomposed with dilute hydrobromic acid or an alkaline bromide, a corresponding result is obtained. By treatment with hydrobromic acid a mixed bromide resulted which proved to contain 66·06 per cent of silver.

A general consideration of all the reactions which I have obtained seems to indicate that the action of sulphuric acid and sodium hypophosphite on silver carbonate does not lead directly to the production of the double salt which I have described, but that the hemisalt is produced in excess, often in large excess; that the nitric acid oxidizes this excess, being able to attack the *free* hemisalt, but not that portion which is combined with protosalt and so rendered stable. It follows that whatever has been the original relative proportion between the two salts the nitric treatment leaves always one molecule of each. If it were possible to control the formation it is not improbable that a pure hemisulphate might be obtained. But the action of the hypophosphite tends so strongly to carry the reaction still further that reduced silver appears, and in removing this with nitric acid the double salt results. A confirmation of this is found in the fact that the treatment with nitric acid much reduces the deep terra cotta color of the original product. If this difficulty can be overcome we may yet obtain hemisalt isolated.

There is reason to suppose that numerous other compounds of silver hemioxide with oxyacids may exist. These compounds cannot be obtained by acting on the normal salts with sodium hypophosphite or with hypophosphorous acid, but it appears probable that they may be produced when the normal salts are formed in the presence of sodium hypophosphite. If to the last named salt we add a solution of a salt capable of precipitating silver nitrate, and then further add silver nitrate, we obtain precipitates which after standing some hours with frequent stirring appear to contain compounds of silver hemioxide. But these products do not resist the action of nitric acid; consequently there appears to be no means of purifying them and of deciding with certainty as to their nature.

When sodium citrate and hypophosphite are dissolved together and a little silver nitrate added to get rid of chlorides, then after standing and filtering more silver nitrate is added, a precipitate is obtained which after a time appears to contain silver hemicitrate in an impure form. When a little of this precipitate is put into much water containing a trace of ammonia (five or six drops to 100 c. c.), a fine rose-red solution results.

Most oxysalts of silver are darkened by light. In a paper published in this Journal for July, 1887, I mentioned that films of these salts exposed to light and then treated with dilute hydrochloric or hydrobromic acid appeared to be converted into hemichloride or hemibromide, and argued therefrom that oxyacid hemisalts of silver must exist, and be formed by action of light on normal salts. I believe that I have been able to prove the existence of a hemisulphate with a strong probability that many other hemisalts may be formed both by the action of light and also by purely chemical means. It is possible that at some future time we may succeed in obtaining some of these compounds in a state of purity.

SCIENTIFIC INTELLIGENCE.

I. Geology.

1. *Geology of the Taylorville Region of California;* by J. S. Diller, pp. 369–394 of the Bull. Geol. Soc. America, 1892.

Jura and Trias at Taylorville, California, by Alpheus Hyatt, pp. 395–412, ibid.

In these two papers is found the first recognition of the Lias in North America. The region of this discovery is in Plumas Co., California, near the summit of the Sierra Nevada, and is the same that afforded the fossils, in the survey under Professor J. D. Whitney, that were studied by Gabb and proved to represent the Upper Triassic and the Jurassic formations. The recent collections of Professor Hyatt have confirmed the results of Mr. Gabb, and, besides adding to the number of Upper Triassic species, have afforded over 40 Liassic, a large number of the Middle Jura or Oolite, and others that are referred to the Callovian and Corallian of the Upper Jura.

Mr. Diller, from his study of the stratigraphy of the region, makes the total thickness of its stratified rocks, exclusive of the gravels, to be over 24,500 feet. Of this series, about 17,500 are Paleozoic, 4700 Triassic, 450 Liassic, 530 Middle Jura, and 1000 Upper Jura—500 of the last in each of its subdivisions. The rocks are shown to be in overthrust flexures and upthrust faults, with the thrust in each to the eastward. Mr. Diller finds evidence that there was a profound upturning at the close of the Carboniferous; another feebler disturbance after the Triassic, and a great upturning again with flexures of the rocks after the Jurassic and probably immediately following this period. His paper contains sections illustrating the flexures and faults, with a full account of the stratigraphical results reached.

2. *Geological Survey of the State of New York. Palæontology: Volume VIII. An Introduction to the study of the genera of Palæozoic Brachiopoda. Part I.* By James Hall, State Geologist and Palæontologist, assisted by John M. Clarke. Albany, 1892, 4to, pp. i–xvi, 1–367, with 39 figures in the text and 44 lithographic plates.—Part I, now published, includes all the genera of palæozoic inarticulate brachiopods, together with the Orthoids, Strophomenoids, and Productoids of the articulate section. The Terebratuloids, Rhynchonelloids, Pentameroids, and spire-bearing forms are to appear in a subsequent volume. Practically this work fulfills the function of a final arbiter on questions of generic limitations. Great care has been taken to investigate type species and upon them to base the generic diagnoses. The manifest plan is to give of each genus, (*a*) accurate illustrations, (*b*) the bibliography and synonymy, (*c*) a diagnosis of internal and external characters, (*d*) the type species, (*e*) general observations on the structure and affinities,

and other facts of interest and importance. It would appear, at first sight, that a large number of new genera are proposed, and that most of the old familiar genera are present under unfamiliar guises, but a closer inspection shows that the number of actual new names is few. The others are rehabilitated terms, nearly forgotten since their origin, and now re-defined and applied to distinct groups of forms or types of structure. Thus the subject has been simplified by breaking up many of the old heterogeneous groups, such as *Discina* and *Orthis*, into clear cut minor genera or subgenera, which are now available for accurate systematic work. The authors have abstained from the exact use of family or other taxonomic designations except the two great divisions Inarticulata and Articulata.

Lingula is the first genus discussed, but it is not necessarily considered as the primitive type of inarticulate brachiopods. This view is supported by the geological history, anatomy, and development. *Lingulella* and *Lingulepis* are regarded as forerunners of *Lingula*, and connecting links to the Obolelloid type. Modifications of the nature of septa produced by the deposition of shelly matter about the muscular and parietal bands produced related genera, such as *Dignomia* and *Glottidia.* Special features developed about the cardinal areas resulted in forms for which the new generic terms *Barroisella* and *Tomasina* are proposed. Other structures arising from mechanical necessity, as the elevation of the anterior edges of the muscular attachments to compensate for hepatic and ovarian pressure resulted in the formation of the vaulted platform of *Lingulasma.* The authors consider this feature of much importance. It first appears in *Lingulops*, and reaches a higher development in *Lingulasma.* Whether this character in these genera is in direct genetic line to *Trimerella*, or whether it is a morphological equivalent, may be questions for further discussion.

Among Discinoid shells the new genus *Discinopsis* of Matthew is first defined, and the subgeneric divisions of *Orbiculoidea*, *Œhlertella*, *Lindstrœmella*, and *Rœmerella*, are proposed, based upon the features of the pedicle opening and form of the ventral valve. Of especial interest and importance are the observations on the development of the pedicle opening in *Orbiculoidea*, *Schizocrania*, *Trematis*, and *Discinisca*, showing their genetic relations in that *Discinisca* and *Orbiculoidea* pass through young stages comparable with adult conditions of *Schizocrania.*

Besides the current terms *Platystrophia*, *Bilobites*, *Schizophoria*, etc., founded upon groups which have been separated from *Orthis*, the authors have introduced seven new divisions making altogether fourteen including *Orthis* as restricted. The new names proposed are: *Plectorthis*, *Dinorthis*, *Plœsiomys*, *Hebertella*, *Heterorthis*, *Dalmanella*, and *Orthotichia.* Three new names are also applied to forms related to *Clitambonites* (= *Orthisina* d'Orb.); viz. *Billingsella*, *Protorthis*, and *Polytœchia.*

Many important changes have been introduced among the Strophomenoids and Productoids. *Strophomena* is restored to its original type *S. rugosa* Raf. = *Leptæna planumbona* Hall. This leaves most of the species known as *Strophomena*, and typified by *S. alternata*, without a name. For this group the genus *Rafinesquina* is proposed. *Leptæna* rests on its original species *L. rhomboidalis* Wilckens, sp. (= *L. rugosa* Dalman), and species for many years passing as *Leptæna sericea*, *L. transversalis*, etc., now fall under *Plectambonites* Pander, *Streptorhynchus* is restricted to a species of the type of *S. pelargonatum*, a Permian fossil, and nearly all the species commonly known under this designation from the Silurian and Devonian now come under the genus *Orthothetes* of Fischer de Waldheim. In addition to *Rafinesquina*, the following names are proposed for new generic and subgeneric types among the Strophomenoids and Productoids: *Orthidium*, *Kayserella*, *Pholidostrophia*, *Leptostrophia*, *Amphistrophia*, *Leptella*, *Christiania*, *Anoplia*, *Chonostrophia*, and *Chonopectus*.

It will probably be found that *Tropidoleptus* and *Vitulina* belong with the genera included in this volume. *Oldhamina*, *Lyttonia*, and *Richtofenia*, also pertain to this portion. It is hoped that a recognition of ordinal, subordinal, and patronymic subdivisions will be accorded in the final work as an expression of the views of the authors. Several anomalous inferences upon related genera which have a structurally intermediate genus appearing at a later geological period could perhaps be better explained as morphological equivalents. In other cases geratology is evidently an important factor.

Any just criticism of this work would deal chiefly with a few details of observations, minor differences of opinion, and trivial points of generic relationships, and would in no way impair its general usefulness. It must therefore stand as of the highest authority on the genera of Palæozoic Brachiopoda. C. E. B.

3. *Report of the Arkansas Geological Survey for 1890*, John C. Branner, State Geologist. Vol. III, *Whetstones and Novaculites of Arkansas*, by L. S. Griswold. 444 pp. 8vo, with colored geological maps and other illustrations.—Mr. Griswold's report has great value, alike historical, practical and scientific. The origin of the novaculite stratum, which in its pure form is 99½ per cent silica, is referred to simple sedimentation, like that of an ordinary sandstone; it is a very fine siliceous sand-deposit, somewhat calcareous, from which the minute calcareous grains have been leached out, so as to render the rock porous. Only small portions of the stratum have the fineness of texture fitted for the best whetstones. The stratum is of the age of the lower part of the Trenton, as proved by the author through the discovery of Graptolites, and has a thickness of about 1200 feet. It is underlaid by 1300 feet of shales, limestones and sandstones of older Paleozoic, and overlaid directly by 1200 to 1500 feet of Subcarboniferous beds, the Upper Silurian and Devonian

being absent. These rocks are upturned and in flexures, making ridges of what is called the Ouachita mountain system, extending from Little Rock, Central Arkansas, westward into the Indian Territory. The axis of uplift, about east and west in direction, "strikes toward the disturbed Paleozoic region between Mississippi and Tennessee, which region has been regarded as a southwestern termination of the Appalachian system."

4. *On the occurrence of Artesian and other underground waters in Texas, Eastern New Mexico and Indian Territory, west of the 97th Meridian;* by ROBERT T. HILL. 166 pp. 8vo, with numerous maps, plates, and sections. From the Final Reports of the Artesian and Underflow Investigations of the Department of Agriculture.—Professor Hill commences his very thorough Report with a general review of the topographical features of Texas. He mentions in detail the results of Artesian borings over the State, and discusses the observed facts in their relation to the several rock strata that underlie the surface, and the topography of the different regions. The special conditions on which in each region success or failure depend are pointed out, and in the explanations many geological details with regard to the stratification are given and made clear by numerous illustrating sections and maps.

5. *Geological Society of America.*—A meeting of the Geological Society, of which Professor G. K. Gilbert, is President, was held at Rochester, New York, on the 15th and 16th of August, immediately preceding that of the American Association. The following papers were read: L. C. Johnson, on Phosphate fields in Florida; C. H. Hitchcock, On the Connecticut Valley glacier; E. W. Claypole, Dentition of Titanichthys and its allies; G. C. Broadhead, On the Ozarks and the geological history of the Missouri Paleozoic; G. F. Becker, On the finite, homogeneous strain, flow and rupture of rocks; W. H. Hobbs, Phases in the metamorphism of schists in Southern Berkshire; C. L. Little, On a metamorphic conglomerate in the Green Mts.; J. Hall, On the Oneonta sandstone; W. Upham, On Drumlins; G. F. Wright, On Extra-morainic drift of the Susquehanna Valley; D. White, A new Tæniopterid and its allies; A. S. Tiffany, Overturn of L. Silurian strata in Rennselaer Co., N. Y.; President Gilbert, On Coon Butte of Arizona and the theories of its origin.

The Society will hold its next meeting at Ottawa, Canada, commencing on the 28th of December.

6. *Albirupean Studies;* by P. R. UHLER. Trans. Md. Acad. Sci., 1892, pp. 185–201.—We have here another strong effort of this author to vindicate his Albirupean formation, as outlined in 1888. He now expands it to include the entire clay series of New Jersey and the Laminated Sands of that state, also all of the Potomac formation of McGee coastward of the Iron Ore Clays of Maryland, and prolongs it southward into Virginia to take in the freestone quarries of Aquia Creek and Fredericksburg. This leaves very little of the great Atlantic Clay Belt for

any one to contend about, because it is now known that the Amboy Clay flora occurs near the base of the Tuscaloosa formation in Alabama and Mississippi. He has therefore proved too much and is anticipated by Dr. Eugene Smith, at least as to his proposed name. And really this is here the main thing, since the facts have been long known and accurately mapped, at least in New Jersey. The great question is that of correlating the Potomac formation with the New Jersey beds, or of showing what relation subsists between them. On this question the present paper throws no clear light. The one service which Prof. Uhler's investigations are doing is that of drawing attention to the fact that the great Lower Cretaceous non-shell-bearing belt of the Atlantic border region, though doubtless a geological unit (which he denies), occupied a vast period in its deposition, was attended by great vicissitudes and oscillations of level, and must be studied as a series of successive deposits rising stratigraphically from its landward toward its coastward margin and changing greatly from one level to another. L. F. W.

7. *The Fossil Flora of the Bozeman Coal Field;* by F. H. KNOWLTON. Proc. Biol. Soc. Washington, vol. vii, July 1892, pp. 153–154.—In this short paper Prof. Knowlton sums up the results of a prolonged investigation soon to be published in full by the Geological Survey. Altogether 43 species of fossil plants have been found in the Bozeman coal field only three of which are new, most of the others occurring in other parts of the west. The small number of Fort Union species seems to show that these deposits do not form a part of the series of beds that extend along the Missouri and Yellowstone rivers in Dakota and Montana. On the other hand the forms found are largely those of the true Laramie and overlying Denver formations of Colorado and Wyoming, between which they are pretty equally divided. This seems to fix the horizon of this coal region with considerable accuracy, and shows that the great Laramie sea occupied the same position relatively to the Rocky Mountain uplift in Montana as it does farther south. The most interesting form is the *Thinnfeldia polymorpha*, which seems to be a sort of connecting link between the ferns and the conifers of the Ginkgo type, and is also strongly suggestive of the Glossopterid forms of Australia and India. L. F. W.

8. *Paléontologie Végétale* (*Ouvrages publiés en* 1890), par R. ZEILLER. Extrait de l'Annuaire Géologique Universel, Tome VII, 1890, pp. 1115–1157, Paris, 1892. This is another of the series of admirable reviews of paleobotanical literature by M. Zeiller, of which four others have previously appeared. It is very thorough and searching, no less than 138 different works and papers being treated. The plan is to deal first with the general works and discussions and then to take up the special works in the ascending geological order of the formations. These are subdivided into Paleozoic, Antecretaceous Secondary, and Cretaceous and Postcretaceous. A special department is devoted to

fossil woods. The method is expository rather than critical and the space is well adjusted to the importance of the subjects reviewed. The literature is referred to by numbers and the titles are collected together in an alphabetical list, but unfortunately in a separate part of the volume (pp. 98–103)—a serious defect in the book-making, but for which our author is not responsible. The most important works that appeared during the year 1890 were Professor Fontaine's Flora of the Potomac Formation, Renault and Zeiller's Coal Flora of Commentry, Saporta's Jurassic Flora (completed in this year), the Paleophytology of Zittel's Handbuch, brought to a conclusion by Schenk, and Zeiller's Fossil Flora of the Carboniferous and Permian basin of Autun and Epinac. Among the leading discoveries of the year may be noted: that by Renault of the large petioles called Myeloxylon in direct relation with the ferns Alethopteris and Neuropteris; that by Williamson of secondary wood in certain ferns; that by Renault of a true Equisetum in the Carboniferous; that by Marion in the Permian of Lodève of peculiar strobiles (Gomphostrobus) which seem to form a connecting link between Walchia and Ginkgo; that by Saporta of dicotyledonous plants in the Lower Cretaceous of Portugal; and that by Dawson and Penhallow of a Rhizocarp (*Azollæphyllum primævum*) allied to Azolla, in the Tertiary of British Columbia. L. F. W.

9. *Sylloge Fungorum Fossilium hucusque cognitorum.* Auctore A. MESCHINELHI. Patavii, 1892.—This is an octavo pamphlet of 73 pages and will form part of the tenth volume o Saccardo's great *Sylloge Fungorum* so well known to botanists. It was well, and in line with modern methods, that Saccardo should include the fossil forms in his description of all the fungi known to botany, and this part could not have been intrusted to any one more competent than Professor Meschinelli. According to this enumeration there are now known to science 329 species of fossil fungi, which are assigned to 41 genera. Most of these latter are named from their resemblance to living genera by adding to the generic name the termination *-ites.* The largest genus is Sphærites with 100 species, which is followed by Xylomites with 56, Rhytismites with 23, Phacidites with 18, Depazites and Hysterites with 16 each, Phyllerites with 15, and Sclerotites with 13. Most of these occur as spots on dicotyledonous leaves, chiefly in the Tertiary. The genera Archagaricon, Peronosporites, Protomycites, Excipulites, and some of the species of other genera, are from the Carboniferous, and there are a few Mesozoic forms. The *Polyporites Bowmani* of Lindley and Hutton from the coal measures of Denbigshire, long regarded as the scale of a fish, is included, as is the *Gyromyces Ammonis* of Göppert, which most other authors treat as a shell, and which has been otherwise named *Spirorbis carbonarii*; but in such doubtful cases attention is called to the conflicting views. The plan of the work embraces pretty full references to the literature of each species, a very brief character, and a statement of the habitat, which

features render the work exceedingly useful independently of any questions as to the real nature of doubtful forms. L. F. W.

10. *I Tronchi di Bennettitee dei Musei Italiani. Notizie storiche, geologiche, botaniche;* dei Professori Senatore G. CAPELLINI e Conte E. SOLMS-LAUBACH. Con cinque tavole. Bologna, 1892. Estratta dalla Serie V, Tomo II delle Mem. Real Accad. Sci. Ist. di Bologna.—Capellini writes the historical and geological, and Solms-Laubach the botanical part of this memoir, giving a very full account of the discovery and the real nature of all the cycadean remains that have been long accumulating in the various Italian museums, one specimen dating back as far as 1745. Besides the eight species of Cycadeoidea which are described and figured one other form is treated as belonging to a different genus and named *Cycadea Imolensis.* Count Solms reserves the name Bennettites for the sole *B. Gibsonianus,* the nature of whose fructification is known and has been fully treated by him in a previous memoir (see this Journal, vol. xli, p. 331). Mention is made of three American forms. The specimen found at Golden, Colorado, to which Lesquereux gave the name *Zamiostrobus mirabilis* was sent to Solms-Laubach by the U. S. National Museum, with permission to dissect and describe it. It has been returned together with two slides showing its internal structure, but the only description is contained in letters from him. In these and in the present work he has renamed it *Cycadeoidea Zamiostrobus,* which name his label with the specimen also bears, but no figures are given. The *Tysonia Marylandica* of Fontaine from the iron ore clays (Potomac formation) of Maryland is also regarded as a Bennettites or a Cycadeoidea, and Capellini says that it closely resembles *C. Maraniana.* The *C. munita* of Cragin from the Cheyenne Sandstone is supposed to be a related form. L. F. W.

11. *Ueber den gegenwärtigen Standpunkt unserer Kenntniss von dem Vorkommen fossiler Glacialpflanzen.* Von A. G. NATHORST. Bihang till svenska Vet.-Akad. Handlingar. Band 17. Afd. III, No. 5. Stockholm, 1892.—It is matter for congratulation that this valuable paper should have been published in German instead of Swedish. It contains a résumé of the prolonged and extensive researches of the author into the occurrence of fossil plants in glacial deposits. These began nearly 25 years ago and his contributions to the subject embrace more than a score of titles. The present summary, however, goes further and includes the results of the labors of others, and, though brief, presents a bird's-eye view of the whole field. It is accompanied by a map of northern Europe with the areas and particular localities where these plants are found clearly marked. The principal countries in which these occur are: Sweden (chiefly in Scania at the extreme south, but also in Ostgothland, Gotland, and Jemtland), Norway (at Leine in Gudbrandsdalen), Denmark (Seeland, Möen, Bornholm, Jutland), Russia (Esthland, Livland), North Germany (East and West Prussia, Pomerania, Mecklen-

burg, Schleswig-Holstein), Great Britain (Devonshire, Norfolk, Suffolk, Yorkshire and near Edinburgh), Switzerland (Cantons of Zurich, Thurgau Luzern, Neuchâtel), Würtemberg (Upper Swabia), Bavaria (Kolbermoor), Hungary (Felek in the South Carpathian mountains), France (near Nancy). In nearly all cases the forms thus discovered have been identified with those now inhabiting the colder parts of the northern hemisphere. Their great southern range is conclusive as to the change that has taken place in the climate of Europe. L. F. W.

II. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *American Association for the Advancement of Science.*—The 41st meeting of this association was opened at Rochester, N. Y., on the 17th of August, under the Presidency of Professor Joseph LeConte. The addresses of the Vice-Presidents of the sections were as follows: Professor J. R. Eastman, of the Astronomical Section, On the neglected field of Fundamental Astronomy; Professor B. F. Thomas, of the Physical Section, On Technical education in High Schools and Universities; A. Springer, of the Chemical Section, On the Micro-organisms of the soil; H. S. Williams, of the Geological Section, On the Scope of Paleontology and its value to Geologists; Professor S. H. Gage, of the Biological Section, On the Comparative Physiology of respiration; W. H. Holmes, of the Section of Anthropology, On the evolution of the Esthetic; Professor J. B. Johnson, of the Section of Mechanical Science and Engineering, On the Applied Scientist; Lester F. Ward, of the Economical Science Section, On the Psychological basis of social economics.

The Address of the retiring President, Prof. A. B. Prescott, considered "the work that is wanted in the science of Chemistry."

Excursions were taken on Saturday in four directions, to Portage, Stony Brook Glen, Niagara Falls and Canandaigua Lake. The salt mines also, 20 to 30 miles south of Rochester, were visited.

The President and Vice-Presidents chosen for the following year were as follows: PRESIDENT, Wm. Harkness. VICE-PRESIDENTS, C. L. Doolittle, in the Mathematical and Astronomical section; E. L. Nichols, in the Physical; E. Hart, in the Chemical; S. W. Robinson, in that of Mechanical Science and Engineering; C. D. Walcott, in the Geological; H. F. Osborn, in the Zoological; C. E. Bessey, in the Botanical; J. O. Dorsey, in the Anthropological; W. H. Branner, in the Section of Economic Science and Statistics. Madison, Wisconsin, was selected for the next place of meeting.

List of papers accepted for reading.

Section A. Mathematics and Astronomy.

J. A. BRASHEAR: European observations.

S. C. CHANDLER: On the conflict of observation with theory as to the earth's rotation.

D. P. TODD: Meteorological observations made in April, 1890, 1891, 1892, in the totality-path of the eclipse of 1893. April 16.

L. A. BAUER: The secular motion of a free magnetic needle.

M. MERRIMAN: On the discriminators of the discriminant of an algebraic equation.

G. E. HALE: The spectroheliograph of the Kenwood Astro-Physical Observatory. Chicago, and results obtained in the study of the sun. Forms of solar faculæ.

C. L. DOOLITTLE: Latitude of the Sayre Observatory. List of 30 new proper motion stars.

ALEXANDER MACFARLANE: On the imaginary of algebra.

R. S. WOODWARD: The iced-bar base apparatus of the U. S. Coast and Geodetic Survey. On the general problem of least squares.

A. W. PHILLIPS: Models and machines for showing curves of the third degree.

T. H. SAFFORD: Least square fallacies. Differential formulæ for orbit corrections. Proper motion of 89 stars within 10° of the north pole, with remarks on the present state of the problem of the solar motion.

E. HASTINGS MOORE: Concerning a congruence-group of order 360 contained in the group of linear fractional substitutions.

W. HOOVER: On the intersection of an equilateral hyperbola and the sides of a plane triangle—a question in trilinears.

W. A. ROGERS: On the construction of a prime vertical transit instrument for the determination of the latitude of Harvard College Observatory.

A. S. HATHAWAY: Lineo-linear vector functions.

E. B. FROST: Thermal absorption in the solar atmosphere.

J. E. KERSHNER: Electric lights for astronomical instruments.

J. D. WARNER: Practical rules for testing whether a number is divisible by 7, or any other small prime; and if not divisible, to ascertain the remainder. Increase in constant for addition in testing for integral values in the equation of quarter squares.

Section B. Physics.

E. S. FERRY: Persistence of vision.

G. W. HOLLEY: Experiments on the ocular spectrum of the eye and the image presented to the brain.

C. A. OLIVER: Description of a contrivance intended for the study of perception at definite distances.

E. MERRITT: Note on the photography of the manometric flame and the analysis of vowel sounds.

G. W. HOUGH: On the sensitiveness of photographic plates.

W. S. FRANKLIN: E. M. F. between normal and strained metals in voltaic cells.

M. MERRIMAN: Influence of the moon on the rainfall.

D. P. TODD: On the mechanical and physical means of aërial transit without a propeller.

E. B. ROSA: Further experiments on the specific inductive capacity of electrolytes.

C. B. THWING: A photographic method of mapping the magnetic field.

F. P. WHITMAN: Constancy of volume of iron in strong magnetic fields. Note on magnetic disturbances caused by electric railways.

E. L. NICHOLS: The distribution of energy in the spectrum of the glow-lamp. Absorption spectra of certain substances in the infra-red.

J. E. OLIVER: Note on the Lesage-Thomson theory of gravitation.

A. E. DOLBEAR: A mechanical model of electromagnetic relations.

W. L STEVENS: An experimental comparison of formulæ for total radiation between 15° C. and 110° C.

H. RUBENS and B. W. SNOW: On the dispersion of radiations of great wave-lengths in rock salt, silvite and fluorspar.

B. W. SNOW: On the distribution of energy in the arc. On the infra-red spectra of the alkalies.

G. HINRICHS: On the mechanics of the three states of aggregation.

Section C. Chemistry.

G. Archbold: The albuminoids of maize.

W. P. Mason: Post-mortem imbibition of arsenic. Effect of sedimentation upon self-purification of running streams. The value of a water analysis.

S. A. Lattimore: Presentation of samples from the salt mines of New York.

G. Hinrichs: On the mechanical determination of the stereographic constitution of organic compounds.

W. R. Orndorff: On the decomposition of acetone with concentrated sulfuric acid.

Laura O. Talbott: Itacolumite from North Carolina.

H. Carrington Bolton: A select bibliography of chemistry.

A. Tuckerman: Notes on a bibliography of mineral waters.

E. Hart: Copper sulfate as a material for standardizing solutions.

W. A. Noyes: An effective condenser for volatile liquids and for water analysis. Di-ethyl-carbinamin and its conduct toward nitrous acid.

A. B. Prescott: The iodomercurates of organic bases.

M. Gomberg: Tri-methyl-xanthin and its derivatives.

H. W. Wiley: Some points in connection with the composition of honey. A method of polarimetric observation at low temperatures.

C. P. Townsend: Note on the effect of fertilizers upon the juice of the sugar-cane.

E. A. de Schweinitz: The enzyms or soluble ferments of the hog-cholera germ.

E. Goldsmith: Catalytic influence of ammonia on amorphous substances to induce crystallization.

Section D. Mechanical Science and Engineering.

J. B. Johnson: Extensometer for measuring distortion of specimens under test (instrument exhibited). Peculiar visible strain in steel when tested in tension, compression and cross-breaking.

Fred. T. Gause: Relative economy of the single cylinder air-compressor with cooling by a spray of water and the present economy of the compound compressors at Qua de la Gare, Paris.

A. M. Rosebrough: A new window ventilating appliance.

Wm. A. Rogers: Investigation of a 21 1–1 feet precision screw. Exhibition and description of combined yard and meter standard bar.

R. S. Woodward: On the use of long steel-tapes in measuring base-line. Report of U. S. C. and G. Survey.

E. W. Bemis: Results of municipal ownership of gas-works in the U. S. during 1891.

G. W. Hough: Description of a transmission dynamometer.

J. B. Webb: Bending tests of timber.

J. E. Denton: Method of measuring loss of power and drop of pressure between cylinders in multiple-cylinder engine.

D. S. Jacobus: Measurements of total heats of combustion. Use of anemometers for measuring velocity of air in mines.

J. E. Denton and D. S. Jacobus: Steam economy of the engines of the screw ferry boat "Bremen."

DeVolson Wood: Negative specific heats.

Section E. Geology and Geography.

A. Hollick: Paleobotany of the yellow gravel at Bridgeton, N. J.

G. F. Kunz: The mining, metallurgical, geological and mineralogical exhibits to be shown at the World's Columbian Exposition

J. Crawford: Cerro-Viejo and its cones of volcanic ejecta and extrusion in Nicaragua.

W. J. McGee: Pleistocene geography. Distributions of the LaFayette formation.

W. Upham: Submarine valleys on continental slopes.

E. D. Cope: Cenozoic beds of the staked plains of Texas.

A. L. Arey: Exhibitions of Guelph fossils found in Rochester, N. Y.

John Kost: The American mastodon in Florida.

N. H. Winchell: Some problems of the Mesabi iron ore.

V. Colvin: The mathematics of mountain sculpture.

R. T. Hill: The volcanic craters of the United States. Recent geological explorations in Mexico. The homotoxic relations of the North American Lower Cretaceous.

S. A. Lattimore: Presentation of samples from the salt mines of New York.

C. H. Hitchcock: Terminal moraines in New England.

E. W. Claypole: A passage in the history of the Cuyahoga River.

F. Leverett: Notes bearing upon the changes of the Pre-glacial drainage of western Illinois and eastern Iowa.

A. A. Wright: Extra-morainic drift in New Jersey.

Section F. Biology.

J. C. Arthur: How the application of hot water to seed increases the yield.

L. H. Bailey: On the supposed correlation of quality in fruits—a study in evolution.

W. J. Beal: Spikes of wheat bearing abnormal spikelets. A study of the relative lengths of the sheaths and internodes of grasses for the purpose of determining to what extent this is a reliable specific character.

N. L. Britton: Notes on Ranunculus repens and its eastern North American allies. Notes on a monograph of the North American species of Lespedeza.

F. V. Coville: Geographic relationship of the flora of the high Sierra Nevada, California. Sketch of the Flora of Death Valley, California. Characteristics and adaptations of desert vegetation.

J. H. Comstock: The descent of the Lepidoptera; an application of the theory of natural selection to toxonomy.

O. F. Cook: Do Termites cultivate fungi?

E. D. Cope: A new form of Marsupialia from the Laramie.

W. M. Beauchamp: Variation in native ferns. Notes on some fresh water Mollusks.

W. A. Kellerman: Notes on yellow pitch-pine, *Pinus rigida* Mill, var. *lutea.* Germination at intervals of seed treated with Fungicides.

M. B. Waite: The fertilization of pear flowers.

C. W. Stiles: On the adult cestodes of cattle and sheep.

H. L. Russell: Non-parasitic bacteria in vegetable tissue. Bacteriological investigations of marine waters and the sea floor.

H. E. Weed: The insect fauna of the Mississippi bottoms.

W. W. Rowlee: The root system of Mikania scandens L. Adaptation of seeds to facilitate germination.

C. W. Stiles: Report of Biological Section of the committee on the Naples table.

D. G. Fairchild: Live-for-ever eradicated by a fungous disease.

G. Vasey: Otto Kunze's changes in nomenclature of North American grasses.

B. E. Fernow and G. B. Sudworth: Revised nomenclature of the arborescent flora of the United States.

A. H. Tuttle: The proposed Columbus biological stations in Jamaica. An interesting case of parasitism.

J. H. Stoller: The conditions which determine the distribution of bacteria in the water of rivers.

C. W. Hargitt: Biological notes on fauna of Cold Spring Harbor. Notes on Daucus carota.

W. P. Wilson: Adaptation of plants to external environment.

S. A. Beach: Notes on self-pollination of the grape.

G. B. Sudworth: Comparative influence of odor and color in attracting insects.

F. B. Maxwell: Comparative study of the roots of Ranunculaceæ.

F. Roth: Shrinkage of wood as observed under the microscope.

L. H. Pammel: Peziza sclerotium. Temperature and some of its relations to plant life.

B. D. HALSTED: Pleospora of Tropæolum majus. Secondary spores of Anthracnoses. A Bacterium of Phaseolus.

T. MEEHAN: The significance of cleistogamy.

E. W. DORAN: The animal parasites of dogs.

P. A. FISH: A preliminary note on the anatomy of the Urodela brain as exemplified by Desmognothus fusca.

J. B. SMITH: The "maxillary tentacles" of Pronuba.

L. M. UNDERWOOD: Preliminary comparison of the Hepatic Flora of boreal and sub-boreal regions.

E F. SMITH: On the value of wood ashes in the treatment of peach yellows. On the value of superphosphates and muriate of potash in the treatment of peach yellows.

G. MACLOSKI: Notes on maize.

G. S. HOPKINS: Contribution on the digestive tract of some N. A ganoids.

M. MILES: Heredity of acquired characters.

E. A. DE SCHWEINITZ: The production of immunity in guinea pigs from hog cholera by the use of blood serum from immunized animals.

S. P. GAGE: A preliminary account of the brain of Diemyctylus viridescens based upon sections made through the entire head.

C. V. RILEY: On Carphoxera ptelearia, the new herbarium pest. The fertilization of the fig and caprification.

R. O MOODY: Note on the appearance of two embryo chicks in a single blastoderm.

Section H. Anthropology.

D. G. BRINTON: Anvil-shaped stones from Pennsylvania. Proposed classification and international nomenclature of the anthropological sciences.

A. W. BUTLER: Some Indian camping sites near Brookville. Prehistoric objects from the White Water valley. On some remains from the oldest river gravels along the White Water river. Earthworks near Anderson, Ind.

L. L. CONANT: Primitive number system.

LAURA O. TALBOTT: A few psychological inquiries.

J. JASTROW: Involuntary movements.

MATILDA C. STEVENSON: Tusayan legends of the Snake and Flute people.

E. W. CLAYPOLE: A skull of a pig having a flint arrowhead imbedded in the bone.

W. J. MCGEE: Comparative chronology.

H. T. CRESSON: Brief remarks upon the alphabet of Landa.

F. W. PUTNAM: The Peabody Museum Honduras expedition. The Department of Ethnology of the World's Columbian Exposition. Exhibition of a large model of the Serpent Mound of Adams County, Ohio.

W. M. BEAUCHAMP: Early religion of the Iroquois. Early Indian forts in New York.

C. A. HIRSCHFELDER: Evidences of prehistoric trade in Ontario. Ancient earthworks in Ontario.

O. T. MASON: A definition of anthropology.

F. H. CUSHING: Pueblo myth and ceremonial dances.

C. P. HART: Demonstration of a recently discovered cerebral porta.

DOUGLAS: Ruins of Tiahuanaco.

S. S. SCOVILLE: Points concerning Fort Ancient.

T. B. REDDING: Pre-historic earthworks of Henry county, Indiana.

W. H. HOLMES: On the so-called paleolithic implements of the Upper Mississippi. The sacred pipestone quarry of Minnesota, and the ancient copper mines of Lake Superior. Aboriginal quarries of flakable stone, and their bearing upon the question of paleolithic man.

M. H. SAVILLE: Explorations on the main structure of Copan, Honduras. Vandalism among the antiquities of Yucatan and Central America.

H. C. MERCER: River pebbles chipped by modern Indians, as an aid to the study of the Trenton gravel implements.

W. K. MOOREHEAD: Cañon and mesa ruins in Utah. Singular copper implements and ornaments from the Hopewell group, Ross Co., Ohio.

2. *British Association.*—The sixty-second meeting of the British Association was held at Edinburgh during the week commencing August 3. Sir Archibald Geikie was the President of the meeting. In his address he speaks of the large contributions of Edinburgh geologists to geological science and dwells at length upon the prominent influence of the views of Hutton. Other Presidential addresses were by Professor Lapworth, of the Geological Section, on some general facts in the earth's development; Professor James Geikie, President of the Geographical Section, on the origin of coast lines; Professor Schuster, of the Physical Section, on the progress in Physical Science during the past year; Professor Wm. Rutherford, of the section on Biology, on the current theories regarding our sense of color. These and other Presidential addresses and reports of papers will be found in the numbers of Nature for the month of August and beyond.

3. *On the periodic variations in Glaciers.* The following is from a recent communication by Prof. Forel, published in Nature of August 18.—The preparatory study which we have made within the last few years has shown us that the periodicity of glacial variations is much longer than was formerly believed to be the case; the popular dictum that the increase in the size of glaciers recurs every seven years is certainly incorrect. We cannot yet give definite figures, but probably the cycle of glacial variation is as much as 35 to 50 years. The latter period alone has been studied attentively; if 1850 or 1855 be fixed upon as the epoch of maximum of glaciers, they have been steadily decreasing in past years, so that from 1870 to 1875 we were not aware of a single one on the increase. In 1875 the Glacier des Bossons du Mont Blanc gave the signal for a new period by commencing to lengthen out; it was followed in 1878 and 1879 by the glaciers of Trient and Zigiorenove; then successively by some thirty glaciers in different valleys of Le Valais; but the phase of increase is not yet general in Le Valais; a number of large glaciers, Arolla, Otemma, Corbassière, Le Gorner, Le Rhone, are still decreasing or stationary. It is only of the Mont Blanc group that the increase can be said to be general; in Le Valais it is in process of development, and we are still very far from the maximum stage of glaciers. If, as is probable, the maximum only arrives at the commencement of next century, the actual period of glaciers will have lasted more than fifty years.

4. *Florida, South Carolina and Canadian Phosphates;* by C. C. Hayes Millar. 224 pp. 8vo. 1892. New York (The Scientific Publishing Co.).—As the preface states, this book is addressed to those who are commercially interested in phosphates, and treats of their mode of occurrence, methods and cost of production, and commercial importance. It contains maps of the phosphate regions of Florida and South Carolina, and will be found a valuable work by those for whom it has been prepared.

APPENDIX.

Art. XLII.—*Restorations of Claosaurus and Ceratosaurus*; by O. C. Marsh. (With Plates VI and VII.)

A number of restorations of Dinosaurian reptiles have been recently made by the writer for the United States Geological Survey, and reduced figures of several of these have already appeared in this Journal; namely, *Brontosaurus* and *Stegosaurus* from the Jurassic, and *Triceratops* from the Cretaceous.* Two others of interest are given in the present article; *Claosaurus* from the Cretaceous, and *Ceratosaurus* from the Jurassic, as shown on Plates VI and VII. The former is a gigantic herbivorous reptile, a typical member of the *Ornithopoda*, and the latter a large carnivorous form of the *Theropoda*, as these orders have been defined by the writer.† Each of these two reptiles is a characteristic example of the great order in which it belongs, but both are highly specialized, and present many features not seen in earlier and more primitive types. Their representatives in the old world are *Iguanodon* and *Megalosaurus*, although each of the four genera may represent a distinct family.

It is especially fortunate that each of the restorations here presented is based upon the remains of a single individual in which both the skull and skeleton were found in position, and in remarkable preservation. Additional remains, apparently identical with each, have also been secured, and these have cleared up several points which otherwise might have been left in doubt. These various remains have already been described by the writer, and the most important parts figured.

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* This Journal, vol. xli, p. 339, April, 1891; and vol. xlii, p. 179, August, 1891.

† Ibid., vol. xxi, p. 423, May, 1881; and vol. xxiii, p. 84, January, 1882.

Claosaurus, Marsh, 1890.*

The most important feature in the restoration of *Claosaurus annectens* given on Plate VI is the skull, which will be fully described elsewhere, but its main features may be noticed here. This skull is long and narrow, with the facial portion especially produced. The anterior part is only moderately expanded transversely, thus differing from that of *Hadrosaurus* (*Diclonius*), a nearly allied form. Seen from the side, the skull of *Claosaurus* shows a blunt, rugose muzzle, formed above by the premaxillary and below by the predentary, both probably covered in life with a thick, corneous integument.

Behind the upper part of this muzzle is an enormous lateral cavity, which includes the narial orifice, but was evidently occupied in life mainly by a nasal gland, somewhat like that in the existing Monitor, and also seen in some Birds. This cavity is bounded externally by the nasal bone and the premaxillary. The orbit is very large, and subtriangular in outline. It is formed above by the prefrontal, frontal, and postfrontal, and below mainly by the jugal. There are no supra-orbital bones. A distinct lachrymal forms a portion of the anterior border. The infra-temporal fossa is large, and bounded below by the jugal. There is a thin quadrato-jugal between the jugal and quadrate. The occipital condyle is directed backward and downward.

The nasals are very long and slender, and in front are separated by the narrow superior processes of the premaxillaries. The frontals are short and broad, and somewhat concave above. The parietals are firmly coössified, and very small, forming a thin partition between the supra-temporal fossæ. The latter are bounded posteriorly by the massive squamosals, which contain a deep cavity for the head of the quadrate, and also overlap the exoccipitals.

The striking features of the lower jaw are the massive, rugose predentary, the large and powerful dentary bone with its robust coronoid process, and the very small angular and articular bones.

The teeth are confined entirely to the maxillary and dentary bones. They closely resemble those of *Hadrosaurus*, are arranged in the same manner, and appear to be equally numerous.† They were well adapted to a diet of soft succulent vegetation.

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* This Journal, vol. xxxix. p. 423, May, 1890; vol. xliii, p. 453, May, 1892; and vol. xliv, p. 171, August, 1892.

† The description given by Cope of the skull of *Hadrosaurus* (*Diclonius*) *mirabilis*, Leidy, is erroneous in various important points. Among the more serious errors are the following: the predentary bone is mistaken for the dentary, the dentary is regarded as the surangular and as the splenial, while the squamosal is called the parietal. See Proc. Phil. Acad., 1883, p. 97, plates iv–vii.

The main characters of the vertebral column of *Claosaurus* are well shown in the restoration. There are thirty vertebræ between the skull and sacrum, nine in the sacrum, and about sixty in the tail. The whole vertebral column was found in position except the terminal caudals, which are here represented in outline. The cervical vertebræ are strongly opisthocœlian, and the first eleven have short ribs. The dorsals are also opisthocœlian. There are no true lumbar vertebræ, as the last of those in front of the sacrum support free ribs. The anterior caudals are opisthocœlian. The first and second have no chevrons. Behind these, the chevron bones are very long, indicating a powerful, compressed tail, well adapted for swimming.

In the median dorsal region, between the ribs and the neural spines, are numerous rod-like ossified tendons, which increase in number in the sacral region and along the base of the tail, and then gradually diminish in number and size, ending at about the thirty-fifth caudal. These ossified tendons are well shown in the restoration, and are of much interest. They are not unlike those in *Iguanodon* described by Dollo, but as a rule are more elongate, and appear to lack the definite arrangement in rhomboidal figures observed in that genus.*

The fore limbs are unusually small in comparison with the posterior, and the relative size of the two is well shown in the restoration. The scapular arch presents many points of interest. The scapula is large, and so much curved that its shaft is nearly at right angles to the articular faces of its lower extremity. On the anterior margin, above the articulation for the coracoid, is a strong protuberance, with a well-defined facet, adapted to the support of the clavicle, if such a bone were present. The coracoid is very small, and is perforated by a large foramen. The two peculiar bones now generally regarded as belonging to the sternum were not coössified.

The humerus is comparatively short. The radius and ulna are much elongated, the latter being longer than the humerus, and the radius about the same length. The ulna has a prominent olecranon process, and is a stouter bone than the radius. The carpal bones were quite short, and appear to have been only imperfectly ossified. The fore foot, or manus, was very long, and contained three functional digits only. The first digit was rudimentary, the second and third were nearly equal in length, the fourth was shorter and less developed, and the fifth entirely wanting, as shown in Plate VI.

In the functional digits (II, III, IV), the phalanges are elongate, thus materially lengthening the fore foot. The terminal phalanges of these digits are broad and flat, showing

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* Archives de Biologie, tome vii, p. 249, Gand, 1886.

that they were covered with hoofs, and not with claws. The limb as a whole was thus adapted to locomotion or support, and not at all for prehension, although this might have been expected from its small size and position.

The elongation of the fore arm and manus is a peculiar feature, especially when taken in connection with the ungulate phalanges. It may, perhaps, be explained by supposing that the animal gradually assumed a more erect position until it became essentially a biped, while the fore limbs retained in a measure their primitive function, and did not become prehensile, which was the case in some allied forms.

The pelvis has already been described by the writer. Its most notable features are seen in the pubis and ischium, the former having a very large expanded prepubis with the postpubis rudimentary, while the shaft of the ischium is greatly elongated.

The femur is long, and the shaft nearly straight. The great trochanter is well developed, while the third trochanter is large and near the middle of the shaft. The external condyle of the distal end is projected well backward, indicating great freedom of motion at the knee.

The tibia is shorter than the femur, and has a prominent cnemial crest. The distal end is much flattened, and the astragalus is closely adapted to it. The fibula is very straight, with its lower end flattened and closely applied to the front of the tibia. The calcaneum is large, with its concave upper surface closely fitted to the end of the fibula. Of the second row of tarsals, only a single one appears to be ossified, and that is very small and thin, and placed between the calcaneum and the fourth metatarsal, nearly or quite out of sight.

The hind foot, or pes, had but three digits, the second, third, and fourth, all well developed and massive. The terminal phalanges were covered with broad hoofs. The first and fifth digits were entirely wanting.

All the limb bones in *Claosaurus* are solid, thus distinguishing it from *Hadrosaurus*. The separate ischium, not coössified with the pubis, the absence of a fourth digit in the hind foot, and other marked characters, also make the genus distinct from *Pteropelyx*, the skull of which is not known.

The reptile here restored was nearly thirty feet in length when alive, and about fifteen in height in the position represented in Plate VI. The remains were obtained by Mr. J. B. Hatcher and Mr. A. L. Sullins, in the Ceratops beds of the Laramie, in Wyoming. Among the associated fossils are the gigantic *Triceratops* and *Torosaurus*, which were also herbivorous Dinosaurs, and with them were found the diminutive Cretaceous mammals recently described by the writer.

Ceratosaurus, Marsh, 1884.*

In the same horizon of the Jurassic in which *Brontosaurus* and *Stegosarus* were found, the skeleton restored in Plate VII was likewise discovered. It is a typical carnivorous Dinosaur of moderate size, and doubtless was one of the various enemies of the large herbivorous forms. The restoration represents the reptile one-thirtieth natural size, and in a position it must have frequently assumed.

The skull of *Ceratosaurus nasicornis* is very large in proportion to the rest of the skeleton. The posterior region is elevated, and moderately expanded transversely. The facial portion is elongate, and tapers gradually to the muzzle. Seen from above, the skull resembles in general outline that of a crocodile. The nasal openings are separate and lateral, and are placed near the end of the snout, as shown in Plate VII.

Seen from the side, this skull appears Lacertilian in type, the general structure being light and open. From this point of view, one special feature of the skull is the large, elevated, trenchant horn-core situated on the nasals. Another feature is the large openings on the side of the skull, four in number. The first of these is the anterior nasal orifice; the second, the very large triangular antorbital foramen; the third, the large oval orbit; and the fourth, the still larger lower temporal opening.

The parietal bones are of moderate size, and there is no parietal foramen. The median suture between the parietals is obliterated. The frontal bones are rather short, and are closely united on the median line. The nasal bones are more elongate than the frontals, and are firmly coössified. These bones support the large, compressed, elevated horn-core, on the median line. The lateral surface of this elevation is very rugose, and furrowed with vascular grooves. It evidently supported a high, trenchant horn, which must have formed a most powerful weapon for offense and defense.

The premaxillaries are separate, and each contained three functional teeth. The maxillary bones are large and massive, as shown in Plate VII. They are provided each with fifteen functional teeth, which are large, powerful, and trenchant, indicating clearly the ferocious character of the animal when alive. These teeth have the same general form as those of *Megalosaurus*, and the dental succession appears to be quite the same. Above the antorbital foramen on either side is a high elevation composed of the prefrontal bones. These protuberances would be of service in protecting the orbit, which they partially overhang.

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* This Journal, vol. xxvii, p. 329, April, 1884; and vol. xxviii, p. 161, August, 1884.

The lower jaws of *Ceratosaurus* are large and powerful, especially in the posterior part. In front, the rami are much compressed, and they were joined together by cartilage only. There were fifteen teeth in each ramus, similar in form to those of the upper jaws.

The cervical vertebræ of *Ceratosaurus* differ in type from those in any other known reptiles. With the exception of the atlas, all are strongly opisthocœlian, the cup on the posterior end of each centrum being unusually deep. In place of an equally developed ball on the anterior end, there is a perfectly flat surface. The size of the latter is such that it can only be inserted a short distance in the adjoining cup. This peculiar articulation leaves more than three-fourths of the cup unoccupied by the succeeding vertebra, forming, apparently, a weak joint.

The dorsal and lumbar vertebræ are bi-concave, with only moderate concavities. The sides and lower surface of the centra are deeply excavated, except at the ends. All the presacral vertebræ are very hollow, and this is also true of the anterior caudals.

There are five well coössified vertebræ in the sacrum of the present specimen of *Ceratosaurus nasicornis*. The transverse processes are very short, each supported by two vertebræ, and they do not meet at their distal ends. The caudal vertebræ are bi-concave. All the anterior caudals, except the first, supported very long chevrons, indicating a high, thin tail, well adapted to swimming. The tail was quite long, and the distal caudals were very short.

The scapular arch of *Ceratosaurus* is of moderate size, but the fore limbs are very small. The humerus is short, with a strong radial crest. The radius and ulna are also very short, and nearly equal in size. The carpal bones were only imperfectly ossified. There were four digits in the fore foot, and all were armed with sharp claws. The second and third digits were much larger than the first and fourth, and the fifth was entirely wanting.

The pelvic arch of *Ceratosaurus* is of special interest. In the type specimen here restored, the ilium, ischium, and pubis, on each side, are firmly coössified. The ilia, moreover, are attached to the sacrum, which was in place in the skeleton. The ilia have the same general form as in *Megalosaurus*. The ischia are comparatively slender. They project well backward, and for the last half of their length the two are in close apposition. Their distal ends are coössified and expanded, as shown in Plate VII.

The pubes have their distal ends coössified, and expand into an elongate, massive foot, which is one of the most characteristic parts of the skeleton. It is probable that this foot in connection with the distal ends of the ischia served to support the body in sitting down. That some Triassic Dinosaurs sat down on their ischia is proved conclusively by the impressions in the Connecticut River sandstone. In such cases, the leg was bent so as to bring the heel to the ground. The same action in the present reptile would bring the foot of the pubes to the ground, nearly or quite under the center of gravity of the animal. The legs and ischia would then naturally aid in keeping the body balanced. Possibly this position was assumed habitually by these ferocious biped reptiles, in lying in wait for their prey.

The femur is much curved, and the shaft very hollow. The tibia is shorter than the femur, nearly straight, and has a large cnemial crest. The astragalus is not coössified with the tibia, and has a strong ascending process. The fibula is well developed, and nearly straight, its distal end fitting into the calcaneum. The tarsals of the second row are very thin, and united to the metatarsals below them.

The most interesting feature in the extremities of this Dinosaur is in the metatarsal bones, which are completely ankylosed, as are the bones of the pelvis. There are only three metatarsal elements in each foot, the first and fifth having apparently disappeared entirely. The three metatarsals remaining, which are the second, third, and fourth, are proportionally shorter and more robust than in the other known members of the *Theropoda*, and being firmly united to each other, they furnish the basis for a very strong hind foot. The phalanges of the hind feet are of moderate length, and most of them are quite hollow. The terminal phalanges evidently supported strong and sharp claws.

The unique cervical vertebræ, the coössification of the pelvic bones, and the union of the metatarsals, as in modern Birds, distinguish *Ceratosaurus* widely from all other Dinosaurs, and make it the type of a well-marked family, the *Ceratosauridæ*. The nearest allied form is apparently *Ornithomimus*, from the Laramie, recently described by the writer.

The type specimen of *Ceratosaurus* was about twenty-two feet long when alive, and twelve feet high as here restored. It was found by Mr. M. P. Felch, in the Atlantosaurus beds of the upper Jurassic in Colorado. The associated fossils were mainly other Dinosaurs, especially *Sauropoda* and *Ornithopoda*, together with various small mammals.

New Haven, Conn., September 22, 1892.

ART. XLIII.—*Restoration of Mastodon Americanus*, Cuvier; by O. C. MARSH. (With Plate VIII.)

THE great abundance and good preservation of the remains of the American *Mastodon* have led to various restorations of the skeleton. The best known of these is that made by Prof. Richard Owen, in 1846, based upon a skeleton from Missouri now in the British Museum.* Another restoration was made a few years later by Dr. J. C. Warren, based mainly on a very perfect skeleton from Orange county, New York.† This skeleton is now preserved in the Warren Museum in Boston. A third restoration was made by Prof. James Hall, from a skeleton found at Cohoes, New York, and now in the State Museum of Natural History, in Albany.‡ These restorations are all of importance, and taken together have made clear to anatomists nearly all the essential features of the skeleton of this well-known species.

Additional discoveries have since brought to light more perfect specimens, one of which, now in the Yale Museum, is perhaps in the best preservation of any skeleton of the American *Mastodon* yet discovered, and this has been used by the writer in the restoration, one thirty-second natural size, given on Plate VI, which is reduced from a large drawing made for the United States Geological Survey.

The position chosen in this restoration is one which seems especially fitted to bring out the massive proportions of the animal, and, at the same time, to show nearly all the characteristic features of the entire skeleton. The animal as thus represented was, when alive, about twelve feet in height, and perhaps twenty-four feet in length including the tusks.

This animal was fully adult, as the last molars above and below are in place and somewhat worn. The epiphyses of the vertebræ, moreover, are nearly all coössified with the centra, and in some of them, the sutures are obliterated. The epiphyses are also firmly united to the limb bones.

The tusks were very large, and considerably divergent. There were no inferior tusks, and no traces of their alveoli remain. The penultimate and last molars are present above and below in fine preservation, the former considerably worn.

Other features of this skeleton, and especially the various new anatomical points it discloses, will be discussed by the writer in another communication.

New Haven, Conn., September 23, 1892.

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* British fossil Mammals and Birds, figure 102, p. 298, London, 1846.

† Description of a skeleton of the *Mastodon giganteus* of North America, plate xxvii, Boston, 1852.

‡ Report of the New York State Cabinet of Natural History for the year 1867 plate vi, Albany, 1871.

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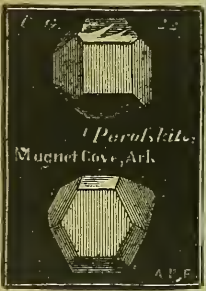

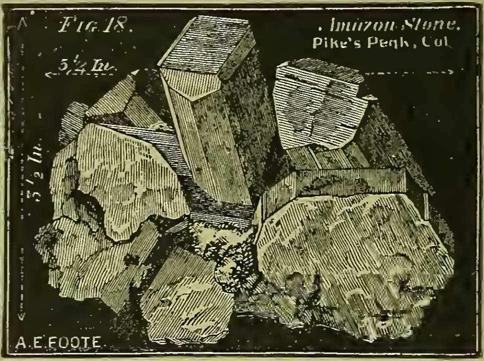

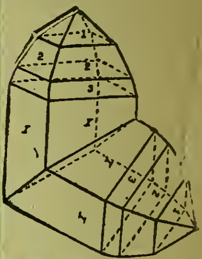

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Art. XLIV.—*Unity of the Glacial Epoch*; by G. Frederick Wright.

A distinction between upper and lower "drift deposits" had been observed some time before Mr. Croll and Professor James Geikie formulated their plausible theory that the ellipticity in the earth's orbit was the cause of the great ice age. But the publication of that theory with the exceedingly able advocacy of two so capable and eminent authorities gave the subject such prominence that evidences of successive glacial epochs have since been sought for in every land, while much of that adduced has been allowed to pass without as close scrutiny as would seem desirable. As I have had occasion frequently to review much of this evidence both in field explorations and in the literature of the subject, it may help to a better understanding of the matter to give somewhat fully the results of my observations and study in this direction. I would premise, however, that I shall discuss merely the glacial phenomena of the post-tertiary epoch. With the supposed evidence of glacial periods in earlier times, this paper has no concern except in a very general way.

At the outset, a question will arise as to what is meant by an "interglacial epoch." The answer to this may show that some who discuss the subject are merely considering the meaning of a word. If every temporary recession of the ice front is looked upon as an interglacial period there can be no question that there have been not merely two but a great many periods in close succession. But the position of most who advocate a succession of glacial epochs is that the continental glacier retreated, during the interglacial epoch, to such an extent that the glaciated area was as free from ice as it is at the present time; and that subsequently the conditions were repeated and there was a re-advance to nearly the farthest limit of the previous movement. It is this view of the case which is advocated so vigorously, in this country by Professor Chamberlin and some of his associates on the United States Geological Survey, and by Professor James Geikie in Scotland, Professor Wanschaffe in Germany, Baron De Geer in Sweden and others. In discussing the problem it will be natural for me to give special prominence to the facts of the American field, and, with all respect to individuals mentioned, to the discussions and reports of my associates in the explorations of this country. But I will not wholly neglect the facts of other lands.

In approaching the subject it is important to notice the fact that Professor Chamberlin inaugurated his induction as director of the glacial division of the United States Survey by publishing a monograph on "The Terminal Moraine of the Second Glacial Epoch," thus assuming the truth of his theory in the title. In the introduction to this paper, however, nothing could be more indicative of the proper spirit with which to enter upon the discussion, or nothing more cordially welcoming discussion, than the following remarks:

"Perhaps no department of geological investigation has greater need of careful discrimination than that which deals with the complex deposits of the Quaternary age. Most formations betray their origin in their salient characteristics, but those of the Quaternary age are apparently capable of diverse interpretation if their general nature alone is considered. It is only by critical discrimination of their special and often quite unobtrusive features that they can be decisively referred to the several agencies that produced them. Most formations owe their origin to the action of some one dominant agency. The Quaternary deposits are, on the contrary, the product of a combination of agencies, the relative work of which is often distinguishable only with difficulty. In these discriminations the individual judgment of the investigator plays an important part. The influence of personal predisposition, therefore, is here liable to be most gravely felt. Probably no investigator is entirely free from the influence of his own preconceptions and methods of interpretations. He, perhaps, does best, who, while duly appreciating these influences and assiduously applying checks for their correction, frankly submits his methods of interpretation to the correction of others."

That Professor Chamberlin has kept his mind open to further light is abundantly evident by comparing his account of "the terminal moraine of the second glacial epoch," in this preliminary paper, with that which appears in his later publications, while at the same time such a comparison is suggestive of possible mistake in his whole interpretation of the facts bearing on the duality of the epoch. In this preliminary monograph (see pp. 322–326) the moraine is made to correspond with the kettle moraine of Wisconsin, and to hug the southern shore of Lake Michigan, but in the Seventh Annual Report of the U. S. G. Survey the later glacial drift is carried down to Bloomington more than a hundred miles farther south, while at the latest date Mr. Leverett (Am. Geol. July, 1892, p. 23) specially deputed by Professor Chamberlin to look after the moraines, draws his later moraine line one hundred miles still farther south, through Litchfield, Hillsboro, Pana, Shelbyville, Mattoon, Charlestown, Paris and Terre Haute. From other information I have evidence that probably this moraine will have to be carried, at least, twenty-five miles still farther south to Greenville, which will be less than 80 miles from the extreme limit of glaciation as determined by me. From this it seems not unlikely that in the near future the closer observation which has found an exterior moraine 200 miles farther south than was at first supposed to mark the limit of the second age, may carry it fifty or sixty miles farther south still, which would be all that it is necessary to make the extreme boundary stand related to the moraine there as it does throughout the eastern part of the Mississippi Valley. This result is the more likely to occur since for a hundred miles or more the whole border of the glaciated area in the valley of the Mississippi is so deeply covered with lœss that the determination of moraine deposits is peculiarly difficult. Mr. Leverett has already found twelve receding moraines in Ohio—the outer one extending to within a few miles of the glacial boundary. When as many are found in Illinois it will, at the existing rate of separation, carry the line as near the border in that State.

The facts pointing toward a separation of the glacial period into two distinct epochs are thus stated by Professor Chamberlin in his monograph on the Driftless Area (pp. 214, 215). "The earlier drift is characterized in the interior basin, [1.] by a wide but relatively uniform distribution, manifesting only occasional and feeble tendencies to aggregation in morainic ridges. [2.] It is not bordered, except in rare instances, by a definite terminal moraine, but ends in an attenuated border. [3.] It is not characterized by the prevalence of prominent drumlins or other similar ridged aggregations. [4.] The phenomena of glacial erosion connected with it are generally feeble. Glacial striæ are indeed present, even in the peripheral portion, but the surface of the rock is not usually extensively planed. [5.] The whole aspect of the deposit indicates an agency which spread the drift over the surface smoothly, and relatively gently, with little forceful action. The drainage phenomena are also of the gentle order. We have yet failed to find evidence of very vigorous drainage connected with the older drift of the interior basin except in osars and kames, whose conditions of formation were exceptional, but, on the contrary, abundant proof of slow-moving waters and imperfect drainage, indicating low slope of the surface.

"The later glacial epoch, on the contrary, was characterized by strong glacial action, planing the rock surface vigorously, even up to the very limit of its advance. The glaciers ploughed up immense moraines about their edges, except on smooth plains whose slope was away from the ice movement. The drainage was usually vigorous, and immense trains of glacial gravel stretch away from the margin of the ice-sheet, reaching great distances down the valleys and frequently filling them to great depths with well assorted material. The vigorous action of the glaciers of the second epoch and the rapid drainage, in general stand in marked contrast with the gentle action and imperfect drainage of the earlier epoch. One of the conditions that determined the distinction was probably the difference in elevation that characterized the two epochs.

"The interval between these two leading epochs we regard as the chief interglacial epoch, representing a greater lapse of time and a greater change in the dynamic agencies of the age than the several other interglacial intervals, or episodes of deglaciation, which mark the complicated history of the ice age.

6. "As belonging to the earlier glacial epoch, we recognize two drift sheets that have been described by the geologists of the respective states as occurring in Southwestern Ohio, Southern Indiana, Central and Southern Illinois, Eastern and Southern Iowa, Northern Missouri, Eastern Nebraska, and Southeastern Minnesota.

"Between these occur, at numerous points, vegetal and ferruginous accumulations, and other evidences of a non-glacial interval. To this horizon belong the larger number of deposits described under the term 'old forest bed,' but very many vegetal deposits so referred do not, in our judgment, belong there, but are referable to several distinct horizons."

7. Another supposed proof of a glacial period long preceding that during which the moraine of the so-called "second glacial epoch" was deposited is the greater oxidation of the glacial drift south of this moraine. This is prominently men-

tioned by Professor Salisbury as among the features "long since recognized by Professor Chamberlin" and which "have been made use of by him and his assistants in field determination." (Bull. Geol. Soc. Am., vol. iii, pp. 181, 182. Also Annual Report of the State Geologist of New Jersey for 1891, pp. 103–108.) Contrasting the earlier with the later drift as seen at Little York, Oxford Furnace, High Bridge and Pattenburg (points from three to fifteen miles south of the moraine as laid down by the New Jersey Report of 1878), Professor Salisbury says, "While the one exhibits oxidation, leaching and disintegration in an advanced stage of development even to its base, where it is thirty feet thick, the other has not suffered oxidation and leaching on any such scale as to make them apparent more than two or three feet from the surface, and the softest and most easily disintegrated varieties of rock often present a degree of freshness which, so far as the eye can see, might characterize masses of rock worked out of their parent ledges within the memory of living men. We hold, therefore, that this extra-morainic drift represents the remnant of a drift covering once much more extensive and more uniformly present than now, and that, like the drift in and north of the great terminal moraine, it was formed by an ice sheet, but by an ice sheet which overspread New Jersey much earlier than that which made the terminal moraine and the main body of drift, which lies north of it." (N. J. Ann. Rep. 1891, p. 105.) Similar remarks are repeated in even more confident tone in the Bulletin of the Geological Society already referred to.

8. Another indication of the great separation in time between the first and the second glacial period, adduced by Professor Chamberlin, presents itself in the extent of erosion which he supposes to have taken place in the river valleys extending southward from the glaciated area, since the upper terraces containing glacially transported material were formed. (Some Additional Evidences bearing on the Interval between the Glacial Epochs, Bull. Geol. Soc. Am., vol. i, pp. 469–480.) In the Mississippi Valley the upper terrace assigned by Professor Chamberlin to the first glacial period consists of the fine silt or lœss deposited on bluffs about 200 feet above the present river bottom. Between the deposition of this silt and the second glacial epoch, according to Professor Chamberlin, a trench about 300 feet in depth and about sixty miles wide was eroded by the Mississippi all the way from Cairo to the Gulf, "with corresponding erosion trenches along the upper branches during the interval between the two epochs" (p. 471). In the upper Ohio valley these high level terraces correspond to what I had assigned to the effects of the supposed glacial dam at Cincinnati. In the valleys of the Susquehanna and the Dela-

ware they correspond to what Lewis denominated the Philadelphia Red Gravel and Brick Clays, and what McGee calls Columbia.

9. Finally, strong confirmatory evidence of a long interglacial epoch is supposed to come from the desiccation of the lakes which have occupied the great arid basin in the United States west of the Rocky Mountains, of which Lakes Bonneville and Lahontan are examples.

Taking up these points in the order mentioned it may be noticed—

1. That on either theory the glacial deposits near the margin are the older, and may be a great deal older than those farther back. How long the glacial conditions continued is an open question, as is also that of how slowly it retreated during its various stages, though it probably was pretty rapid as compared with the advance. Again, it is as much in place for the advocate of the unity of the glacial period to suppose a subsidence in the valley of the Mississippi and elsewhere at the time of the climax and during the earlier retreat, coupled with a re-elevation towards the close, as for the advocates of duality to suppose the same earth movements in connection with two periods. Therefore the "relatively uniform distribution" of the marginal drift, may be accounted for on one theory as well as on the other. On either theory the marginal drift has been longer subjected to erosive and leveling agencies, and, on account of the submergence during the climax of the period, the deposition of lœss has done much to disguise the surface features. I can cite a locality near Yankton, S. Dakota, where the original irregularity of the morainic drift was completely disguised by the superficial water deposits which were altogether above the reach of any present stream. Kettle holes have there been filled up with silt and were only revealed in the process of obtaining the sand for commercial purposes. At Sarahsville, in Williamson County, Illinois, within a few miles of the extreme border of glacial deposits there is a section showing ten feet of lœss upon the surface underlaid by twenty feet of till containing granitic bowlders two and a half feet in diameter. (See my report in Bull. Geol. Surv., No. 58, p. 71, on Southern Illinois.) Until all that region is explored with much more minuteness than it has been so far, it is proper to regard the generalizations which are made about it with a good deal of allowance for the personal equation of the observer.

2. The fact that the oldest part of the glaciated region "is not bordered by a definite terminal moraine, but ends in an attenuated border," is only another way of stating the fact which Lewis and I began to urge upon the attention of the

public ten years ago during the early part of our investigations. In the map of the glacial boundary prepared for my volume on The Ice Age in North America (p. 175), the legend for the line marking the border of the glaciated area west of Pennsylvania, is not "terminal moraine," but simply "southern limit of the ice sheet." East of that point, indeed, a moraine is marked as the boundary, but emphatic attention is called, both in my own language and in that of Professor Lewis, to the probability that here also an unexplored border of thinner glaciated material is to be found south of the moraine. (Ice Age, p. 135.) Recent observations enable me to determine the extent of this "fringe" as we proposed to call it, in the Delaware and Susquehanna valleys, and to give an entirely different interpretation to certain facts in that region from that proposed by Professor Salisbury in support of his theory of a prolonged interglacial period. Of this I will speak under No. 7. Suffice it here to say that the word "fringe" seems a fair term to apply to such a bordering formation whose character is still in dispute. Professor Chamberlin's phrase, "attenuated border," would, however, be equally good. But to insist on calling it the drift of the first glacial epoch is to beg the whole question in the terms chosen, and tends to serious confusion of the public mind as to what the facts really are. The facts are well stated in the sentence quoted from Professor Chamberlin. But it would seem that occasionally in the discussion inferences are mistaken for facts of observation. For example, it is pretty generally assumed in the discussion that originally there was a much greater amount of drift over the attenuated border than there is now and that this has largely disappeared by erosion. But there does not seem to be adequate ground for this supposition. A pronounced terminal moraine is by no means a necessary result of an ice occupation. The extent of the deposits of till and other morainic material, depends in large measure upon the amount of ice movement which has actually reached a given point, which, in turn, depends on the time during which the front of the ice remained stationary at a given point. If there was a gradual approach to a given boundary and a gradual retreat after a pause of moderate length we could not expect a large accumulation of drift. It is too often forgotten that the ice movement diminishes to zero at the very border and that for some distance back of the border all the effects of the movement are specially feeble. A fringe of direct glacial deposit would, therefore, seem to be the normal result near the border. By "fringe" is meant an "attenuated border" of direct deposits from land ice such as might naturally occur near the limit of an ice invasion. This, which was at first supposed to be characteristic only of the Mississippi

Valley, is now found to be equally characteristic of the region east of the Alleghenies.

3. The lack of drumlins and other ridged accumulations along the glaciated border need indicate only a small amount of ice movement over the region, or a depressed slack condition of drainage which, as already stated, may be supposed in case of one glacial period as well as of two.

4. The feebleness of glacial erosion over the fringe follows from the reasons already stated. Of course there was less movement over the fringe than farther back. Still that there was some vigorous movement close to the very margin is shown by the glacial striæ which I have reported from Carbondale, Ill. and from St. Louis, Mo. (See Bull. Geol. Surv., No. 58, pp. 71–73). Dr. Max Foshay has also discovered very pronounced groovings in Western Pennsylvania in the area covered by the fringe several miles south of the moraine as there laid down by Professor Lewis and myself.

5. The fifth point is in part a mere repetition of the first, and to some extent the reply will be the same. The slack drainage indicated in the deposits near the border was caused probably by the changes of level which have been connected with the Champlain epoch. A part of this evidence of slack drainage is found along the Susquehanna and Delaware Valleys, in the Columbia deposits of Mr. McGee. A natural supposition is that the climax of the period was characterized by a depression of land considerably greater than is indicated by the level of the deposits in the Champlain Valley at the time of the disappearance of the ice. But as this point involves a theory concerning the cause of the period and of the changes of level attending it, a few paragraphs may well be devoted to a fuller statement of the reasons for believing that a subsidence may naturally be supposed to have attended the climax of the epoch on the supposition that it was single.

Whatever subsidiary aid the eccentricity of the earth's orbit may provide for the production of glacial conditions, there is now little doubt that the ice age was introduced and closed by marked changes of level, both in North America and in Northern Europe. The fiords which characterize the coast of Norway, and which are brought to light by the sounding line along both the Atlantic and the Pacific coast of North America bear striking witness to the extent of this elevation during the period just preceding the glacial epoch. (See Appendix to The Ice Age in N. A by Warren Upham.) So great was this late Pliocene elevation that it seems to many that it might have been sufficient to have produced the glacial conditions of the succeeding age even without the aid of astronomical changes. An elevation of 3,000 feet would probably be sufficient, and this is much less than we know has occurred in central Europe since Miocene times. Miocene shells are found on the Alps and Pyrenees at an elevation of more than 10,000 feet. An elevation of our glaciated region in its northern parts of 3,000 feet is therefore not out of analogy with the movements during contiguous eras.

Supposing therefore the elevation of the region south of Hudson Bay to amount to 3,000 feet, this would provide the conditions necessary for the beginning of an ice age. But when such a career is once started it is difficult to imagine how it can stop, for the accumulation of ice at once lowers the temperature and adds to the elevation of the surface of the plateau on which it rests; thus tending to increase the depression of the land. The ice piles up and makes an elevation of its own, additional to that of the land, and overloads it with its own weight.

There is certainly much plausibility in the supposition that the subsidence which accompanied the glacial period, and from which the continents have not yet fully recovered, was in part due to the weight of the ice piled up over the glaciated area. The conditions were then unique in the geological history of the earth. About 4,000,000 square miles of territory in the northern part of North America and about half that amount in Northern Europe were covered with ice averaging, probably, three-quarters of a mile in depth, making in all 5,500,000 cubic miles of ice whose weight had first been abstracted from ocean beds, thus relieving the pressure there, and then centered over a restricted area at the north. The relative extent of this disturbance of equilibrium can be appreciated only by comparing this mass of ice with the solid contents of that portion of the continent which is above ocean level. The mean elevation of North America above the sea is estimated by Wallace (Island Life, p. 205) to be 748 feet, while the total area is less than 9,000,000 square miles. This would give about 1,300,000 cubic miles of land in North America above the water level, as against 3,000,000 cubic miles of ice over the northern half of the continent during the climax of the glacial period. Taking the specific gravity of the rocks as two and a half times that of ice, the total weight of ice piled up over British America and the Northern United States, at the time referred to, was nearly equal to that of the whole land surface of the continent which is above sea level. That this enormous change in the distribution of weight and pressure on the surface of the earth should occur without any effect on the configuration of the globe is difficult to believe. When therefore we find that extensive changes in level seem actually to have been correlated with this loading and unloading of the strata which took place during the progress of the glacial age, it is not a wholly unwarranted step in reasoning to connect the two as cause and effect. The supposition, therefore, of a marked subsidence of the northern part of the continent contemporaneous with the climax of the period is a fair one to use in explanation of the complex phenomena of the time.

To appreciate the degree of probability attending the explanation, however, it is important to consider still more closely the natural operation of the forces at work. Upon doing this it is evident that glacial conditions would continue some time after the land subsidence had begun. For a long period the accumulation of ice might be faster than the subsidence of the plateau on which it rested. The anticlimax, when the melting began to proceed faster than the accumulation, was doubtless reached only after a very prolonged period. But when the tide of affairs had really turned and the land had begun to rise the melting of the ice had also progressed to a great extent and the final ending up of the period and the return of the land to a higher level doubtless proceeded with great relative rapidity. On this provisional hypothesis most of the facts indicating slack drainage during the deposition of the marginal deposits will be as readily explained as on that of two distinct epochs with different attitudes of land level during their existence.

6. The occurrence of vegetal and ferruginous accumulations between successive strata of glacial deposits, has long attracted wide attention. At first these were taken to indicate interglacial periods of wide extent and of long separation in time. The occurrence of such deposits seems to be still the chief reliance of many European geologists, as well of some in this country, for belief in successive glacial periods. Professor Chamberlin, however, is not among those who place undue reliance upon this class of evidence, as the quotation from him already given shows; for in his judgment very many of the vegetal deposits occurring in the till "are referable to several distinct horizons." The hazard of inferring a prolonged interglacial epoch from such deposits, also very forcibly appears in view of some recent facts brought to light by study of the glaciers of Alaska.

In this Journal for January, 1887 (pp. 11 to 15, more fully stated in The Ice Age of N. A., pp. 51–62), I have given the facts concerning certain buried forests at the mouth of the Muir Glacier which are standing in undisturbed strata of sand and gravel, from which the ice is slowly withdrawing. I adduced evidence also to show that the ice front had withdrawn several miles during the present century, uncovering forest beds on its way. These inferences have been fully confirmed by the investigations of Professors Reid and Cushing who spent the summer of 1890, on the same ground (see National Geographic Magazine for March, 1892, and The American Geologist for Oct., 1891). Indeed Professor Reid's photographs show that the ice front had receded 3,000 feet during the four years intervening between our visits and he is confident that the glacier has receded fourteen miles during the century. These observations reveal also unexpected rapidity in the movements of great glaciers and remarkable capacity of ice in certain conditions to creep over unsolidified strata of sand and gravel without disturbing them. From the rapidity with which both forests and ocean fauna follow up a retreating ice front where, as in this case, it debouches into an arm of the sea, it is clear that two or three centuries are sufficient to produce a forest bed of considerable extent with all its accompaniments of glacial deposits below and above.

In addition to this Mr. Russell (National Geographic Magazine, vol. iii, p. 92, Am. Geologist, March and May, 1892; and this Journal, March, 1892) reports from the great Malaspina glacier, whose foot spreads out over an area of 1,500 square miles on the low lands southeast of Mt. St. Elias, that on the belt of morainic accumulations which conceal the extreme margin of the glacier for a width of five miles or more there is a dense forest growth. This forest has every appearance of considerable age. It consists principally of spruce trees, some of which are three feet through, but there are many alders "and a great variety of shrubs and bushes, together with rank ferns which grow so densely that one can scarcely force a passage through them." (This Journal, p. 178.) In many places this vegetation is on a moraine which is underlaid by ice not less than a thousand feet in thickness. These forests appear also on the north border of the glacier. The whole area of ice observed by Mr. Russell to be covered by forests was estimated at from twenty to twenty-five miles. Such facts as these should make us hesitate about attributing every forest bed buried in glacial deposits to a distinct glacial period. In the complicated movements which doubtless attended the advance and retreat of so vast an ice sheet there is room for the burial of a great many forest beds, and Professor Chamberlin is doubtless correct in thinking that those discovered in the Mississippi Valley may belong to several different horizons. In my "Ice Age" (pp. 484–488), I have quoted at length from the late Mr. Lesquereux to show that two or three hundred years is ample time to allow for the accumulations of peat which have been found embodied in glacial deposits. (See also Penn. Ann. Geol. Report for 1885, pp. 106 to 114.)

From the discussions in the International Congress of Geologists at Washington in 1891, it would appear also that a fair share of the European members did not regard the interstratified gravel deposits of North Germany as indicative of anything more than a temporary oscillation of the ice. (See Am. Geol., Oct., 1891, pp. 241 to 247.) The "interglacial shell beds" at elevations of 1,000 and 1,400 feet above sea in England at Macclesfield and Moel Tryfaen, have been shown to be shells pushed up from the Irish Sea, and washed out and stratified in thin beds by the local streams of water accompanying the departure of the ice sheet. (See my paper in this Journal, Jan. 1892; but especially Professor Kendall's comprehensive discussion of the evidence in my volume just published by D. Appleton & Co., entitled Man and the Glacial Period, pp. 136–182.) Professor Lewis's conjecture seems to be amply sustained by subsequent investigations. The evidence for a succession of glacial periods in Great Britain is inconclusive, while the evidence against it is overwhelming. Professor James Geikie has indeed recently returned to the defence of his favorite theory (see On The Glacial Period and the Earth Movement Hypothesis, being a paper read before the Victoria Institute, London), in which he relies almost wholly upon evidence of successive glacial periods to prove that the astronomical theory, to which we have referred, is the only adequate cause. His evidence is largely drawn from interglacial beds on the continent of Europe containing remains of plants and animals. The strongest instance adduced by him is still that of the interglacial lignite beds of Dürnten and Utznach in Switzerland. But it would seem that the inference of great oscillations of climate which he draws from the character of the vegetation composing the lignites rests upon very uncertain data. The remarks of Professor Prestwich upon the deposits are of great weight:

"Admitting the fact that the Dürnten Lignites rest on beds of undoubted glacial (ground moraine) origin, and that the trees grew on the spot where their stumps and remains are found, it by no means follows, as contended, that because these trees are all of species now living in Switzerland that the temperature was as high as that of Switzerland at the present day. *The Pinus sylvestris*, *Abies excelsa*, the Yew, the Birch, and the Oak, flourish equally in Sweden and far north in Siberia, and there is an absence in the scanty Dürnten flora of those plants which, while having a more southern range, also now live in Switzerland. On the other hand, there is there one species of *Pinus* (*P. Montana*) which is spread over the mountain country up to heights of 7,000 feet, and is rare in the lowlands, while one of the mosses in the lignite is closely allied to a species now growing on the hills of Lapland. The few species of mammalia have a distinctively arctic facies. The *Elephas primigenius*, *E. antiquus*, the *Ursus spelæus*, and even the *Cervus elaphus* and *Bos primigenius*, are commonly associated with Reindeer, Musk-ox, and other arctic animals of cold post-glacial times. Further, both the trees and animals are those of our "forest bed," the last land survival before the climax of the glacial period.

"Is the return, therefore, of the retreating glacier,—supposing the boulder gravel above the lignites of Dürnten to be due to direct ice action,—to be ascribed to anything more than a comparatively slight temporary change of climate, like those, only more marked, that now for a succession of seasons cause, from time to time, a temporary advance of the glaciers? We must allow, of course, for greater differences, and possibly longer intervals of time than now obtain." (Geology, vol. ii, pp. 458, 459.)

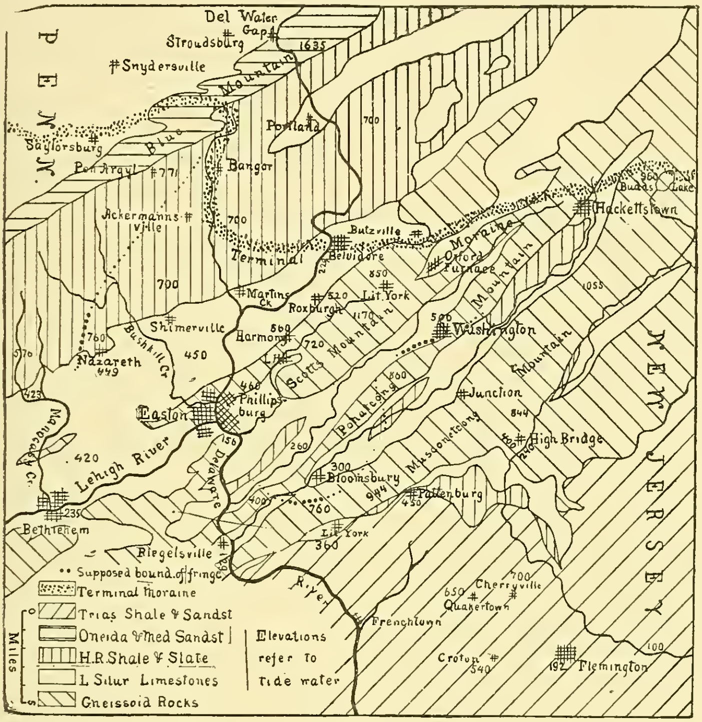
I have elsewhere called attention to the semi-arctic facies of the vegetation found in our own interglacial beds. (See Ice Age in N. America, pp. 482–496.)

7. The supposed proof of the great age of the marginal deposits drawn from their superior oxidation, is partly an illusion of observers and partly a normal result of the fact that the continental glacier moved over a region which was at the start deeply covered with oxidized material derived from the long secular disintegration which had preceded. The results of this secular disintegration are abundantly evident everywhere south of the glaciated area, especially over the regions containing granitic and gneissoid rocks. For scores and sometimes for hundreds of feet in depth these rocks are frequently so disintegrated by the long continued percolation of water charged with acids, that the mass is as loose in texture as a gravel bank. (See especially "On the Formation of Bowlders and the Origin of Drift Materials" by L. S. Burbank, in Proc. Bost. Soc. Nat. Hist., Nov. 19, 1873; also a paper by Professor Pumpelly, in this Journal, 1879, pp. 13–14. A valuable summary of discussions upon this important point is given by Mr. Ralph S. Tarr in the American Geologist for July, 1892.) Naturally the material first and farthest moved by the ice would be this which was already well oxidized to begin with. To this cause there can be little doubt is to be ascribed the oxidized character of the material contained in the "fringe" and of that composing the Philadelphia Red Gravel and Brick Clay, which is the overwash of the ice sheet when it was at its climax and when the drainage was sluggish from the differential northward depression which characterized that portion of the period.

The extensive oxidation spoken of by Professor Salisbury in the quotation made from his recent reports on the glacial deposits of New Jersey, is clearly of preglacial origin. In company with Professor A. A. Wright (a very competent geologist and mineralogist who is familiar with the region described by Professor Salisbury) I have, during the past summer, gone over the field pretty thoroughly so as to complete work which the late Professor Lewis and I had contemplated before his death. The area is that occupied by the southern part of Morris county and the northern part of Hunterdon county, New Jersey, and Northampton county, Pennsylvania. These counties border the Delaware River below the terminal moraine as delineated by the New Jersey geologists in 1878 and by Professor Lewis and myself in 1880 and 1881. Until recently this moraine has stood as the southern boundary of the glaciated region, and has been regarded as a place where there was no fringe and where the glacial moraine of what was called the "second glacial epoch" coincided with that of the first. It is fair to say, however, that this part of our work was done by Professor Lewis and myself at the outset of our attempts to trace the glacial boundary and that we then shared with others the supposition that the boundary was everywhere marked by a distinct terminal moraine.

But in the progress of our work we had our attention called more and more to an attenuated border which we called the "fringe" and which I have attended to almost exclusively in my later explorations of the boundary in the Mississippi Valley. In commenting upon this fringe Professor Lewis (see 2d Penn. Geol. Surv. Rep., vol. Z, p. 201) remarks that traces of this "fringe" may be looked for in Pennsylvania and New Jersey, and that the impression had grown upon him "that this fringe is destined to play an important part in glacial geology." Professor Lewis's early death prevented his following out the clues already then in mind, and I have been unable until the present season to examine the region with sufficient care to enable me confidently to say anything about it. Nevertheless, in view of what Mr. McGee has been writing about the Columbia deposits I ventured three years ago to utter a warning, and to suggest that he might be drawing some unwarranted conclusions from the facts he was presenting, in view of the probability that some of his facts belonged to the fringe which Professor Lewis and I had overlooked in that region. (See Ice Age in N. A., p. 135.) I am now able to demonstrate that both Mr. McGee and Professor Salisbury have been led astray in their recent publications by their failure to notice some of the characteristics of the "fringe" in the Delaware valley.

The true glacial deposits in the Delaware valley below the Water Gap can be readily traced by the distribution of Medina sandstone which forms the crest of Blue Ridge, rising everywhere as a solid wall about 1,000 feet above the country to the south. This is a very characteristic and enduring rock, and forms a large part of the moraine in the counties mentioned. South of the moraine, on the New Jersey side of the Delaware, within a distance of fifteen miles, there are three low mountain ridges (Scott's, Pohatcong and Musconetcong) separated by valleys. These ridges and valleys run northeast by southwest parallel with Blue Ridge. The mountains consist of gneissoid rocks, and are evidently the remnants of three anticlinals which were once covered with strata of Lower Silurian limestone and Hudson River slate, remnants of which appear both in the hollows between the ridges and on both the north and their south flanks of the ridges as a whole. South of Musconetcong Mountain stretch the Triassic red shales which cover so much of the central part of New Jersey. But



Map of the Delaware valley in the vicinity of the Terminal Moraine.

in this portion of the state there has been absolutely no transportation of northern material out upon the Triassic shales, showing that no glacial movement here ever passed Musconetcong Mountain.

These Archæan ridges everywhere exhibit remarkable effects of secular disintegration. Gneissoid bowlders are creeping down their sides in all directions of slope, and, in favorable places for observation, the rock is seen to be disintegrated to a great depth. Many cuts show that the softer material is washing out and working down toward the valley, and leaving the harder masses to follow at a slower rate. Doubtless the original height of the mountain has been thus reduced thousands of feet, thus entirely removing the covering of lime and slatestone. We have here now but the cores of the original ranges. But guided by the material transported by what we may call the Delaware River lobe of the ice sheet, we find that in the vicinity of the river the ice actually overran Scott's Mountain as far east certainly as Bethel, and left Medina bowlders in considerable numbers in the Pohatcong Valley near Washington. The actually transported material here cannot be distinguished in its oxidation from that in the moraine north of Oxford Furnace. The oxidation of which Professor Salisbury speaks at Oxford Furnace and Little York is the secular oxidation which we have described as characterizing the whole mountain. But with this local material at the places mentioned there is mingled on the surface a considerable deposit of the northern rocks belonging to the fringe. The ice here barely went over Scott's Mountain to Washington. It did not here cross Pohatcong Mountain so as to reach Musconetcong Mountain.

Nearer the river, however, it crossed the low Pohatcong ridge also and, at one point, about five miles south of Philipsburgh, reached a col in Musconetcong Mountain, landing there a good many Medina bowlders, and allowing some of them to be carried down a small streamlet on the south side which for a time offered an outlet for the drainage in that direction. That the ice did not extend farther is shown by the fact that there is absolutely no transported material out on the Triassic rocks beyond the influence of this little stream, and in the case of that, the Medina pebbles have all worked down towards the Delaware River.

On the west side of the Delaware, below the moraine, there is a similar extension of the phenomena of the fringe; as there is also in the Valley of the Susquehanna below Berwick. To obtain the sections of these river valleys given by Mr. McGee to prove a subsidence in that region of several hundred feet during the Columbia (Philadelphia Brick Clay) period (see this Journal, vol. cxxxv, pp. 376–379) he has certainly gone above the boundary of the fringe, and confounded direct glacial deposits with those made by the flooded streams of the period.

At Pattenburg and High Bridge there are cuts in deposits which at first look very much like true till, and they have been adduced by Professor Salisbury as unquestionable instances of its occurrence at these points, which demonstrate by the oxidation its great age. But a fact which Professor Salisbury failed to notice would seem to be fatal to his theory. There is no foreign material in the cuts; at least Professor A. A. Wright and I could not find any. All the fragments of the rock found in them are from the strata which have demonstrably been in place in the mountain, and may have worked down in the course of the slow disintegration to which it has been subjected since the beginning of Mesozoic time. An additional proof of this is that there is a significant cessation of Medina bowlders before reaching the north side of Musconetcong Mountain in the vicinity of both these places. There are, it is true, in the deposits many pieces of slate which are scratched as in true till, and very rarely there is a bowlder of gneissoid rock which shows faint scratches on some of its faces. But in all these cases it is impossible to tell whether the scratching has been done by an ice movement or by land slides and by the slower process of "creep," which is everywhere going on in the region. In both these places the mountain in close proximity rises several hundred feet above the deposits, and bowlders are creeping down from them. Taking the whole situation into view it seems far more probable that these deposits are the product of the degrading agencies at work in wearing down the mountain than that a northern ice sheet should have suddenly ceased to deposit Medina bowlders upon reaching the vicinity of this mountain, unless the ice ceased to move any farther. If there had ever been any such amount of Medina sandstone mingled with local material as is found in the moraine at Oxford, or at Little York, no lapse of time could have eliminated it. For this sandstone is far more enduring than the slate of which there are so many fragments both at High Bridge and Pattenburg. The evidence relied upon by Professor Salisbury from the excessive oxidation of these deposits is thus seen to be illusory. He has misread the facts.

8. The most weighty considerations favoring the duality of the glacial period are found under the eighth head. Yet it is more than possible that the apparent conclusiveness arises from an incomplete comprehension of the facts which confessedly are of a very complicated character, and but imperfectly known.

In the present state of evidence as made known to the general scientific public it is difficult to discuss the progress of events since the beginning of the glacial period in the lower Mississippi Valley. But according to Professor Chamberlin what is called the Orange Gravel and has heretofore been regarded as of glacial age, is preglacial. It does not contain granitic pebbles. His study of the deposit also convinces him that it was originally continuous over the entire trough which has a width of about sixty miles (Bull. Geol. Soc. Am. p. 471). The only relic of the earlier glacial deposits which he would recognize over this area is the silt which everywhere caps the Orange Sand and extends beyond it to the east. This he would connect with the lœss in the upper part of the valley extending to the moraines. Apparently he does not regard this silt as a deep water deposit but as a deposit spread out over a vast flood plain when the drainage was slack both from a depression northward and from the previous filling up of the trough by the Orange Sand. But granting that this is the correct interpretation of the phenomena, it is difficult to see how the erosion is shown to be "interglacial." If that depressed condition of things occurred at the climax of the period, why may not the erosion simply gauge the time since that climax? I will, however, leave others more familiar with the facts to discuss the various assumptions underlying the argument from the Lower Mississippi, and turn to the problem of erosion and deposition in the valley of the Ohio River of which I have more personal knowledge.

In brief the facts are that the Ohio occupies a trough, from three to five hundred feet in depth and averaging from a half mile to a mile in breadth, which has been eroded from nearly parallel strata of Palæozoic time. Nor does the present depth of the trough represent the whole extent of erosion. The channel is filled with gravel to a depth of from fifty to a hundred feet or more below the low water mark. Two sets of terraces containing granitic, and therefore glacial, drift mark this trough all the way from Louisville to the head-waters of the Allegheny River up to a level between 1,000 and 1,100 feet above tide. The lower terrace is continuous and is definitely traced up all the northern tributaries to the terminal moraine and is much higher and coarser near the moraine, and wherever tributaries come into the Ohio from the glaciated region, than it is below. This terrace rises at its highest points to about 120 feet above low water mark, that being the height at Cincinnati and at the mouth of Beaver Creek in Western Pennsylvania. Evidently the channel was at various places originally filled up to this height so as to raise the water level by that amount all the distance above Cincinnati.

The second series of terraces connected with the glacial period occur in various oxbows and on numerous shelves of rock bordering the channel at elevations of from 200 to 300 feet above the present river level and at about 1,000 feet above tide. Two of the best known localities are Bellevue about five miles below Pittsburgh, and Parker about thirty miles up the Allegheny from Pittsburgh.

The glacial terrace at Bellevue is 300 feet above the river, and is supported by a shelf of rock about one half mile wide. At Parker the glacial deposits are in a deserted oxbow of the river formed when the level was 200 feet higher than now. Up the Monongahela River there are corresponding terraces to which Professor I. C. White has called attention which are at about the same absolute level, and entirely above the regular river terraces which have been formed in process of the lowering of the channel. One of the chief differences between these high-level terraces on the two rivers is that those on the Allegheny have granitic pebbles derived from the glaciated region while those on the Monongahela do not. Professor White describes extensive areas where this mantling of what seems like a lacustrine deposit, consisting of pebbles, and deposits of clay sometimes thirty feet thick, containing fresh leaves, characterizes the Monongahela up to a level of from 1,000 to 1,100 feet and there suddenly cease.

Professor Chamberlin maintains that these high-level terrace deposits are merely the remnants of flood plains when the whole drainage level was at that elevation. As a corollary to this he contends that the drainage level was at that height at the time of the first glacial epoch, admitting of the distribution of the granitic pebbles in the Allegheny drift, and that the erosion of the Ohio gorge below that level (i. e. to a depth of about 250 feet for a distance of about 1,000 miles as the water runs) was eroded during the interglacial epoch. To that first epoch he would also attribute the glacial deposits on the south side of the Ohio opposite Cincinnati which I had adduced as rendering it probable that there was an ice dam across the river at that point. Professor Chamberlin, on the contrary, supposes these deposits to have been made so much earlier than those a short distance north of Cincinnati that the interval is marked by the whole erosion of the gorge of the Ohio through its whole extent.

I was not present at the discussion of the Cincinnati ice dam at the Geological Society a year ago. But, from what has been published since, it is evident that the last word has not yet been said about it. Mr. Leverett in particular has attempted to correlate some of the clay and lœss deposits in southeastern Indiana, with deposits of similar character in Illinois, attributing both to the earlier glacial period during its slackened drainage. But he does not seem to have duly considered the facts which I have presented making probable an obstruction of the channel of the Ohio near Madison, Indiana, in Jefferson and Ripley Counties which might well account for the facts in that part of the state most like those in Southern Ohio. (See Bull. U. S. Geol. Surv., 58, pp. 65, 66.) Something more than similar microscopical results must be relied on to demonstrate chronological identity of deposits.

The theory of a somewhat prolonged obstruction of the channel at Cincinnati by ice has received strong confirmation in Professor James's investigations, going to show that the preglacial channel of the Ohio ran at Cincinnati still farther north, following up the valley of Mill Creek until it joined the Big Miami near Hamilton. At any rate it is certain that the Ohio did not in preglacial times flow in its present channel from Cincinnati to the mouth of the Great Miami, for I am informed by Mr. Charles J. Bates, inspector of masonry for the Cincinnati Southern Railroad whose bridge crosses the river just below the city, that bedded rock was found by him a few feet below the present bottom of the river extending across its whole width. But at Hamilton in the valley of the Miami where the depression of Mill Creek joins it, the rock bottom is as much as ninety feet below the level of the bottom of the Ohio at Cincinnati. This northern bend of the river in preglacial times adds greatly to the argument from direct evidence of a prolonged ice dam there. The gorge for several miles below Cincinnati is comparatively narrow and its erosion in good part may perhaps measure postglacial time.

In all this discussion it should be borne in mind that we cannot assume an absolutely constant level of the land in the region of the Upper Ohio Valley. Indeed, the subsidence proved by the Champlain deposits to exist at the close of the ice age involved a differential in the depression of the land to the north which is very suggestive, while another class of facts, equally suggestive of considerable changes of level in connection with the glacial period, appears in the northerly slope of the bed of many northern tributaries of the Upper Ohio and Allegheny rivers. The Shenango, Mahoning and Beaver rivers, and French, Oil and Conewango creeks, all have a rock bottom which slopes to the north, or away from their present outlets. Mr. Carll and some others have argued from this that there must have been a system of northern outlets into Lake Erie in preglacial times. (2nd Penn. Geol. Surv. iii, pp. 330 to 366.) The actual existence of such northern outlets has, however, not been proved by direct evidence. The theory of a general elevation of the country to the north in preglacial times, such as is supposed to have brought on the period would seem to provide a natural explanation. But Mr. Leverett, under guidance of Professor Chamberlin's theory of the course of events in the Upper Ohio is compelled to resort to the hypothesis that a part of this lowering of the channels of these streams to the northward was done by subglacial currents of water forced by hydraulic pressure to run up hill to find exit. (See this Journal, Sept. 1891, p. 209.) A theory driven to such extremities cannot be said to be altogether free from difficulty.

A simple statement of the rival theory concerning the course of events in the Upper Ohio Valley is its own best defence. I suppose that the erosion during early Tertiary times had proceeded so far that base levels had become established, and that the rock shelves at Bellevue and Parker mark the flood plain of the river at that time. During the close of the Tertiary period the land underwent elevation until it stood much higher than now over all the northern part of the United States and Southern Canada. During this time the rivers lowered their beds to the extent shown by their present rock bottoms. The channel of the Ohio was a product of that period. The differential northerly elevation permitted the erosion of the northern tributaries of the Ohio spoken of. Their present attitude is the result of subsequent differential subsidence. This subsidence occurred in connection with the climax of glacial conditions when the ice extended so as to dam up the Ohio at Cincinnati. This dam coöperated with the slack drainage attending the differential subsidence to produce many of the phenomena which Prof. Chamberlin attributes to a first glacial period. Floating ice came down the Allegheny River in great quantities and drifted into the oxbows and upon the shelves of the earlier epoch of erosion, and left the glacial material which is found in such places as Parker and Bellevue. Similar conditions in the Monongahela favored the deposits of pebbles and silt at the high levels described by Professor I. C. White. The deposits in Teases Valley between the Kanawha and the Ohio in West Virginia probably belong to a somewhat later stage when the barrier below Cincinnati had been worn down to a considerable extent. For it should be observed, that the preglacial channel of the Ohio at Cincinnati toward Hamilton was permanently closed by glacial deposits.

The Columbia terraces of the Susquehanna and the Delaware were deposited under somewhat similar conditions. There was a depression of the coast level of about 200 feet in New Jersey allowing the great ice rafts loaded with Medina bowlders which came down the river to tide level to be floated over the lowlands of the state south and east of Trenton, and to be stranded along the shore on the west side of Philadelphia to a height of 175 feet. The subsidence to the north was so much greater than that at the south that the drainage of these rivers was much slacker than now, but nowhere do the terraces of this period on the Delaware and Susquehanna rivers extend much above 175 feet except inside the region actually covered by glacial ice. How much these rivers have lowered their beds since that time it is difficult to tell, but probably not a great deal.

I cannot well close this part of the discussion without reference to a recent attempt of Professor Winchell (Am. Geologist, Aug. 1892, pp. 69 to 80) to measure the length of the interglacial epoch in Minnesota. Professor Winchell presents strong evidence to show that the preglacial channel of the Mississippi above St. Paul ran in a nearly straight line with the lower valley and reached the present valley again seven or eight miles north of Minneapolis. This he supposes to have been filled up during the first glacial epoch, while in the interglacial epoch the channel that has long been known west of Minneapolis was eroded, to be filled on the advance of the last glacial ice sheet. This amount of work he estimates would not have required more than 9,750 years, which would be the length of the interglacial epoch in that latitude. Though this is as nothing to the length of the period as estimated by Professor Chamberlin for the southern part of the glaciated area, it is sufficiently long to make us ask whether the data are sufficient by which he would establish the different ages of those preglacial channels? The aspect of the unglaciated areas where secular erosion is open to inspection is such as to throw much doubt over surface indications in the glaciated region. I should be inclined, therefore, to wait for further light before committing myself unreservedly to the theory in question.

9. The final consideration bearing on the duality of the glacial period is drawn from the successive enlargement and desiccation of Lakes Bonneville and Lahontan, in the arid basin west of the Rocky Mountains. This coincidence is certainly very striking, and the theory that there is a causal connection between the phenomena of the glacial periods and the enlargements of these lakes is very plausible. But in our general ignorance of the causes of local climatic changes such a coincidence should not go far in face of other evidence. There are, for example, successive salt deposits in many regions which indicate local variations of climate equal to anything which can be demonstrated in the great Rocky Mountain Basin, but in geological periods when we have no reason to suspect glacial conditions. That the last enlargement of Lake Bonneville coincided with the glacial period is pretty certain,

but that there were glacial periods to accompany the earlier enlargements is by no means so evident.

Futhermore, as bearing against the duality of the glacial period it may be urged with great force that it is improbable that two periods should so nearly duplicate one another as these two are supposed to have done. To those who maintain the sufficiency of Croll's astronomical cause, however, this is rather an argument in favor. But on the other hand, that cause would also demand a long succession of periods during all the geological ages, and of these we lack sufficient proof; while it would throw the two periods which Professor Chamberlin recognizes back much farther than the facts will admit. It must be said, however, that it is not wholly out of analogy with known earth movements to suppose that there has been, in connection with the glacial period, a succession of oscillations of the earth's crust nearly duplicating each other. Such oscillations seem to have occurred in various geological ages, as for instance during the coal period when the successive coal beds were formed. And indeed, much can be said in favor of the view that such an oscillation, when once begun would perpetuate itself. The loading of one part of the land surface and its consequent subsidence would naturally, if not necessarily, be attended with the elevation of other and perhaps distant portions of the crust. This might secure the beginnings of a glacial period in another hemisphere, which when fully grown, would return the favor, and by its weight cause the earth's crust to bulge out again where it had been depressed. But our knowledge of these matters is too vague to reason on it with any confidence, as is also that of the other causes which have been suggested for the production of the phenomena of the period.

In conclusion it is sufficient to remark that our present state of knowledge on the subject seems so imperfect that it is not conducive to success in investigation to hold any theory as to the unity or duality of the period with great positiveness. Over-confidence on this point at the present time is likely to blind the eyes of the investigator, and to hinder progress, both in the collection and in the interpretation of the multitudinous and complicated facts which everywhere invite our close attention.

Art. XLV.—*A Photographic Method of Mapping the Magnetic Field;* by Charles B. Thwing.

The common method of obtaining a cross section of the field of force of a magnet by means of iron filings is very satisfactory when only temporary representations of the field are desired. There has been wanting hitherto a suitable method of making a permanent map of the magnetic field.

A method employed in the physical laboratory at Northwestern University has been found to give results so far superior to any hitherto obtained, that a description of the method employed will probably prove of value to others who may be engaged in the study of the magnetic field.

While studying the magnetic field, it was suggested by Mr. John Lamay that a permanent record of the field could be obtained by securing a map upon blue print paper, exposing to the sun, and washing as usual. The results obtained were beautiful; but it was of course necessary to repeat the process for every copy of the field desired. It at once occurred to the writer that by employing a photographic dry plate, in place of the blue print paper, a negative would be obtained from which any desired number of prints could be made and which would have the additional advantage of representing the figures in their true colors.

Fig. 1. Apparatus employed.

The apparatus employed is shown in fig. 1, which also illustrates the method used in distributing the iron filings and exposing the plate.

For obtaining the field of a bar magnet, the magnet was placed upon a large card, previously marked with concentric circles and parallel lines to facilitate the centering of the magnet. The photographic plate was placed, film side up, directly upon the magnet. The iron filings were held at a distance of a foot above the plate in a bag of loosely woven flannel, from which, by shaking the bag, they could be evenly distributed over the surface of the plate The plate was then held at two points and tapped gently until the filings had arranged themselves along the lines of force. The room was, of course, up to this point illuminated only by non-actinic light. The exposure was now made by turning the key of an incandescent lamp, supported at a convenient distance directly above the center of the plate. The position of the lamp is a matter of considerable importance, as the light from a gas jet at one side of the plate will cause the filings to cast a shadow and give an incorrect representation of the lines of force. Where an electric lamp is not convenient, nearly as good results may be obtained by holding a lighted match above the plate. It is more difficult, however, to time the exposure correctly by this method, and the match will often so cast a shadow upon the plate as to cause irregularity of illumination. After exposure, the plate is tipped so that the filings may slip off, and the few which still cling to the surface of the film are carefully removed by means of a fine, camels-hair brush. The negative is then developed and fixed in the usual way.

The plates employed should be of a sort to give the strongest possible contrasts A slow plate such as Carbutt's process plate was found to give most satisfactory results. This plate required an exposure of twenty seconds, when a sixteen-candle power lamp was placed at a distance of eighteen inches from the plate. If a match is employed to illuminate the plate, Carbutt's B 16 may be used, with an exposure of about three seconds, and nearly as good results will be obtained.

For making prints from these negatives, any paper may be employed which will give good black and white tones. I have found the aristotype paper to give beautiful results when printed deeply and toned to exactly the right point Reduced positives from these negatives make very brilliant lantern slides, by means of which a great variety of magnetic fields may be shown to a large audience. The want of such lantern slides for illustrating popular lectures has been felt by the writer and doubtless by many others.

Figures 2 to 5 show typical forms of the field of a bar magnet. To obtain the best results, the bar magnet should be a strong one and of considerable size, since the film is of necessity placed the thickness of the glass plate away from the magnet, and with a weak magnet the lines will not be sufficiently distinct; especially since it is necessary to employ a considerable quantity of the iron filings in order to make a brilliant negative.

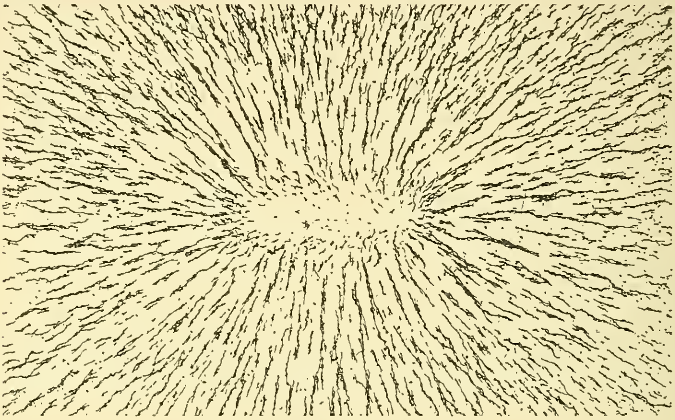


Fig. 2. End of Bar Magnet.

Fig. 6 was made on a 5 by 8 plate with a four inch horseshoe magnet.

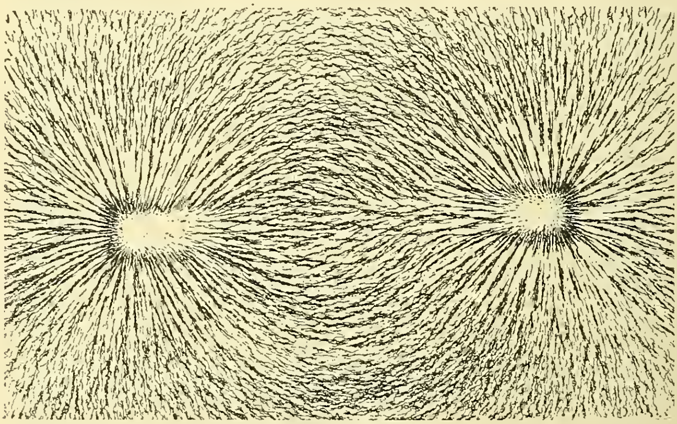


Fig. 3. Bar Magnet.

In fig. 7, six similar eight inch square bar magnets were employed, and placed with alternate poles toward the center. This is the arrangement commonly employed in the fields of an alternating dynamo; and the figure gives a very good idea of the lines of force in such field.

In the preparation of this plate, a marked distinction was noticed between the north and south poles of the magnets. This difference is fairly well shown in the cut.

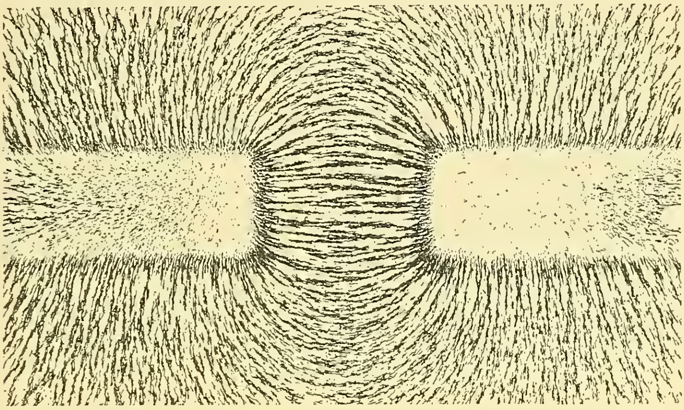


Fig. 4. Unlike Poles.

The alternate poles beginning with the pole upon the left of fig. 7 are south poles. The filings in the neighborhood of these poles are in every case more erect and exhibit greater intensity of action than those at the north poles. Whether this is due to a real difference between the north and south poles of the magnet or is to be explained as a mere coincidence, can only be determined by more careful observations than those which I have yet made.

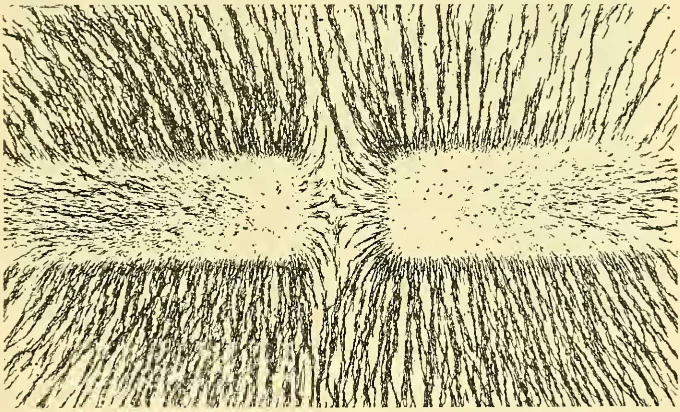


Fig. 5. Like Poles.

Figure 8 is a representation of the field of a disc magnet, made by magnetizing a small circular slotting-saw of $2\frac{1}{2}$ inches diameter and $\frac{1}{8}$th of an inch thickness. The lines of force bear a striking resemblance to some drawings of the solar corona, and may suggest the correct explanation of that but little understood phenomenon.

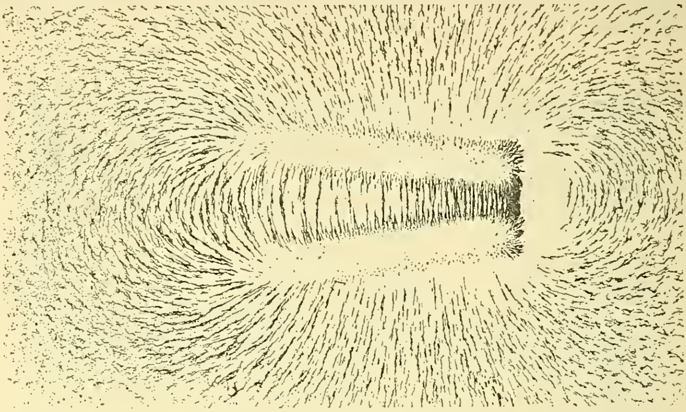


Fig. 6. Horseshoe Magnet.

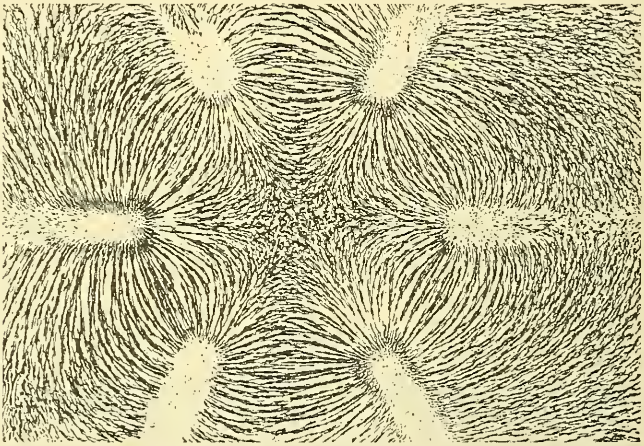


Fig. 7. Alternate Poles.

The remaining figures illustrate sections of fields of various forms of electro-magnets.

Figure 9 is a section of the field of a small motor of the closed field type, and resembles quite closely the field of the disc magnet shown in fig. 8. The leakage indicated by the lines at the right of the figure is due to the iron base upon which the fields were mounted.

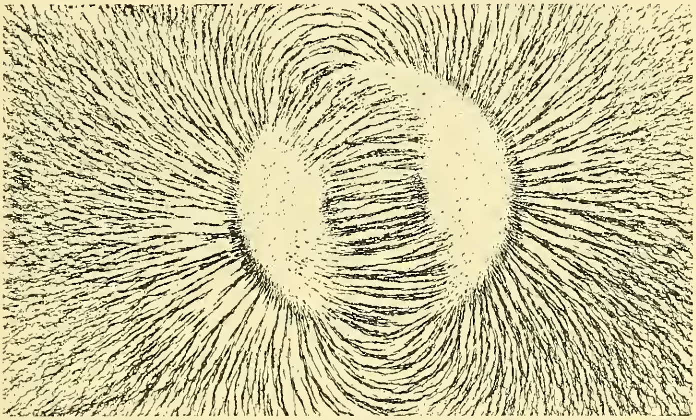


Fig. 8. Disc Magnet.

Figure 10 is the field of a small motor of the common horseshoe type.

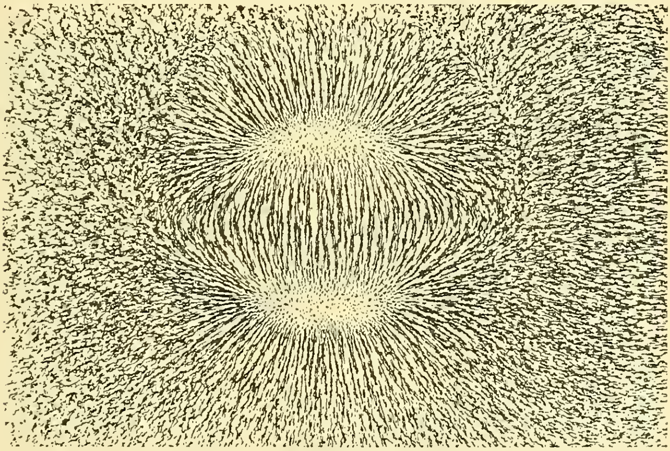


Fig. 9. Motor-Field—Closed Type.

Both figures 9 and 10 were obtained by removing the armature and one bearing so as to make it possible to place the plate within a short distance of the field, at right angles to the armature shaft.

Interesting figures might be obtained by inserting rings between the poles similar in form to the rings of which the armature is composed. These figures illustrate a large class of very instructive maps which might be made of the various types of magnetic fields now in use. A careful study of a set of such figures should afford valuable suggestions to the designer of field magnets and transformers.

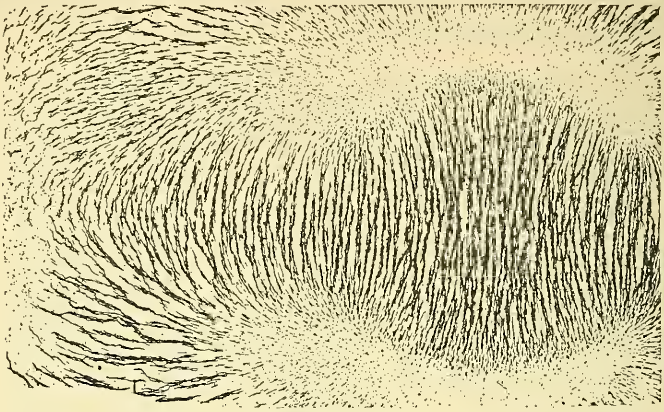


Fig. 10. Motor-Field—Horseshoe Type.

The motors used in Figures 9 and 10 are shown with the bearings removed in figure 1.

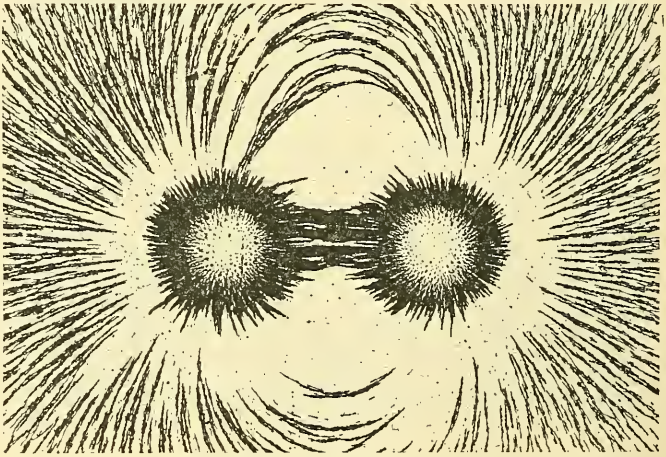


Fig. 11. Electro-Magnet.

Figures 11 and 12 represent the field above the poles of the small electro-magnet shown in figure 1.

In figure 11 the filings in the regions near the poles are drawn to the poles, leaving those regions bare.

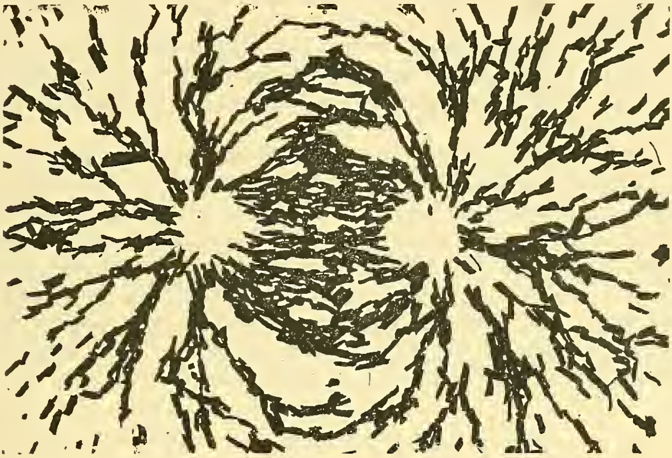


Fig. 12. Electro-Magnet—Iron Chippings.

The somewhat fantastic field shown in figure 12 was obtained from the same electro-magnet by employing coarse iron chippings, instead of the finer iron filings used in the remaining figures. The position of the bits of iron parallel to the lines of force is distinctly shown.

Note.—Since preparing the above, my attention has been called to the excellent article of Professor Houston in the Electrical Engineer for July 20th, in which a method exactly similar to the one here described was briefly outlined. This furnishes another instance of the simultaneous invention of a process by two investigators, each working wholly without knowledge of what the other is doing.

ART. XLVI.—*Contributions to Mineralogy, No. 54*; by F. A. GENTH. *With Crystallographic Notes*; by S. L. PENFIELD.

1. *Aguilarite.*

SINCE the publication of my investigations on aguilarite,* I had an opportunity to examine quite a number of specimens of this mineral. Only a *very few small fragments of pure aguilarite in skeleton dodecahedrons*, like the original, were found among them; most of them were altered, as previously

* This Journal, xli, 401.

described. There were several, however, which deserve a short notice.

a. One variety in irregular flat particles between the cleavage cracks of calcite or calcite and quartz, with a hackly fracture and iron black color had the composition of nearly pure aguilarite (*a*).

b. A second variety made up of small capillary needle- and wire-shaped individuals without any distinct planes, also minute rounded particles, all forming an irregular spongy mass of an iron gray color and metallic luster. Between this are small crystals, not over 5^mm^ in diameter, apparently hexagonal and much resembling forms of polybasite, produced by twinning. The material for the analysis (*b*) was selected with great care, but, as the results show, gave the composition of aguilarite, slightly contaminated with a sulphantimonide.

	a.	*b.*
Ag	79·41	80·27
S	5·93	6·75
Se	13·96	12·73
Cu	0·50	0·07
Fe	----	0·26
Sb	----	0·41
	99·80	100·49

c. Similar crystals, as mentioned under *b*, were found on quartz, associated with calcite, some of them were over 10^{mm} in diameter. On examination with a lens they could easily be seen to be made up of different minerals and were evidently the result of the alteration of aguilarite into stephanite, as previously described, with metallic silver, argentite, etc. The outer portion was brittle, the inner malleable—but neither could be obtained in a state of purity. They gave :

Brittle portion.					Malleable portion.				
Ag	67·58	or	Ag_2S	62·85	Ag	84·05	or	Ag	25·28
Cu	6·83		Ag_2Se	16·35	Cu	1·83		Ag_2S	55·49
Fe	0·42		CuS	9·27	Fe	----		Ag_2Se	14.28
Sb	6·83		FeS	0·56	Sb	1·24		CuS	2·75
As	----		Sb_2S_3	9·56	As	0·28		Sb_2S_3	1·74
Se	3·51		----	----	Se	3·82		As_2S_3	0·46
S	14·76		----	----	S	8·76		----	----
	99·93			98·59		99·98			100·00

These crystals had been considered to be a *new* species.

d. In the lot of aguilarite specimens was noticed a small piece of quartz and calcite with *solid* dodecahedral crystals, mostly distorted, from 1–2^mm^ in size. As there was no indication of any cavernous crystals I thought they might show a different composition.

The analysis gave:	
Ag	84·40
Cu	0·49
S	11·36
Se (by diff.)	3·75
	100·00

Calculated:		
Ag	85·06	per cent.
S	11·03	"
Se	3·91	"
	100·00	

This is the composition of argentite in which $\frac{1}{8}$ of the sulphur is replaced by selenium. The composition corresponding to: $\frac{1}{8}Ag_2Se + \frac{7}{8}Ag_2S$ is given above.

e. A specimen of *acanthite* from Guanajuato, Mexico, presented to me by Messrs. Geo. L. English & Co., was analyzed for the purpose of seeing whether it contained selenium, but was found to be entirely free from it.

Elongated, wirelike distorted crystalline particles in calcite. The analysis gave a trace of quartz and calcite and—

Ag	86·79
S	13·20
	99·99

2. *Metacinnabarite.*

To Professor Gustav Guttenberg of the Central High School at Pittsburg, I am indebted for an interesting occurrence of metacinnabarite in irregular particles of from 5 to 10^{mm} in diameter, disseminated through a ferruginous, laminated barite, from San Joaquin, Orange County, California, where it had been collected by one of his pupils.

Color iron-black, but many pieces show already a partial change into ordinary cinnabarite, both by a good lens and the reddish black powder which some of the particles yield on pulverizing. Fracture conchoidal, brittle, soft. Sp. gr. 7·706. The analysis gave:

Hg	85·89
S	13·69
Cl	0·32
	99·90

It is remarkable that all the fragments which were examined showed the presence of chlorine. The 0·32 per cent of Cl which were found would indicate an admixture of 1·23 per cent of calomel.

3. *Löllingite.*

The arsenide of iron from Halyburton's and Drum's farms which, from qualitative tests, had been mentioned in my Minerals of North Carolina,* as leucopyrite, was found to be löllingite.

A specimen from Drum's farm, Alexander County, mostly oxydized into scorodite, etc., yielded some very pure fragments of from 4 to 6^{mm} in size. They did not show any crystalline faces, apparently amorphous; fracture conchoidal. Sp. gr. 7·031. The analysis gave:

Fe	70·83
Cu	trace
As	27·93
S	0·77
	99·52

4. *Rutile.*

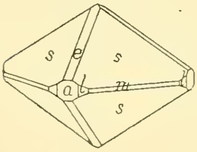
The flesh-colored orthoclase from West Cheyenne Cañon, El Paso Co., Colorado, contains minute black crystals which were identified by Professor Penfield as rutile.

From the specimens received by Messrs. Geo. L. English & Co. it appears that these crystals are rarely in contact with the orthoclase, but generally implanted in the more recent quartz, resulting from its alteration and filling its cavities.

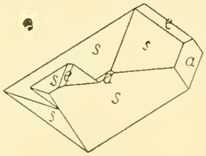
The rutile crystals are from 0·5 to 4^{mm} in size.

The forms which have been observed on them are *a*, 100, *i-i*; *m*, 110, I; *l*, 130, *i*-3; *e*, 101, 1-*i* and *s*, 111, 1. Some of the crystals are like fig. 1, a habit which is not common with rutile but reminds one rather of cassiterite. Many of the crystals have four of the pyramid faces, *s*, larger than the others and developed apparently into monoclinic prisms. Fig. 2 represents one of the distorted crystals in ordinary projection and fig. 3 is a basal projection of another, with a still more pro-

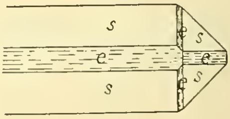
1.



2.



3.



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* The Minerals of North Carolina, by Frederick Augustus Genth, Bulletin No. 74, U. S. Geol. Survey, Washington, 1891.

nounced prismatic habit. They are iron-black. Sp. gr. 4·249. The analysis gave, after deducting 0·7 per cent of quartz:

SnO_2	1·40
TiO_2	91·96
Fe_2O_3	6·68
	100·04

5. *Quartz resulting from the alteration of the flesh-colored orthoclase of W. Cheyenne Cañon.*

The orthoclase crystals become rounded and in their decomposition leave cavities which are partially filled with grayish-white porous and cavernous coatings either directly upon the orthoclase or with some space between, filled with earthy limonite. The pure grayish or slightly greenish white material shows a cryptocrystalline structure, dull or with a faint vitreous luster. H.=8; Sp. gr.=2·552.

In appearance it somewhat resembles some varieties of the so-called damourite.

The analysis gave:

Ignition	0·95
SiO_2	96·63
Al_2O_3	0·93
Fe_2O_3	0·85
Na_2O	trace
K_2O	0·46
	99·82

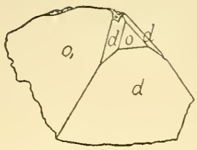
from which it is evident that it is quartz, slightly contaminated with orthoclase.

In the same orthoclase is a mineral in very fine and minute needle-shaped crystals of a greenish yellow color which could not be identified for want of material.

6. *Danalite.*

Among some specimens from W. Cheyenne Cañon, El Paso County, Colorado, which were given to me for identification by Messrs. Geo. L. English & Co. were two fragments, one of a crystal 15×17^{mm} in size, the other not showing any crystalline form. Both were discolored by iron and manganese oxides and were found to be an interesting variety of danalite.

4.



The fragment is part of a modified tetrahedron, having the forms *o*, 111, 1 ; *o*′, $1\bar{1}1$, −1 and *d*, 110, *i*, fig. 4. One of the dodecahedral faces is larger than the other two and, as it makes a right angle with the large tetrahedral faces adjacent to it, it gives the crystal the appearance of being part of a modified cube.

No cleavage has been observed ; fracture uneven, splintery to subconchoidal, color of some portions pale rose color to brownish, owing to slight oxidation. Sp. gr. = 3·626 to 3·661. Luster vitreous.

The material used for analysis was purified by digesting with very dilute hydrochloric acid and had a fine pale rose color, like a deeply colored rose quartz. The mean of two closely agreeing analyses is as follows :

				Mol. ratio.		
Ignition	0·21					
SiO_2	30·26	Si	14·12	·504		2·93
BeO	12·70	Be	4·70	·500		
CuO	0·30	Cu	0·24	·004		
ZnO	46·20	Zn	37·07	·570	1·187	6·90
FeO	6·81	Fe	5·37	·096		
MnO	1·22	Mn	0·95	·017		
S	5·49			·172		1·00
	103·19					
Less O for S	2·78					
	100·41					
O	35·04	2·78	32·26	2·016		11·72

closely agreeing with the formula :

$$(Be, Zn, Fe, Mn)_7Si_3O_{12}S$$

Associated with quartz, astrophyllite and a mineral which appears to be *new*.

7. *Yttrium-Calcium Fluoride.*

On some of the quartz associated with astrophyllite was a mineral in granular crystalline particles. Some fragments show reflections from cleavage planes. White, grayish white and reddish white. H. = 4. Sp. gr. = 4·316.

In the analysis of the best fragment which I could get, a little over one gram, the mineral was decomposed by sulphuric acid, by which the fluorine was expelled as HFl and the little silica as $SiFl_4$. The analysis gave :

		Calculated as fluorides.	Molecular ratio.		
Ignition	1·57				
$(Yt, Er)_2O_3$*	47·58	58·05	·317	·331	1
CeO_2	0·83	0·96	·005		
$(La, Di)_2O_3$	1·55	1·86	·009		
CaO	19·41	27·03	·347		1
Fe_2O_3 and other admixtures not det.		89·47			

This gives the formula $CaFl_2 . (Yt,Er,Ce,La,Di)Fl_3$.

8. *Altered Zircon or Cyrtolite.*

Messrs. Geo. L. English & Co. sent me for identification crystalline groups of about 10 to 15^{mm} in size. They consisted of bundles of crystals of columnar structure, radiating from a center with their prismatic planes mostly obliterated and terminated by rounded planes of the common pyramid of zircon.

They were stained with a greenish brown coating of the oxides of iron and uranium, and, for purification, had to be treated with dilute hydrochloric acid after which the color is a very light greenish gray. Sp. gr. = 4·258.

Associated with muscovite, flesh-colored orthoclase and quartz, at Mt. Antero, Chaffee Co., Colorado.

The analyses gave :

	a.	*b.*
Ignition	2·42	2·47
SiO_2	30·38	30·66
ZrO_2	61·38	60·89 (by diff.)
Yt_2O_3	0·60	0·65
Fe_2O_3	0·70	0·63
UO_2	4·82	4·70
MnO, MgO, CaO	traces	traces
	100·30	100·00

9. *Lepidolite.*

A very beautiful variety of lepidolite, associated with albite and quartz, from Tanagama Yama, Japan, has been received from Messrs. Geo. L. English & Co. It occurs in crystal-

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* The molecular weight of Yt and Er was found to be 126. The oxides were yellow and the sulphates and oxalates slightly rose-colored. Although these results are somewhat unsatisfactory, on account of the contaminated condition and small amount of the material at my command, I thought them of sufficient interest, to place them on record, as great pains were taken to arrive at the most perfect separation of the constituents. Should it be my good fortune to get larger quantities of this mineral, I intend to repeat this investigation.

line plates from 30 to 80^{mm} in size. Professor Penfield says: The form of the plates was not determined. The clear portions show a biaxial interference figure with wide divergence of the optical axes, about like muscovite.

Color grayish white, slightly pinkish, luster vitreous to pearly. Sp. gr. = 2·883. B.B. it fuses readily to a brown glass, coloring the flame intensely a deep red. The analysis, being the mean of two or three determinations, gave:

SiO_2	53·34
Al_2O_3	17·76
Fe_2O_3	3·25
MnO	2·77
MgO	0·05
CaO	0·37
Li_2O	4·60
Na_2O	1·55
K_2O	10·90
H_2O	0·65
Fl	7·78
	103·02
Less O for Fl	3·28
	99·74

The lepidolite plates were all more or less coated with minute brownish white scales, which appeared to be a product of the alteration of lepidolite. With great difficulty I picked out 0·2563 grm. of pretty pure material which gave:

SiO_2	52·91
Al_2O_3	21·15
Fe_2O_3	3·59
MnO	0·94
Li_2O	2·19
Ignition	5·97
Fl, K_2O, Na_2O, etc.	not det.

Therefore not cookeite, but lepidolite altered by hydration.

10. *Fuchsite.*

In a peculiar mica schist, consisting of a gray muscovite with quartz in Habersham County, Ga., occurs associated with chromite and interlaminated with gray muscovite a deep emerald green mica in scales, sometimes from 10–12^{mm} in diameter. Professor Penfield writes me about it as follows: "The fuchsite does not show crystalline outline and the scales are small for optical examination. I observed the following. The sections show a biaxial interference figure, the divergence of the optical axes being large, about like muscovite. The cleavage plate shows a decided pleochroism, for rays vibrating parallel to 𝔠 bright chrome green, and parallel to 𝔟 yellowish green.

Sp. gr. = 2·983.

The analysis gave:

Ignition	6·04
SiO_2	46·73
Al_2O_3	29·00
Cr_2O_3	2·73
Fe_2O_3	2·59
MgO	3·03
CuO	0·14
Na_2O	0·26
K_2O	9·25
	99·77

Chemical Laboratory, 111 S. 10th St.
Philadelphia, August 29th, 1892.

ART. XLVII.—*The Effects of Self-induction and Distributed Static Capacity in a Conductor;* by FREDERICK BEDELL, Ph.D., and ALBERT C. CREHORE, Ph.D.

THE solution obtained by Sir Wm. Thomson for the variation of the current and the potential at different points in a conductor possessing static capacity is given by Mascart and Joubert, L'Électricité et Le Magnétisme, vol. i, § 233, and is treated at length by Mr. T. H. Blakesley in his book on Alternating Currents. The object of the present communication is to give the solution for the case of a conductor possessing self-induction as well as distributed capacity, and to note the effects produced by the introduction of the self-induction.

The rate of change of the charge on an element of the cable is equal to the difference of the currents flowing into and out from it; and so, writing q for charge and i for current at any time, and x for the distance of any point from the origin—positive direction being that of current flow—we have

$$\frac{dq}{dt} = -\frac{di}{dx}dx.$$

If e is the potential of an element, its charge is $q = \mathrm{C}e\,dx$, where C denotes the capacity per unit length of the cable, and the first equation may be written

$$\text{(1)} \qquad \mathrm{C}\frac{de}{dt} = -\frac{di}{dx}.$$

By Ohm's law the current in an element is equal to the total E. M. F. (the sum of the impressed and that of self-induction) divided by the resistance; and, if R is the resistance per unit length and we assume the back E. M. F. of self-induction per unit length to be equal to the rate of change of the current multiplied by a constant L, we may write

$$\text{(2)} \qquad i = -\frac{\left(\frac{de}{dx}\,dx - \mathrm{L}\frac{di}{dt}\,dx\right)}{\mathrm{R}\,dx}.$$

In some cases this assumption may approximately represent the true effect of self-induction, and the results obtained from this particular assumption may show the nature of the effect of self-induction even in cases where the assumption is not justifiable.

The differential equation for potential is obtained by eliminating i from (1) and (2) and is

$$\frac{d^2e}{dx^2} + \mathrm{LC}\frac{d^2e}{dt^2} - \mathrm{RC}\frac{de}{dt} = 0.$$

The current equation, obtained in the same way, is similar when i is written instead of e.

The general solution of these equations is

$$e = \sum_{h,k} hk\varepsilon.^{\frac{\mathrm{R}}{\mathrm{C}k^2+\mathrm{L}}(t-\mathrm{C}kx)}$$

$$i = \sum_{h,k} h\varepsilon.^{\frac{\mathrm{R}}{\mathrm{C}k^2+\mathrm{L}}(t-\mathrm{C}kx)}$$

where ε is the Naperian base, and h and k are constants to be determined.

If the impressed E. M. F. is harmonic, and at the origin $e = \mathrm{E}\sin\omega t$, where ω denotes angular velocity, the solution for the potential at any point of the conductor at any time becomes

$$\text{(3)} \qquad e = \mathrm{E}\varepsilon^{\pm px}\sin(\omega t \pm \alpha x).$$

The solution for the current at any time across any section of the conductor is

$$\text{(4)} \qquad i = \frac{-\mathrm{E}\sqrt{\mathrm{C}\omega}}{\sqrt{\mathrm{Im.}}}\varepsilon^{\pm px}\sin\left(\omega t \pm \alpha x + \tan^{-1}\frac{p}{\alpha}\right).$$

In these equations Im. denotes the impedance, $(\mathrm{R}^2+\mathrm{L}^2\omega^2)^{1/2}$;

$$p=\sqrt{\frac{\mathrm{C}\omega}{2}}\sqrt{\mathrm{Im.}-\mathrm{L}\omega}\text{ ; and }\alpha=\sqrt{\frac{\mathrm{C}\omega}{2}}\sqrt{\mathrm{Im.}+\mathrm{L}\omega}.$$

The solutions in equations (3) and (4) show that the potential and current are propagated in harmonic waves whose amplitudes decrease with the distance from the origin according to a logarithmic decrement. At any point of the conductor the potential and current vary as simple harmonic functions of the time with constant amplitudes which are different for every point of the conductor. The current wave is propagated in advance of the potential wave by an angle θ such that $\tan\theta=\frac{p}{\alpha}$. This phase difference diminishes with increase of frequency when there is self-induction, but becomes a constant angle of 45° when L=0. The wave length is $\frac{2\pi}{\alpha}$ and the rate of propagation is $\frac{\omega}{\alpha}$. The wave length and rate of propagation each become less as the self-induction increases. The wave of higher frequency will have the shorter length and be propagated the faster. This difference in rate of propagation of waves of different frequencies is most marked when there is no self-induction.

The distance at which the amplitude decreases to $\frac{1}{\varepsilon}$th of its value is $\frac{1}{p}=\frac{\lambda}{2\pi\tan\theta}$; the time for the decrease is $\frac{1}{\omega\tan\theta}$. The rate of decay is most rapid when there is no self-induction. The waves of higher frequency decay more rapidly than those of lower frequency; when there is no self-induction this difference in the rate of decay is the greatest.

The difference in the rates of propagation and decay of waves of high and low frequency doubtless constitutes the limitations to the use of the telephone. As the several harmonic components of a complex tone advance along the conductor, they keep shifting their relative phases according to the difference in their rates of propagation, and also change their relative intensities according to the difference in their rates of decay, thus changing the resultant combination tone and materially altering its quality. These effects are always present in circuits containing distributed static capacity but are not so marked when there is also self-induction.

Physical Laboratory of Cornell University, July, 1892.

ART. XLVIII.—*The Quantitative Determination of Rubidium by the Spectroscope;* by F. A. GOOCH and J. I. PHINNEY.

[Contributions from the Kent Chemical Laboratory of Yale College—XVIII.]

IN a recent paper issued from this laboratory* the possibility of determining small amounts of potassium quantitatively by means of the flame spectrum was demonstrated. The work which we are about to describe was performed in the endeavor to see how far similar methods might be applicable to the quantitative determination of rubidium. It was shown in the former work that hollow coils of platinum wire may be adjusted to hold definite amounts of liquid and that, by taking care to plunge the coil while hot into the liquid and to remove it from the liquid with its axis inclined obliquely to the surface, it is possible to take up constant amounts through a long series of experiments. It thus becomes possible to bring definite amounts of any soluble substance into a flame to be viewed spectroscopically. The potassium salt best adapted to spectroscopic use proved to be the chloride, and it was found to be advantageous to dry the coils over a hot radiator before introducing them into the flame. A large Muencke burner gave the best sort of flame, an ordinary single prism spectroscope provided with an adjustable slit (the width of which we were able to fix by closing it upon wires of known diameter) and an observing telescope moveable so that different portions of the spectrum might be shut out at will, served sufficiently well for the work. The coils were made of No. 28 platinum wire ($0{\cdot}32^{mm}$ in diameter) wound in about thirty turns to a spiral 1^{cm} long by 2^{mm} in diameter and twisted together at the ends to form a long handle. With the apparatus described it was found possible, under the most favorable conditions, to recognize the characteristic red line of the potassium spectrum when only $\frac{1}{1000}$ mg. of potassium, in the form of the chloride, was brought to the flame. It appeared, furthermore, that a comparison of the brightness of two spectra produced in close succession could be made with all the accuracy to be anticipated in photometric measurements, and that therefore by gradual dilutions and successive testings a solution of potassium chloride of unknown strength could be brought to the point of containing as much potassium to the coil-full (and so, of course, to the cubic centimeter or any other chosen volume) as a standard solution of known strength. By noting the final

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* Gooch and Hart; this Journal, xlii, p. 448.

volume to which such an unknown solution was brought in the process of equalizing its spectrum with that of the standard its total contents in potassium was determined. In this manner the strength of solutions of pure potassium chloride proved determinable with accuracy, but when the effect of intermixing pure sodium chloride with the potassium salt was studied it transpired that the brilliance of the potassium spectrum was markedly increased by the presence of the sodium in the flame, the maximum increase, which amounted to twenty per cent, appearing when the ratio of sodium chloride to potassium reached 100 : 1. It was found, however, that the practical difficulty of determining potassium in presence of sodium could be largely overcome by taking the precaution to bring the test solution and the standard to apparent equality as regards the potassium line, then to bring the solutions to an equality in respect to the sodium line by addition of sodium chloride to the standard, and finally to readjust the volumes of test and standard until the potassium lines were again equal. The accuracy of the determination of the potassium is, however, in spite of the precaution, somewhat affected by the presence of sodium,—the error, though, sometimes falling as low as $\frac{1}{10}$ mg. in 10 mg., rising occasionally to 1 mg. in 15 mg. With the excellent gravimetric method which we possess for the determination of potassium recourse would, naturally, never be taken to the spectroscopic method except in cases when the determination of small absolute amounts are concerned, but in such cases the spectroscopic method may prove a convenience.

In the work upon potassium the observations of the red line were made in the ordinary laboratory in diffused light, but preliminary experimentation upon the rubidium spectrum immediately developed the fact that the blue lines are better to work by in the case of this element, and that a dark room becomes a necessity. For the experiments to be described pure rubidium chloride was prepared by many fractional precipitations by alcohol out of aqueous solutions, and in settling the question as to the coils which should be used the choice fell upon the size holding 0·02 grm. of water and made of the No. 28 wire, the superior stiffness of these and consequent constancy in capacity giving them the advantage over smaller coils of finer wire, though the latter are capable of bringing out greater sensitiveness of the reaction. We found, for example, that under the most favorable conditions as to height of flame and width of slit, 0·0002 mg. of rubidium chloride produced the blue lines at the last limit of visibility when the larger and heavier coil was in the flame; with a coil holding 0·006 grm. of water and made of very fine wire the more immediate volatilization of the chloride so increased the delicacy of the spectroscopic reaction that it was possible to see the lines from 0·00005 mg. of the salt. These figures serve as an indication of the possible delicacy of this method of producing spectra, but it should be remembered that all eyes do not see the rubidium lines with equal ease.

In experimenting with rubidium sulphate in place of the chloride the lighter coil appeared to lose its advantage in point of delicacy of the indication over the larger coil, possibly because the amount of metal introduced into the flame has less influence upon the rate of vaporization of the less volatile sulphate, and the lines of the sulphate appeared equally distinct and of longer duration than those of the chloride; but, while we judged the sulphate to be rather preferable in qualitative work, our earlier preliminary quantitative experiments led us to abandon it for the purposes of our investigation on account of the great uniformity in the lines yielded by the chloride. We found it desirable in comparative tests of brightness to employ as the standard the lines given by amounts of the chloride not exceeding 0·0005 mg. to 0·0007 mg., to set the slit at a width of 0·2^{mm}, and to bring the coils to the flame in sets of three—the first, usually a standard, serving to fix the position of the lines so that the comparative distinctness of the lines given by the other two might be the more readily determined. The tables below contain the record of an attempt to dilute a solution of the pure chloride to the strength of the standard solution under the guidance of comparative tests of the brilliance of the spectral lines yielded by the residue left upon the wires after the evaporation of the solutions taken up by coils of equivalent capacity. Dilutions were made in ordinary graduated cylinders of suitable capacity.

EXPERIMENT I.

Standard. Rubidium in a coil-full ($\frac{1}{50}$ cm^3).	Test (known to contain 10 mg Rb.). Volume in cm^3.	Line of test compared with standard.
0·0005 mg.	200	Brighter.
" "	300	Brighter.
" "	350	Brighter.
" "	370	Brighter.
" "	390	Brighter.
" "	400	Brighter (faintly).
" "	400	Brighter (faintly).
" "	400	Doubtful.
" "	410	Brighter (faintly).
" "	410	Weaker.
" "	420	Equally bright.
" "	420	Weaker.
" "	430	Invisible.

When the volume of the test-solution reaches 400 cm^3 the indications are, on the whole, that the solution is still stronger than an equal volume of the standard; and when the volume amounts to 420 cm^3 it is safe to conclude from the indications that the test-solution is the weaker. If the mean of the numbers representing these two volumes be taken as probably indicative of the volume at which the test and standard lines are at an equality we have the estimated amount of rubidium in the test-solution given by multiplying the volume in cubic centimeters by the number of coil-fulls in 1 cm^3 and the product by the amount of rubidium contained in a coil full of the standard solution—$410 \times 50 \times 0{\cdot}0005 = 10{\cdot}25$ mg. The amount of rubidium actually taken in the test-solution was 10 mg., and the error of the mean value assumed is 2·5 per cent+, between extremes corresponding to an error of 0 and 5 per cent +, respectively.

Experiment II.

Standard. Rubidium in a coil-full ($\frac{1}{50}$ cm^3.)	Test (known to contain 10 mg. Rb.). Volume in cm^3.	Line of test compared with standard.
0·0005 mg.	340	Brighter.
" "	370	Equally bright.
" "	370	Brighter.
" "	390	Weaker.
" "	390	Weaker.

$$\text{Found } \frac{370+390}{2} \times 50 \times 0{\cdot}0005 = 9{\cdot}5 \text{ mg.}$$

Taken .... 10·0 "
Error .... 0·5 " = 5 per cent.

Experiment III.

Standard. Rubidium in a coil-full ($\frac{1}{50}$ cm^3).	Test (known to contain 10 mg. Rb.). Volume in cm^3.	Line of test compared with standard.
0·0005 mg.	300	Brighter.
" "	360	Equally bright.
" "	380	Brighter.
" "	380	Brighter.
" "	390	Brighter.
" "	400	Weaker.
" "	410	Weaker.

$$\text{Found } \frac{390+400}{2} \times 50 \times 0{\cdot}0005 = 9{\cdot}875$$

Taken .... 10·
Error .... 0·125 = 1·25 per cent.

These results make it plain that when the comparison is made between solutions of pure rubidium chloride the spectroscopic method is capable of yielding fair approximations to truth. In the practical determination of rubidium, however, the question of the effect of the presence of sodium and potassium which naturally accompany it is of importance. Attention was therefore turned next to the consideration of this point, and the record of observations as to the influence of sodium upon the brightness of the rubidium spectrum is contained in the accompanying tabular statement.

Standard. Rubidium in a coil-full ($\frac{1}{50}$ cm^3).	Test solution. Sodium in a coil-full.	Comparison of lines of test by pairs.	Comparison of lines of test with standard.
0·00066 mg.	0·00026 mg.	Slightly brighter.	Brighter.
	0·00260 "	Slightly fainter.	
" "	0·00130 "	Equally bright.	Brighter.
	0·00260 "		
" "	0·00260 "	Equally bright.	Brighter.
	0·00520 "		
" "	0·00260 "	Brighter.	Brighter.
	0·00660 "	Fainter.	
" "	0·00260 "	Brighter.	Brighter.
	0·00780 "	Fainter.	
" "	0·00260 "	Brighter.	Brighter.
	0·01500 "	Invisible on account of glare.	Invisible.

It appears that within limits the presence of sodium in the flame increases the brilliance of the rubidium spectrum. The brightness of the lines is raised under the conditions to a maximum by the presence of sodium to forty per cent of the weight of the rubidium, and increase in the amount of sodium does not further influence the brightness of the lines until the proportion of sodium to rubidium is as ten to one; or, speaking broadly, the difference between the dissociating effect of sodium upon the rubidium chloride (to which we attribute the effect noted) does not appear to be materially different whether one or a score of molecules of sodium chloride are present to one of the rubidium chloride. But when the proportion of sodium to rubidium much exceeds ten to one the glare of light diffused through the entire spectrum (though the sodium line itself may be cut off) begins to affect the vision, and as the increase advances ultimately extinguishes the rubidium lines utterly. The degree of increase in brilliance when the lines are at a maximum was determined by diluting the test-solution until a coil-full gave a line equally brilliant with that of the standard.

Standard. Rubidium in a coil-full ($\frac{1}{50}$ cm^3).	Test solution. Rubidium in a coil-full with $\frac{8}{10}$ of its weight of sodium.	Line of test compared with standard.
0·00066 mg.	0·00066 mg.	Brighter.
" "	0·00048 "	Brighter.
" "	0·00046 "	Brighter.
" "	0·00044 "	Equally bright.

It is plain that at the maximum degree of brilliance the sodium is responsible for an increase of fifty per cent in the brightness of the lines.

The details of similar experiments in which potassium chloride was introduced into the flame with the pure rubidium chloride are given in the accompanying tabular statement.

Standard. Rubidium in a coil-full ($\frac{1}{50}$ cm^3).	Test solution. Potassium in a coil-full.	Comparison of lines of test taken by pairs.	Comparison of lines of test with standard.
0·00066 mg.	0·00020 mg.	Slightly fainter.	Brighter.
	0·00040 "	Slightly brighter.	
" "	0·00020 "	Fainter.	Brighter.
	0·00340 "	Brighter.	
" "	0·00040 "	Equally bright.	Brighter.
	0·00066 "		
" "	0·00040 "	Brighter.	Brighter.
	0·00340 "	Fainter.	
0·00066 mg.	0·00066 "	Equally bright.	Brighter.
	0·00132 "		
" "	0·00066 "	Brighter.	Brighter.
	0·00346 "	Fainter.	
" "	0·00066 "	Brighter.	Brighter.
	0·00660 "	Fainter.	
" "	0·00066 "	Brighter.	Brighter.
	0·01320 "	Fainter.	
" "	0·00066 "	Brighter.	Brighter.
	0·02000 "	Fainter.	Equally bright.
" "	0·00066 "	Brighter.	Brighter.
	0·02660 "	Fainter.	Equally bright.
" "	0·00066 "	Brighter.	Brighter.
	0·03340 "	Fainter.	Equally bright.
" "	0·00066 "	Brighter.	Brighter.
	0·03340 "	Invisible.	Invisible.

From these results it appears that the presence of potassium produces an effect upon the rubidium lines similar to that of sodium; and, furthermore, the addition of 0·0004 mg. of potassium in the form of chloride to 0·00066 mg. of rubidium also in the form of chloride brings out the maximum brightness which is not materially changed by further addition of potassium up to about 0·0013 mg., but that the increase of the potassium to 0·0034 mg. results in diminution of brightness. In other words, it seems that a single molecule of potassium chloride has approximately the same dissociating effect upon the molecule of rubidium chloride in the flame as that brought about by a greater number, that the presence of potassium in the proportion of five parts to one of the rubidium begins to influence visibility unfavorably, that when this proportion rises to thirty to one of the elements (or twenty to one of the chlorides) the lines appear about as distinctly as if no potassium were present, and that an increase of proportion to fifty to one may bring about a sufficient glare of light to reduce the rubidium lines to invisibility. The degree of increase in brilliance due to the action of potassium when that element is present in proportions suitable to induce the maximum effect is shown in the following record.

Standard. Rubidium in a coil-full ($\frac{1}{50}$ cm^3).	Test solution. Rubidium in a coil-full with its own weight of potassium.	Line of test compared with standard.
0·00066 mg.	0·00066 mg.	Brighter.
" "	0·00064 "	Brighter.
" "	0·00057 "	Brighter.
" "	0·00049 "	Brighter.
" "	0·00044 "	Equally bright.
" "	0·00040 "	Fainter.

It appears that the presence of 0·00044 mg. of potassium is capable of increasing the brilliance of the lines yielded by 0·00044 mg. of rubidium to an equality with the lines given by 0·00066 mg. of the pure salt; or, that the maximum increase of brightness amounts to fifty per cent.

It is evident, therefore, that means must be found to effect the separation of the rubidium from sodium and potassium, or of bringing test and standard to the same condition as regards the presence of these elements, before any reasonable degree of accuracy can be expected in the spectroscopic determination of rubidium as it ordinarily occurs in nature. The separation from sodium is easily accomplished by the conversion of the salts to the form of chloroplatinates; but for the quantitative separation of rubidium from potassium there is no good method known. The question as to the practical value of the spectroscopic reaction of rubidium for purposes of approximative quantitative analysis resolves itself into the problem as to whether by matching potassium lines as well as the rubidium lines (following the method outlined in the determination of potassium in presence of sodium), and so bringing the lines of test and standard equally under the influence of potassium, it is possible to make the comparison between the rubidium lines trustworthy. It was shown in the former paper that in matching solutions of potassium by means of the red line there is no difficulty; but the convenience of being able to use the spectroscope without readjustment throughout the entire experiment made it desirable to see whether the blue line of potassium might not serve sufficiently well in the comparison. It is hardly necessary to reproduce here in detail the evidence bearing upon this point, but we found as the result that the potassium may be determined by the use of the blue line with an error amounting to 10 per cent or 20 per cent, which, though far greater than that inherent in the use of the red line, admits of the attainment of determinations which should be accurate enough for the present purpose. We proceeded, therefore, to make a determination of rubidium in presence of potassium by the process referred to, the details of which are given in Experiment IV.

EXPERIMENT IV.

Standard solution containing $\left\{\begin{array}{ll} 0{\cdot}0005 \text{ mg.} & \text{Rubidium} \\ 0{\cdot}0015 \text{ “} & \text{Potassium} \end{array}\right\}$ to the coil-full.

Test solution contained 8 mg. rubidium and no potassium.

Step 1.	Step 2.	Step 3.	Step 4.	Step 5.
Preliminary test for Rb.	Preliminary matching of K line.	Rematching of Rb line.	Readjustment of K line.	Final matching of Rb line.
Test at 20 cm^3 gave Rb line like standard.	Test at 20 cm^3 gave K line like standard when 1 mg. of K had been added.	Test at 35 cm^3 gave Rb lines like standard.	Test at 35 cm^3 gave K line like standard when 2 mg. were present.	Test at 35 cm^3 gave Rb line like standard.

Rubidium found $35 \times 50 \times 0{\cdot}0005 = 0{\cdot}875$ mg.
“ taken .... = 0·8 “
Error .... = 0·075 “ = 9·4 per cent.

It is evident that the percentage error is considerable, but inasmuch as the application of the process would naturally be to the determination of small absolute amounts of rubidium we thought it desirable to go a step further to see whether means are at hand for separating large amounts of potassium from small amounts of rubidium with an approach sufficiently near to completeness to bring the potassium present within the limits allowed by the spectroscopic method. After some experimentation we fixed upon the simplest possible procedure, viz: the solution of the salts in the least possible amount of water, precipitation of the mass of potassium chloride by addition of alcohol, filtration, and the evaporation of the filtrate.

In Experiments V, VI, VII, this mode of working was put to the proof. The amounts of rubidium indicated were dissolved in the form of the chloride in water, 0·1 grm. of potassium chloride was added, and the solution was evaporated and treated as described.

	Rubidium taken in the form of chloride.	Potassium taken in the form of chloride.	Rubidium found.	Absolute error.	Percentage error.
V.	1 mg.	0·1 grm.	0·8 mg.	0·2 mg.	20 per cent.
VI.	2 "	0·1 "	1·7 "	0·3 "	15 per cent.
VII.	1 "	0·1 "	0·9 "	0·1 "	10 per cent.

The error of the process is manifestly large, and only roughly approximate results can be hoped for when large amounts of rubidium are dealt with; but, if the question is the estimation of only a few milligrams of rubidium, it will appear, we think, in view of the fact that the only alternative is an indirect process, that even this great error is not absolutely prohibitive of what may be called fair determinations.

XLIX.—*Notes on the Farmington, Washington County, Kansas, Meteorite;* by H. L. Preston.

Professor Henry A. Ward has just cut several slices from his 136¼-pound Farmington meteorite, which have unveiled some interesting facts.

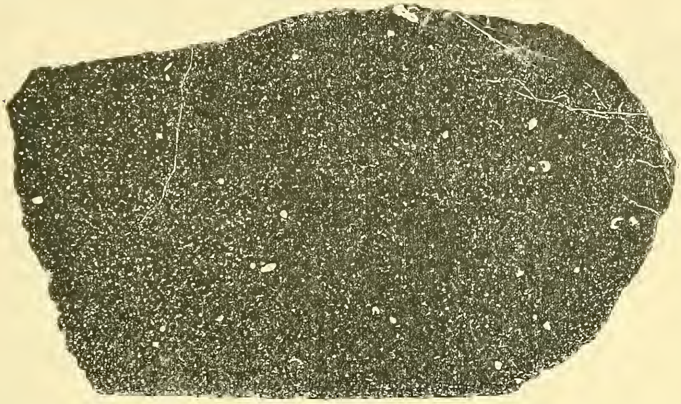
In appearance the slices resemble a section of a dark gray conglomerate (in color much like some trap rocks) with numerous small patches or grains of iron scattered through it, the largest of which is 11x6^{mm} in its greatest diameters.

In the corner of three of these slices there are several veins or fissures extending from 10 to 75^{mm} from the edge of the slice toward the center; and some of these fissures or fractures are filled with iron for 65^{mm} in length from the edge of the slice inward, while in width they are but one millimeter or less.

On the opposite end of the slice there is a very narrow vein, about 90^{mm} long, which for the greater part of the way is filled with iron. Beyond the larger grain or nodule spoken of and these veins, the balance of the iron is scattered rather evenly throughout the mass in comparatively small grains.

For the origin of these fissures and their partial filling up with iron, as seen in the accompanying cut, I would suggest the following explanation:

That, as the meteor struck our atmosphere, the concussion was so great that the mass was fractured in various places, of course extending from the surface inward, and the larger of these fissures or fractures were then filled by the metallic iron which was fused on the exterior surface of the mass, due to its velocity through the atmosphere, and was thus forced in a molten state into its present position, thus forming the metallic veins.



Diagrammatic sketch of slice of Farmington meteorite, showing metallic veins. (¼ natural size.)

I have attempted to obtain the Widmanstätten figures on the largest nodule of iron in the mass, but thus far have been unsuccessful.

ART. L.—*A Note on the Cretaceous of Northwestern Montana*; by HERBERT WOOD.

THE geographical position of the Flathead Coal Basin is indicated by the accompanying map, it being a continuation southward of the Flathead Valley, south of the North Kootanie Pass, the Elk River and Crows' Nest Basins* in Southern British Columbia or more particularly Alberta Province. It is the inter-mountain Cretaceous which forms the connecting link between the Cretaceous of British Columbia and Tobacco Plains to the northwest and the Sand Coulee, Bozeman and Rocky Fork Cretaceous† east of the main range or Rockies

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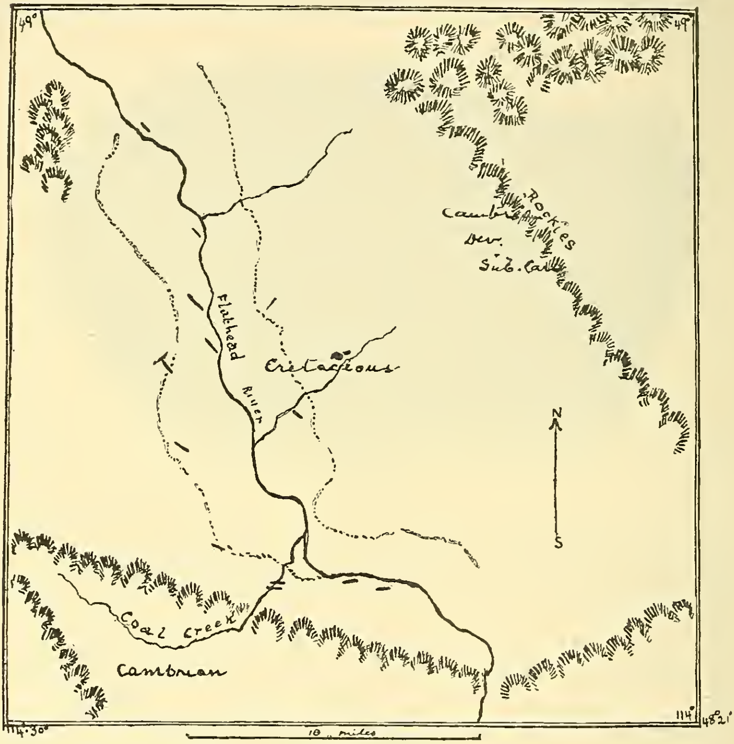
* Dawson, G. M.: Report (map) 1886, Can. Geol. Sur.
† W. H. Weed: Engineering and Mining Journal, May, June, '92.

proper in Montana. Exposures of this inter-mountain series are found as far south as the 48th parallel along the banks of the south fork of the Flathead River, also in the vicinity of Marias Pass through the Rockies. Still farther south, a hundred miles or more from the 49th parallel, a younger series of

1.



.... represent the limit of Gravel Deposits.
— represent the Coal Exposures examined.

the Cretaceous has been observed in the vicinity of Missoula extending 18 miles east and west and dipping into the mountains at 30° northwest. It consists of clays, shales and sandstones, with small seams of impure lignite, and capped with a heavy conglomerate, the series resting unconformably on the greatly denuded upturned beds of the Cambrian or Pre-Cambrian rocks which dip south 25°. The valley is a plateau valley from fifteen to twenty-five miles in width and thirty to forty in length, with heavy beds of bowlder and gravel detritus, the grooved and polished rocks (gray quartzites of the Cambrian), on the flanks of the southern range showing the glacial path as 40° north of west. These gravel deposits, consisting largely of greenish and greenish-black amygdaloidal traps, have a thickness of one hundred to one hundred and fifty feet on the upturned edges of the Cretaceous rocks, their lower portions being formed into beds of calcareously cemented sandstones and conglomerates. The origin of the amygdaloidal trap bowlders is no doubt in the intercalated eruptive rocks of the Cambrian and Cretaceous at the north and south Kootanie passes.* All the valleys of this portion of Montana have a southerly or southeasterly direction exhibiting evidences of glaciation as bowlder clays, lakes behind terminal moraines, and rounded hummocky remnants of ranges, in some cases extending for 150 miles from the boundary or those higher altitudes which existed during or at the close of a supposed epirogenic movement.† The range flanking the valley on the south has a course a little northwest with numerous transverse valleys, and corresponds with the lower Cambrian Quartzitic series or Bow River series, as noted by McConnell.‡ It dips east-northeast under the upturned coal-bearing Cretaceous rocks. The Cambrian here consists of heavily bedded red quartzites changing to sandstones alternating with thinly bedded dark red argillaceous shales, and lower in the series with greenish quartzites of ribbanded character, the upper portion of the series immediately underlying the Cretaceous consisting of greenish gray quartzose slates. The total thickness of this lower Cambrian, i. e., all that below the dolomitic limestone and shales, as given by Dawson§ is 11,000 feet; by McConnell‖ and Walcott¶ 10,000 feet—the latter of whom has recorded his results from the Gallatin section, eastern Montana. A rough traverse made here along Coal Creek gave me 2½ miles of upturned Cambrian rocks. The total thickness of the series as given by Dawson is 29,000 feet.

A search was made for fossils but none were obtained, nor does it appear that any were found in this series in southern British Columbia. The dip of the red quartzites is 25° E.N.E., while the dip of the gray quartzose slates immediately under the Cretaceous is 35° to 40° E.N.E., with a strike 20° north of west. Evidences of shore lines were observed in the shape of ripple marks, but no conglomerates or intercalated contemporaneous trappean rocks. The direction of this range is nearly

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* G. M. Dawson: Report 1886, pp. 46, 47, 57.

† Upham: Class. of Mount. Ranges.

‡ McConnell: Rep. 1887, C. G. S., p. 29.

§ Dawson: Rep. 1886, C. G. S., p. 51.

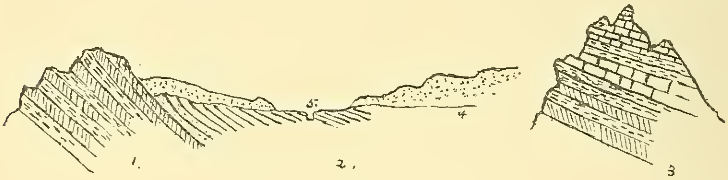
‖ McConnell: Rep. 1887, C. G. S., p. 29.

¶ Walcott: Correlation papers Camb. G. Survey. U. S.

east and west while the range west of the Flathead at the boundary has a northwesterly trend, the rocks as noted by Dawson, "greenish close-grained quartzites[*] and red sandstones" being altogether likely the same geological horizon as those farther south.[†] He notes, however, farther west "a hard greenish amygdaloidal diorite." If such intercalations are present south of here they escaped my notice.

The Cretaceous beds rest with their upturned edges against the greenish gray quartzose slates of the Cambrian. It constitutes a series of clays, clay shales, coarse and fine-grained sandstones of about 7,500 feet in thickness[‡] corresponding with that of the North Kootanie series. At the base of the Cambrian range the dip of the Cretaceous is 50° E N.E. and 1¾ miles north across the strike the dip is 8° and 10° E.N.E., this section at Coal Creek showing the greatly denuded southern margin of a synclinal fold. The basal portion of 1,000 feet of the series is coal-productive, exhibiting 15 or 20 seams of lignite. The upper portion of the series consists of heavily bedded sandstones with shaley partings with some small seams of impure lignite. A phenomenal local thickening[§] of the coal seams was observed two miles south-

2.



Section at Coal Creek.

1. Cambrian.
2. Cretaceous.
3. Camb. Dev. Sub-Carb. (Rockies).
4. Gravel Deposits.
5. Flathead River.

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[*] Dawson: Rep. 1886, p. 55.

[†] One hundred miles directly south of this in the vicinity of Missoula, a few fossils were obtained in the siliceous limestone (dolomite) identified by Mr. Chas. Schuchert as Obolella. One or two fossils were found in the red semi-argillaceous slates also but are not yet identified.

[‡] This is the result of a tape line measurement and foot traverse made at Coal Creek.

[§] Coal	6 inches.	Coal	22 inches.
Clay shale	16 "	Free Sandstone	77 "
Coal	33 "	Coal	3 "
Clay shale	6 "	Clay shale	58 "
Coal	45 "	Coal	40 "
Sandy clay	96 "	Clay	38 "
Coal	2 "	Coal	13½ feet.
Clay	3 "	Clay	21 inches.
Coal	7 "	Coal	48 "
Clay	3 "		

Three additional seams of coal outside the tunnel aggregated 12 feet.

east of Coal Creek canyon at the Emerson Tunnel, thirteen seams being exposed in 150 feet. One seam measured 13½ feet and the combined thickness of the different coal seams equalled 42 feet.

No fossils* were observed in the series nor intercalated traps, ash beds or agglomerates, as noted by Dawson.†

Ten miles northwest of Coal Creek and four miles north of the Cambrian range, a heavy conglomerate of red and green quartzite pebbles (presumably of Cambrian origin) was found. These heavy conglomerates are described by Dawson as occurring at Crow's Nest, Kootanie Passes, and other places—the volcanic horizon occurring apparently above this. My detour did not extend to the boundary, but eight or ten miles south of it. It is not improbable that the upper portions of the series might be found near the line. My observations extended over fourteen miles along the strike of the rocks, and I found that the margin of the fold swings from 12° S. of west at the Emerson Tunnel, through all intermediate variations to 25° north of west, this latter observation being taken 14 miles northwest of the first. This last strike was taken four miles north of the Cambrian, and suggested the assumption of some intervening formations between this and the Cambrian, possibly Devonian.‡ A large number of dips taken throughout the series, gave a gradual variation from 51° E.N.E. to 8° E.N.E. Across the strike of two miles or a little less, a rapid change in dip was noted at the Emerson Tunnel, two miles southeast of Coal Creek. The tunnel is 102 feet in length and gave a variation from back to front of ten degrees—51° to 41° northeast. The presence of the conglomerate, the absence of any evidences of volcanic action, as well as fossils, the relative position in the series of the clays, shales, and sandstones, with a basal coal productive series, as well as the thickness of the whole, seems to correlate these beds with Dawson's series observed at North Kootanie,§ making this region identical with the Crow's Nest valley. The latter beds, however, seem to display a greater variety of fossiliferous forms.

It may be said here that the Bozeman, Cinnabar and Rocky Fork Fields‖ are of Laramie age, while the Sand Coulee is lower in the geological horizon.

The coal is a lignite, exhibiting no changed condition resulting from crushing or violent metamorphic action as shown by

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* One fossil plant form was found in a heavily bedded series of sandy clays 30 feet in thickness, 10 miles west of Coal Creek.

† Dawson: Report 1886, pp. 57, 59.

‡ The Report of '86, Can. Geol. Survey, shows the Devonian as crossing the boundary on the west side of the Flathead River.

§ Dawson: Report 1886, pp. 64, 69.

‖ Weed: Engineering and Mining Journal.

the Elk River,[*] Crows' Nest,[†] Cascade coal, these being semibituminous and anthracitic in character. In these latter instances the flexure is more complex and shows evidences of great crushing and metamorphic action. The coal of Sand Coulee and Bozeman and Rocky Fork,[‡] is also bituminous in character—the latter region having been subjected to volcanic action, intercalated beds and dikes of eruptive rocks being a feature, which indeed characterizes many sections of the Cretaceous in the west. The Cretaceous here has not been thus disturbed, the coal being purely lignitic throughout, containing nodules or lumps of mineral resin, presumably succinite or an allied mineral. The series has been subject to lateral squeezing, folding and upheaval which turned the beds up against the Cambrian on the south, and against the Rockies, the Cambrian, Devonian and Sub-Carboniferous on the north.

No examination was made along the north side of the valley for Cretaceous, but the evidence all affirms the supposition of a simple synclinal fold,[§] much the same as exhibited at the North Kootanie Pass—the upheaval following at the close of the Cretaceous period. The Cambrian has been subjected at least to two periods of upheaval, if not more, the first being Palæozoic and the last as above mentioned. This is shown in the position of the Cretaceous, one hundred miles south of this resting unconformably on the greatly eroded, upturned edges of the Cambrian,[‖] where, however, the Cretaceous has not been subjected to any flexure or folding, but to a slow upheaval or movement of the crust which must have been pretty general in its character.

ART. LI.—*The Deep Artesian Boring at Galveston, Texas;* by ROBERT T. HILL.

AN experimental well has recently been drilled for the city of Galveston, Texas, to the depth of nearly three thousand feet, the results of which are of great value to geologists interested in the sedimentation of the Gulf of Mexico.

Galveston is situated on one of the island sand bars that mark the western border of the Gulf and nearly the entire depth of the drill hole is below sea level. Hence the accom-

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[*] Dawson: Rep. 1886, p. 69.

[†] Ibid.: Mineral Wealth, Br. Columbia.

[‡] W. H. Weed: Eng. and Min. Jour.. May and June.

[§] Some evidences have been obtained from the descriptive topography of surveyors of minor flexure.

[‖] Provisionally given—may be Pre-Cambrian.

panying record is entirely of sediments constituting the present sea bottom.

In the Engineering News of August 11, 1892, Mr. Byrnes, the contractor, published a valuable article on the engineering problems involved, together with the following section illustrating the character and thickness of the sediments passed through up to that date. Work has since been continued on the well and it is no doubt at present down to three thousand feet:

Gray sand	0 ft.
Red clay, with shells	46
Red and blue clay with shells	63
Same with fragments of wood	84 to 100
Gray and reddish sand, with occasional logs,	84 to 100
Red clay and shell of 337	338
Sand with wood and shell	400
Sand and sandy clay to	
Top of water sand	827
Water sand, 827 to	882
Sand (principally) and clay with wood and shell	882 to 1089
Very hard rock, probably conglomerate	1089 to 1090
Sandy clay and sand to	1260
Water sand 1260 to	1228
Sandy clay, varying hardness	
Sandstone	
Water sand 1493 to	1510
Clay with shell, pebble and lime	1520
Sand with same clay strata to	
Calcareous sandstone probably	1754 to 1758
Sand to	1862
Clay (principally) and sand to	2153
Clay with shell and wood fragments	2153 to 2196
Same. Also sand and joint clay to	
Concretionary limestone, probably	2288 to 2291.5
Sand and joint clay with shell and wood	2349
Water and sand to	2349
Clay and fine sand	2397
Red and blue clay	2425
Water sand	2425 to 2443
Red and blue clay and lignite	2443
Red and blue clay with alternating sand strata	2504
Water sand and blue clay	2504 to 2567
Indurated gray sand to	2598
Blue and red clay, some gravel to	
Very fine gray sand at	2631 to 2637
Red and blue clay	2653
Pale yellow clay	2698

Blue and yellow clay, and gray sand	2773
Very soft blue clay and reddish clay	2733 to 2871
Coarse sand	2871 to 2863
The drill was in soft clay and fine sand at	2863

No paleontologic data having been given I can only interpret these through my knowledge of the outcrop of the strata on the adjacent coastal plain bordering the Gulf east of Austin and San Antonio. It is said that Mr. Singley, a local observer, has carefully collected the paleontologic data, which it is hoped, he will publish.

In studying the section one is impressed by the littoral character of its material and the absence of indurated or consolidated rock, and the chalky marls and limestones characteristic of the Upper Cretaceous formation, leaving the impression that the 2863 feet of sediments are almost if not entirely composed of post Cretaceous beds.

Every foot of the deposits passed through in the well can be seen in the adjacent outcrops of Texas to-day. These belong to three formations. The provisional interpretations I would place upon the well are as follows:

No.	Strata in well.	Formation.	Age.
1	0–827	Coast Prairie Beds.	Pleistocene.
2	827–1754	Fayette Sands of Penrose.	Pliocene Miocene.
3	1754–2653	Lignitic Eocene.	Eocene.
4	----------	----------	----------
5	2653–2863	Probably Eocene but may be Upper Cretaceous.	

These formations have been described by Penrose, McGee and the writer. No. 1, the Coast Prairie beds are supposed by McGee to represent the southern stage of the former Columbian formation, and were laid down at marine base-level continuing around the coast into Louisiana, No. 3, is the well known Eo-Lignitic formation of the southern United States, as described originally by Hilgard as the Great Northern Lignite.[*] Penrose[†] has shown the general character of the formation in Texas and the writer[‡] in Arkansas. It is undoubtedly the direct geographic continuation in part of the Laramie beds of the Rocky Mountain region, as shown by Dr. C. A. White[§] and the writer.[‖] No. 2—the Fayette Sands—is a more problematical formation. Its general occurrence has

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[*] Agriculture and Geology of Mississippi, Jackson, 1860.

[†] Preliminary Report on the Geology of the Gulf Tertiary of Texas, from Red River to the Rio Grande. Austin.

[‡] The Neozoic Geology of Southwestern Arkansas, Little Rock, 1887.

[§] This Journal.

[‖] Notes on the Texas New Mexican Region, Bull. Geol. Soc., vol. iii, 1891.

been pointed out by Penrose, but no satisfactory interpretation has been made of its limitations and history. As shown by Shumard* and Cope† it contains the wonderful mammalian vertebrate fauna of the Loup Fork and Equus beds which are supposed to be of Miocene and Pliocene age. Its sediments are identical in many unique characters with those of the formations I have seen in Nebraska and on the Staked Plains containing besides the same vertebrate remains the peculiar opalized wood and quartz grains imbedded in a lime matrix identical with the mortar beds of Kansas described by Hay. It is evidently the coastward extension of the Great Plains formation which, as I have shown, extends over the whole Llano Estacado to the Rio Grande‡ as far as Spofford Junction. Whether this formation was deposited at marine base-level or was laid down upon the land after the manner of deposition now going on so extensively over the arid region of Mexico is an interesting problem. One fact is positive, however, and that is that it represents a period of great aridity which prevailed in Miocene and Pliocene time throughout the region of its occurrence.

These three sheets of sedimentation, representing 827 feet of Pleistocene beds, 927 feet of later Tertiary—Miocene and Pliocene—and 2000 feet of Eocene deposits reveal a great load upon the coastal plain, and each, according to the doctrine of isostasy, would afford a sufficient factor to account for the important movements of their respective epochs.

Could the well go deeper into the 2500 feet of Upper Cretaceous chalks and clays and the 2500 feet of Comanche deposits the total load upon the Gulf's margin since the sea first began its oscillations over the Texas region in Wealden time would amount to 8000 feet.

The oldest and latest of the three divisions into which I have divided the section, the Eocene and Columbian respectively, were deposited in very shallow water under conditions identical with the sedimentation of to-day, while the middle division no doubt represents even as shallow if not shallower deposits but under entirely different climatic conditions. All must represent subsidence, although there were no doubt intervening periods of elevation which can only be interpreted upon the land, according to the methods of the modern school of physical geologists. The total subsidence of the old Eocene shore line, according to this boring has amounted to nearly three thousand feet.

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* Trans. St. Louis Academy of Science, vol. ii, 1868, pp. 140–141.

† Various papers of Professor E. D. Cope.

‡ Occurrence of Underground Water in the Texas New Mexican Region. Washington, D. C., 1892.

ART. LII.—*Notice of a new Lower Oriskany Fauna in Columbia County, New York;* by C. E. BEECHER. *With an annotated list of fossils;* by J. M. CLARKE.

I.

IN 1890, while making collections and geological sections in the Becraft's Mountain region of Columbia County, New York, a fauna was discovered by the writer, which in many respects is new to the State. Its affinities are with the Oriskany, but its geological position is below the true Oriskany sandstone. It appears to include a part, at least, of what has been considered as the Upper Pentamerus limestone, and has been referred to the Lower Helderberg group on account of its lithological characters and upon insufficient paleontological grounds. The fauna of the Upper Pentamerus in its original locality (Schoharie, N. Y.) has previously been recognized to contain several species quite distinct from the Scutella, Shaly, and Lower Pentamerus limestones, which represent the typical Lower Helderberg group. Moreover, as the complete fauna has remained unknown and the series has been confused with the underlying Scutella limestone, no exact correlations have been made.

From the fossils now known from Becraft's Mountain and several other localities, it is evident that the relations of the fauna contained in the upper beds of the series above the Scutella limestone and just below the Oriskany sandstone are with the latter, and not with the Lower Helderberg group. This is shown by the presence in these beds of such typical Oriskany species as *Edriocrinus sacculus*, *Pholidops terminalis*, *Leptostrophia magnifica*, *Hipparionyx proximus*, *Leptocœlia flabellites*, *Spirifer arrectus*, *Spirifer arenosus*, *Cyrtina rostrata*, *Rhynchonella oblata*, and *Rensselæria ovoides*. This list has been revised by Mr. C. Schuchert, who has made a careful study of the Oriskany brachiopods.

At Becraft's Mountain the rock is a hard, cherty, arenaceous limestone, weathering into a rotten fine-grained sandstone, preserving the moulds of the fossils or their silicified replacements. On Catskill Creek, near Leeds, as shown by specimens received from Mr. W. W. Dodge, the rock contains less sand, and does not weather into a softer condition. At Port Jervis, N. Y., it is in general still more calcareous, although there are some cherty layers, and many of the fossils are silicified. Here, too, the series is continuous from the Oriskany sandstone down through the trilobite beds of Mather, Horton and Barrett. The arenaceous character of the beds gradually decreases downwards, carrying the typical Oriskany species into the *Dalmanites dentatus* layers and below, and making the whole series of this group at Port Jervis probably over two hundred feet in thickness, of which one hundred or more belong to the Lower Oriskany. The relations of these beds to the Oriskany was appreciated by Barrett,* who was led, however, to refer them to the Lower Helderberg on account of the occurrence of some doubtful Lower Helderberg species and their stratigraphical position.

In the paper on Becraft's Mountain by W. M. Davis,† the Upper Pentamerus, including the Scutella limestone, is stated to have a thickness of from forty to fifty feet, followed directly by the Cauda-galli shales. At Rondout, he recognized a recurrence of the Shaly limestone above the Scutella beds. The same conditions obtain at Becraft's Mountain, and at the top occur the few feet of cherty and arenaceous beds containing the Lower Oriskany fossils.

The paleontological aspect of this fauna is of much interest, especially on account of the large number of genera and species new to the Oriskany group and species new to science. Even the forms which are characteristic of the Oriskany sandstone above offer slight variations in size and features which enable them to be recognized as from a somewhat older horizon. As a whole, the fauna is transitional. A few of the Lower Helderberg types lingered; others were changed into species intermediate between Lower Helderberg and true Oriskany and Corniferous forms; and new types also appeared, which in the higher rocks reached a greater development. Among some of the new types of structure may be mentioned the coarsely plicate Leptocœlia, the Spirifers with plications in the sinus and the Corycephalus group of Dalmanites, having the outer margin of the cephalon denticulate. C. E. B.

II.

A preliminary List of the Species constituting the Oriskany fauna of Becraft's Mt., N. Y.

(Names in roman are of species present in the normal Oriskany or *Hipparionyx* fauna of Central New York and the Schoharie Section; for convenience of reference the letters H and D are placed before names of species belonging respectively to Lower Helderberg and upper-Lower, or Middle Devonian types.)

FISHES. 1. Spine of undetermined species.

ANNELIDS 2 *Spirorbis* sp.

(D) 3. *Autodetus* sp n. This genus is also represented in the Hamilton shales, but by a much larger species.

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* Ann. Lyceum Nat. Hist. N. Y., vol. xi, p. 297, 1876.

† This Journal, III, vol. xxvi, pp. 381–389, Nov., 1883.

TRILOBITES. (H) 4. *Dalmanites* sp. n. A. A large *Odontochile* with a series of marginal crenulations about the cephalon, of the character of those in *D. pleuroptyx* of the Shaly limestone and *D. anchiops*, of the Schoharie grit, but more extensive than either. The lateral glabellar lobes are more confluent than in the earlier (Niagara and Lower Helderberg) species. The genal angles end obtusely or in small spines. The pygidium is broad and unusually short, ending in a sharp, angular termination, but not in a spine. Annulations simple and very distinct; about 10 on the axis and 9 on the pleuræ. This is the largest and most abundant of the species. Some of the cephala measure 3½ inches in diameter.

(H) 5. *Dalmanites* sp. n. A. var. This is represented by a series of pygidia similar in annulation to the foregoing but persistently different in much smaller size, more slender form and tapering outline. It is closely similar to *D. micrurus*, of the Lower Helderberg, but less abundantly annulated.

6. *Dalmanites* sp. n. B. Long, slender pygidia with acute but not extended terminal spine. Annulations of axis about 15; of pleuræ, 12. On the axis is a double median row of conspicuous tubercles and there are irregularly scattered tubercles on the pleural ribs. This may be compared in form and ornament with *D. dentatus*, of the Port Jervis series, but it is more abundantly annulated and without the strong caudal spine of that species.

7. *Dalmanites* sp. n. C. A single pygidium, quite distinct from the rest, has a tapering outline, high convexity, broad, acute caudal extremity and strong simple annulations. There are 7–8 annulations on the axis, 8–9 on the pleura, all terminating at a considerable distance from the extremity of the shield. The expression of this pygidium is well defined and suggests in some respects, that of a small, sharply annulated *Homalonotus*.

(H) 8. *Dalmanites* sp.? D. There is evidence of another species of this genus with a pygidium somewhat similar to that of *D. pleuroptyx*.

(D) 9. *Dalmanites phacoptyx*, Hall. This species has heretofore been known only in the Upper Helderberg limestone of the Province of Ontario.

(H, D) 10. *Phacops* sp. n. Heads and pygidia are not uncommon. The form of the glabella is somewhat appressed laterally and is suggestive of *P. cephalotes* Barr. The genal extremities bear a single spinule or tubercle as in *P. Logani*, of the Shaly limestone, and *P. pipa*, of the Upper Helderberg, but the glabella does not show the lateral furrows distinctive of the earlier species of this genus. The segments of the thorax bear nodes at the axial furrows, such as characterize *P. Logani*, though the annulations of the pygidium do not appear to be duplicate as in the Lower and Upper Helderberg species. Some small examples do not have the thoracic nodes and these may represent a distinct specific form.

(D) 11. *Phacops* (*Acaste*) cf. *anceps*, Clarke. This species has heretofore been found only in the Upper Helderberg of the Province of Ontario.

(D) 12. *Homalonotus* sp. Occasional fragments indicate a species of small size, differing from the gigantic *H. major*, occurring in the Oriskany sandstone of Ulster Co.

(H) 13. *Cordania** sp. n. Allied to *C. cyclurus*, Hall, of the Shaly limestone but differing in details of ornamentation.

(H, D) 14. *Cyphaspis* sp. n. Of the type of *C. cœlebs* (Lower Helderberg) and *C. minuscula* (Upper Helderberg) but with proportionately much larger cephalon.

(D) 15. *Proetus* sp. n.? A. A small form of the *P. angustifrons-clarus-Rowi* type.

(D) 16. *Proetus* sp. n. B. A much larger form with highly convex glabella and multiannulate pygidium; of the type of *P. crassimarginatus* of the Upper Helderberg.

(H) 17. *Acidaspis tuberculatus*, Conrad. A characteristic species of the Shaly limestone.

OSTRACODES. 18. *Leperditia* sp. 19. *Primitia* sp.

CIRRIPEDES. 20. *Turrilepas* sp.

(CEPHALOPODS. No representative of these fossils has been observed.)

GASTROPODS. 21. Platyceras tortuosum, Hall. 22. P. nodosum, Conrad. 23. Strophostylus expansus, Conrad. 24. Diaphorostoma ventricosum, Conrad.

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* The writer has introduced this name in a paper now in press, for certain American species which have been referred to the genus *Phaethonides*, Angelin.

(D) 25. *Diaphorostoma* sp. n. In external ornament similar to *D. lineatum* of the Hamilton shales.

26. Cyrtolites expansus? (D) 27. *Pleurotomaria* sp. n. 28. *Bellerophon* sp. n.?

PTEROPODS. 29. *Conularia* sp.? 30. *Coleolus* sp.?

(H) 31. *Tentaculites* cf. *elongatus*, Hall. A very large species differing, if at all, from the Lower Helderberg form, in its coarser annulations.

32. *Tentaculites* sp. n. A very slender form, covered with minute, equal and closely crowded annulations.

PELECYPODS. (H) 33. *Actinopteria* cf. *textilis*, Hall. This shell is nearer to the typical lower Helderberg species than to the var. *arenaria* occurring in the *Hipparionyx*-fauna.

(H) 34. *Aviculopecten* of the type *A. Schoharie*, Hall, of the Shaly limestone, but covered with radial ribs in addition to the very fine concentric lines.

35. Megambonia bellistriata, Hall 36. M. lamellosa, Hall (?) 37. *Goniophora* sp. n. (H) 38. *Cypricardinia* cf. *lamellosa*, Hall, of the Shaly limestone. 39. *Conocardium* sp.

BRACHIOPODS. 40. *Lingula* sp. 41. *Orbiculoidea* sp.

42. *Crania* sp. n. A large shell with fine, rapidly bifurcating surface striæ. This is of the type of *C. agaricina* of the Shaly limestone, but larger and more finely striate. Not uncommon. 43. *Crania* sp. n. A smooth species.

44. Pholidops terminalis, Hall. This, and *P. arenaria* both of the Oriskany, are probably but the exterior and the internal cast of the same species.

45. *Pholidops* sp. n. A small species of the type of *P. squamiformis*.

(H) 46. *Orthis perelegans*, Hall, of the Shaly limestone.

(H) 47. *O.* cf. *oblata*. Hall of the Shaly limestone. A small form of this type. 48. *O.* sp? A small, subcircular species.

(H) 49. *Orthothetes* cf. *Woolworthana*, Hall, of the Shaly limestone.

50. *O.* sp. n. A small, very abundant shell, in size and expression suggestive of *O. lens*, of the Choteau limestone, but more variable in form and contour.

51. Hipparionyx proximus, Vanuxem. A single specimen of a very large and typical brachial valve.

52. *Leptæna rhomboidalis*, Wilckens. The Lower and Upper Helderberg form, rather than the Oriskany var. *ventricosa*.

53. Stropheodonta Lincklæni, Hall. (H) 54. *S.* cf. *radiata*, Vanuxem. In some of these shells the radial striæ are sharp and strongly fasciculate, producing an expression similar to that of *S. demissa* of the Middle Devonian.

55. *S.* sp. n. A. A large, strongly arcuate form with fine fasciculate striæ, as in *Rafinesquina alternata*.

(D) 56. *S.* sp. n. B. A small convex form of the type of *S. alveata* of the Schoharie grit.

57. Leptostrophia magnifica, Hall. A small variety.

(H) 58 *L.* cf. *Becki*, Hall. A perplane species with low, irregular, concentric rugæ extending to the anterior margin. The prevailing size of the shell is much smaller than in the Lower Helderberg form. Very abundant.

(D) 59. *L. perplana*, Conrad. Persistently more convex than the middle Devonian form; the difference however is no more than varietal. Everywhere abundant.

(H D) 60. *Strophonella* cf. *Headleyana*, Hall, of the Shaly limestone.

61. *Vitulina?* If this identification, founded on a single internal cast, be correct, this genus appears for the first time on this continent in its normal association with a lower Devonian fauna, as in South America and Africa.

(D) 62. *Chonetes* sp. n. A small shell of the type of *C. coronata*, Conrad.

63. *Chonostrophia* sp. n. Differs from *C. complanta* of the Oriskany in smaller size, greater reversed convexity and distinct fasciculation of striæ. 64. Anoplia nucleata, Hall.

65. Spirifer arrectus, Hall. This abundant species varies considerably in size and plication and frequently suggests the Lower Helderberg S. cyclopterus. 66. S. arenosus, Conrad. 67. S. pyxidatus, Hall. (H) 68. *S. modestus*, Hall, of the Shaly limestone. 69. *S.* cf. *fimbriatus*, Conrad. A sparsely ribbed, coarsely fimbriated shell. Specific relations can not be more closely determined with the material at hand.

70. Cyrtina rostrata, Hall. 71. *C.* cf. *Dalmani*, Hall, of the Shaly limestone

72. *Meristella* sp. n. This shell has many points of similarity with *M. oblata* of the Oriskany. It is, however, a smaller, much more strongly trihedral shell, with the aspect of a gigantic *M. lenta.* 73. *Meristella* cf. *laevis* of the Lower Helderberg. 74. *Meristella* sp. n? A large non-sinuate species.

(H) 75. *Trematospira multistriata*, Hall, of the Shaly limestone.

(D) 76. *Cœlospira* sp. n. In size this shell resembles *C. Camilla*, of the Corniferous limestone, while it bears the external ornament of *C. concava* of the Shaly limestone, though the plications are rather more numerous.

(H) 77. *Cœlospira* sp. of the small size of *C. concava* but more regularly plicate.

78. Leptocoelia flabellites, Hall. (D) 79. *L. acutiplicata*, Hall, of the Corniferous limestone.

(H) 80. *Anastrophia* sp. n. A very finely plicate species.

81. Rensselæria ovoides, Eaton. 82. R. Suessiana, Hall? 83. R. ovalis, Hall?

84. Rhynchonella oblata, Hall. 85. R. Barrandii, Hall. 86. R. cf. speciosa, Hall. 87. R. sp.?

(H) 88. *Eatonia medialis*, Hall, of the Shaly limestone. 89. E. peculiaris, Conrad.

(D) 90. *Centronella*, sp. n. of the type of *C. glans-fagea*, but of great size.

(H) 91. *Cryptonella* sp. n. Similar to an undescribed species in the Shaly limestone.

BRYOZOANS. (D) 92. *Fenestella celsipora*, Hall, of the Corniferous limestone.

93. *F.* sp.?

(D) 94. *Hemitrypa* cf. *columellata*, Hall, of the Corniferous limestone.

95. *Polypora* sp? 96. *Reptaria* sp. 97. *Hederella* sp. 98. *Clonopora* sp. 99. *Fistulipora* sp.

CORALS. (H) 100. *Zaphrentis* cf. *Rœmeri* of the Shaly limestone. 101. *Z* sp.? 102. *Romingeria* sp. 103. *Monticulipora*, a branching species. 104. *Trachypora*, sp.

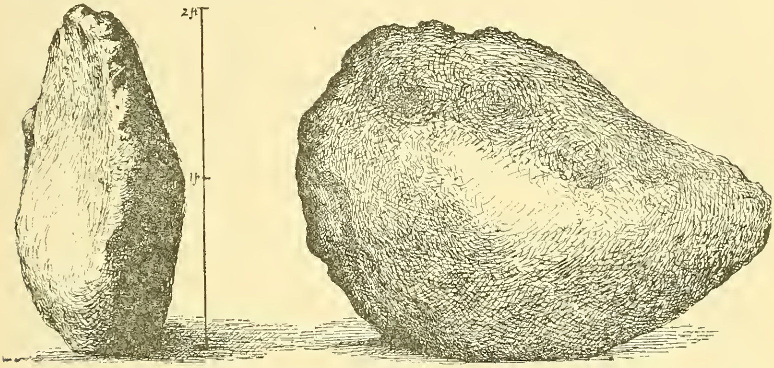
CRINOIDS. 105. Edriocrinus sacculus, Hall.

SPONGES. 106. *Hindia* sp.

This remarkable association of species furnishes the missing link in the evolution of the Lower Helderberg into the typical Lower Devonian fauna. While the presence of so many positive Oriskany types determines the faunal quantivalence, the perdurance of species and modifications of specific expressions characteristic of the Shaly limestone fauna, and the inception of upper Lower Devonian specific forms, render this combination altogether unusual and of prime significance in the correlation of our earlier Devonian. The southwestern extension of the Oriskany (*Hipparionyx*) fauna, as in Maryland, is complicated with the Lower Helderberg, but to a less degree than here; while in the representative of the same fauna in the Province of Ontario there is a great predominance of Upper Helderberg species. With the 46 species which have been identified in the *Hipparionyx* fauna of New York (see list published by Mr. Charles Schuchert, in Eighth Annual Report of the New York State Geologist, p. 50, 1889), the 106 *or more* species of the Becraft's Mt. fauna are in striking contrast, and no element so strongly enforces this contrast or is so unique in itself as the *crustacean*. The association is indubitably of early Oriskany age and is eminently the *Trilobite* or *Dalmanites* facies of the Oriskany fauna. J. M. C.

Art. LIII.—*Description of the Mt. Joy Meteorite*; by Edwin E. Howell.

The accompanying cut gives a good idea of the form of the third largest meteorite found in the United States, and the largest east of the Mississippi River.



It was found in November, 1887, on or about the 16th of the month, by Jacob Snyder, about a foot below the surface while digging to plant an apple tree near his house, five miles to the southeast of Gettysburg, in the township of Mt. Joy, Adams Co., Penn. It was supposed by the finder and his friends to indicate the near presence of an iron mine, and considerable prospecting was done to locate it. The meteorite was placed on some timbers in the open air where it remained until the summer of 1891, before it was seen by any one who surmised its true character.

Professor F. W. Clarke induced Mr. Snyder to send it to the National Museum for inspection, but was finally unable to secure it, as Mr. Snyder was unwilling to part with it for a price, which the museum felt justified in paying. I, therefore, purchased it from Mr. Snyder on the 15th of August, 1891. The three largest dimensions of the meteorite are 11, 24, and 33½ inches and it weighed on the museum scales 847 lbs. Professor Clarke had a few ounces taken off for examination; with this exception and the scaling of decomposed crust, from the outside, the mass still remains as it was found.

Professor Clarke has kindly furnished me with the following analysis, made by Mr. L. G. Eakins in the laboratory of the United States Geological Survey.

Professor Clarke did not succeed in developing the Widmanstättian figures satisfactorily, and the small amount of nickel shown by the analysis would indicate a poor etching iron; when larger surfaces are available, we shall doubtless obtain better results.

Fe	93.80
Ni	4·81
Co	0·51
Cu	0·005
P	0·19
S	0·01
	99·325

No idea can be formed of the length of time the meteorite had lain in the ground and very little of the amount of surface decomposition, it has undergone ;—sufficient, however, to remove all the finer pittings, leaving a comparatively smooth surface.

Having been much interested in Mr. Davison's examination of the magnetic properties of the Welland meteorite, and thinking that this line of investigation in other meteorites, might lead to interesting results, I requested Mr. Marcus Baker of the U. S. Geological Survey, to make an examination of the meteorite, which he kindly consented to do.

The result of this examination is to show that the meteorite, as a whole, acts as a mass of soft iron, gaining polarity under the inductive action of the earth. The lower portion on the north side became a north-seeking pole, while the upper part became a south-seeking pole; a pretty distinct neutral line was shown, inclined to the horizon at an angle (20°–25°) which is approximately the complement of the local inclination of the dipping needle. This induced polarity shifted with each change in the position of the whole mass, and in general this shifting of the poles took place promptly though not always at once. Mr. Baker also states that his observations suggested the probable existence of an unequal distribution of permanent magnetism, but this matter requires further investigation.

ART. LIV.—*On the Influence of the Concentration of the Ions on the Intensity of Color of Solutions of Salts in Water;* by C. E. LINEBARGER.

THE color of a solution of a salt in water depends upon the color of the ions into which it is decomposed by the act of solution as well as the color of the salt itself. If the salt is colorless and contains but one colored ion, any circumstance tending to increase the number of dissociated ions, tends to intensify the color of the solution. If the salt is colored and contains one or more colored ions, the colors of the salt and the ions will mix, and the solution will have an intermediate color. Any circumstance causing a change in the state of dissociation of the dissolved salt will change the character as well as the intensity of the solution.

Of course, the more concentrated the solution of a salt, the more intense its color; but there is another way by which the color may be rendered more intense, while the concentration of the salt, i. e. the amount of salt to fixed amount of water, does not change at all. This consists in heating the solution. Abundant experimental proof of this statement is found in an investigation by Gladstone,* "On the Effect of Heat on the Colour of Salts in Solution," which was published in 1857. Let us see why this change of intensity of color should take place in heating a solution.

It has been found that the electrical conductivity of solutions of salts increases as the temperature rises, about 2 per cent for each degree of temperature. In the light of Arrhenius's electrochemical theory this means that salts in solution become more and more decomposed into their ions as the temperature rises; the higher the temperature, the more concentrated the solution *with ions.* Accordingly, as the intensity of the color of a solution depends in a great measure upon the number of ions contained in it, if a colored solution be heated, its color deepens.

Gladstone's paper commences with these pregnant sentences:—"As a general rule, the solution of a salt has the same power of absorbing or transmitting the rays of light at all temperatures. I am not acquainted with any instance of a dissolved colorless salt which assumes a color when the solution is either heated or cooled; nor does the converse seem ever to occur,—a salt colored at the ordinary temperature, which loses that color when heat is applied. Nevertheless it is not rare to find colored salts which, when dissolved in water, vary in shade or in tint according to the temperature.

In some cases, heating the solution seems merely to intensify the color. This is the case with the following red, orange, yellow, and green salts:—

Meconate of iron—red.
Terbromide of gold—red.
Red nitrate of cerium.
Bichromate of potash—orange.
Ferrocyanide of potassium—yellow.
Molybdous chloride—green."

A number of instances are now given of changes in the character as well as in the intensity of the color, when the

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* Phil. Mag., xiv, 423.

solution is heated, the change of the character of the color being due, as mentioned above, to the fact that the undissociated molecule as well as its dissociated ions are colored. In reference to these observations he says:—"A glance at the above observations will suffice to show that where the color is not materially altered in character, it invariably becomes more intense when heated, that is to say fewer rays are transmitted; * * * The elevation of temperature seems to heighten the absorbent power of the dissolved salt, so that the light absorbed by a certain quantity of the heated solution is the same as would have been absorbed by a larger quantity of the same solution, if cold."

We now know that this absorbing power is exercised by the ions as well as by the salt in solution, and that just as the color is the more intense the more concentrated the solution, so is it also, the more numerous the dissociated ions. And, to repeat, as heat increases the number of dissociated ions of a salt in solution, so does it deepen the shade of color of the solution.

NOTE.—Just before receiving the proof of the above paper, there came to my notice the articles "On the Dissociation of Electrolytes in Solution as shown by Colorimetric Determinations" (Chem. News, vol. lxvi, pp. 104, 114, 141, 152) by H. M. Vernon. B.A., the experimental data of which afford additional proof of the correctness of the views expressed above.

Chicago, Ill.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On the Relative Densities of Hydrogen and Oxygen.*—RAYLEIGH has continued his researches on the relative densities of hydrogen and oxygen. In his first paper (1888) he gave 15·884 as the ratio obtained. Subsequently he effected a direct synthesis of water and obtained the ratio 15·89. He says: "I had intended further to elaborate and extend my observations on the synthesis of water from weighed quantities of oxygen and hydrogen, but the publication of E. W. Morley's masterly researches upon the 'Volumetric Composition of Water' (*Amer. Jour. Sci.*, March, 1891) led me to the conclusion that the best contribution that I could now make to the subject would be by the further determination of the relative densities of the two gases. The combination of this with the number 2·0002 obtained by Morley as the mean of astonishingly concordant individual experiments, would give a better result for the atomic weights than any I could hope to obtain directly." In the present experiments, the gases were obtained electrolytically, the generator being a long U-tube containing a solution of potassium hydrox-

ide, furnished with platinum electrodes and supplied with about three amperes of current by means of a Grove battery. Only one of the gases is collected, the other being allowed to escape through a mercury seal. If the hydrogen is to be collected, this gas is led, first, through a tube of hard glass containing metallic copper and heated to redness, thence through a flask containing a strong potassium hydroxide solution, then through a second hot tube containing copper, through a regulating tap and a tube containing solid hydroxide, through a long tube containing phosphoric oxide, and finally through glass-wool. The globe in which the gas is weighed is connected to one terminal of a four-way tube, the other terminals leading to the pump, to the generator and to a blow-off tube of the barometric length, respectively. In making an experiment, gas from the generator was allowed to flow through the purifying train, under the action of the pump, for half an hour. Then the pump was put into communication with the globe and with its set of tubes and a high vacuum produced in them. On making connection with the generator the globe slowly filled with gas, the operation taking from two to three hours. The gas was allowed to escape from the blow-off tube for some minutes, under a pressure of half an inch of mercury. The cistern was then lowered, leaving the end of the tube free, and the flow of gas was continued for two minutes. Four minutes were allowed after the tap to the generator was closed, for equilibrium of pressure to be attained. Then the tap to the globe was turned off, the barometers and thermometers read, and the globe weighed. The finally corrected values obtained were for hydrogen 0·158531 gram, and for oxygen 2·51777; so that the density-ratio is 15·882. Combining this with Morley's ratio of volumes 2·0002 : 1, the value 15·880 is obtained as the ratio of the atomic masses. The following summary of the results of different experimenters is given in the paper:

Name.	Date.	Atomic masses.	Densities.
Dumas,	1842	15·96	
Regnault,	1845	----	15·96
Rayleigh,	1888	----	15·884
Cooke and Richards,	1888	15·869	----
Keiser,	1888	15·949	----
Rayleigh,	1889	15·89	----
Noyes,	1890	15·896	----
Dittmar,	1890	15·866	----
Morley,	1891	15·879	----
Leduc,	1891	----	15·905
Rayleigh,	1892	----	15·882

—*Proc. Roy. Soc.*, Feb. 18, 1892; *Nature*, xlvi, 101, June, 1892.

G. F. B.

2. *On the Properties of liquid Oxygen and liquid Air.*—In a recent lecture at the Royal Institution, DEWAR illustrated the properties of liquid oxygen by some remarkable experiments.

Upon the lecture-table stood a liter flask full of liquid oxygen. On filling a test-tube with it, it appeared milky, but became clear on passing it through filter paper. The image of the liquid thrown on a screen, appeared of a pale blue color. The liquid in the tube boiled violently at the temperature of the air, with a hissing noise, giving off a white smoke due to the frozen moisture of the surrounding air. Its boiling point, determined thermo-electrically, is —180°. Liquid oxygen is a non-conductor of electricity. Moreover, a spark $0{\cdot}1^{mm}$ will not pass through it from a coil giving a long spark in air; so that it is also a good insulator. Interposed in the path of a beam of light, its absorption spectrum showed clearly the lines A and B of the solar spectrum, which lines as is well known, are due to absorption by the oxygen in our atmosphere. On accelerating the evaporation of some liquid oxygen by reducing the pressure upon it, Dewar liquefied air in an open test-tube under atmospheric pressure. The liquid air was clearer and fumed less than liquid oxygen. It also boiled more quietly. Common air liquefies at a much lower temperature than oxygen, both gases being liquefied together. In evaporating however, the nitrogen boils off before the oxygen. Placing two or three ounces of liquid air in a test-tube, a smoldering splinter of wood, placed in the upper portion, was not at first ignited. But after the nitrogen had for the most part boiled off, which took nearly five minutes, the wood when immersed burst into flame. He then poured out a wineglassful of liquid air and presented it to Lord Kelvin, who was in the chair. The magnetic properties of liquid oxygen were shown by placing some of it in a cup made of rock salt (in which it assumes the spheroidal state) and putting the cup beneath the poles of a powerful electromagnet. On completing the circuit, the liquid oxygen rose from the cup and attached itself to the poles, thus connecting them together. There it boiled gradually away, sometimes more on one pole than on the other, falling back into the cup when the circuit was opened. With a single pole the oxygen was drawn up out of a tube. Compared with iron, liquid oxygen is about one thousandth as magnetic. Liquid air also goes to the poles of a magnet, there being no separation of the oxygen and nitrogen. It has the same high insulating power as liquid oxygen. Although phosphorus is not attacked on being dropped into liquid oxygen, yet a photographic plate immersed in liquid oxygen at —200° was found to be sensitive to light. Dewar gives the following boiling points under atmospheric pressure: carbon dioxide —80°, nitrogen monoxide —90°, ethylene —103°, oxygen —184°, nitrogen —198·1°, air —192·2°, carbon monoxide —193°, nitrogen dioxide —153°, marsh gas —164°. Under only 5 to 10^{mm} pressure the boiling points are for CO_2 —116°, N_2O —125°, C_2H_4 —142°, O —211°, N —225° (solid), air —207° (solid), CO —211°, N_2O_3 —176°, CH_4 —201° (solid).—*Engineer*, lxxiii, 516, June, 1892. G. F. B.

3. *On the Industrial production of Liquid Carbon dioxide.*—In a report lately made to the Société d'Encouragement, TROOST has called attention to the extent to which liquid carbon dioxide is prepared for commercial purposes, the chief use in Germany being in the preparation of beer and in France for the preparation of salicylic acid by the reaction of liquid CO_2 on sodium-phenol. At the works of the Compagnie Générale des Produits Antiseptiques, the carbon dioxide is produced by the combustion of coke and is collected in a gasometer; from this it is drawn, dried and compressed into iron bottles under pressures of 5, 25 and 71 atmospheres. Most of it is used in the manufacture of salicylic acid, though it has other uses. At present the daily output is 300 kilograms, but the capacity of the works is to be increased to 1000 kilograms. It is sold at sixty centimes per kilogram. It is used in making aerated waters, in the filtering of wine, for cooling purposes in consequence of the absorption of heat on vaporizing and for producing a high pressure in the solidification of metals.—*Bull. Soc. Enc.*, July, 1892; *Nature*, xlvi, 399, Aug., 1892. G. F. B.

4. *On the Oxidation of Nitrogen by the Spark.*—The production of small quantities of nitrous and nitric acids during the passage of electric discharges through moist air, is well known. LEPEL has undertaken an investigation to determine the precise nature of the chemical changes taking place, with a view of increasing the yield. The first product, when the spark passes through air, apparently, is nitrogen dioxide; which becomes tetroxide by the oxygen of the air. This reacts with the aqueous vapor, forming nitric acid and setting free nitrogen dioxide again, thus: $(NO_2)_6+(H_2O)_2=(HNO_3)_4+N_2O_2$. On further passing the sparks, however, decomposition of the nitrogen oxides into their constituents takes place; so that in a closed space a limit is soon reached beyond which there is no further increase in the production of nitric acid. Hence the author has used a slowly moving atmosphere, varying the pressure and the spark through a wide range; and he has already increased the amount of combination up to ten per cent of the air employed. The best effect is obtained when the air is exposed under increased pressure to a series of parallel spark-discharges in the same tube. The air in the tube is changed intermittently, the gases passing into a large absorption vessel containing water or alkali-solution. In his later experiments Lepel has used a Töpler machine having 66 revolving plates; and he thinks that with the high voltage discharges lately produced by Tesla and others, the problem of producing nitric acid from the atmosphere may be a commercial success.—*Ann. Chem. Phys.*, II, xlvi, 319, June, 1892. G. F. B.

5. *On the Inorganic synthesis of Azoimide.*—Hitherto, azoimide N_3H has been obtained only from organic substances. WISLICENUS has now effected its synthesis from purely inorganic materials. His method depends upon the interaction between nitrogen monoxide gas and ammonia in presence of sodium.

These two gases do not react upon each other even when a mixture of them is passed over heated soda-lime. But in presence of sodium, action readily takes place, owing to the production first of sodium amide, which then reacts with the monoxide to yield the sodium salt of azoimide, thus: $NaNH_2+N_2O=NaN_3+H_2O$. The sodium salt being less explosive than most of the other salts of azoimide, the experiment may be safely performed if proper care is exercised. The sodium in small pieces is placed in several porcelain boats in a combustion tube and the air is displaced by a current of ammonia gas. On heating the tube the sodium fuses and is converted into sodamide. Then the current of ammonia is replaced by one of nitrogen monoxide, and the temperature is reduced to between 150° and 250°, by surrounding the tube by an air bath. The sodamide increases in bulk and becomes sodium azoimide, the reaction being completed when ammonia no longer escapes. This salt may also be obtained by passing a mixture of nitrogen monoxide and ammonia over metallic sodium; but the yield is smaller and the sodium sometimes inflames in the monoxide. On throwing the product into water, and distilling the filtered solution with dilute sulphuric acid, the distillate possesses the intolerable odor of azoimide and gives precipitates with silver, lead, and mercurous nitrates, which correspond in properties with these salts of azoimide. The silver salt gave 71·7 per cent of silver, AgN_3 requiring 71·8 per cent. Potassium and zinc may also be used in place of sodium.—*Ber. Berl. Chem. Ges.*, xxv, 2084, July, 1892; *Nature*, xlvi, 286, July, 1892. G. F. B.

6. *On Metallic Carbonyls.*—On the 3d of June, a Friday evening discourse on metallic carbonyls was given at the Royal Institution by LUDWIG MOND. After referring to the potassium-carbonyl of Liebig as the first metallic carbonyl, he entered upon a consideration of the nickel-carbonyl, discovered three years ago by himself, in connection with Langer and Quincke. The nickel, prepared in a fine state of division by heating the oxalate in a current of hydrogen, is treated with carbon monoxide at a low temperature. The escaping nickel-carbonyl, cooled in a freezing mixture, is condensed to a colorless liquid, which freezes at −25° in needle-shaped crystals. The vapor has a characteristic odor and is poisonous. It decomposes at about 200° depositing a mirror of metallic nickel. Its magnetic properties, according to Quincke, are remarkable since it is diamagnetic to a high degree, all other nickel compounds being paramagnetic. It is also an excellent insulator. Its spectrum, observed by Liveing and Dewar, shows that it is opaque for all rays beyond wave-length 3820. On diluting its vapor with hydrogen, the flame on burning is bright yellowish green and gives a spectrum having a bright background on which are superposed a number of bands. In the ultra-violet fifty well-defined lines are observed corresponding exactly to lines in the spark spectrum of nickel. The magnetic rotation of nickel carbonyl, as observed by Dr. Perkin, is found to

be greater than that of any other known substance excepting phosphorus. The atomic refraction of nickel in this substance is nearly two and a half times as large as in any other nickel compound. In accordance with the view that the valence of an element is higher in proportion as its compounds have a higher refractive power, the valence 8 has been assigned to the nickel in nickel-carbonyl. Ferro-carbonyl is prepared in a similar way. It is an amber-colored liquid, solidifying below −21° to a mass of needle-shaped crystals, and decomposing at 180°. Its formula is $Fe(CO)_5$. It is permanent in the dark but on exposure to sunlight is decomposed, yielding a fine gold-colored solid. Experiments on a somewhat large scale to test the practicability of utilizing nickel carbonyl in the extraction of nickel from its ores, proved entirely successful.—*Nature*, xlvi, 230, July, 1892.

G. F. B.

7. *Rapid Electrical Oscillations.*—In the experiments by Hertz on electrical oscillations and also in the experiments of subsequent investigators, Ruhmkorf coils have been used to propagate the electrical oscillations. It is well known, however, that the oscillation in the sparks from a Holtz machine or a Leyden jar are far more rapid than those produced by the aid of a Ruhmkorf coil. TOEPLER, therefore, has endeavored to study electrical oscillations by the aid of a Toepler-Holtz machine. His attempt has met with success and he describes his experiments at length in the paper we cite. His conclusions state the ratio between the primary and secondary circuits which he employed in order to produce the phenomena of resonance. He also studied the electric spark between a conductor and a surface of water, and discovered that this spark did not oscillate and he therefore concludes that it is probable that the ordinary lightning discharge does not oscillate. A loud noise and strong development of light in an electric spark is not in general a criterion of oscillatory character of the spark.—*Ann. der Physik und Chemie*, No. 7, 1892, pp. 464–484; No. 8, 1892, pp. 642–665. J. T.

8. *Electricity of Waterfalls.*—PH. LENARD refers to the opinion formerly held upon this subject, and after an exhaustive examination conducted in the Alps and also in the laboratory, concludes that drops of water which fall upon water or wet bodies develop electricity. The water is positively electrified. The air moves away from the place of the fall of the drops charged negatively. The charge of the water can become so great as to produce small sparks. The air potential in a room can become strongly negative. Slight impurities in the water have very great effect upon its electrification. A simple explanation is afforded by the hypothesis that contact electricity is developed between fluid and gaseous bodies.—*Ann. der Physik und Chemie*, No. 8, 1892, pp. 584–636. J. T.

9. *Photography of Color.*—At a meeting of the Physical Society in Berlin, June 17, 1892, H. W. VOGEL read a paper on the various attempts which have been made to reproduce

natural colors by photography. He pointed out that the Lippmann process requires great care in the preparation of the bromide of silver emulsion in order to obtain the layer of finely divided silver which is essential to the success of the Lippmann process. Moreover there is no possibility of the multiplication of copies of the photograph. Each copy requires an exposure and a separate development. A resumé is then given of the endeavors of various workers to combine three negatives taken through red, yellow and blue glass. Later investigators employed (in 1869), red, green and violet. Suitable plates of the required sensibility, however, could not be obtained. In 1873 Vogel prepared orthochromatic plates of greater sensibility and an advance was made in the representation of the values of colors. Further improvement has been made in orthochromatic plates and in the method of using suitable color screens. What formerly could be accomplished by chromo-lithography after a month's labor by the employment of twenty stones can now be done in eight days with only three plates.—*Ann. der Physik und Chemie*, No. 7, 1892, pp. 521–527. J. T.

10. *Electrical Resistance of Allotropic Silver.*—A. OVERBECK has examined the resistance of the new forms of silver discovered by M. Carey Lea, of Philadelphia. The latter has shown that allotropic silver can be converted into the ordinary silver in the following ways:

1. By heating.
2. Mechanical means (pressure).
3. By intense light.
4. By electrical discharges.
5. By treatment with different acids and solutions of salt.

Overbeck finds that all operations which tend to approximate allotropic silver to ordinary silver lessen its electrical resistance. The electrical resistance proves to be a very sensitive reagent, far more sensitive than any chemical process, to show differences of molecular state.—*Ann. der Physik und Chemie*, No. 6, 1892, pp. 265–280. J. T.

11. "*On the Simultaneity of Magnetic Variations at different places on occasions of Magnetic Disturbance, and on the relation between Magnetic and Earth Current Phenomena;*" by WILLIAM ELLIS. (Abstract.)—In this paper the author refers to the ordinary variations of the magnetic elements as observed at Greenwich; the annual progressive change; the diurnal variation—large in summer, small in winter, and also larger when sun spots are numerous and smaller when sun spots are few; the irregular magnetic disturbances and magnetic storms, and the accompanying earth currents; phenomena which are generally similar at other places.

He then invites attention more particularly to magnetic disturbances. Those at Greenwich may, after a calm period, arise gradually, or commence with great suddenness. When sudden, the movement is simultaneous in all elements. The first indication may be a sharp, premonitory, simultaneous movement, followed after a time by general disturbance, or the movement may at once usher in the disturbance. These initial movements are not always great in magnitude, sometimes, indeed, small, but they have a very definite character, and frequently occur nearly instantaneously, as is shown by the character of the photographic traces.

It has been long known that magnetic disturbances occur at the same time over wide areas of the earth's surface, but the accidental comparison in past years of the times of commencement of one or two disturbances at Greenwich with the times at other places has led the author to suppose that the coincidence in time is much closer than had been before supposed, and the definite, and on occasions isolated, character of the initial movement induced him to undertake the collection and comparison of the times of such movements for a number of days at observatories geographically widely separated.

The times of such movements cannot be caught by eye observation without continuous watching of the magnets, so that the photographic registers have to be relied upon, which is better, excepting that the scale of time is necessarily contracted; but, though in individual measures there might be variations, it was conceived that (supposing no systematic error to exist) the mean of a number of comparisons should give a good result. Seventeen days occurring in the years 1882 to 1889 were selected for comparison, the observatories being those of Toronto, Greenwich, Pawlowsk, Mauritius, Bombay, Batavia, Zi-ka-wei, and Melbourne, and, for a less number of days, Cape Horn (as obtained from the Mission Scientifique du Cap Horn, 1882–83.) It was desired to have times for Pola, but it was found that photographic registers during great part of the period did not exist. The variation in time at each place from the mean of times for all places is given for each day. The mean deviation at the different places varies from +2·4 minutes to −2·9 minutes, the agreement between four of the places, Greenwich, Pawlowsk, Mauritius, and Bombay, being very much closer, the mean values of deviation for Greenwich, Pawlowsk, and Bombay differing, indeed, by only 0·1 minute, equivalent to 6 seconds.

The question arises, Are the differences real, or due (considering the contracted time scale) to accidental error? If the magnetic impulse is really simultaneous over the whole earth, it is a striking physical fact, and if not entirely so, the circumstance is no less interesting; but greater attention to accuracy of time scale, or a more extended scale, may be necessary before the point in question can be definitely settled.

A table is added, showing the character of the magnetic movement at the several observatories, from which it appears that at any one place the movements on different days were in most cases similar, though different at different places, indicating on these occasions the occurrence usually of one general type of disturbance.

Reference is made to the question of earth currents. A comparison for thirty-one days, between 1880 and 1891, of cases of sudden magnetic movement and earth current, shows the earth current to precede the magnetic movement by 0·14 minute, equivalent to 8 seconds. The question of the relation between magnetic movements and earth currents is discussed. The desirability of being able temporarily to obtain, when occasion requirès, a more extended time scale for all magnetical and meteorological phenomena is pointed out.

The general result is that in the definite magnetic movements preceding disturbance the magnets at any one place are simultaneously affected; also that in places widely different in geographical position the times are simultaneous, or nearly so, a small constant difference existing at some places which may be real or may be accidental, but the character of which it seems desirable to determine. It is shown also that at Greenwich definite magnetic movements are accompanied by earth current movements which are simultaneous, but that neither magnetic irregularities nor ordinary magnetic variations seem to admit of explanation on the supposition of being produced by the direct action of earth currents.—*Proc. Roy. Soc.*, No. 313, p. 445.

12. *Physics, advanced course*, by GEORGE F. BARKER, Professor of Physics in the University of Pennsylvania. 902 pp. 8vo. New York, 1892 (Henry Holt and Company.)—The subject of Physics has grown to so large proportions of recent years that to present it adequately, in systematic shape and with such thoroughness as the higher grade of students demands, is a work of ever increasing difficulty. To the accomplishment of this task Professor Barker has brought a thorough grasp of the subject as a whole, a comprehensive and minute acquaintance with the writings, both practical and theoretical, of the foremost workers and thinkers in the science, and an unusual degree of skill and experience in the clear presentation of facts and principles for the benefit of students. The results of his labors, the careful and patient nature of which are obvious from beginning to end, is a work modern in method and fresh in matter, not indeed beyond criticism at some points, but which commends itself to the attention of every teacher who has to do with this department.

Physics in general is treated as "the science of energy" and the three fundamental divisions adopted for the subject are those of (1) mass-physics, (2) molecular physics and (3) physics of the ether. In the first division the subjects discussed are kinematics, dynamics, work and energy, attraction and potential, also the properties of matter and finally the energy of mass-vibration or sound. The second part includes heat; while the third gives the discussion of radiation in general: of electrostatics, called the energy of ether-stress; magnetism, "the energy of ether vortices"; electrokinetics, "the energy of ether flow". The last chapter treats of the electromagnetic character of radiation.

The above classification will serve to show the point of view adopted by the author, which he has systematically followed throughout the development of the different parts of the subject. There is thus a unity of general treatment which adds much to the value of the work. The book is also consistent in minor points, as in the use of the units adopted, in employing diagrammatic illustrations instead of pictorial representations of elaborate apparatus and in other respects. It is compactly printed, so that the large amount of matter included is embraced in 900 pages; the reader could wish, however, that a little less compression had been used by the printer at some points, for the printing of analytical expressions in the body of the text detracts much from their clearness, especially as first presented to the mind of the student.

The ultimate test of the adaptability of a text book to the purposes of general instruction must always be its actual use in the class-room, and it is to be hoped that this new Physics may here meet with the success which the author's careful labor makes it merit.

II. GEOLOGY AND MINERALOGY.

1. *Geological Survey of Texas*, 3d Annual Report for 1891, E. T. DUMBLE State Geologist. 410 pp. 8vo, with maps and plates.—This volume, after the general Report of the State Geologist, contains papers on Houston Co., and on a section from Terrell to Sabine Pass, by W. KENNEDY; on the Llano Estacado with a geological map and notes on the geology of the country west of the Plain, by W. F. CUMMINGS; on the Triassic in northwestern Texas, by N. L. DRAKE; on shells of a northern character in a dry salt lake near Eddy, New Mexico, by V. STERKI; on the Cretaceous of Texas, north of the Colorado River, by J. A. TAFF; on Trans-Pecos Texas, by W. H. VON STEERUWITZ. On the map of the Llano Estacado the general surface is made Tertiary, on the basis of the fossil Vertebrates found in surface deposits. In the southern part of the Plain there are Cretaceous beds, and beneath these and along a large part of its border, Triassic beds, as described by Mr. Drake. The Vertebrate fossils of the Llano Estacado, here described by Prof. Cope (and also in the Proceedings of the Amer. Phil. Soc. 1892, p. 128), occur in Crosby County, in a white diatomaceous deposit, the so-called Blanco beds. They are species of *Equus*, *Mastodon*, *Creccoides* (a new genus of birds), and *Testudo*: *Equus simplicidens* Cope, *Mastodon angustidens* (or a related species), *Creccoides Osborni* Cope, and *Testudo turgida* Cope. The Blanco beds are regarded as older than the Equus beds and newer than the Loup Fork, the latter containing *Mastodon angustidens* but no species of *Equus*. The specimens described for the Survey by Professor Cope were collected by Mr. Cummins.

2. *Geological Survey of Alabama*, by E. A. SMITH, State Geologist. Bulletin No. 3, On the lower gold belt of Alabama

by William B. Phillips. 98 pp. 8vo, with a map. 1892.—The gold belt described occurs in the counties of Chilton, Coosa and Tallapoosa.

3. *Annual Report of the Arkansas Geological Survey for 1892*, vol. i. 152 pp. 8vo.—This volume consists of a report on the Iron Ores of Arkansas by Dr. R. A. F. PENROSE.

4. *On the Osteology of Poëbrotherium, a Contribution to the Philogeny of the Tylopoda.* 74 pp. 8vo, with 3 plates: *On the Osteology of Mesohippus and Leptomeryx, with Observations on the mode and factors of Evolution in the Mammalia.* 104 pp. 8vo, with 2 plates; by W. B. SCOTT, College of New Jersey, Princeton. From the Journal of Morphology, v, Nos. 1 and 3, Boston, 1891.—These papers are the first and second parts of a Memoir bearing on questions in mammalian evolution. The osteological character of Poëbrotherium, Mesohippus and Leptomeryx are presented in detail after a thorough study of the large collection at Princeton, and made the basis of comparisons between them and the near and more distantly related species in and near the successional lines severally of the Camel, Horse and Tragulus. The specimens in the Museum include a nearly complete skeleton of *Poëbrotherium labiatum* of Cope, from the White River beds, a restoration of which is given, and also numerous bones illustrating the other genera. From his critical study, Prof. Scott draws conclusions as to the changes which took place in the course of development, and thence deduces principles as to "the modes and factors in the evolution." His method is the only right one, and it is used with great caution and excellent judgment. The closing part of his chapter on Evolution takes up the question as to *factors;* and in the introductory remarks he expresses his dissent from Weissmann's theory of the continuity of the germ-plasm, and says that in his opinion "so far from rendering the phenomena of heredity more intelligible, it tends to confuse them still further, and to end logically in a system very like the old preformationism. As Lloyd Morgan has very pithily put it, 'I cannot but regard Weissmann's doctrine of the continuity of germ-plasm as a distinctly retrograde step. His germ-plasm is an unknowable, invisible, hypothetical entity, material though it be, it is of no more practical value than a mysterious and mythical germinal principle.'" Prof. Scott in summing up the results of his examination says, that it is clearly seen "that transformation, whether in the way of the addition of new parts, or the reduction of those already present, acts just *as if* the direct action of the environment and the habits of the animal were the efficient cause of the change, and any explanation which excludes the direct action of such agencies is confronted by the difficulty of an immense number of the most striking coincidences."

5. *On Palæaspis of Claypole.*—A paper by Mr. Claypole on his genus *Palæaspis* was read before the Geological Society of London on the 22nd of June. In it he "describes two specimens from the Onondaga group (referred to the Lower Ludlow), which

indicate the existence of a ventral plate. The fossil which he described as *P. bitruncata* is maintained to be the Scaphaspid plate of *P. Americana*." The genus is compared with other Pteraspid genera, and a restoration in accordance with his conclusions is given.—*Ann. Mag. Nat. Hist.*, Oct. 1892, 334.

6. *Devonian fossils from the Islands and vicinity of Lakes Manitoba and Winnepegosis*, by J. F. WHITEAVES, Canada Geological Survey.—Mr. Whiteaves enumerates and describes a large number of Devonian fossils from North-Central America and illustrates them with many lithographic plates. The species are in part identical with those of the United States. But a considerable number are new; and they are of unusual interest also "on account of the close relations brought out in many respects between the fauna of these rocks and that of the Devonian rocks of Europe." The collections were made by Mr. Tyrrell and the author of the papers, and the localities are laid down on Mr. Tyrrell's "geological map of Northwestern Manitoba, and portions of the districts of Assiniboia and Saskatchewan," recently published by the Canadian Survey.

7. J. P. IDDINGS: "*The Eruptive Rocks of Electric Peak and Sepulchre Mt., Yellowstone Nat. Park.*" *Annual Report U. S. Geolog. Survey, Vol. XII.*—The writer presents the result of his studies on groups of igneous rocks occurring in the northwest corner of the Park. At Electric Peak occurs a stock of diorite accompanied by a great number of dikes and of sheets extensively intruded into Cretaceous strata. These rocks are described in considerable petrographical detail with tables of variation in structure and in chemical and mineralogical composition. From this it is shown that the variations in all directions are most gradual and transitional and that it is impossible to distinguish sharply differentiated types. The rocks of Sepulchre Mountain, a series of andesitic dikes cutting breccias, are treated with like results and the relationship of the two occurrences shown. Then follows a discussion of the bearing of the observed facts on theoretical petrography: the writer establishes that the same magma under differing physical conditions produce rocks mineralogically different. In conclusion the subject of classification is touched upon and the writer expresses himself in favor of a system based on crystalline structure. The paper is ably written and a most important contribution to petrographical literature. L. V. P.

8. A. SAUER: (*Mittheilungen der Grossh. Badischen Landesanstalt. II. Bd.*)—In a petrographical and geological study of "The Granite of Durbach" the author describes a peculiar syenite of lamprophyric character which surrounds the granite as an outer zone and to which he gives the name of Durbachite. Particularly interesting are the author's researches on the chemical composition of the hornblende of this syenite. This obtained in a state of great purity and freshness yielded 2·72 per cent of water by the Sipöcz-Ludwig method, although over the blastlamp

and heating to incipient white heat only 1·63 per cent could be obtained, regard being paid to the oxidation of the ferrous iron present. The water being considered as basic the analysis showed the mineral composed of a mixture of $RSiO_3$ and $\overset{III}{R}_2SiO_5$ silicates and as a result of his work the writer urges that more attention should be paid to the determination of water in hornblende analyses, since small quantities escaping determination may cause great differences in the molecular formulæ, on account of its low molecular weight. L. V. P.

9. *Danalite from Cornwall.*—The occurrence of the rare mineral danalite at Redruth, Cornwall, has been recently described by Miers and Prior (*Min. Mag.*, vol. x, p. 10). The only specimen thus far known was obtained in 1864; it shows a group of large reddish crystals of tetrahedral aspect which were formerly supposed to be pseudomorphs of garnet after tetrahedrite. The danalite is associated with quartz, small crystals of arsenopyrite and sphalerite. The hardness of translucent crystalline fragments of a columbine-red color is 5·5; the specific gravity is 3·350. An analysis gave the results in 1, while a new analysis of the Schwarzenberg helvite gave the numbers in 2; from the latter a little fluorite has been deducted.

	SiO_2	FeO	MnO	ZnO	BeO	CaO.	S		
1.	29·48	37·53	11·53	4·87	14·17	*tr.*	5·04	= 102·62	
2.	33·33	4·45	44·43	--	14·92	--	5·03	Al_2O_3 0·77	= 102·93

A new occurrence of danalite from Colorado is described with analysis by Genth and Penfield on p. 385 of this number.

10. *Mineral Resources of the United States*, Calendar years 1889, 1890. David T. Day, Editor, 671 pp. Washington, 1892 (U. S. Geol. Survey, J. W. Powell, Director).—The seventh volume of this valuable series has recently been issued and like its predecessors gives a careful review by competent writers of the mineral industries of this country; the period embraced by the report covers the years 1889 and 1890. It is announced that the volume for 1891 is also well under way.

Temperature of the Circumpolar region.—A short paper on the temperature of the Circumpolar regions, by Jules Girard, along with a map, is contained in the Bulletin of the Société de Géographie of Paris, for the 2nd trimester of 1892. It is based on the International observations during the year August 1882 to August 1883, and the reports furnished by the expeditions. There were 15 stations occupied by the several nations—the United States, England, Germany, Denmark, Austria, Sweden, Norway, Holland and Russia—which took part in the observations.

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[THIRD SERIES.]

Art. LV.—*An Experimental Comparison of Formulæ for Total Radiation between 15° C. and 110° C.*; by W. LeConte Stevens.

The earliest attempt to express the rate of cooling of a heated body was that made by Newton and embodied in a simple formula, which states that this rate is directly proportional to the difference of temperature between the radiating body and the medium surrounding it. It has long been known that this law is only approximately true when these temperature-differences are small, and that it is wholly inapplicable when they are large.

During the early part of the present century an elaborate research on the measurement of temperature and the communication of heat was made by Dulong and Petit.* Such instruments as the thermopile, the bolometer, and the galvanometer had not yet been invented. Their method was to employ as radiating body a large thermometer whose bulb contained more than a kilogram of mercury. This was placed within an envelope which was kept at constant temperature and made nearly vacuous as quickly as possible after the introduction of the heated bulb. The rate of cooling was found to be a function of the temperature of the envelope, the latter being kept constant during any given experiment, but varied for different experiments. For a given difference of temperature between the bulb and its enclosure it was found that the rate of radiation increases very nearly in geometrical progression while that of the enclosure increases in arithmetical progression. If

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* Annales de Chimie et de Physique, vol. vii, 1817.

S represent the quantity of heat radiated in unit of time, θ the temperature of the enclosure, t the excess of temperature of the radiating body over that of the enclosure, a a constant whose value they determined to be 1·0077, and m another constant whose value depends on the nature of the substance and the condition of its surface, the law of Dulong and Petit is expressed by the formula

$$S = m(a)^{\theta}(a^{t}-1) \tag{1}$$

In order to compare this formula with others presently to be given, it will be best to express θ and t in terms of absolute temperature. Letting T stand for the absolute temperature of the heated body, and T_0 that of the enclosure, we have $\theta = T_0 - 273$, and $t = T - T_0$. The formula now becomes

$$S = m(1{\cdot}0077)^{T_0-273}(1{\cdot}0077^{T-T_0}-1) \tag{2}$$

The range through which the value of $T-T_0$ was varied in these experiments was 240° C., while the temperature of the enclosure was varied from 0° to 60° C.

Subsequent investigators have tested the formula of Dulong and Petit, and have found that although it may seem to correspond nearly to the truth within the limits selected, it gives very erroneous results at higher temperatures, the radiation revealed by measurement being much less than that which is calculated by means of the formula. De la Provostaye and Desains tested it with thermometers whose bulbs were covered with a plating of metal, and found that under this condition the factor, m, varies with the temperature.* Draper, Tyndall, and Ericsson have published researches which showed the insufficiency of Dulong and Petit's formula. This formula may therefore be considered now as of only historic interest.

In an exhaustive comparison of the work done by these physicists, Professor Stefan, of Vienna, proposed a formula which, like those that preceded it, is empirical, but which corresponds much more nearly to the results of measurement than does that of Dulong and Petit.† He found that the amount of heat emitted in unit of time was proportional to the fourth power of the absolute temperature; or, in the notation already employed,

$$S = mT^4 \tag{3}$$

Since there is an exchange of heat between the radiating body and the surrounding medium, the effective radiation is

$$S = mT^4 - mT_0^{\,4}$$

This is obviously reducible to the form

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* Ann. de Chimie et de Physique, III, xvi.

† Sitzungsberichte der K. Akademie der Wissenschaften, Wien, lxxix, 1879.

$$S = mT_0^4\left(\frac{T^4}{T_0^4} - 1\right) \tag{4}$$

This formula has the advantage of great simplicity and ease of application.

Almost simultaneously with the publication of Stefan's paper in Vienna appeared an experimental research on the temperature of the sun, by M. F. Rosetti, of Padua.* Rosetti employed the thermopile and galvanometer for measuring the radiation from a Leslie cube covered with lamp-black and filled with water, which was stirred in order to secure uniformity. For temperatures between 100° and 300° mercury was substituted for water. In the liquid were immersed the bulbs of two thermometers whose readings gave the mean temperature at any selected moment. For still higher temperatures a copper ball was heated to redness, then exposed at a fixed distance in front of the thermopile long enough to produce a galvanometer deflection, and immediately afterward thrown into a calorimeter. The specific heat of copper being known, it becomes possible to compute the temperature of the ball at the moment of its immersion in the water. From these and other experiments Rosetti was led to adopt the empirical formula,

$$S = aT^2(T - T_0) - b(T - T_0) \tag{5}$$

Here a and b are two constants whose values for the particular instruments he employed were determined to be $a = 0{\cdot}00000335131$, and $b = 0{\cdot}0636853$. Rosetti considered the first term of his formula to represent the heating effect if the body were radiating in a vacuum, and the second term to represent the radiation of the air in which the body is immersed. Comparing this with Newton's formula,

$$S = a(T - T_0),$$

it is seen that while Newton regarded the emissive power, a, as independent of temperature, Rosetti regarded it as proportional to the square of the absolute temperature.

The accordance between the results of experiment and of calculation by means of this formula, as published by Rosetti, are quite remarkable, though the experiments seem liable to some criticism. Any assumptions regarding the uniformity of temperature in a Leslie cube are subject to challenge, if the water be not kept boiling. The calculations of temperature from calorimetric measurements is usually affected with a large probable error. For temperatures higher than those employed in calorimetry Rosetti used small disks of metal which were rendered incandescent in the hottest flames at his command,

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* Annales de Chimie et de Physique, V, vol. xvii, 1879.

and their radiation while thus glowing was measured by means of the thermopile. Finding his formula apparently satisfactory, he assumed it to be applicable to yet higher temperatures. Exposing his thermopile to the sun and comparing the deflection thus obtained with that given by a body of known temperature and area, at a known distance, the temperature of the sun was computed to be about 10,000° C. The work done by Rosetti was valuable; but his formula, involving two undetermined constants which vary with every thermometric instrument employed, may be considered, like that of Dulong and Petit, as of little more than historic interest.

In 1888 an important communication regarding the radiation of solid bodies was given to the Berlin Academy of Sciences by Professor H. F. Weber, of Zürich.* He had been engaged in an extended investigation of incandescent electric lamps for the purpose of finding, if possible, a general formula for the relation existing between the quantity of light emitted, the area of the radiating surface, the quality of the substance raised to incandescence, and the amount of electric energy expended. Among the results attained was the establishment of a formula expressing the relation between the intensity of any selected homogeneous radiation, the corresponding wave length, the temperature, and the quality of the radiating substance. An indispensable factor in the determination of this formula was the previous admirable work of Langley on radiation from the sun and various terrestrial sources, expressed in an energy curve which is now familiar to all physicists. From the study of this energy curve and of all other published results that were accessible, as well as his own experiments, Weber obtained the following formula:

$$s = c\pi \mathrm{F} \frac{1}{\lambda^2} e^{a\mathrm{T} - \frac{1}{b^2 \mathrm{T}^2 \lambda^2}}$$

Here T denotes the absolute temperature of the radiating body, expressed in degrees centigrade, λ the wave length of the homogeneous radiation considered, F the area of the radiating surface in square centimeters, e the base of the Naperian system of logarithms, and s the amount of energy radiated by the body in all directions in unit of time. The constant, c, depends on the nature of the radiating surface; it is the "emission constant." The constant b^2 depends also on the nature of the radiating body. Its mean value, as determined from a large number of experiments has been found to be

$$b^2 = 0{\cdot}196 \times 10^{-6}$$

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* Sitzungsberichte der K. Akademie der Wissenschaften, Berlin, 26 Juli, 1888.

To determine the value of the constant a, experiments were made upon a variety of solid conductors, including carbon, platinum, iron, and copper, raised to incandescence. For each of these the same value was found,

$$a = 0{\cdot}0043$$

If it be desired to find the total radiation, rather than that of a single wave-length, the equation just given must be integrated between the limits $\lambda = 0$ and $\lambda = \infty$. We have then for the total radiation, S,

$$S = \int_0^\infty s d\lambda$$

The result of the integration is

$$S = \tfrac{1}{2}\pi\sqrt{\pi}\ cbFe^{aT}T$$

Or, letting C represent the total emission constant, $\frac{1}{2}\pi\sqrt{\pi}\,cb$, we have

$$S = CFe^{aT}T$$

If the radiating body be surrounded by another body whose constant absolute temperature we may call T_0, there is mutual radiation between the two, and the resultant radiation of the first becomes

$$S = CFe^{aT}T - CFe^{aT_0}T_0$$

This is obviously reducible to the form

$$S = CFe^{aT_0}T_0\left(\frac{T}{T_0}e^{a(T-T_0)} - 1\right)$$

Here the quantity outside of the parenthesis is made up of constants, and the variation of S is dependent only on T. For purposes of comparison therefore we may employ only what is found within the parenthesis.

This formula has been tested by applying it to the results of experiments already published by Schleiermacher, Graetz, and Magnus in Germany, Bottomley and Tyndall in England, Violle, Garbe, Becquerel and Mouton in France, and Langley and Nichols in America. A part of these results were included in the communication to which reference has already been made.

In testing Stefan's formula* Schleiermacher measured the loss of energy sustained in unit of time by a platinum wire, heated to a given temperature within a good vacuum by means of the electric current and surrounded by an envelope kept at

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* Wiedemann's Annalen, xxvi, p. 287.

a lower fixed temperature. The temperature of the wire was deduced from the variation in its resistance. The result was to show that for low temperatures Stefan's formula gives results that are too great, and for high temperatures they are too small. The application of Weber's formula to Schleiermacher's data yields results that are more consistent.

The following experiments have been made with a view to comparing the formulas of Dulong and Petit, Rosetti, Stefan and Weber in their application to temperatures but little removed from that of the atmosphere, not employing the indirect method of Schleiermacher, but measuring temperatures directly with the thermometer and radiation with the thermopile.

The radiating body was a metallic disk instead of the Leslie cube. A hole was drilled into it, parallel to one of its flat surfaces and extending nearly to the center. This was for the reception of a thermometer. The disk could therefore be raised to any desired temperature within the range of the thermometer, and its temperature be noted at any moment while it was cooling. One face was kept always scrupulously clean and smooth so as to prevent variations in emissive power. This face was turned toward a thermopile at a fixed distance from it. The thermopile was enclosed in a double-walled box of sheet brass for the purpose of preventing draughts and other disturbances that might affect its temperature. Through the cover of this box a delicate thermometer was passed, so that its bulb rested almost in contact with the thermopile. Variations of temperature within the box were thus measurable to within a hundredth of 1° C. In the end of the box turned toward the disk was a circular opening, 7^{cm} in diameter, provided with a double-walled adjustable brass cover. This was controlled by means of a string so that the thermopile could be exposed to radiation for a brief interval and then shut off from this. The thermopile was connected with a very delicate mirror galvanometer of low resistance, and all readings were taken by means of telescope and scale. The sensitiveness of this galvanometer was tested from time to time by putting it in circuit with a standard Clark cell and a resistance of 72,000 ohms. Around the suspended disk, except on the side toward the thermopile, double brass screens were placed, and a screen also above the space between it and the box. Disturbing air currents were thus avoided, not completely, but as far as possible. The entire apparatus was in a basement room whose temperature remained very nearly constant from day to day. A thermometer, hung outside of the brass screens, permitted comparison between the temperature of the room and that within the box containing the thermopile.

Before beginning any one series of observations, readings were taken from each of the three thermometers. These had of course been previously compared and found reliable, so that the correction for difference between them was very small. The disk had been hanging in position for some hours, but on exposure the thermopile always indicated a slight difference of temperature between itself and the disk, amounting to one or more scale divisions. This deflection was recorded, to be used as a correction to subsequent readings. The disk was then removed, heated up to a given temperature in excess of any to be measured, and hung again in position. After a few minutes its temperature was noted, the thermopile exposed long enough only to produce a throw of the galvanometer needle, the temperature of the disk immediately again noted, and also the temperature of the thermopile as indicated by the thermometer in the box. This procedure was repeated at intervals of two minutes during one or two hours, in which the disk became cooled down to a temperature differing but little from that of the room.

The arrangement of apparatus and the procedure just described was that finally adopted after many days had been spent and many hundreds of observations taken which had failed to yield satisfactory results. With the utmost care it is impossible to exclude air currents from the disk, and hence irregularities in its radiation. The same remark would apply equally to the Leslie cube, with the additional consideration that convection currents within the cube during its cooling would be very hard to control, even with assiduous stirring. At each exposure of the thermopile the air around it becomes warmed slightly by the disk, and it cannot be assumed that the temperature of the room is that of the thermopile after the first few exposures have been made. By enclosing the instrument in a box, this warm air, it is true, is prevented from passing away ; but this disadvantage is much more than offset by the possibility of measuring and recording the increase of temperature, for which a curve of corrections is afterward made.

To continue any one series of observations until the difference of temperature between disk and thermopile vanishes is obviously impossible. Even when this difference amounts to several degrees disturbances are apt to produce such irregularities in the indications of the thermopile as to introduce serious error. By artificially cooling the disk until it seemed to indicate the same temperature as the box it was found that uncontrollable errors were introduced. It was best therefore to allow the cooling by radiation to continue until a temperature-difference of 5° or 10° remained, recording the corresponding deflections at the usual intervals. To find out what would be the residual deflection, if this temperature-difference as indicated by the thermometers were reduced to zero, advantage is taken of the fact that for such small differences the curve expressing the radiation is approximately a straight line. Taking therefore the recorded small temperature-differences as abscissas and the corresponding deflections as ordinates, a straight line is drawn through the points thus found. Prolonging the line in a negative direction until it cuts the axis of ordinates, the distance of the point of intersection above or below the origin gives the correction to be applied to these final readings. The correction to the initial readings having been taken before heating the disk, and the slight variation of temperature in the box having been recorded, we have the means of constructing at least an approximate curve of corrections for all intermediate readings.

It is scarcely necessary to add that all thermometer readings were corrected for the difference of temperature between bulb and tube, and that all scale readings were reduced to those which would have applied to a circular arc.

The disk employed in the majority of the experiments was made of iron, though a number of measurements were made also with one of copper of the same dimensions. The distance from disk to thermopile was kept constant for each single series of observations. but this distance was varied from 30^{cm} to 40^{cm} according to necessity, and the sensibility of the galvanometer likewise varied, for different ranges of fall of temperature. The superior conductivity of copper ensures quicker equalization of temperature throughout the disk of this metal, but that of iron is amply sufficient, while its higher coefficient of emission makes the experiments less tedious and less subject to error than when a disk of copper is employed. The disk constitutes a short cylinder whose radius is $r = 7{\cdot}3^{cm}$ and whose length is $2\,l = 1{\cdot}4^{cm}$ or the distance from center to flat surface of the cylinder is $l = 0{\cdot}7^{cm}$. It can be shown* that if a thermometer bulb be placed within such a cylinder of heated iron at its center, and if it be assumed that a brief interval of time, such as one minute, has elapsed, then between the center of the disk and the nearest point on its face, at a distance of $0{\cdot}7^{cm}$ the absolute temperature does not vary more than 0·0002 of itself, or 0·02 of 1 per cent; also that the temperature-difference between center and circumference of the flat surface, an interval of $7{\cdot}3^{cm}$, does not exceed 0·18 of 1 per cent. It is safe to assume therefore that no error so great as the necessary errors of observation can be introduced by accepting the temperature

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* Lectures of H. F. Weber on the Theory of Cylinder Functions and their application to the Problems of Physics.

indicated by the thermometer as the temperature of the radiating surface.

The method of work and the degree of accuracy attained may now be further illustrated by tabulating some of the results.

Tables I and II exhibit two independent series of measurements, on a fall of temperature through 40° C., the initial temperatures being approximately 60° C. as shown. For convenience the tables are arranged in the order of the intervals of time included in each, rather than in that of increasing temperature-difference which would on some accounts be preferable. The measurements were on the radiation of the iron disk. For the series indicated by Table I the initial deflection obtained before heating the disk was $\delta_1 = +0{\cdot}3$ scale division. The disk was then heated up to a temperature a little in excess of 60° and hung in position. While it cooled down to 21°·6 a series of 57 observations were made at intervals of two minutes. The residual correction was then found to be $\delta_2 = -2{\cdot}0$ scale divisions. The sensitiveness of the galvanometer remained unchanged during the 114 minutes of work, while the temperature within the box was raised from 16°·16 to 16°·72. For the purpose of tabulation the absolute temperatures, time intervals, and corresponding galvanometer deflections were obtained by interpolation for intervals of 5° in succession, after all necessary corrections had been applied to the recorded readings. The horizontal column H gives the hour and minute at which the record thus obtained should have been made. Column T gives the absolute temperatures of the disk, T_0 those of the thermopile, and $T - T_0$ the temperature differences. Column E gives the experimental result in radiation, as obtained in scale divisions of deflection. Column W gives the numbers for $\left(\frac{T}{T_0} e^{a(T-T_0)} - 1\right)$, which is the factor involving the variable, T, in Weber's formula. Column S gives the numbers for $\left(\frac{T^4}{T_0^4} - 1\right)$, involving the same variable in Stefan's formula. Each number thus obtained by formula is then divided by the corresponding values of E in the same vertical column obtained by experiment. The quotients are arranged in the horizontal columns W ÷ E and S ÷ E respectively, and multiplied by a power of 10 for the purpose of avoiding inconvenient decimals. This has no influence since our object is only that of comparison. If a formula be correct, and if the measurements be free from error, the numbers contained in the corresponding horizontal column of quotients should be identical. If they progressively increase or decrease through the series, this shows that the formula gives results that are progressively too high or too low, as the case may be.

The explanation just given applies equally to Tables II, III and IV, the last two of which represent a fall of temperature through 80°.

TABLE I.

H	$9^h\,29^m$	$9^h\,33^m$	$9^h\,39^m$	$9^h\,45^m$	$9^h\,53^m$	$10^h\,3^m$	$10^h\,19^m$	$10^h\,38^m$	$11^h\,18^m$
T	334·16	329·20	324 26	319·33	314·43	309·52	304·61	299·65	294·72
T_0	289·16	289 20	289·26	289·33	289·43	289·52	289·61	289 65	289·72
$T-T_0$	45	40	35	30	25	20	15	10	5
E	419·1	366·9	315·4	264·6	218·6	171·0	126·6	83·8	41·3
W	0·403	0·352	0·302	0·255	0·210	0·165	0·122	0·080	0·040
S	0·783	0·680	0·578	0·485	0·392	0·306	0·225	0·145	0·069
$W \div E$	962	959	957	964	960	965	964	966	968
$S \div E$	187	185	183	183	179	179	178	175	167

TABLE II.

H	$9^h\,47^m$	$9^h\,53^m$	$9^h\,58^m$	$10^h\,5^m$	$10^h\,13^m$	$10^h\,24^m$	$10^h\,38^m$	$10^h\,59^m$	$11^h\,37^m$
T	332·98	328·08	323·18	318 32	313·46	308·63	303·82	299·00	294·13
T_0	287·98	288·08	288·18	288·32	288·46	288·63	288·82	289·00	289·13
$T-T_0$	45	40	35	30	25	20	15	10	5
E	426·1	374·4	321·4	271·0	221·9	173·7	127·3	84·7	42·0
W	0·403	0·352	0·302	0·255	0·210	0·155	0·122	0·080	0·040
S	0·783	0·680	0·578	0·485	0·392	0·306	0·225	0·145	0·069
$W \div E$	946	940	940	941	946	950	958	945	952
$S \div E$	184	182	180	179	177	176	177	171	164

TABLE III.

H	$10^h\,16^m$	$10^h\,20^m$	$10^h\,25^m$	$10^h\,30^m$	$10^h\,36^m$	$10^h\,44^m$	$10^h\,54^m$	$11^h\,9^m$	$11^h\,32^m$
T	384·21	374·25	364·33	354·40	344·49	334·57	324·65	314·70	304·70
T_0	289·21	289·25	289·33	289·40	289·49	289·57	289·65	289·70	289·70
$T-T_0$	95	85	75	65	55	45	35	25	15
E	347·6	302·7	256·3	214·2	175·0	138·7	103 9	72·2	42·0
W	0·999	0·865	0·739	0·619	0·508	0·403	0·302	0·210	0·122
S	2·113	1·803	1·514	1·249	1·006	0 780	0·578	0·392	0·225
$W \div E$	287	286	288	289	290	290	291	291	290
$S \div E$	608	596	591	583	575	562	556	543	536

TABLE IV.

H	$10^h\,35^m$	$10^h\,39^m$	$10^h\,43^m$	$10^h\,45^m$	$10^h\,54^m$	$11^h\,2^m$	$11^h\,12^m$	$11^h\,27^m$	$11^h\,49^m$
T	385·27	375·30	365·35	355·43	345·50	335·61	325·68	315·71	305·81
T_0	290·27	290·30	290·35	290·43	290·50	290·61	290·68	290·71	290·81
$T-T_0$	95	85	75	65	55	45	35	25	15
E	432·0	376·0	320·0	266·2	218·2	173·0	129·5	89·8	52·6
W	0·999	0·865	0·739	0·619	0·508	0·403	0·302	0·210	0·122
S	2 113	1·803	1·514	1·249	1·006	0·780	0·578	0·392	0·225
$W \div E$	231	230	231	233	233	233	233	234	232
$S \div E$	489	480	473	469	461	451	446	437	428

If now each one of the series of numbers in column $W \div E$ or $S \div E$ be divided by the mean of the series the successive quotients will differ but little from unity. The corresponding horizontal column of results we may call the column of deviations. If the numbers in this column be represented by a curve, with temperature-differences for abscissas, this curve should be very nearly a straight line parallel to the axis of abscissas. It will be most convenient to arrange such a series therefore in the order of increasing temperature-differences, which is the reverse of that in the tables just given. Any irregularities in the curve must be due to the errors of experiment, and partly to the fact that logarithmic results are only approximations. Table V is made up of the deviation columns from five independent series of observations ranging through 40°, to which Weber's formula has been applied. Table VI contains the application of Stefan's formula to the same series.

Table VII shows Weber's formula, and Table VIII Stefan's formula, applied to six independent series of observations ranging through 80°. In each case the mean of each vertical column is shown.

TABLE V.—*Weber.*

$T-T_0$	5	10	15	20	25	30	35	40	45
I	0·983	0·989	1·005	1·007	1·007	0·997	1·001	1·007	1·007
II	1·008	0·998	1·013	1·004	1·000	0·993	0·992	0·993	0·999
III	1·006	1·002	0·998	1·003	0·998	1·001	0·995	0·997	0·999
IV	----	1·001	1·006	1·006	1·006	0·994	0·993	1·002	0·994
V	----	1·002	1·009	1·011	0·996	0·996	0·996	0·996	0·997
Mean	0·999	0·998	1·006	1·006	1·002	0·996	0·995	0·999	0·999

TABLE VI.—*Stefan.*

$T-T_0$	5	10	15	20	25	30	35	40	45
I	0·906	0·971	0·991	0·998	1·008	1·012	1·027	1·040	1·046
II	0·928	0·980	0·998	0·995	1·000	1·008	1·017	1·025	1·045
III	0·928	0·987	0·988	0·995	0·999	1·016	1·021	1·007	1·039
IV	---	0·973	0·983	0·989	0·997	1·000	1·009	1·043	1·024
V	----	0·977	0·986	0·993	0·988	1·002	1·012	1·020	1·026
Mean	0·921	0·978	0·989	0·994	0·998	1·008	1·017	1·023	1·036

TABLE VII.—*Weber.*

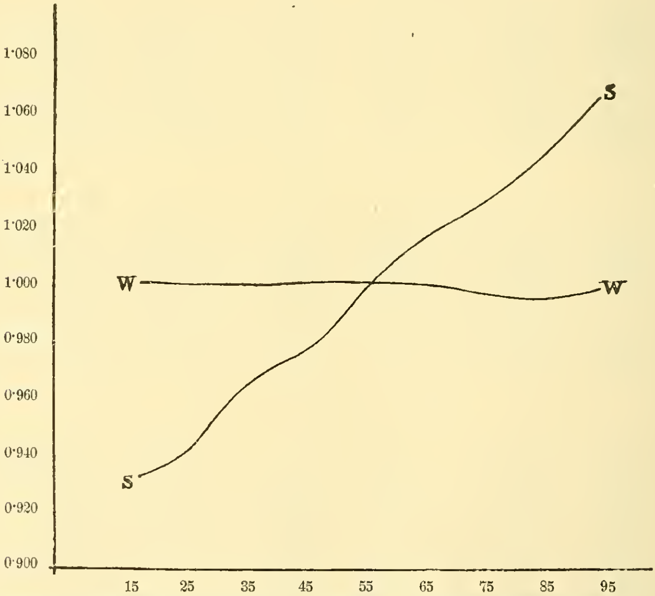
$T-T_0$	15	25	35	45	55	65	75	85	95
I	0·993	0·977	0·997	1·001	1·014	1·024	0·992	1·006	0·996
II	1·004	1·006	1·005	1·004	1·003	0·999	0·996	0·988	0·996
III	1·014	1·009	1·003	1·002	0·999	0·993	0·990	0·993	0·995
IV	0·997	1·011	1·002	1·002	0·997	0·990	1·014	1·001	1·017
V	0·999	1·001	1·004	1·003	1·002	1·001	0·995	0·991	0·996
VI	----	----	1·000	1·001	1·001	1·001	0·999	0·998	----
Mean	1·001	1·001	1·001	1·002	1·002	1·001	0·998	0·996	1·000

TABLE VIII.—*Stefan.*

$T-T_0$	15	25	35	45	55	65	75	85	95
I	0·925	0·922	0·965	0·979	1·014	1·044	1·027	1·059	1·064
II	0·937	0·949	0·973	0·983	1·005	1·019	1·032	1·041	1·063
III	0·945	0·953	0·971	0·981	1·000	1·014	1·026	1·047	1·064
IV	0·926	0·951	0·966	0·977	0·995	1·006	1·046	1·051	1·083
V	0·931	0·950	0·972	0·982	1·003	1·021	1·030	1·042	1·065
VI	----	----	0·957	0·970	0·993	1·024	1·024	1·042	----
Mean	0·933	0·945	0·968	0·979	1·002	1·019	1·031	1·047	1·068

The mean results of Tables VII and VIII are expressed graphically in the curves of fig. 1. Here it is seen that Weber's formula is expressed by a curve (WW) nearly parallel to the axis of abscissas, but with slight irregularities, as might be expected in any representation of experimental results. At no point is the deviation so great as 0·5 of 1 per cent. Stefan's formula is expressed by a curve (SS) which is plainly oblique to the axis of abscissas, the greatest deviation being more than 6 per cent. These experiments therefore confirm the result otherwise attained by Schleiermacher, indicating that for temperatures but little above that of the atmosphere Stefan's formula gives a rate of increase of radiation that is too rapid, while Weber's formula coincides very closely with the results yielded by experiment.

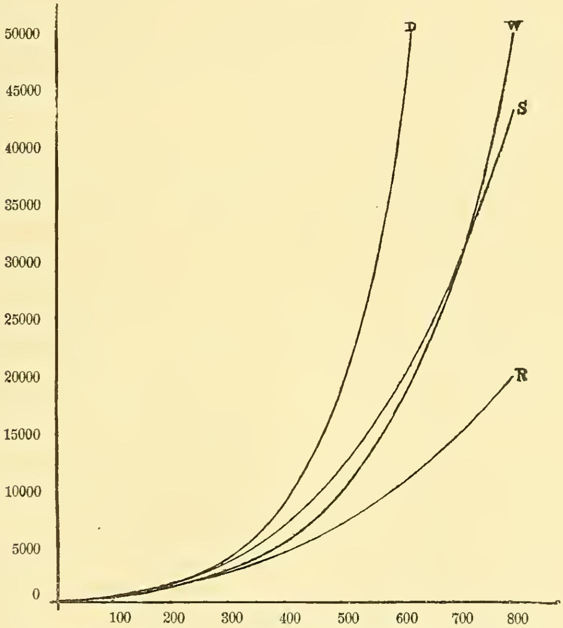
Fig. 1.



Curves of deviation for formulas of radiation for temperatures from 30° to 110° C.

It may be of some interest in this connection to exhibit the application of these formulas to a wider range of temperature difference. For this purpose the constants of each formula have been determined from the data contained in the tables just given; those of Rosetti's formula being obtained by method of least squares. In fig. 2, the abscissas represent temperature differences from 0° to 800° C., the temperature of the thermopile being taken as 17° C., which was the mean temperature of the room in which the measurements were made. The ordinates are to be read in units of deflection on a scale such as was employed in the galvanometer readings representing radiant energy. For temperature-differences less than 100° these curves are nearly coincident. For high temperatures Stefan's formula gives results that are higher than those of Weber's formula; but the rate of increase by Weber's formula grows more rapidly, and for a temperature difference of about 720°, about that of red heat, the two curves cross each other, and, from this point on, the indications of Stefan's formula become lower than those of Weber's formula. In this connection we may again refer to the experiments of Schleiermacher, who, by estimating change of temperature through variation of electrical resistance, found the indications of Stefan's formula to be less than the results obtained by experiment. The curve of Rosetti's formula gives a rate of increase in radiation that is about as much too low as that of Dulong and Petit is too high.

Fig. 2.



Curves of radiation for temperatures from 17° to 817° C.

D. Curve for formula of Dulong and Petit.
W. " " " " Weber.
S. " " " " Stefan.
R. " " " " Rosetti.

ART. LVI.—*Notes on Silver;* by M. CAREY LEA.

Action of Ammonia.—Aqueous ammonia is supposed to be without action on normal silver but this is not so: under favorable conditions, silver is gradually taken up by this solvent.

The first experiments were made with silver reduced from the nitrate by the action of sodium hydroxide and milk sugar. The silver was very carefully purified from any possible trace of oxide. Placed in contact with ammonia for a few hours, silver was taken up. Its presence could be recognized either by ammonium sulphide or by adding a drop or two of hydrochloric acid and then supersaturating with dilute sulphuric acid; a dense cloud of silver chloride forms and this result can be obtained any number of times in succession by acting with ammonia on the same portion of silver.

A similar reaction was obtained with silver reduced from chloride by cadmium and hydrochloric acid removing afterwards all traces of cadmium. Silver reduced in this way is liable to contain traces of chloride. These were removed by covering the silver with strong ammonia, letting it stand over night and thoroughly washing out. This was repeated five times. From this silver, ammonia by twenty-four hours contact always took up enough to give a dense white cloud when treated as above.

Portions of solutions obtained in the last mentioned manner were evaporated to dryness over the water bath and left brownish black films. These were non-explosive and therefore did not consist of silveramine: they yielded a large proportion of silver to acetic acid. leaving behind a little metallic silver. The ammonia therefore, does not dissolve the silver as metal but as oxide. The presence of a little metallic silver in the residue left by evaporation was probably due to slight traces of oxidable organic matter contained in the ammonia. This opinion was confirmed by the fact that the solution when heated acquired a transparent red color.

It appears therefore that in the presence of ammonia, silver has a tendency to oxidize, for when the silver was placed in a vial with an air-tight fitting stopper, filling it about half full, and was then completely filled with liquid ammonia and tightly closed, it was found that in twenty-four hours a mere trace of silver was taken up. On the other hand when the silver was placed in a flat basin and merely moistened with ammonia more silver was taken up in five minutes than in the preceding case in twenty four hours.

This action of ammonia in promoting oxidation recalls its behavior with cobaltous salts and with copper. It is probably the only case in which silver is oxidized (at ordinary temperatures) by atmospheric oxygen.

Action of Dilute Sulphuric Acid.—It is generally held that silver is insoluble in cold dilute sulphuric acid. Almost any form of silver, providing it is finely divided, is slightly soluble in sulphuric acid diluted with four or five times its bulk of water. With more dilute acid different varieties of silver act very differently. The most easily attacked is that which is obtained by reducing the oxide with alkaline hydroxide and milk sugar; from this a distinct trace is dissolved by sulphuric acid diluted with 100 times its bulk of water. From silver reduced from the chloride by cadmium this very dilute acid takes up nothing.

Nitric acid, sp. gr. 1·40, diluted to ten volumes and allowed to stand for an hour with finely divided silver, took up an extremely faint trace.

Hydrochloric acid, sp. gr. 1·20, was totally without action. The silver after being well boiled with water to remove every trace of acid, dissolves completely in nitric acid.

Acetic acid has no action upon metallic silver.

Various Reactions of Normal Silver.

Normal metallic silver even in a state of very fine division does not abstract the slightest trace of nitric acid from perfectly neutral cupric nitrate obtained by acting on pure cupric sulphate with barium nitrate. After fifteen hours of contact not a trace of silver had been dissolved.

But silver easily reduces cupric chloride with formation of purple photochloride. If the copper salt is present in slight excess the silver is so thoroughly acted upon that nitric acid does not extract a trace of it from the purple photochloride.

Metallic mercury instantly reduces silver nitrate but metallic silver takes chlorine from corrosive sublimate. The precipitate contains calomel and blackens with ammonia.

Silver in fine division slowly reduces a neutral solution of potassium permanganate.

Silver nitrate, as is well known, is reduced by ferrous sulphate, or ammonia ferrous sulphate, the iron at the same time becoming peroxidized and the silver assuming the gray metallic form. On the other hand silver powder rapidly reduces a neutral solution of ferric sulphate. A solution of iron alum readily dissolves metallic silver without the aid of heat;* in a few seconds the solution strikes a blue color with potassium

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* The statement in the new Encyclopédie Chimique that heat is required and that the metal separates again on cooling (Tome iii, cahier 15, p. 248) appears to be incorrect.

ferricyanide and if the iron alum is in excess the whole of the silver is dissolved. It has been before noticed that the reactions between silver salts on the one hand and iron salts on the other are to some extent reversible, the observations just described place the matter in a somewhat clearer light. With a view of ascertaining whether ferrous sulphate could be completely oxidized by argentic oxide a portion of the ferrous solution was treated with successive portions of the oxide until the latter was no longer affected by it. But when this stage was reached the solution no longer contained a trace of iron, the whole of it had entered into combination with the silver. This combination is perfectly black and may probably have consisted of the compound described by H. Rose, as Ag_4O, $2FeO$ Fe_2O_3 and obtained in the same way.

When ammonia iron alum is placed in contact with finely divided silver in considerable excess in a tightly closed vial the solution after a few days standing with frequent shaking acquires a deep red color. This may last for a week or more. The solution then decolorizes and becomes greenish but still contains abundance of ferric salt. Thus it appears that although silver has a powerful reducing action on ferric salts the action is self-limited and ceases long before complete reduction is effected for after many weeks contact in a closed vial there are abundant indications of the presence of ferric salt, although silver has been present in large excess.

ART. LVII.—*Notes on Silver Chlorides;* by M. CAREY LEA.

EXPERIMENTS made by J. J. Acworth* at the suggestion of E. Wiedeman showed that by heating silver chloride to a temperature of 220° C. it passes into a modification that was insensitive to light.

I think this change may be due to the complete driving off of moisture. Abney showed by a well-known experiment that silver chloride when exposed perfectly dry in vacuo in a glass tube was totally unaffected by light, but I have shown that fused silver chloride poured into petroleum and placed in the sun-light without removing it from the liquid, was instantly darkened.

These three experiments taken together lead to the following conclusions:

1. Silver chloride dry and perfectly isolated is insensitive to light. (Abney's experiment.)

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* Wied. Referate, 1890, p. 518.

2. The presence of atmospheric air does not restore the sensitiveness, if the silver chloride has been absolutely dehydrated at 220° C. (Acworth's experiment.)

3. The presence of oxygen is not necessary or important for the darkening of silver chloride. The presence of moisture is not essential; its place may be taken by another substance capable of taking up chlorine. This follows from my experiment above mentioned.

There is no doubt that silver chloride retains the last portion of water with great obstinacy. I have frequently tried to dry silver chloride in hot air so that it should lose nothing further by fusion, but never quite succeeded. There is always a loss which may be roughly taken at a half a milligram and from thence upwards to nearly one milligram, in a gram. When the water is thoroughly driven off it is probable that the silver chloride is left in an insensitive condition. Acworth's experiments seem to show this.

So long as moisture is present the molecule of silver chloride easily breaks up, not merely by the action of light but by the application of any form of energy. The part played by moisture in chlorine reactions is somewhat remarkable. It has been lately stated that absolutely dry chlorine has no action upon copper foil. As soon as a trace of moisture is introduced, energetic action sets in.

ART. LVIII.—*A remarkable Fauna at the Base of the Burlington Limestone in Northeastern Missouri*;[*] by CHARLES ROLLIN KEYES.

IN the description of a certain gasteropod (*Porcellia nodosa* Hall), in the third volume of the Illinois Geological Survey[†] occurs the following paragraph, in connection with the assigned horizon and locality: "Lower Carboniferous; Barry, Pike county, Illinois; from a peculiar cherty, calcareous band at the base of the Burlington limestone, formerly supposed to belong to that rock, but now known to contain fossils characterizing the oolitic upper bed of the Kinderhook group, at Burlington, Iowa."

This allusion though merely incidental is the only direct one ever known to be made to the particular beds now under consideration.

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[*] Published by permission of Mr. Arthur Winslow, Director of the Geological Survey of Missouri, from work prosecuted during the years 1891–92.

[†] Geol. Surv. Illinois, vol. iii, p. 459. (1868).

At Louisiana, in Pike County, Missouri, which is separated from Pike County, Illinois, only by the Mississippi River, the "white chert" beds are much better developed than any where else in the region. It is from the Missouri locality that the recent collections have been made. Here the Burlington limestone is well exposed in the hilltops, where extensive quarries have been opened.

For more than 70 miles, from above Quincy to below Louisiana, the Burlington limestone forms an almost continuous mural escarpment capping the high bluffs on either side of the Mississippi River. These bluffs rise to a height of from 300 to 400 feet above the water level. In many places they form bold, overhanging cliffs, with a heavy talus at the base.

A vertical section of the rocks at Louisiana is as follows:

		Feet.
16.	Brown and white, compact, encrinital limestone, thinly bedded, with some chert	75
15.	White, encrinital limestone, very heavily bedded,	12
14.	Coarse-grained, encrinital limestone, with irregular chert bands	20
13.	Very heavily bedded, white encrinital limestone, with a peculiar white chert in nodules and irregular bands	11
12.	Brown, encrinital limestone, compact and heavily bedded, somewhat earthy in places	15
11.	Compact, fine-grained, buff limestone, with few or no partings	15
10.	Sandy shales, brownish, forming soft, friable sandstone locally	12
9.	Greenish, clayey shales	70
8.	Thin-bedded, compact limestone, fine-grained, with conchoidal fracture, in layers 4 to 6 inches in thickness, like lithographic stone in texture and appearance	50
7.	Sandy clay-shale	3 inches.
6.	Drab or greenish clayey shale	2
5.	Black, fissile clay-shale	4
4.	Buff, magnesian limestone, very heavily bedded	10
3.	Compact, white oolite	5
2.	Blue clay-shale, with thin bands of impure limestone rich in fossils	60
1.	Heavily bedded limestone, exposed	5

Number 1 is the Trenton limestone; 2 the Hudson River shales. 3 and 4 probably represent the Niagara limestone; the first increasing rapidly in thickness southward and in a distance of 20 miles reaches a vertical measurement of 30 to 40 feet. 5 and 6 are probably Devonian, equivalent to the "black shale" of adjoining States. Number 7 is a thin seam 2 to 4 inches in thickness and highly fossiliferous. With few exceptions the "Lithographic" fossils come from this layer. It probably belongs more properly with beds 5 to 6. Apparently the organic remains are nearly all identical with forms from the Hamilton rocks farther northward. Should the union of this thin, highly fossiliferous seam to the underlying shales be more in harmony with the real relation of the faunas of the respective beds, as now seems likely, than with the faunas above, it would remove to a great extent the present Devonian facies from the Lithographic (Louisiana) limestone. 8 is the Louisiana limestone, a compact rather thinly bedded rock, breaking with a conchoidal fracture. It is very poor in fossils. Numbers 9 and 10 are the Hannibal shales. 11, the Chouteau limestone, with a few fossils. Number 12 is the Burlington limestone with the characteristic basal fauna of the Burlington. 13 is also the lower Burlington, carrying considerable chert and containing the most prolific fauna in the section. 14, 15 and 16 belong to the Burlington limestone ; the upper portion containing the typical fauna distinctive of the upper division.

From Quincy southward the strata rise very gradually, until the Burlington limestone, which appears a few yards above the water level at that place, has an elevation of more than 250 feet above the river, at Louisiana. Below the limestone as will be seen from reference to the section, the beds are principally soft shales, which are eroded much faster than the great thickness of heavy, compact lime-rock overlying. High hills with precipitous slopes are formed. These are capped by the more indurated layers, rising in almost vertical walls from about midway up the elevations. In consequence of this, a peculiar and very striking phase of topography is produced, reminding one very forcibly of the topographical effects in a great driftless area of northeastern Iowa and the adjoining States.

North of Quincy, as already stated, the Burlington rock dips below the water level of the Mississippi and does not appear again until just above Ft. Madison, in Iowa, while at the city of Burlington the base of the limestone is nearly 100 feet above low water-mark. At this place the organic remains have received more attention than anywhere else, while the vertical ranges of the different species have been determined with great accuracy. From this locality, also, the extensive faunas of the Kinderhook were first made known, and many species described.

A third of a century has passed since the investigations of Hall, White, and Winchell brought to light so many interesting forms which characterize the beds immediately below the Burlington limestone. At Burlington, too, the Kinderhook and Burlington formations are sharply contrasted lithologically; while faunally the two horizons are equally well defined.

Passing southward one hundred miles, to Louisiana, Missouri, the same lithological and faunal features are found as at Burlington. These characters are shown for 50 miles along the great river in this vicinity.

In the lower bed of the Burlington limestone (Number 12 of the section) is found the typical and well marked basal fauna of this formation. Many of the species, however, have a somewhat greater vertical range than at the Iowa localities.

Among the most characteristic species of Crinoids to be mentioned are:

Orophocrinus stelliformis (Owen & Shumard).
Cryptoblastus melo (Owen & Shumard).
Granatocrinus projectus (Meek & Worthen).
Rhodocrinus Wachsmuthi Hall.
Rhodocrinus Wortheni Hall.
Agaricocrinus brevis (Hall).
Dorycrinus unicornis (Owen & Shumard).
Dorycrinus subaculeatus (Hall).
Batocrinus aequalis Hall).
Batocrinus longirostris (Hall).
Batocrinus elegans (Hall).
Actinocrinus proboscidialis Hall.
Actinocrinus tenuisculptus McChesney.
Physetocrinus ornatus (Hall).
Steganocrinus sculptus (Hall).
Steganocrinus araneolus Meek & Worthen.
Platycrinus Americanus Owen & Shumard.
Platycrinus Burlingtonensis Owen & Shumard.
Platycrinus discoideus Owen & Shumard.
Platycrinus subspinosus Hall.

The fauna of this bed (about 15 feet in thickness) is primarily a crinoidal one. The above mentioned forms are some of the most important marking the limited horizon. Many other crinoids as well as brachiopods, corals, gasteropods, etc., are mingled; but they range upward into other layers more or less extensively.

Above the basal bed is a slightly thicker member, of an intensely white color (number 13 of the section). It is chiefly encrinital like the other, but in addition contains a larger amount of comminuted shell material derived from molluscan remains. In places the shell fragments predominate, forming a fine shell breccia not unlike the well known coquina rock of Florida; but it is, however, so compact that good specimens of fossils are almost impossible to dislodge. The layers of this bed contain also considerable amounts of chert in small nodules and nodular bands. When first exposed in quarrying these cherts are very compact, translucent, and breaking with a conchoidal fracture. Upon exposure to the weather these flints quickly slacken like quick-lime to a fine intensely white powder. If examined before the process of disintegration has proceeded more than half way the white nodules are found to be charged with fossils, which when taken out cannot be told from plaster-of-paris casts. Before affected by the atmospheric agencies, few or no traces of organic remains can be detected in the cherts. But they actually contain a very extensive assemblage of fossils; and in a perfect state of preservation when collected at the right time. They afford unusual opportunities for both structural and systematic studies; for many of the features commonly not met with are here found beautifully preserved; such as the internal characters of crinoids and brachiopods, and the delicate ornamentation in nearly all groups.

Upon careful comparison of the fossils in the cherts and in the surrounding limestones, so far as is possible in the latter, the fossils are found to be identical to a great extent. Moreover, numerous shells and crinoids are found partly embedded in the chert and partly in the limestone, with a sharp line of separation, showing clearly that the siliceous impregnation had been acquired long after the original deposition of the beds, and was not due to a greater silicity of waters in which the calcareous deposits were made. This is in accordance with observations made elsewhere in the Burlington limestone of other localities.

The faunal aspects of the bed in question (number 13 of the section) are particularly interesting. Some of the more common as well as more important species are enumerated below;

Lingula melie Hall.
Discina Newberryi Hall.
Terebratula Rowleyi Worthen.
Productus arcuatus Hall.
Productus lævicostus White.
Productella Shumardiana (Hall).
Rhynchonella Missouriensis Shumard.
Spirifera peculiaris Shumard.
Strophomena rhomboidalis var.
Allorisma Hannibalensis Shumard.
Edmondia nuptialis Winchell.
Edmondia Burlingtonensis White & Whitfield.
Conochardium sp.?
Lithophagus occidentalis (White & Whitfield.)
Aviculopecten circulus Shumard.

Phanerotinus paradoxus Winchell.
Capulus paralius (White & Whitfield).
Capulus formosus (Keyes).
Porcellia nodosus Hall.
Loxonema prolixa White & Whitfield.
Loxonema sp.?
Spherodoma penguis (Winchell).
Pleurotomaria sp.?
Holopea subconica Winchell.
Murchisonia sp.?
Bellerophon bilabiatus White & Whitfield.
Straparollus ammon (White & Whitfield).
Straparollus luxus ? (White).
Omphalotrochus Springvallensis (White).

The forms in the accompanying list are all species which characterize the Kinderhook of Burlington, Iowa; most of them being originally described from that place. In addition many more species of lamellibranchs, brachiopods and gasteropods occurring very abundantly at the latter locality are found in the white chert of Louisiana along with a few of the Burlington limestone species.

It is to be noted that:

(1) The fauna of this horizon is predominantly molluscan, representing a marked contrast with that of the typical Burlington limestone, which is prevailingly crinoidal, with some brachiopodal forms.

(2) The fauna is the typical one of the Kinderhook beds.

(3) There is mingled with this fauna some of the forms from both above and below, which are thus associated with the species representing the typical lower Burlington limestone.

Here, then, is a well defined Kinderhook fauna intercalated in the Burlington limestone, with practically no change of lithological characters; a lower fauna suddenly appearing in the midst of a higher. This is the most marked instance of the kind that is at present known in the Carboniferous of the Mississippi Valley. Though the time separation is not very great, the present case is a striking illustration of Barrande's celebrated "doctrine of colonies," so clearly developed in the Système Silurien du Centre de la Bohème,* and so ably defended in his "Défense des Colonies."

It is not to be inferred, however, that during the short supremacy of the lower fauna in midst of an upper there was a complete extinction of the deposed forms; but rather that owing to peculiar conditions the lower fauna merely displaced the upper temporarily; or pushed it aside into other districts for the time being.

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* Vol. i, p. 73, (1852.)

ART. LIX.—*Glacial Pot-holes in California;* by H. W. TURNER, of the United States Geological Survey.

IN the cañon of the North Fork of the Mokelumne River, California, about thirty miles a little west of south from Lake Tahoe, and at an elevation above sea level of about 4,500 feet, is a group of pot-holes in the granite. The cañon here was formerly the bed of a glacier, as is evidenced by the polish and grooving of the rock and the perched bowlders. The rock about is quite devoid of soil. The pot-holes are from two to four feet in diameter and some of them are four feet deep. The shape of some of them is nearly conical, others more nearly cylindrical. Most of the pot-holes are eroded vertically, but some of them are inclined. A number are quite shallow, but even these are broad and saucer-shaped. The granite flakes off in shells nearly parallel to its surface, and this would account for the broad form of the pot-holes at the commencement of their formation.

The pot-holes are about 250 in number and from six inches to six feet apart. They seldom or never coalesce and the regularity of their arrangement is noticeable. The interior of all of the holes is well rounded and smooth, as pot-holes usually are. In some of them are rounded fragments of rocks; others are filled with sand and gravel. They cover a gently inclined surface of about two thousand square feet. To the north is a glaciated bank of granite, and the pot-holes occupy about the position that would be expected if formed by water falling over this bank. The height of the bank above the pot-holes is approximately forty feet. One pot-hole exists in the side of this bank several feet above its base.

The river at the present time runs at a level of perhaps twenty or thirty feet below the lowest pot-holes. The place is locally known as Ham's Salt Springs. Salt water oozes out from crevices in the rock and collects in several of the lower pot-holes. By evaporation, salt (NaCl) crystallizes out so that the water is usually covered with a thick layer of very pretty hopper-shaped crystals.

The Indians are said to have formerly congregated here, attracted no doubt by the salt springs. Numerous small arrow-heads, chiefly of jasper and obsidian, were found by my party a little west of the pot-holes. At a point on the bare granite below the pot-holes and very near the river are several small mortar holes such as are used by the Indians to grind up acorns, and which are frequently found in bare rocks in the Sierra Nevada.

At the time of my visit an old white man named Carlton was camped there with some Indians. He has been living with the Indians in the neighborhood of the Mokelumne River since 1851. He states that these pot-holes were made by the Indians for the purpose of collecting the salt water, in order to allow the salt to crystallize from it. On questioning him I could not make out that he himself had known of any such holes being excavated by the Indians. It would not, however, be a very difficult matter for the Indians to have made them. If a fire is built on the granite it flakes off very readily, and by repeating this operation for some time and using utensils in addition, cavities could be made. Mr. W. Q. Mason, of Volcano, California, who guided my party to the spot, believes the pot-holes to be the work of Indians.

Plate IX represents a partial view of the pot-holes above described. The salt water at present oozes out at a point which may be located in the plate as about one-half inch from the middle of the left-hand side. It therefore runs only into some of the lower holes not represented in the picture.

On a granite spur just south of the pot-holes and perhaps 100 feet vertically above them is a little lake, partially filled with flags and tules. It has no outlet, but when the water is high it can readily escape at its west end. The water is brackish. Some salt water must therefore have a higher source than that above indicated; and it is possible that salt water formerly flowed from crevices at points above the pot-holes and may have filled more of them than it does at present.

The fact that few or none of the pot-holes coalesce perhaps favors the theory that they were made by the Indians, since in nature, pot-holes near one another frequently coalesce. The pot-hole, above described, in the side of the granite bank is evidently the work of falling water. It seems most likely that all the pot-holes were formed by the action of water, probably in some way connected with the glacier that formerly filled the cañon.

In this connection the reader is referred to an article by T. T. Bouvé* who describes some glacial pot-holes near Cohasset, Mass., and to Brögger and Reusch† who have studied those of Norway where pot-holes are numerous.

It is interesting to note that in Norway they were at one time considered the work of the giants supposed once to inhabit that region, and that in America they are ascribed to the aboriginal Indians.

Washington, D. C., September 5, 1892.

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* Indian pot-holes or giants' kettles of foreign writers, Proc. Boston Soc. Nat. Hist., vol. xxiv, pp. 218–226.

† Giants' kettles at Christiana, Quart. Jour. Geol. Soc., vol. xxx, pp. 750–771.

Art. LX.—*The Lavas of Mount Ingalls, California;* by H. W. Turner, Washington, D. C.

[By permission of the Director of the U. S. Geological Survey.]

Mount Ingalls is situated just south of the fortieth parallel in Plumas county, California. It forms a portion of the eastern crest of the Sierra Nevada. Its elevation is 8,484 feet above sea level, according to the determinations of the topographers of the U. S. Geological Survey.

Mount Ingalls was a center of volcanic activity during much of later Tertiary time. The lavas which originated in its vicinity form an interesting series. The following rocks are represented:

I. *Late basalt*, a rather coarse gray rock with much pyroxene and some olivine. It is usually massive.

II. *Andesite*, containing both pyroxene and hornblende, and occurring chiefly as a breccia.

III. *Older basalt*, a dense black rock with little olivine, and a good deal of magnetite. It seems always massive.

IV. *Rhyolite*, in very small amount.

The order of succession is that indicated by the Roman numerals with the exception of rhyolite (IV.) As has been previously noted* the rhyolite of the Sierra Nevada underlies the andesites, but its relation to the older basalt (III) is undetermined. The rocks may be roughly characterized as follows:

I. *Late basalt.*—This is macroscopically a coarse to medium grained light gray rock, sometimes pinkish, with large scattered olivines. Under the microscope it is seen to be nearly holocrystalline and to be composed of lath-like plagioclase, augite and magnetite, with occasional large olivines. One of the slides shows a hypocrystalline glassy base containing abundant grains of magnetite, with numerous phenocrysts of plagioclase and augite, and a few hypersthenes and olivines. In general, however, very little glass is to be seen.

The late basalt is the most recent of the lavas of this portion of the Sierra Nevada. It forms the summit and nearly all of the sides of Mount Ingalls down to and in places below the 7,000 foot contour. It rests, to a large extent, on andesitic breccia. Similar basalt caps a number of the higher points to the south and southwest of Mount Ingalls. Two of these are Mount Jackson and Penman Peak. There also the basalt rests on andesite. The later basalt is almost everywhere a massive

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*Mohawk Lake Beds, Bull. Wash. Phil. Soc., vol. xi, p. 389.

rock, but a small amount of basalt-breccia and scoriaceous basalt forms two points on the summit of Mount Ingalls, perhaps remains of a former crater. In the ravine that heads just east of the summit of Mount Ingalls the basalt is glaciated. Its age, therefore, antedates that of the glaciers of the Sierra Nevada.

II. *Andesite.*—This is chiefly a breccia. The angular fragments of andesite from this breccia are usually coarsely crystalline and frequently vesicular. The color is dark gray, the feldspars showing as white spots. Frequently hornblende needles are macroscopically visible.

Under the microscope the andesite is composed of phenocrysts of plagioclase and pyroxene and of occasional hornblendes in a groundmass sometimes very glassy, sometimes hypocrystalline with abundant plagioclase microlites and usually considerable magnetite. The pyroxene in some cases is largely augite; but there is frequently a good deal of hypersthene. Sometimes the rock is nearly holocrystalline. In some dark compact specimens of the andesite hypersthene is the most abundant bisilicate, but the prevailing type is the coarser one above described, and usually the predominant bisilicates are augite and hornblende.

Andesitic breccia forms most of the ridge that extends southeasterly from Mount Ingalls. The same area continues to the north of Red Clover Valley.

III. *Older basalt.*—This is a dense black rock usually showing macroscopically no porphyritic constituents except occasional olivines. It is frequently roughly columnar, the prisms being small, seldom more than three or four inches in diameter. The rock has been nowhere seen by the writer except in the massive form.

Microscopically the rock is composed of lath-like plagioclase with more or less olivine and some augite in a groundmass which is rendered dark by the abundant magnetite. The groundmass sometimes contains considerable glass and frequently specks and minute prisms of augite. Much of the olivine is altered to serpentine. The plagioclases are usually small and of nearly even size. One slide, however, shows porphyritic plagioclases and olivines in a groundmass of plagioclase microlites, magnetite and glass.

The older basalt forms an area of several square miles to the east of Mount Ingalls and west of Red Clover Valley. There is a smaller area at the southwest base of Mount Ingalls east of Little Grizzly Greek, and also another just southwest of the last and on the west side of Little Grizzly Creek. It is the lava of Walker Plains, in Plumas county, and of Mooreville Ridge and Oroville Table Mountain, and the Iron Cañon of Chico Creek in Butte county. So far as I am aware, this dense black older basalt is found only in Plumas and Butte counties. At numerous points it rests on Tertiary sediments, chiefly river gravels. It has nowhere been seen by the writer overlying or cutting through other Tertiary lavas. Its relation to the andesite (II) is very evident about four miles east-southeast of Mount Ingalls on the ridge to the east of the road from Red Clover Valley to Genesee Valley. Here a nearly horizontal bluff of andesite above five hundred feet vertically above the road may be seen resting on the older basalt (III). A vertical section here would be approximately as follows:

1. Andesitic breccia, thirty feet in thickness. This is made up of angular fragments of andesite cemented by volcanic ash. It shows no evidence of stratification. A little to the east of the bluff, lying on this breccia and presumably weathered from it, were found fragments of silicified wood.
2. Fine even-grained andesitic tuff, one to four feet thick. The tuff layer is approximately horizontal. It is made up of minute fragments of plagioclase, augite, hypersthene, green hornblende, and apparently some quartz, with opaque and discolored particles. It is very plainly fragmental. It contains also fragments of plant stems.
3. Andesitic conglomerate, fifteen feet thick. Immediately under the tuff and plainly resting on the older basalt is a volcanic conglomerate containing some fragments of the older basalt as well as granite pebbles but chiefly made up of pebbles and fragments of andesite.
4. Older basalt, five hundred feet thick. This reaches from the bluff of the above fragmental materials 1, 2, and 3, down to Red Clover Creek below, a vertical distance of about five hundred feet.

To the observer it is very manifest at this locality that the above series of volcanic fragmental rocks are of later date than the underlying basalt. The great thickness and extent of the basalt and the thinness of the overlying andesite renders it extremely unlikely that it is an intruded sheet. Moreover, the same superposition of the andesite on the older basalt may be noted at other points, as for example, at the southwest base of Mount Ingalls, at Iron Cañon in Butte county, and on the ridges to the north and south of Onion Valley Creek, in Plumas county. It is most probable that a period of erosion occurred between the time of the older basalt flows and that of the andesitic eruptions.

IV. *Rhyolite.*—A small area of this rock was noted four miles to the southeast of Mount Ingalls, to the west of Red Clover Valley. The exposure is surrounded by andesitic breccia. Wherever in the Sierra Nevada its relation to the andesite is evident, it is the older rock. The relative age of the rhyolite and the older basalt has not been made out. I have nowhere seen them in juxtaposition.

It is expected that the above rocks will be studied in more detail later, with the aid of chemical analyses, so that their exact position in the series of Tertiary lavas may be determined. The subject is of especial interest in relation to Richthofen's law of succession of volcanic rocks, to which this forms an apparent exception.

The subject of the succession of the igneous rocks of the Great Basin has been considered in detail by Hague in the forthcoming monograph of the U. S. Geological Survey on the Eureka District, Nevada, and by Iddings* who states that igneous rocks of a mean composition are usually followed by both highly basic and highly acid types.

The Tertiary lavas of Mount Ingalls rest on a base of much older rocks, schists, metamorphic tuffs and granite. The latter rock is of igneous origin, as is shown by the inclusions in it of the older clastic rocks which are here in part at least, of Carboniferous age. These inclusions are numerous at a point on the southwest slope of the mountain, three miles from the summit.

Since writing the above, the following analyses have been obtained :

	Older basalt (No. 276.)	Late basalt (No. 311.)
SiO_2	50·56	53·91
TiO_2	1·71	·52
Al_2O_3	14·71	17·95
Fe_2O_3	3·54	2·21
FeO	8·90	4·80
MnO	·13	·10
CaO	7·58	10·40
SrO	trace ?	trace.
BaO	·25	·05
MgO	4·07	5·52
K_2O	2·10	1·34
N_2O	2·94	2·90
Li_2O	trace ?	trace.
H_2O at 100° C.	1·06	·20
H_2O above 100 C.	1·12	·20
P_2O_5	1·14	·21
	99·81	100·31

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* "The Origin of Igneous Rocks," by J. P. Iddings, Bull. Phil. Soc. Washington, vol. xii, pp. 89–214.

The analyses were made by W. F. Hillebrand of the U. S. Geological Survey. It will be noted that the two basalts, so different in age and in habitus, are quite similar in composition. As would be expected in the dense black older basalt containing a large amount of magnetite, the iron contents are much greater than in the coarse-grained gray basalt of later age.

Washington, D. C., Sept. 9, 1892.

Art. LXI.—*A Method for the Quantitative Separation of Barium from Strontium by the action of Amyl Alcohol on the Bromides;* by Philip E. Browning.

[Contributions from the Kent Chemical Laboratory of Yale College—XIX.]

The existing methods upon which dependence can be made in the separation of barium from strontium are few in number. Dr. R. Fresenius in discussing them through several numbers of his journal* concludes that the only one which gives perfectly reliable results consists of the precipitation of the barium by a double treatment with ammonium chromate in acetic acid solution. Having demonstrated the possibility of separating both barium and strontium from calcium by the dehydrating and appropriate solvent action of boiling amyl alcohol on the nitrates† the possibility of a similar method of separation by the use of suitable salts of barium and strontium seemed worthy of investigation and necessary to complete the series as applied to this group. In looking about for suitable salts upon which to experiment the behavior of the chlorides was suggestive. Barium chloride is completely insoluble in amyl alcohol while the corresponding strontium salt is somewhat soluble. The possibility of finding strontium bromide more readily soluble than the corresponding chloride seemed worthy of attention. The method of preparation followed was the treatment of the precipitated and thoroughly washed carbonates of barium and strontium with hydrobromic acid prepared‡ by mixing definite proportions of potassium bromide in solutions with sulphuric acid and water while hot, filtering off the potassium sulphate which separates on cooling, and redistilling the filtrate until the distillate contains no appreciable trace of sulphuric acid. The standards of the solutions of barium and strontium bromides made in this way were determined by precipitating definite portions, measured and weighed, with sulphuric acid,—the strontium after the accepted method of adding ethyl alcohol to increase the insolubility and the

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*Zeitschrift für Anal. Chem., xxix, 20, 143, 413.

†This Journal, xliii, 50, 314.

‡Proceedings Amer. Acad., xvii, 30.

barium after the manner suggested by Dr. F. W. Mar,* precipitating with an excess of sulphuric acid in the presence of hydrochloric acid. The mean of closely agreeing results was taken as the standard. Preliminary experiments on the bromides formed in this way gave encouraging results, the barium salt appearing to be almost completely insoluble while the strontium salt dissolved freely. The first series of experiments were directed toward a quantitative determination of the solubility of barium bromide in the alcohol. Definite portions of the standardized solution of barium bromide were measured from a burette into counterpoised beakers of about 50 cm^3 capacity and weighed as a check on the burette reading. This solution was then evaporated to dryness, and the residue was dissolved in a few drops of water and boiled with 10 cm^3 of amyl alcohol. The separating bromide was filtered off on an asbestos felt contained in a perforated platinum crucible, the whole having been previously ignited and weighed. The crucible containing the bromide was at first dried at 140°–150° C. in an air bath after the manner described in the previous papers, and weighed. The unsuccessful attempt to get a constant weight, however, proved the impossibility of weighing as bromide, the weight decreasing rapidly with each successive drying. It was deemed best accordingly to dissolve the bromide from the felt into a beaker placed to receive it, and to precipitate with sulphuric acid in the presence of hydrochloric acid, after the same manner followed in the determinations of the standards. The precipitated sulphate, which in a few minutes settles completely, was filtered off upon the same felt from which the bromide had been dissolved, dried, ignited to low redness, and weighed. Series I gives the results of several experiments made after this manner which show the solubility of the barium salt to be about 0·0013 grm. on the oxide in 10 cm.^{3} of amyl alcohol. The filtrate after boiling with amyl alcohol was evaporated and the residue was treated with sulphuric acid and weighed; or the filtrate was precipitated directly by adding sulphuric acid, enough ethyl alcohol being added to secure thorough mixture. The amount of sulphate found agreed uniformly with the loss determined in the residue after boiling. A portion of the salt which dissolved in the alcohol on being examined before the spectroscope gave only the green bands characteristic of barium.

SERIES I.

	BaO taken.	BaO found.	Error.
(1)	0·1234 grm.	0·1222 grm.	0·0012— grm.
(2)	0·0824 "	0·0809 "	0·0015—
(3)	0·0823 "	0·0809 "	0·0014—
(4)	0·0818 "	0·0803 "	0·0015—
(5)	0·0733 "	0·0720 "	0·0013—

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* This Journal, xli, 288.

Several methods of treatment were followed to prevent if possible this solubility, such as the addition of a few drops of hydrobromic acid before boiling, of the same after the barium bromide had separated, of a few drops of ethylene dibromide or ethyl bromide at the completion of the boiling, of a few drops of bromine water before boiling, etc. The results of these experiments showed these modifications to be of little or no value.

On boiling the strontium bromide with the alcohol slight spots separated occasionally, which on the addition of a drop of hydrobromic acid went into solution and did not appear on re-boiling. In order to determine the solubility of the strontium bromide in the alcohol a saturated solution was obtained by boiling an excess of the strontium salt with the alcohol, the salt in a measured portion of 10 cm^3 was precipitated as sulphate by the addition of ethyl alcohol, and sulphuric acid, and weighed. Duplicate determination showed the solubility to be about 0·2 gram on the oxide in 10 cm^3 of the alcohol. The mode of procedure for the separation of these elements was identical with that already described in the case of barium alone up to the point at which the barium was filtered off, except, of course, the addition at first of a measured and weighed amount of a previously standardized solution of strontium bromide. The strontium was precipitated from the filtrate as sulphate by dilute sulphuric acid, ethyl alcohol being added to secure thorough mixture. These precipitates were generally filtered off upon asbestos felts, and, although their gelatinous character delayed the filtration somewhat, the drying and burning of a filter paper with the possible danger of loss by reduction in the presence of burning paper was avoided. Series II gives the results of a single treatment, and it will be seen that there is apparently a slight contamination of the barium by the strontium which where the latter is present in large quantities balances the solubility of the barium (0·0013 grm. on the oxide.) Where the amounts of strontium taken are small the loss of barium due to solubility appears.

SERIES II.

	BaO taken. grm.	BaO found. grm.	Error. grm.	SrO taken. grm.	SrO found. grm.	Error. grm.
(1)	0·1228	0·1225	0·0003 −	0·1070	0·1065	0·0005 −
(2)	0·1227	0·1231	0·0004 +	0·1074	0·1069	0·0005 −
(3)	0·1224	0·1228	0·0004 +	0·1070	0·1067	0·0003 −
(4)	0·1217	0·1201	0·0016 −	0·0364	0·0372	0·0008 +
(5)	0·1216	0·1222	0·0006 +	0·0133	0·1124	0·0009 −
(6)	0·0974	0·0970	0·0004 −	0·0719	0·0721	0·0002 +
(7)	0·0971	0·0973	0·0002 +	0·0730	0·0727	0·0003 −
(8)	0·0970	0·0971	0·0001 +	0·0718	0·0716	0·0002 −
(9)	0·0411	0·0390	0·0021 −	0·0365	0·0385	0·0020 +
(10)	0·0243	0·0234	0·0009 −	0·1072	0·1072	0·0000

Series III gives the result of a double treatment. In this series the contaminating effect of the strontium salt disappears almost entirely leaving a deficiency of about 0·0025 grm. on the oxide to be added to the barium, and a corresponding amount of sulphate (0·0040 grm.) to be subtracted from the strontium sulphate before calculating it to the condition of the oxide. The manipulation is the same as that outlined for the single treatment, as far as the completion of the first boiling. At this point the amyl alcohol containing most of the strontium in solution was decanted upon a weighed and ignited felt and collected in a beaker placed to receive it. The residue of barium with traces of strontium was then dissolved in a few drops of water, a drop of hydrobromic acid was added and the boiling was repeated with another portion of 10 cm^3 of amyl alcohol. Upon reaching the boiling point of the alcohol the beaker was removed, and the barium salt was filtered upon the felt through which the first portion had been decanted, and treated as before described.

Series III.

	BaO taken. grm.	BaO found. (Corrected.) grm.	Error. grm.	SrO taken. grm.	SrO found. (Corrected.) grm.	Error. grm.
(1)	0·1212	0·1219	0·0007 +	0·1068	0·1071	0·0003 +
(2)	0·1215	0·1219	0·0004 +	0·0358	0·0359	0·0001 +
(3)	0·1220	0·1221	0·0001 +	0·0353	0·0347	0·0006 –
(4)	0·1212	0·1220	0·0008 +	0·0363	0·0358	0·0005 –
(5)	0·1219	0·1221	0·0002 +	0·0361	0·0354	0·0007 –
(6)	0·1211	0·1218	0·0007 +	0·1126	0·1116	0·0010 –
(7)	0·1319	0·1319	0·0000	0·0577	0·0586	0·0009 +
(8)	0·0496	0·0492	0·0004 –	0·0574	0·0579	0·0005 +

The method is rapid, and while the correction to be applied owing to the solubility of the barium salt is large it is so definite that it cannot be objectionable. The author in conclusion would express his indebtedness to Prof. F. A. Gooch of the Kent Laboratory for the many helpful suggestions received from him bearing upon this investigation.

Art. LXII.—*A Note on the method for the Quantitative Separation of Strontium from Calcium by the action of Amyl Alcohol on the Nitrates;* by Philip E. Browning.

[Contributions from the Kent Chemical Laboratory of Yale College—XX.]

Recent work on my method for the quantitative separation of strontium from calcium by the action of amyl alcohol on the nitrates* has demonstrated the possibility of using very much smaller amounts of amyl alcohol in the boiling than the amounts formerly used (30 cm^3 for each treatment). By the use of smaller beakers (50 cm^3 capacity) 10 cm^3 of the alcohol can be conveniently substituted for 30 cm^3, and the correction for solubility of the strontium nitrate is thus reduced from 0·001 grm. on the oxide to 0·0003 grm. in each treatment, and the corresponding amount of sulphate to be substracted from the calcium sulphate before calculating to the condition of oxide is reduced from 0·0017 grm. to 0·0005 grm. in each treatment. The necessity of a double treatment, or the use of two portions of 10 cm^3 each of the alcohol, brings the total correction to 0·0006 grm. on the strontium oxide, and 0·0010 on the calcium as sulphate. For ordinary work such a correction may be disregarded. The following tables give the corrected and uncorrected results.

TABLE I (correction disregarded).

	SrO taken. grm.	SrO found. grm.	Error. grm.	CaO taken. grm.	CaO found. grm.	Error. grm.
(1)	0·0570	0·0565	0·0005 −	0·0534	0·0540	0·0006 +
(2)	0·0573	0·0567	0·0006 −	0·0534	0·0543	0·0009 +
(3)	0·0285	0·0274	0·0011 −	0·0272	0·0276	0·0004 +
(4)	0·0568	0·0560	0·0008 −	0·0535	0·0537	0·0002 +
(5)	0·0568	0·0561	0·0007 −	0·0533	0·0535	0·0002 +
(6)	0·0288	0·0280	0·0008 −	0·0271	0·0272	0·0001 +
(7)	0·1420	0·1416	0·0004 −	0·0535	0·0544	0·0009 +
(8)	0·1419	0·1416	0·0003 −	0·0665	0·0669	0·0004 +
(9)	0·1135	0·1132	0·0003 −	0·1066	0·1070	0·0004 +
(10)	0·1137	0·1126	0·0011 −	0·1064	0·1070	0·0006 +

TABLE II (correction applied).

	SrO taken. grm.	SrO found. (Corrected.) grm.	Error. grm.	CaO taken. grm.	CaO found. (Corrected.) grm.	Error. grm.
(1)	0·0570	0·0571	0·0001 +	0·0534	0·0536	0·0002 +
(2)	0·0573	0·0573	0·0000	0·0534	0·0539	0·0005 +
(3)	0·0285	0·0280	0·0005 −	0·0272	0·0272	0·0000
(4)	0·0568	0·0566	0·0002 −	0·0535	0·0533	0·0002 −
(5)	0·0568	0·0567	0·0001 −	0·0533	0·0531	0·0002 −
(6)	0·0288	0·0286	0·0002 −	0·0271	0·0268	0·0003 −
(7)	0·1420	0·1422	0·0002 +	0·0535	0·0540	0·0005 +
(8)	0·1419	0·1422	0·0003 +	0·0665	0·0665	0·0000
(9)	0·1135	0·1138	0·0003 +	0·1066	0·1066	0·0000
(10)	0·1137	0·1132	0·0005 −	0·1064	0·1066	0·0002 +

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* This Journal, xliii, 50.

ART. LXIII.—*A Study of the Formation of the Alloys of Tin and Iron with descriptions of some new Alloys;*[*] by WILLIAM P. HEADDEN.

ABOUT three years ago I had occasion to investigate some tin buttons obtained in assaying tin ore by the potassic cyanide method, and observed that the alloy obtained by oxidizing the buttons with hydric nitrate and treating the oxidized mass with potassic hydrate was not only significant in quantity, ranging from one and a half to ten and a half per cent, but varied in form also, though obtained under similar conditions of charge and temperature. Subsequent investigations convinced me that the same is true of dross obtained by melting larger quantities of tin ore with anthracite dust, lime and fluor spar in a graphite pot. As the latter method yields larger quantities at less expense, the dross from such fusions was used, as a rule, in my investigations.

Of the buttons first investigated, the first yielded about 7 per cent of a non-magnetic alloy corresponding to the formula Fe_2Sn_3; the second yielded a quantity of magnetic alloy corresponding to the formula Fe_4Sn_5; while the third yielded a non-magnetic alloy, so small in quantity, however, that no analysis was attempted, but its form differed from that of the other two, and I had no reason for believing it to be identical with either of them. Its form was that of a six sided prism with etched and pitted basal plane which was seldom perfect though always present. This was probably an imitative form after an orthorhombic combination.

The results of the investigation to which this led may be briefly given as follows: i. e. that there is a series of stannides of iron of which I obtained the following members, $FeSn_2$, Fe_2Sn_3, Fe_3Sn_4, Fe_4Sn_5, Fe_5Sn_6 and FeSn—and in addition to these, the following, Fe_3Sn, Fe_4Sn and Fe_9Sn.

Some of these have been described before, but the descriptions given by the various investigators agree in assigning them properties, some of which differ widely from those observed in my alloys. Those previously described are $FeSn_2$, Noellner; FeSn, Deville and Caron; Fe_3Sn, Lassaigne, and Fe_4Sn, Bergman. The first of these has more recently been studied by A. C. Oudemann, Jr. Noellner says that $FeSn_2$ is insoluble in hydric chloride. While Oudemann makes no definite statement on this point, merely stating that he prefers to use hydric nitrate in separating it from the excessive tin leaving it to be inferred that he found it at least difficultly

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[*] Abstract of article read before Colo. Scientific Society—Address of retiring President for 1891.

soluble in the hydric salt. Deville and Caron describe FeSn as insoluble in hydric chloride and crystallizing in plates. The alloys which I have obtained, giving these formulas, do not agree with these descriptions. All writers on these alloys agree in giving aqua regia as the solvent for them. I have uniformly used hydric chloride and have found but a small amount of any one of them insoluble in this agent, and the portion insoluble in it was almost as insoluble in aqua regia. The description of forms is also quite at variance. This may be due to difference of interpretation of the forms, or it may indicate that these alloys vary greatly, both in form and properties according to the conditions under which they are formed; my observations tend to establish the latter. The compounds Fe_2Sn_3, Fe_3Sn_4. and Fe_4Sn_5 vary in their property of being magnetic, sometimes being almost or quite non-magnetic, and it will require a more exhaustive study of their crystal form to establish any distinctive difference between them in this respect; the habit of the crystals as obtained is, it is true, somewhat different, but it is doubtful whether it is uniform and persistent enough to be relied upon as distinctive. I have recognized but one form with certainty, a rhombic prism, which is the crystal form of the alloy $FeSn_2$. Though some crystals of this form were observed which have not been proven to be this alloy and this form may be common to several alloys. Furthermore certain rough six-sided imitative forms have been observed, which are not characteristic of any one of at least three alloys. These facts indicate as already suggested, that the various observations may not be contradictory because made on material which is not perfectly comparable.

The members of this series are all brittle, so much so that in the form in which they were obtained, they can be rubbed to a powder between the thumb and finger; they all burn, readily and quite brilliantly, when strewn into the flame of a candle or alcohol lamp with the formation of a dense smoke, and the emission of an intense odor of tin, best observed a short distance above the flame. This odor was so intense and similar to that of arsenic that it was with difficulty, and only after repeated experiments, that I convinced myself of the absence of this element.

These alloys require so high a temperature to fuse them that I was able to fuse only small portions of them before the blowpipe, and that not very satisfactorily; whether they suffered decomposition thereby was not evident, but with soda on charcoal they were decomposed with emission of sparks and the separation of malleable tin. Concentrated hydric sulphate acts upon them violently with copious evolution of sulphur dioxide.

That iron and tin readily unite with one another is well known, but the character of the iron and the temperature are important factors. When reduced iron was used the combination ensued quickly and the solution of the iron in the tin was perfect, but when cast iron was used this was not the case; but the presence of the carbon did not prevent the formation of these alloys.

Whether these alloys can endure remelting without decomposition or not was not decisively proven, but the experiments made tend to show that they can be melted by themselves and kept at a temperature sufficient to melt cast iron for an hour without perceptible decomposition, and if melted with tin already saturated with the alloy they may be remelted several times without material change, at least within the limits of temperature under which my experiments were made. While it is evident from my experiments that the frequent remeltings to which the reguluses were subjected had at most only a very subordinate influence in determining the alloy formed, it is equally evident that the influence of the ratio of tin to iron is very great; it appearing to be the determinative condition in the formation of the series from FeSn to $FeSn_2$, but for the alloys Fe_3Sn, Fe_4Sn and Fe_9Sn it would seem that we will have to look for some other condition as the ratio of iron to tin alone will evidently not suffice in explaining their formation.

It is probable that the alloy first formed during the reduction is not that with the highest ratio for the tin, as is indicated by the results of the investigation of the buttons from the cyanid assay which had not been remelted and some of them had been in the fire but eight minutes and still yielded the intermediate members of the series which according to our observations are formed between wide limits in the ratio of tin to iron, and this too when the atomic ratios of the iron to tin in the buttons was such as to justify the expectation of finding an alloy having a higher tin ratio. It is difficult to say in which experiment we approached most nearly to the conditions existing in the original mass of tin but probably in the first in which the regulus resembled pure tin but yielded an alloy having the ratio (Fe : Sn) 1 : 1; in another in which case the fusion was effected at a higher temperature and continued longer the alloy had the ratio of 1 : 1·25; but in this case we had a small amount of a very rich iron alloy with the approximate ratio of 9 : 1 separated from the regulus which might have had some influence upon the ratio of the alloy, especially if this iron alloy is a product of the decomposition of alloys richer in tin which already existed in the mass which, however, I hold to be doubtful. In still another the alloy obtained had the ratio of 1 : 1 and there was a large portion of iron alloy or bottom with the ratio 4 : 1 and in a fourth one the alloy had the ratio of 1 : 1 though the bottom amounted to over 33 per cent of the weight of the regulus. An examination of the ratios of the alloys yielded by the different reguluses shows that the presence of an iron bottom does not necessitate the lowest ratios for the tin; for in such cases we have the ratios 100, 1·20, 1·25, 1·33, and 1·5 nor does its absence indicate the highest ratios; for in such cases we have the same ratios as before,—still, in a general way, those reguluses having an iron bottom yield alloys with lower ratios than those which have none, but the difference is neither decided enough, nor sufficiently constant to justify the conclusion that they are end-products of a series of decompositions, with successive eliminations of tin and consequent enrichment of iron in the alloy. The ratio of the alloy depends upon the ratio of the iron to the tin in the mass rather than upon any possible decomposition.

Some experiments were made with the object of building up the series from the lowest to the highest ratio with the following results. A quantity of dross containing the alloy FeSn was fused with one and a fourth times its weight of bar tin and the principal portion of the resulting alloy had the ratio of 1·25 but further changes also took place as indicated by such ratios as 1·33 and 1·66 obtained for smaller portions of alloys. When the atomic ratio of the iron to tin in the mixture was made as 1 : 6 the ratio of the alloy was changed from 1 : 1 to 1 : 1·33 and the same result was obtained when the tin in the mixture was increased so that the atomic ratio of the Fe : Sn was as 1 : 18. When I used the alloy Fe_4Sn_5 and the atomic ratio of the mixture was made 1 : 25, the ratio of the alloy was changed from 1 : 1·25 to 1 : 1·33; the same result was obtained by using the alloy FeSn and making the atomic ratio of the mixture 1 : 41, i. e. the ratio of the alloy was raised from 1 : 1 to 1 : 1·33; using the same alloy and making the ratio of the mixture 1 : 98 a mixed result was obtained the ratio was raised in part to 1·25 but principally to 2 but when the atomic ratio of the mixture was made 1 : 124 the ratio of the alloy, insoluble in hydric nitrate always understood was raised from 1 : 1 to 1 : 2. Equally satisfactory results were obtained when I used reduced iron "Ferrum reductum," instead of the alloys so long as I observed the ratios in the mixture, showing that the use of the alloy had no influence upon the result of the reaction.

It is evident that the ratio of Fe : Sn in the mixture has a determining influence upon the resulting alloy, also that the limits of this ratio for some of the alloys is quite wide especially for the alloys Fe_3Sn_4 and Fe_4Sn_5 but it seems that the formation of others is confined to narrow limits or peculiar conditions as Fe_2Sn_3 which was found to be the chief alloy in only one instance, i. e., where the atomic ratio of the mixture was 1 : 22 and this is singular; for in other instances where the ratio was 1 : 25 and 1 : 41 respectively an alloy with a lower ratio, i. e. 1·33 was obtained and, moreover, 1 : 22 is the ratio given in Watts's Chemical Dictionary for a definite alloy. The regulus from which I obtained this alloy and having this ratio could not in any sense be considered an individual alloy.

I have not intended to even intimate that the whole of the iron in the reguluses obtained existed in the form of alloys difficultly or insoluble in hydric nitrate; for at least one alloy soluble in this agent and crystallizing in long and wide but thin plates was observed.

The temperature, duration of fusion, and rate of cooling are very subordinate in their influence upon the alloys formed both in regard to their properties and their distribution through the regulus.

The only alloy whose form could be definitely made out was the alloy $FeSn_2$ which crystallizes in bright shining rhombic prisms, being combinations of 001, 110, 010, from brownish black to black in color with metallic luster.

Another form is a six-sided often furrowed, almost always, if not always hollow form. This form is very interesting but not characteristic as it is common to several compounds.

The terms iron alloy and iron bottom have been used to designate a hard, gray and strongly magnetic mass forming the lower part of some of the reguluses and amounting in one case to rather more than one-third of the same by weight. My analyses of these contain two errors which being in opposite directions about neutralize each other, only one of them, however, affects the ratio of the iron to tin when these are calculated to one hundred, i. e. the carbon which seriously impairs the value of the ratios obtained and it is no matter for surprise that only one of the analyses gives even an approximate ratio; the fact that the material analyzed had to be used just as it was taken from the crucible may account for this in part but it is a question whether these bottoms are other than gray cast iron alloyed with or containing varying quantities of tin. My experiments seem to prove that their formation does not depend upon the presence of a large quantity of iron, i. e. that they are not products of dissociation, but that the presence of carbon is absolutely necessary to their formation.

These compounds, which I have classed with the tin compounds despite this degree of uncertainty as to their true nature, demand our attention and awaken our interest even if they are related to cast iron, for they have been found to collect other compounds still to be described.

State School of Mines, Rapid City, S. D.

ART. LXIV.—*Notes on the Cambrian Rocks of Pennsylvania and Maryland, from the Susquehanna to the Potomac;* by CHARLES D. WALCOTT.

[Read before the Philosophical Society of Washington, Oct. 29, 1892.]

THE special study of the Cambrian rocks of the Southern Appalachians* was limited during the past field season to an examination of some of the more important exposures of the group in central Pennsylvania and Maryland. Within this area between the Susquehanna and the Potomac rivers two points have been the subject of investigation by geologists, and decided differences of opinion exist in regard to the stratigraphy and the geological age of the rocks embraced within them. One is that of South Mountain as it occurs in Franklin, Cumberland, York and Adams counties, in Pennsylvania. The second is the area about Harper's Ferry, Virginia. After an examination of the published literature, including geological sections and maps, it was decided to begin work in York county on the Susquehanna and to extend it southwest to the Potomac. Prior to this three days were spent at Mount Holly Springs, in the northwestern part of South Mountain, in a preliminary examination of the quartzites exposed at that point. The discovery of the lower Cambrian or Olenellus fauna in a synclinal trough near the western foot of the mountain, gave an important datum point which was afterwards of great service in work to the south in Franklin county.

York County.

Dr. Persifor Frazer considers the Lancaster limestones as probably the equivalent of the Calciferous and Trenton limestones of the New York series, and mentions that the York limestone is a slender offshoot.† The Hellam quartzite of York is called the "Chikis" quartzite, and is described as a basal formation upon which a series of schists occur that to the south "are, at all events, those slates in which the iron ores of Lancaster and York are invariably found, the transition series between the Primal and Auroral."‡ Professor Lesley describes in his final report§ the "Chiques" sandstone as the same formation as the Hellam quartzite of York county (as

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* Notes on the Cambrian rocks of Virginia and the Southern Appalachians, this Journal, vol. xliv, 1892, pp. 52–57.

† 2d Geol. Survey of Penn. Report of Progress in 1877. Geology of Lancaster County, 1880, p. 4.

‡ Loc. cit., p. 7.

§ Geol. Survey of Penn. Summary Description of the Geology of Penn., vol. i, 1892, p. 165.

named by Frazer) and equivalent to the upper Cambrian quartzite of Walcott. He prefers to use the older name "Chiques" for these sandstones, stating that it is best to get rid of the old name "Potsdam" sandstone, as there does not seem to be any satisfactory evidence that the proper Potsdam sandstones of the Canada line and Lake Champlain extended as far south as southern Pennsylvania. He says that the section at "Chiques Rock" is not quite comprehensible at one or two points. I found that it was so complicated by thrust faulting that it is not a typical section. It exposes, however, the lowest of the Cambrian rocks now known to me in central Pennsylvania. The "Chiques Rock" proper, near Chiques, is the Scolithus quartzite, and is in an unbroken section at the summit of the series of the quartzites and slates of the Chiques section although now apparently at the base of the section. The quartzites to the south, between "Chiques Rock" and the limestones at Columbia, are older and have been raised up from beneath and thrust over on the Scolithus quartzite at "Chiques Rock." This is determined by the succession shown in the section exposed on the flanks of South Mountain, in Franklin county west of Monterey, reference to which is made in the notes on the geology of South Mountain. In relation to the stratigraphic position of the slates, etc., beneath the Lancaster limestone, I will quote the statement of Professor Lesley, "The geographical proof that the slates *overlie* the quartzite is complete; and establishes the correctness of Professor Rogers' *Upper Primal slate* formation. The geological evidence is equally conclusive; for the general dip in the Chiques rock is southward, under the slates; and of the slates southward under the limestone."*

The continuation of "Chiques Rock" to the westward, in York county, forms the Hellam hills † and shows a broad anticlinal of quartzite surrounded by schists. Numerous sections along the southern and western sides of the Hellam hills show that the quartzites pass beneath a series of shales, slates, sandy and calcareous layers that, in turn, pass beneath the limestones of the valley.

It was my good fortune to have the acquaintance of Prof. A. Wanner, superintendent of public schools at York. He volunteered to be my guide to localities where there were good exposures of the quartzites, schists and limestones, and he gave me valuable assistance. A reconnaissance was first made of the section at "Chiques Rock" south to Colum-

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* Loc. cit., p. 172.

† I did not learn of any local name for this ridge of hills when in York county, and as most of the ridge is within the township of Hellam I shall speak of them as the Hellam hills.

bia, and then on the western side of the river from Wrightsville north to the quartzites. On the western side of the river the section appeared to be unbroken from the Hellam hills to Wrightsville, and to be as represented by Dr. Frazer* in his section along the right bank of the Susquehanna. In this the succession is from a quartzite (1) to shales (2) and to limestone (3), the latter in Wrightsville, at the Columbia bridge; the sandy shales and argillites (2) pass conformably beneath the massive limestone (3) which forms a deep synclinal fold before being cut off to the south by a fault.

The second section examined was No. 2 of Dr. Frazer's, extending from Emigsville south through Red Lyon station.† In the description of this section ‡ he refers the sandstone in the railroad cut just north of Emigsville to the Triassic New Red sandstone. At the northern end of the cut he noted a fine-grained sandstone, dipping 15° west, north 52 degrees. To the southward of this he describes a calcareous, sandy, pink shale, dipping south 5°, east 20°. This is subjacent to 27 feet of blue, finely laminated limestone, with white streaks, upon which rests a red bed of calcareous conglomerate two feet thick: this in turn is subjacent to a belt of reddish shaly sandstone, nine feet in thickness, which is capped by 156 feet of arenaceous shales of a somewhat flaggy character.

He says: "There would seem to be, therefore, an anticlinal in the Triassic measures—the only instance of one recorded within the limits of this district. The contact line of limestone and Mesozoic sandstone lies within or just north of the town of Emigsville. The first recorded dip in the older formation when projected upon the line of section is 2,160 feet, or a little more than a third of a mile from the last dip."§ I mention the details of Dr. Frazer's section as it is the one which led me to the determination of the stratigraphic position in the geologic series of the Chiques quartzites and the York shales ‖ which are subjacent to the Lancaster limestone.¶ The fault betweeen the Paleozoic (Lower Cambrian) rocks and the New Red sandstone of the Mesozoic occurs in the railroad cut, at the point indicated in Dr. Frazer's section as the crest

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*Second Geol. Survey of Penn., 1876. Section 1, accompanying Report of Progress in the district of York and Adams counties for 1874.

† Loc. cit., Section 2. ‡ Loc. cit., p. 88. § Loc. cit., p. 89.

‖ The name York shale is proposed for the band of shales resting upon the quartzites surrounding the Hellam hills. It is peculiarly well developed in York county, and appears to be absent in many of the sections about South Mountain and about the same series of quartzites in Lancaster county.

¶ The term York limestone was proposed by Dr. Frazer for this limestone; but as he states that it is a prolongation of the Lancaster limestone into York county, and that it is more fully developed in Lancaster county, I think it best to retain the term Lancaster limestone, as it is hardly necessary to call the same limestone by two different names in adjoining counties.

of the anticlinal in the New Red sandstone. No such anticlinal exists. The southern leg of Dr. Frazer's anticlinal is formed of rocks that bear no resemblance to the Mesozoic Red sandstone, and fossils of lower Cambrian age are abundant in the nine feet of compact, fine grained sandstone described by him. The section, from the fault line southward, is as follows:

Thickness. Feet.

1. Gray, banded and mottled limestones, with purplish bed of limestone at summit three feet thick. This limestone weathers into a more or less arenaceous shale.
   Strike, E. & W. (Mag.) Dip, 25° S. 33
2. Gray and buff sandy shales passing (at 21 feet) into shaly sandstone and then into sandy shale, where a belt of calcareous quartzite occurs in layers varying in thickness from 2 to 12 inches 105
   Fossils:—*Camerella minor*, and fragments of Olenellus, showing portions of the head and thoracic segments.[*]
3. From the fossiliferous beds just mentioned, for a distance of 500 feet the hillside on the east of the railroad is covered with the debris of sandy shales, and several exposures occur along the wagon road. From the last of these to the first outcrop of limestone, a distance of 250 feet, the debris of sandy shales and thin-bedded calcareous quartzite occur abundantly in the southward-facing hillslope. As the last observed dip was 25° S., it is assumed that the section is unbroken, and a thickness is assigned to this division of 315
   Fossils:—Numerous fragments of Olenellus and casts of *Camerella minor* occur in the calcareous quartzite interbedded in the shale.
4. Massive-bedded, dove colored, banded limestones. Strike N. 20° W. (Mag.) Dip, 25° S.[†] near base of series. Although the section is more or less concealed by soil, numerous outcrops occur in quarries to the south. These show a banded limestone in the lower portion of the section with numerous irregular, small, concretionary bits of limestone, usually elongated with the bedding plane. The average dip of the beds is from 20° to 25° S. A beautiful section is shown in a quarry about one-fourth of a mile east of Emigsville, and in a quarry on the turnpike west of the railroad in the outskirts of the town. A little higher up in the section the limestones are massive, light colored, and, in places, almost a white crystalline marble.

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[*] On the line of strike of these beds, two miles northwest of Emigsville, the following fauna was found in the calcareous sandstones: *Camerella minor*, *Obolella crassa*, *Hyolithes communis*, and fragments of Olenellus.

[†] Dr. Frazer's section indicates a dip of 85°. I was not able to discover the locality where he observed it.

At a quarry in a field east of the railroad track and near where the roadway turns to the eastward towards Codorus creek, the strike of the limestone is N. 15° W. (Mag.), and dip 15° S. One of the layers is quite fossiliferous and gave fine specimens of a species of Salterella and Kutorgina, heads of small trilobites of the genera Solenopleura and Zacanthoides, and numerous fragments of the head and thoracic segments of a species of Olenellus.

Further to the westward in an old quarry east of the Northern Central R. R. track, massive layers of limestone are shown that have a strike N. 20° W. (Mag.); dip 20 S., and contain fragments of the genus Olenellus and Protypus. The next higher exposure in the section is in a large and deep quarry just west of the R. R. track, between one-fourth and one-half mile south of Emigsville. About 60 feet of limestone is exposed. The strike is E. and W. (Mag.), with a dip of 10° to the south. In the lower portion of the quarry there are massive layers of arenaceous limestone, and about ten feet from the summit of the section, alternating bands of earthy and pure limestone in which numerous fossils occur. In the collection obtained I have recognized:

Plates of Cystids.
Kutorgina, n. sp.
Orthisina festinata Billings.
Olenellus (fragments).
Protypus senectus Billings.

The fragments of Olenellus indicate individuals as large as any known. The fossils range through about twenty to twenty-five feet of the limestone. The layers above the fossiliferous band are largely brecciated and form a limestone conglomerate. The estimated thickness of the entire series of limestone is 750

In the railroad cut the limestone is shown, and, a little to the south of them, cleaved slates the bedding of which strikes east and west (Mag.) and dips 10° south. There is an interval of 20 feet between the limestone and slates covered by debris. The limestone appears to pass beneath the slates, and from the areal distribution of the slates and limestone to the south and southwest it is probable that this upper band of slates has a wide distribution; its thickness is unknown.

An area of quartzite, No. 2 of section, is colored on the map two miles N. W. of Emigsville as of the same age as the Hellam quartzite. It is, as we now know, a thinner belt of quartzite resting in the calcareous and sandy shales above the quartzite of the Hellam hills. The next point determined was the actual relation of the Olenellus quartzite at Emigsville with the massive Scolithus quartzite of the Hellam hills. In passing from Pleasureville towards York, on the steep side hill two miles west of York there are exposures in the roadside of shales and calcareous sandstone above the massive quartzite of the Hellam hills. At a point probably 100 feet beneath the ferriferous shale in which the numerous ore pits occur on the south side of the Hellam hills, a species of *Obolella*, very closely allied to *Obolella crassa*, and fragments of Olenellus were found in the decomposed calcareous sandstone. At a locality about one mile south of Mt. Zion church, in Hellam township, and four miles northeast of York, numerous specimens of *Camerella minor* and fragments of Olenellus occur in a calcareous quartzite identical in character with that of the Emigsville section. These two localities prove that the Scolithus quartzites of the Hellam hills and of "Chiques Rock" are beneath the Olenellus calcareous quartzite of the Emigsville section and, therefore, of Lower Cambrian age.

Search was next made for fossils near the base of the limestone above the ferriferous shales resting on the quartzites of Hellam hills. They were found at a short distance above the shales in a small quarry of thin-bedded limestone by the roadside, one and one-eighth miles north of Stoner's station on the York & Wrightsville railway. The strike is a little north of west, and dip 45° south. Finely preserved specimens of Linnarssonia, closely allied to *Linnarssonia sagittalis* are abundant, and easily recognized fragments of a species of Olenellus are associated with them. Crossing the section to the south, occasional exposures were seen of massive bedded, light-colored limestones, much of the same character as those exposed in the quarries north of Wrightsville three miles to the eastward. The dip increased to 85° at the railroad track, which indicated that a compressed synclinal had been passed over in the section. The only locality where fossils were found within the main body of the limestone in York County was one and one-half miles southwest of the public square at York, Pa., on the north side of Highland Park. The species recognized are: one closely allied to *Olenoides Marcoui*, *Protypus senectus*, and two species of Ptychoparia, all of which belong to the Lower Cambrian fauna. When examining the section on the east side of the Susquehanna, in Lancaster county south of Columbia and north of Washington Manor, with Messrs. A. Wanner and Arthur Keith, a locality of lower Cambrian fossils was found in a narrow belt of limestone about half a mile north of Washington Manor. *Hyolithes communis* and fragments of Olenellus showing portions of the head and thoracic segments were recognized in the material collected.

A glance at Dr. Frazer's map of York county shows that it is probable that all of the limestones, quartzites and schists of the central portion of the country are of Lower Cambrian age. The Hellam quartzite ridge is, as stated by Dr. Frazer, evidently an anticlinal ridge broken on the northwest side by a fault that has brought the quartzite up against the higher horizons of the shales and limestones. The anticlinal structure apparently extends to the southwest past York and towards Hanover.*

The discovery of Lower Cambrian fossils in the compressed synclinal of limestone in Lancaster county, south of Columbia, indicates that the limestone on the west side of the river is of the same geological age; and that the shales and schists beneath it (called chlorite schists, etc., by Frazer) are of Lower Cambrian age; and I doubt if there is a sedimentary rock,—other than the Mesozoic New Red sandstone—of later age than the Cambrian in York county, unless it may possibly be the Peach Bottom slate and chlorite schists of the southeastern corner of the county; and from the closely related structure of Lancaster county it is probable that all of the Lancaster limestones will fall within the Cambrian unless it be that some portions of the upper series of limestone may pass into the Ordovician. This generalization will also apply to the limestones of the adjoining counties of Berks and Chester and, in fact, to the entire extension of this series northeastward, to the Delaware. All of the quartzites, that have been referred to the Potsdam, will necessarily fall into the Lower Cambrian, as they are beneath the limestones.

When it is once considered that the quartzites, called the Potsdam by the Pennsylvania Survey, are of Lower Cambrian age; that a series of shales and limestones, superjacent to these, are of Lower Cambrian age: that the Potsdam horizon of the New York series is represented by limestones in the Auroral series of Rogers; and that the Calciferous-Chazy terrane of the New York section is represented only by the upper portions of the Auroral limestones, geologists will have little difficulty in determining the geologic horizons of the various outcrops of quartzites, schists, shales and limestones,—provided careful attention is paid to their sedimentary character and to the discovery of occasional localities of fossils.

South Mountain.

Prof. Lesley states that "the South Mountains," separating the Cumberland valley from the lower country of York and

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* Southeast of the Hellam hills the limestones appear to form a compressed synclinal and this structure may extend to Hanover and beyond to the S.W. My time was too limited to study the details of structure off of the line of the sections mentioned in these notes.

Adams counties, form the northernmost end of the Blue Ridge range of Virginia. . . . . . . The whole measures upon the map ten miles in breadth by fifty in length upon a curve extending from the Maryland line to its eastern edge, fifteen miles west of Harrisburg.*

From the Pennsylvania line southwest across Maryland, South Mountain extends, as the Blue Ridge, to Harper's Ferry, and thence southwest across Virginia. It, also, practically includes the Cotoctin range, on the eastern side, which extends south from the southwestern portion of Adams county, Pennsylvania, and crosses the Potomac at the Point of Rocks, and from thence extends south a little west of Leesburgh, Va. The Blue Ridge and the Cotoctin Ridge are the eastern and western sides of the mountain uplift of which the South Mountain, Pennsylvania, is the northern terminus.

The classification of the rocks of Pennsylvania was summed up by Prof. H. D. Rogers as follows:—The Hypozoic rocks, or those *underneath* any life-bearing strata; Azoic, or those destitute of any discovered relics of life; and Paleozoic, or those entombing the remains of the earth's most extinct forms once living beings.†

It is evident from Prof. Rogers' definition of the Azoic group, that it included what we now recognize as the lower Cambrian sedimentary strata beneath the Scolithus quartzite and, also an extended series of altered rocks that form the nucleus of the Blue Ridge, and which are now included in the Algonkian of the classification of the U. S. Geological Survey. He regarded the sandstone with *Scolithus linearis* as at the base of the Paleozoic series, and considered that the Primal slates beneath the sandstone, and in intimate alternation with it, did not possess a vestige of organic life.

The conclusions of the geologists of the second geological survey of Pennsylvania, are that there are two groups of rocks forming South Mountain.

Prof. Lesley says: "The northwestern (Mt. Holly) ridge is made by several thousand feet of the lower quartzite and quartz conglomerate beds. The southeastern (Adams county) ridges are made by several thousand feet of an overlying feldspathic, micaceous and chlorite series, intersected by veins of milky quartz."‡ . . . . "It is hard to avoid the inference that our South Mountain rocks represent the Huronian section of Murray and Logan. It is impossible not to compare them also with

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* Second Geol. Survey of Penn. A summary description of the geology of Penn., vol. i, 1892, p. 142.

† The Geology of Pennsylvania, vol. i, 1858, p. 64.

‡ Second Geol. Surv. of Penn A summary description of the geology of Pennsylvania, vol. i, 1892, p. 144.

the great quartzite masses, the roofing slates, etc., of Walcott's upper, middle and lower Cambrian system."*

When I began the investigation to ascertain, by stratigraphic and paleontologic evidence, the geologic age of the South Mountain quartzite and the associated schists and slates, I soon discovered that there was very little prospect of finding the true geologic succession in the northern portion of the mountain, in Cumberland and York counties, owing to the folding of the strata and also to the fact that there were a number of westward thrusts of lower on higher beds, and that as a result of this the central core of the Blue Ridge had been broken and thrust over on the Lower Cambrian beds and, also, in places, resting apparently conformably upon the latter,—all having an eastward dip. The discovery of Olenellus with *Hyolithes communis* in the massive quartzite series in the Mt. Holly ridge, just above Mt. Holly Springs in Cumberland county, proved that the great western mass of quartzites of South Mountain, with the interbedded shales, slates and conglomerates, were of *Lower* Cambrian age; but it did not throw light upon the geologic age of the orthofelsite series of Frazer and the epidotic rocks of Rogers. In company with Mr. Arthur Keith, of the U. S. Geological Survey, who had mapped the Harper's Ferry sheet, an examination was made across the ridges, from Mechanicstown, Md., to Monterey and westward to Pikesville, in Franklin county, Pennsylvania.

On entering the gorge, a little west of Mechanicstown, on the line of the Western Maryland R. R., an extended series of shales and slates was passed,—all having a very high dip to the southeast. About two miles from Mechanicstown, massive quartzites were observed with a high dip to the east, and, higher up in the gorge, there was a repetition of the slates found east of the quartzites. This section, from the dip of the quartzite, indicated a synclinal resting on a considerable thickness of slates and shales. A series of sections, by Mr. Keith, of the western, or Blue Ridge ridge extending from a point eleven miles south of Mechanicstown to Harper's Ferry, shows that this same synclinal structure prevails all along the ridge, and that a synclinal fold of massive sandstone forms the summit of the ridge, below which a series of shales rests unconformably upon the subjacent crystalline rocks.† The synclinal structure is also shown for the quartzites of the eastern or Cotoctin ridge.

From a point two and one-half miles west of Mechanicstown to Monterey, the road led across the epidotic schists of

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* Loc. cit., pp. 147, 148.

† The structure of the Blue Ridge near Harper's Ferry. Bull. Geol. Soc. America, vol. ii, 1891, pls. 4 and 5.

the central mass of the range, which is now a mountain valley between the Cotoctin and Blue Ridge ridges. The schist extends to a point one-fourth to one-half a mile beyond the Blue Ridge station, on the Western Maryland R. R. Fragments of a rhyolite-like, porphyritic rock* were also seen, that probably represent the "bedded petrosilex" of Dr. Hunt, as shown two miles south of this Monterey road, near Foxville, Maryland. Going down the road beyond Pen Mar towards Pikesville, there was an apparent repetition of the section on the eastern side of the ridge, near Mechanicstown. Subsequently, an examination was made of the section from Monterey, Franklin county, Pennsylvania, to the valley on the line of the Waynesborough turnpike. Just west of Monterey a massive quartzite forms a plateau, upon which the Monterey hotel is situated. The dip of the quartzite is slightly to the northwest. A short distance beyond the toll-gate the dip to the northwest increases, and a series of sandy and argillaceous shales succeeds the quartzite. Following down the turnpike toward Waynesborough and near the foot of the ridge, these shales were found to pass beneath a light-colored, hard, compact quartzite dipping northwest, in which numerous remains of *Scolithus linearis* occur. By breaking the white quartzite many fragments of Olenellus showing parts of the head and thoracic segments were also found. In calcareo-arenaceous layers, just beneath the quartzite, fragments of Olenellus occur associated with specimens of *Camerella minor*. A series of more or less sandy shales next appears resting upon the Scolithus quartzite and having a northwesterly dip, toward the valley. Along the foot of the ridge, low hills of sandy shale and slate appear, capped with a thin-bedded calcareous quartzite or sandstone. In the latter, *Camerella minor*, *Hyolithes communis*, and fragments of Olenellus are abundant. A little west of these hills the limestones of the valley appear. In this limestone, *Kutorgina* n. sp., and fragments of the head and thoracic segments of Olenellus were found a little east of the road leading up the east branch of Little Antietam creek and about three miles east of Waynesborough.

If reference is now made to the York county section it will be seen that the upper portion of the Monterey section is essentially a repetition of it—from the Scolithus quartzite to the limestones of the valley. The same fossiliferous Scolithus quartzite passes beneath sandy shales and slates, in which are interbedded calcareous quartzites carrying the Olenellus fauna; these pass beneath the limestones of the valley in York county in which the Olenellus fauna occurs. In the Monterey

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* The description of the volcanic rocks of South Mountain by Dr. G. H. Williams is contained in the following article, p. 482.

section, however, there is in addition a series of shales beneath the Scolithus quartzite. that rests upon a massive quartzite forming the summit of the Blue Ridge, west of Monterey and beneath this a bed of slates unconformable to the subjacent crystalline rocks.

The Blue Ridge was followed south into Maryland and crossed at several points before reaching Harper's Ferry. All of the section shows the synclinal structure of the slates and quartzites as represented by Messrs. Geiger and Keith, in their paper upon the structure of the Blue Ridge near Harper's Ferry.* South of Keedysville, Washington county, Maryland, the quartzite, capping the slate hills west of the main ridge, was observed to pass conformably beneath the limestone at Eakle's Mills, and *Hyolithes communis* and fragments of Olenellus were found in the calcareous quartzite. The relatively simple stratigraphic structure of the Monterey section is complicated at, and near, Harper's Ferry by the lower massive quartzite forming a synclinal and being thrust to the westward over the more recent shales, slates and limestones. The structure is still more complicated by the fact that the hills of sandy shale and slate (capped by the upper Olenellus quartzite) are thrust, on the line of a fault, over on to limestones which, in an unbroken section, rest upon the quartzites.

It was this primary folding and subsequent westward thrusting, on the line of two or more faults, of the older upon the more recent strata at and to the north and south of Harper's Ferry that led Messrs. Geiger and Keith to consider that the lower quartzites rested conformably upon the limestones and were of Silurian age.†

Returning to South Mountain with the information gained between the Potomac and the line of the Chambersburgh and Gettysburgh pike, in Pennsylvania, and studying Dr. Frazer's sections (Nos. 7, 8, 9, 10, 11 and 13)‡ and also reading the descriptions of them, as well as Professor Lesley's description of South Mountain (contained in Vol. I of his final report), it is evident that they have misinterpreted the true geologic structure of the mountain and the relations of the rocks composing it. Professor Lesley states that a massive fault must run along the foot of the mountain, along the low drift-filled valley of Yellow Breeches creek; and this I think is correct, as the Olenellus fauna of the Scolithus quartzite zone occurs but a short distance east of the foot of the mountain, in a syn-

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* Bull. Geol. Soc. America, vol. ii, 1891, pls. 4 and 5.

† Loc. cit., pls. 4 and 5. A paper by Mr. Arthur Keith describing his present view of the structure will be found in the Dec. No. of the Am. Geologist for 1892.

‡ Second Geol. Surv. Pa. Report of Progress in the counties of York, Adams, Cumberland and Franklin for 1875 published 1877.

clinal fold, at Mt. Holly Springs. Their error, however, is in considering that the "orthofelsite" series is superior to the conglomerates, quartzites and schists which they referred to the Lower series. The Monterey section shows that the epidotic schists are inferior to the quartzites and slates and, a section west of Wolfsville, Md., that the "petrosilex" or rhyolite-like eruptive occupies a similar position. This type of section is repeated many times, both on the Cotoctin and Blue Ridge sides, from the Maryland line to the Potomac and south through Virginia.

Professor Rogers and also Professor Lesley, referred the offsets of the ranges of hills of South Mountain, as shown in Franklin county and also on the north end of South Mountain, to the terminations of successive folds of the rocks forming the mountain. My impression is that these offsets and also the complicated structure of the mountain arise partly from folding, but more largely from the westward thrusts of masses of strata along the line of faults of a low hade. This westward thrusting on the fault planes, complicated by previous foldings of strata, leaves masses of the subjacent pre-Paleozoic rocks resting, in various places, on different members of the lower Cambrian series, and also appears to interbed the quartzites and slates of the Cambrian in the schists, eruptives, etc., of the Algonkian.*

The key to the succession of the lower sedimentary rocks of Maryland and Pennsylvania is contained in the Balcony Falls section of Virginia, although it can now be determined by a study of the section at Monterey and to the south, along the Blue Ridge toward Harper's Ferry.

In a letter received from Professor Lesley and dated February 22d, 1891, he asks: "Is it impossible that there should be agreement between the Balcony Falls section of Virginia and the Mt. Holly Springs section, three hundred miles apart?" He says, further, after commenting upon the possible relations between the Balcony Falls section and that at South Mountain, in speaking of the strata of the Balcony Falls section: "But what is 2,000 feet or 2,500 feet to 10,000 feet to 20,000 feet of quartzites and slates making (apparently—not certainly—) the South Mountains? We are still in the dark about *super-* and *sub*-positions; about absence or presence of overturn rolls, etc. I am only greatly impressed with the broad fact that we seem

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* From the finding of fragments of the eruptive rocks in the conglomerates at the base of the quartzite series, and from the numerous synclinals showing that the epidotic rocks and also certain rhyolitic eruptives are beneath the quartzite series I refer the similar rocks of South Mountain to a pre-Paleozoic age; and, as they are not of the character of the Laurentian crystalline complex, I would refer them to the Algonkian, but *not* correlate them with the Huronian or with any known division of that group of rocks.

to have the Huronian mass rising to view in the South Mountains of the Atlantic States."

I think that the view of Messrs. Frazer and Lesley that such great thicknesses of strata occur in South Mountain arises from the fact that these "great thicknesses" are but repetitions of both the Cambrian and pre-Cambrian strata from foldings and overthrust faultings and also from their not differentiating between the cleaved schistose eruptives of the Algonkian and the bedded and often cleaved sedimentaries of the lower Paleozoic.

The section at Monterey and along that portion of the Blue Ridge is roughly, as estimated from the data obtained by Mr. Keith to the south and from the Monterey section, reading from below upwards, as follows:

Feet.

1. Shales and slates, well shown near Mechanicstown, Maryland, and in numerous sections along the Blue Ridge — 300 feet to 400
2. Coarse-grained and bluish-gray quartzite — 1000 to 1200

    At several localities the shales of (1) appear to be replaced by bands of conglomerate and shale; and many of the layers of (2) are conglomeritic to a greater or less extent.
3. Sandy shale, with interbedded layers of quartzite — 800
4. Scolithus quartzite, with interbedded calcareous sandstones and shales — 500

    Fossils:—Camerella minor, and fragments of Olenellus.
5. Sandy shales, with a series of calcareous quartzite near the summit; about — 450

    Fossils:—Camerella minor, *Hyolithes communis*, and fragments of Olenellus.
6. Mottled limestone, with intercalated sandy and shaly layers — 800 to 1000

    Fossils:—Kutorgina n. sp., and fragments of Olenellus.

    This portion of the section is succeeded by the valley limestone, more or less of the lower portion of which is probably of middle and upper Cambrian age.

The section includes from 3,000 feet to 3,500 feet of sandstones and shales before reaching the limestones. In a number of localities a conglomerate was observed in the Lower sandstone series, in which fragments of the pre-Paleozoic crystalline rocks were imbedded. This phenomenon was observed on South Mountain, in the conglomerates mentioned by Prof. Lesley, and also along the Blue Ridge and the Cotoctin ridge to Harper's Ferry; the conglomerate character of the rock varying very much in the character and size of the coarser material. The feldspathic character of these shales and sandstones is very distinctly marked beneath the Scolithus quartzite, both in the Balcony Falls and the Monterey sections.

If these two sections are compared with that at "Chiques Rock" and south to Columbia, in Lancaster county, Pa., it will be at once observed that the Scolithus quartzite, while the highest band of quartzite in the Balcony Falls and the Monterey sections, is the lowest in the "Chiques Rock" section which has the lower feldspathic sandstone and shales apparently above the Scolithus quartzite. It is from this fact that it is stated, in the first part of this paper, that the feldspathic sandstones and shales were thrust over on the Scolithus sandrock in the "Chiques Rocks" section.

ART. LXV.—*The Volcanic Rocks of South Mountain in Pennsylvania and Maryland;* by GEORGE H. WILLIAMS. With Plate X.*

Contents.—1. Object of this paper. 2. Supposed sedimentary origin of the South Mountain volcanic rocks. 3. Petrographical character: *a*) The acid rocks —rhyolites; *b*) The basic rocks—basalts; *c*) The pyroclastic deposits—tuffs and breccias. 4. Geological occurrence and relations to the sandstone. 5. Chemical alteration and metamorphism. 6. Comparison with other regions.

[Read before the National Academy of Sciences, Nov. 2, 1892.]

1. *Object of this paper.*—It is the object of the present communication to announce the identification of an extensive area of very ancient volcanic rocks which compose an important part of the South Mountain, south of the Susquehanna River. The brief preliminary description of these rocks, which is all that can now be attempted, will, it is hoped, suffice to show that the hitherto accepted theory of their sedimentary origin has been based on a misinterpretation of the facts which they exhibit.

The rocks in question preserve abundant and convincing evidence—both structural, chemical, and petrographical—of their original character and genesis. At the same time they show various phases of alteration by recrystallization and dynamic agencies which render them valuable for the study of many problems of metamorphism.

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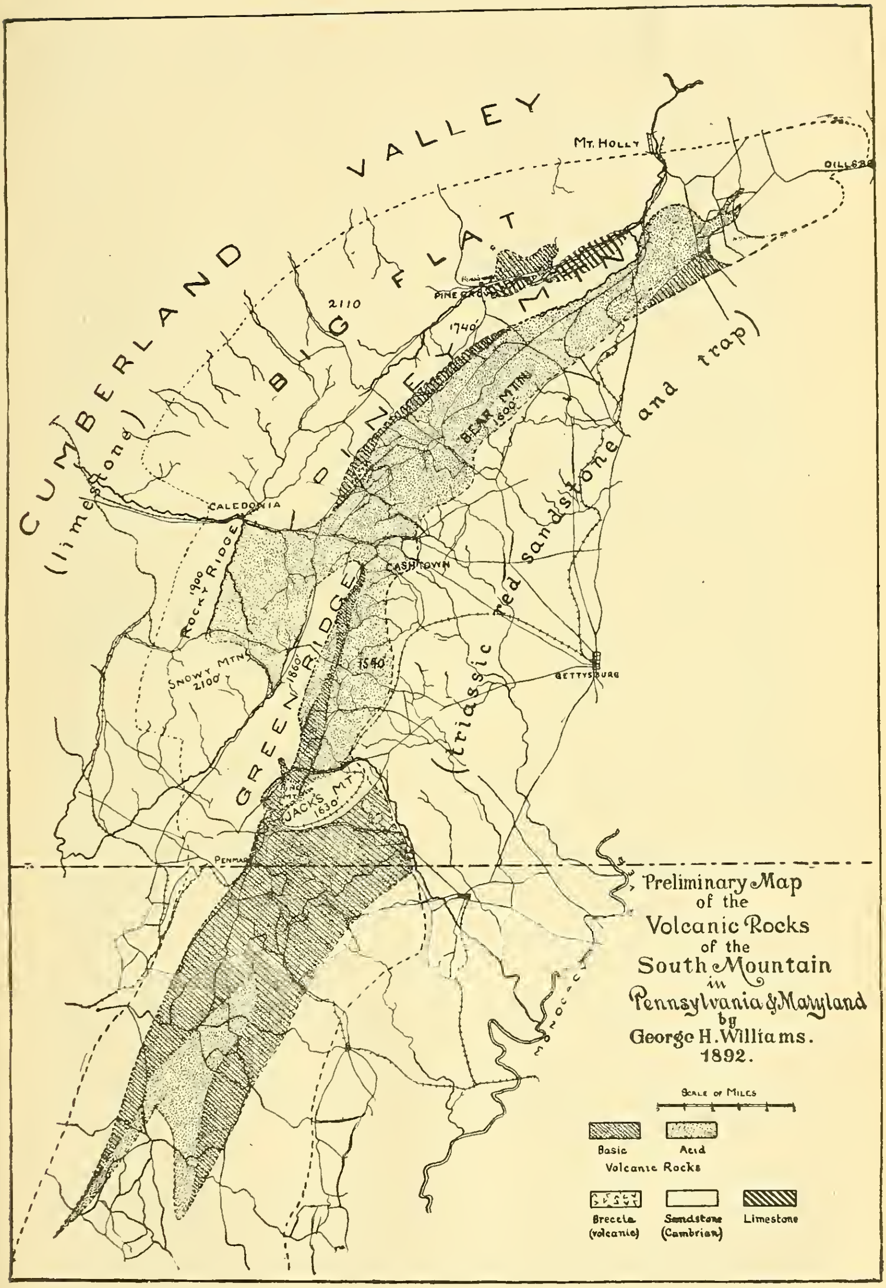
* The writer is under great obligations for many of the facts contained in this paper to Miss Florence Bascom, who has mapped in great detail one of the most diversified portions of South Mountain, near Monterey, Pa. She has collected a large material upon which she is now at work at the Johns Hopkins University, and her results, to be published in due time as a thesis, will go far toward furnishing detailed proof of the general conclusions here set forth.



Preliminary Map
of the
Volcanic Rocks
of the
South Mountain
in
Pennsylvania & Maryland
by
George H. Williams.
1892.

South Mountain rises about fifteen miles west of Harrisburg and extends, as may be seen on the accompanying map, in a great sickle-shaped curve to the Maryland line. Here it divides into two parts, known as Catoctin Mountain and the Blue Ridge, which diverge at a small angle and enclose the triangular Middletown valley, north of the Potomac.

During the past summer the writer devoted considerable time to mapping the volcanic rocks of this region and to collecting suitable material for laboratory study. This has at present only been fairly entered upon, so that subsequent communications giving more detailed results, may be expected.

2. *Supposed sedimentary origin of the South Mountain Volcanic rocks.*—As far as is known to the writer, volcanic rocks have not hitherto been definitely described as such in the Appalachians. The rocks here under consideration have long been known to geologists, but they have before, with the exception of a few of the most massive greenstones, been generally regarded as of sedimentary origin.

Professor Henry Rogers in 1858 speaks of South Mountain southwest of the Susquehanna, as embracing "a singularly small amount" of igneous rock. He alludes to the cleaved greenstones as "dark green slate," and to the acid porphyries and felsites as "highly metamorphic Primal slate." He continually contrasts the highly altered slate and the unaltered sandstone,* although in reality one rock is scarcely more changed than the other.

Philip Tyson, in his first report as State Agricultural Chemist made in 1860, speaks of the sandstone of South Mountain as Potsdam and says that it contains fossilized stems of plants. He also says: "A slate, varying in color from gray to brownish and greenish, is ranked as an argillite, but portions of it assume a marked talcose appearance, especially in Catoctin mountain, where it has been much disturbed and altered by proximity to intrusive rocks. These last consist of amphibolites (trap), porphyries, amygdaloid, serpentine and epidote."†

In 1877 appeared the results of Dr. Persifor Frazer's studies of South Mountain. He regarded it as composed essentially of a westerly (older) portion, consisting of various modifications of a quartz-conglomerate (Mountain Creek rock) and an easterly (younger) portion composed of orthofelsite, inter-

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* Geology of Pennsylvania, vol. i. pp 203–5, 1858.

† First Report of P. T. Tyson, State Agricultural Chemist, to the House of Delegates of Maryland, January, 1860, pp. 34, 35 (cf. also p. 18). In his second report (1862, p. 70) he gives further particulars regarding Catoctin Mountain. He says "a vast mass of epidotic trap, five miles wide, was forced up from below in a state of fusion. This embraces a mass of chert (rhyolite) 3000–4000 feet thick." He describes the trap as carrying metallic copper, and regards it as the cause of the elevation of the mountain sandstone.

bedded with hydromica and chloritic schists.[*] Regarding the origin of these latter rocks, which like the conglomerate were placed below Rogers' primal sandstone, Dr. Frazer made the following statement in 1877,[†] repeating it two years later:[‡] "The porphyry which carries the copper of this region shows no character of igneous action, but occurs in coarse and thin beds, more or less disintegrated, and in some localities reduced almost to the state of kaolin."

Dr. T. Sterry Hunt announced to the American Association for the Advancement of Science in 1876 that he had identified petrosilex or hälleflinta in South Mountain, which he had examined with Dr. Frazer.[§] Dr. Hunt's concurrence in 1879 with Dr. Frazer's opinion above cited, and his constant use of the term *bedded petrosilex* sufficiently indicate that he regarded these rocks as sedimentary. He however correctly compares the South Mountain rocks with others in Missouri, the Lake Superior region, eastern Massachusetts, Maine, and New Brunswick, since shown to be volcanic, although he saw in this similarity only evidence of their "Huronian" age.

The nearest approach to a recognition of the South Mountain rocks in Pennsylvania as volcanic was made by Mr. J. F. Blandy, who described the copper-bearing rock in 1879 as *amygdaloid trap*, and correlated it with the similar flows near Lake Superior. The acid felsites however were regarded by Mr. Blandy as slate.[‖]

In his recent final volume on the Geology of Pennsylvania, Professor Lesley follows in the main Dr. Frazer's classification of the rocks of South Mountain. Although he considers that the sandstone probably represents the "Huronian" of Logan and Murry, he says it is impossible not to compare it with Walcott's Cambrian System. The supposed overlying feldspathic felsite series (orthofelsite of Frazer) Lesley estimates as 6,000 feet in thickness, and everywhere speaks as though he regarded it of sedimentary origin.[¶]

The cause of the prevailing misconception regarding the volcanic rocks of South Mountain is not difficult to find. Their accompanying accumulations of tuff beds and breccias, and the fact that they are generally cleaved parallel to the

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[*] Report of Progress in the counties of York, Adams, Cumberland and Franklin. Second Geol. Surv. of Penn. CC for 1875. Harrisburg, 1877, p. 285.

[†] "Copper Ores of Pennsylvania." Polytechnic Review, vol. iii, p. 170, April 28, 1877.

[‡] Trans. Am. Inst. Min. Engineers, vol. vii, p. 338, 1879.

[§] Proc. Am. Assoc. Adv. Sci., 1876, pp. 211, 212, and Second Geol. Survey of Penn., vol. E, 1878, p. 193.

[‖] "The Lake Superior Copper Rocks in Pennsylvania." Trans. Am. Inst. Min. Engineers, vol. vii, p. 331, 1879.

[¶] A Summary description of the Geology of Pennsylvania by J. P. Lesley, State Geologist, vol. i, p. 146, 1892.

great structure-planes of the mountain, have all been readily interpreted as indications of stratification and conformity. The cleavage-dip in the sandstone has often been mistaken for bedding, while the thin jointing and slaty structure of the lavas, though a secondary feature, have seemed to geologists not very familiar with recent volcanic rocks, sufficient proof of sedimentary origin.

In spite of great age and some alteration, however, the volcanic rocks of South Mountain have preserved all the essential characteristics of our recent rhyolites and basalts in such perfection that the proofs of their real nature are, to the student of comparative petrography, overwhelming, while to all who will candidly examine them they must be at least convincing.

3. *Petrographical Character.*—Approximately 175 square miles of the area of South Mountain is occupied, between Mt. Holly and the head of the Middleton valley, with volcanic rocks. These belong to two types which exhibit sharp contrasts of color, composition and weathering. One type is inclined to tints of red, pink, blue, or purple; is acid in composition; generally porphyritic; and weathers into thin slabs. The other type is almost invariably of a green color; basic in composition; frequently amygdaloidal; and weathers into rough, angular blocks. The rocks of the first type have been called felsite, orthofelsite, porphyry, or petrosilex; those of the second, trap, greenstone, chlorite-slate, or epidote-slate. In view, however, of the perfection with which these rocks have preserved the most characteristic features of their modern equivalents, there is no reason why they should not, like them, be termed *rhyolites* and *basalts.* The insignificance of mere age as a factor in rock nomenclature is now so fully recognized that we may with propriety employ the names of our recent lavas for rocks of any geological horizon, when we can prove beyond doubt their identity.

It is, of course, to be expected that many rocks of intermediate character will be found within this volcanic area. Since the petrographical and chemical study has, however, only begun, and since the contrast above noted is so well defined, the distinction of two types may at present be regarded as sufficient.

a). *The acid rocks, rhyolites.*—The rocks of the acid type occupy somewhat more than two-thirds of the volcanic area of South Mountain—(see map). They occur in dykes and flows forming a body of great thickness; they are accompanied by ashes, tuffs and breccias; they are usually porphyritic, though not always so; they exhibit the characteristics of recent glassy and half-glassy rocks—flow-structures, perlitic structure, lithophysae, spherulites (in masses, in layers and in chains), axiolites, pumice, amygdaloids, etc., etc.—in hardly less perfection than the specimens which Professor Iddings has so admirably described from the Yellowstone Park.

These structures are preserved, in spite of the recrystallization of the entire rock-substance into a fine mosaic. They are therefore most apparent in hand specimens, especially when brought out by weathering; or, under the microscope, they are better seen in ordinary than in polarized light, as was the case with the old glass breccia, recently described by the writer from the Sudbury region.*

The following is an analysis of a rhyolite specimen from the Gladhills road, near the Bigham Copper mine, on the north side of Pine Mountain, made by Mr. C. Hanford Henderson of Philadelphia, and published in 1884.† This is a quite typical rhyolite analysis. When compared with analyses of our most recent acid lavas, the iron may seem a little high and the alumina a little low, but on the whole the close agreement is a surprise.

SiO_2	73·62
Al_2O_3	12·22
Fe_2O_3	2·08
FeO	4·03
CaO	0·34
MgO	0·26
Na_2O	3·57
K_2O	2·57
Ign.	0·40
Total	99·09

The macroscopic features of the rhyolite are the best proofs of its true nature, for weathering brings out on the surface of the rock each delicate detail. In this way we discover every characteristic of glassy rocks, though there is no glass now remaining. Plate X, fig. 1, shows in photographic reproduction a specimen five inches long, covered with lithophysæ as perfect as any the Yellowstone can furnish. Their delicate petals are a pale pink, while the base has weathered white. With a lens the radiating and minutely fluted, concentric structure can be traced distinctly. Fig. 4 (p. 488), gives a somewhat diagrammatic idea of this structure.

Plate X, fig. 2, shows the delicate lines of flow-structure as they are displayed on the weathered surface of a specimen which

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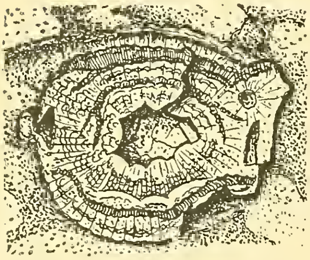
*Bull. Geol. Soc. Am., vol. ii, p. 138, 1891. Ann. Rept. Geol Surv. Can. for 1889–90, F, p. 75, 1891.

† "The Copper Deposits of South Mountain," by C. H. Henderson. Trans. Am. Inst. Mining Engineers, vol. xii, p. 90.

in its interior is a homogeneous, dark purple felsite. On other specimens these flow lines are even more sinuous. This specimen was merely selected from a great variety because it appeared well-fitted for reproduction.

At some localities the rhyolite is crowded with spherulites. Plate X, fig. 3, represents a large specimen found north of the junction of Copper run with Tom's Creek. Here the spherulites make most of the mass and have no regular arrangement. They have the size of large peas. In other cases the spherulites are of smaller size and more sparsely distributed. They are then not infrequently arranged in layers as described by Iddings in the Yellowstone obsidian.* One specimen from Raccoon Creek (No. 143) shows small but very perfect, grey spherulites distributed, singly, in layers or in large aggregates through a black base which was once probably obsidian. In appearance it is not unlike the well known specimens from the Lipari Islands.

4.



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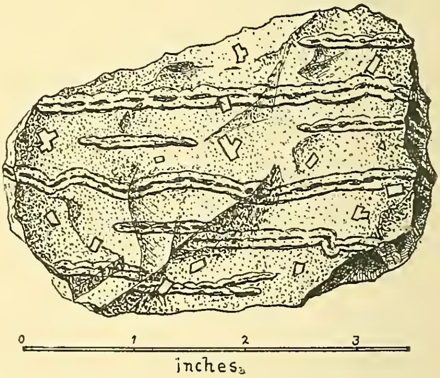

Fig. 4. Structure of a lithophysa brought out by weathering—natural size—No. 129, from Raccoon Creek.

Fig. 5. Hand specimen showing chains of spherulites—No. 78, from near Snowy Mountain.

Another very common arrangement of spherulites is shown in fig. 5. Here they occur in single layers, which, in cross-section, appear like chains, bent more or less out of their normal horizontal position by the flow-motion of the magma. The individuality of these spherulites is preserved, though they are so merged into one another that they approach the axiolitic structure. This structure is so frequent that it has doubtless helped confirm the idea that the felsite and porphyries were

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* Obsidian Cliff, 7th Ann. Rept. U. S. Geol. Surv., p. 276, Plate xviii, 1888.

stratified. It seems to be quite independent of the presence or absence of phenocrysts in the rock.

Still another characteristic, which the South Mountain rhyolites possess in common with many recent lavas, is what we may call the *eutaxitic* structure.* This consists of the close intermingling of two portions of the magma which, on account of some slight differences in chemical composition or hydration, show a marked contrast in color. The two portions may be, for instance, black and white, pink and blue, or red and gray. They mingle so as to produce in some cases an irregular mottling; in others a complex series of interlacing bands which bring out the flow-structure in a striking manner. Specimen No. 145, from Raccoon Creek, shows small black areas resembling shreds of glass, imbedded in a pink base which, on a weathered surface, appears snow-white.

Amygdaloidal structure, representing old vesicles more or less elongated by motion in the viscous mass, is much less common in the acid, than in the basic rocks. Fine examples of it were, however, found at the Bigham Copper mine; along Raccoon Creek and at the eastern end of the Jack's Mountain tunnel (Nos. 20, 147 and 7). As a microscopic feature this vesicular structure is still more common, (see fig. 6). Perlitic parting, so characteristic of glassy rocks, may be detected macroscopically in many felsite specimens.

The microscopical characters of the South Mountain rhyolites are far too varied to be described in a brief paper like the present. It must suffice to say that, in spite of the recrystallization of the substance, we still find in great perfection all the essential features of the most recent acid lavas. Corroded and skeleton phenocrysts of quartz, micropegmatitic intergrowths of quartz in feldspar phenocrysts,† and phenocrysts broken by the flow movement. In the groundmass we find spherulitic tufts, axiolites, elongated vesicles filled with quartz, trichites and globulites in great variety, which bring out each detail of flow-structure. All the particulars of microscopic structure call for extended study and description. For the present purpose, however, which is merely to establish the character of these rocks, what has been said must suffice.

In mineralogical composition the South Mountain rhyolites are quite uniform. When phenocrysts are present, the most abundant are alkali feldspar. Quartz in rounded bipyramids is always to be found with the feldspar under the microscope, although it is not so often apparent to the unaided eye. In only a single instance (No. 257D, from the head of Miney

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* Fritsch and Reiss: Tenerife, p. 414, 1868. Rosenbusch: Die Massigen Gesteine, 2d Ed., p. 625.

† J. P. Iddings: loc. cit., p. 274 and Plate xv.

run) has any ferro-magnesian constituent as yet been detected. In this case biotite is abundant as an original mineral. The groundmass of the rhyolites is for the most part a quartz-feldspar mosaic of varying grain, much of which is the result of devitrification and recrystallization, though some of it is also probably original microgranite.

6.

Fig. 6.—Axiolitic and vesicular flow structures. No. 77 from near Snowy Mtn., mag. 5 diameters.

7.

Fig. 7.—Flow structure. No. 61, South of Willow Grove, Pa., mag. 5 diameters.

Attention has been called by Tyson,* Hunt† and Frazer‡ to the beauty of the South Mountain porphyries, and to the fact that they are so susceptible of a high polish as to make them valuable for decorative purposes. Many of them closely resemble the famous *porfido rosso antico* of Egypt, which is largely used by the lapidaries of Rome.

b) *The basic rocks, basalts.*—The basic lavas of South Mountain occupy an area about one-half as large as that covered by the acid ones. They reach their maximum development near the State line, where, along the southern edge of Pennsylvania and for a considerable distance into Maryland, they form the entire width of the volcanic belt. North and south of this main body, the basic rocks or greenstones are everywhere met with as narrow bands intersecting the rhyolites and following the general trend of the mountain. These bands differ much in their width, but seem to be most developed along the eastern flanks of Green Ridge and Piney Mountain.

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* First Annual Report, 1860. Appendix, p. 3.

† Proc. Am. Assoc. Adv. Science, 1876, p. 212 (compares them with the Elfdalen porphyries).

‡ Second Geol. Survey of Penn., vol. CC, p. 285.

These rocks have been more generally sheared into slates than the acid lavas. The chemical alteration which has gone on in them is also in general greater. Still large masses of the basic rocks have been but little altered and remain quite massive. These, which are locally known as "copper rock," are the only members of the volcanic series whose igneous origin has been heretofore conceded. They are for the most part very fine grained, vesicular flows, whose original structure is still so well preserved that they may with propriety be called basalts.

The following analysis, also by Mr. C. H. Henderson, of a massive greenstone from the Bechtel copper shaft, Russel mine, is published by Dr. Frazer.* This is a normal basalt analysis, indicating as little chemical change in the basic rocks as the one given above does in the acid rocks.

SiO_2	41·280
Al_2O_3	18·480
Fe_2O_3	9·440
FeO	8·200
CaO	7·040
MgO	7·486
Na_2O	3·523
K_2O	2·208
Ign.	2·740
Total	100·397

Basic volcanic rocks never exhibit so great a variety of structure forms as characterize the more acid rhyolites. The South Mountain basalts are usually homogeneous, dark to pale green masses which rarely show any microscopical phenocrysts and whose most constant feature is amygdaloidal structure. These cavities vary greatly in size, shape, and abundance. They are often elongated by flow-motion in the lava and are now filled with a number of secondary minerals, the most abundant of which are epidote, chlorite, quartz, and zeolites. Traces of original glass or spherulitic structure (variolite) have not yet been detected in the basalts.

The mineral constituents of basic rocks are more subject to alteration than those of acid ones. It could not be expected that basalts so ancient and so vesicular as those of South Mountain would escape all change, but it is a surprise in many cases that this change has been so small. The ferro-magnesian constituents have always altered to epidote, chlorite or serpentine, but the structure is frequently preserved in its minutest

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* "Hypothesis of the structure of the Copper belt of South Mountain," Trans. Am. Inst. Min. Engineers, vol. xii, p. 82, 1883–4.

detail. Under the microscope the ophitic network of feldspar laths is still fresh, and the delicate twinning as distinct as in a recent lava. The form of the basaltic magnetite, of the olivine phenocrysts, and of the interstitial pyroxene is also plainly visible, while the arrangement of the feldspar microliths among the oval vesicles clearly indicates the motion of the still viscous mass.

Fig. 8 gives two types of the basaltic structure. The one on the left shows skeleton phenocrysts of olivine and a fine grained, ophitic groundmass.

8.

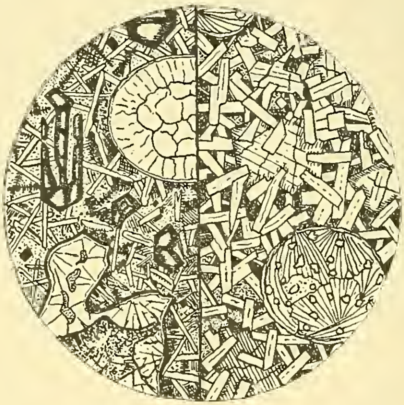

Fig. 8, mag. 5 diameters.

Left half.—Basalt with skeleton olivines, ophitic structure, fresh feldspar. Amygdules filled with quartz and chlorite. Railroad, east of Monterey, Pa.

Right half.—Somewhat coarser grained basalt. Amygdules filled with zeolites and quartz grains. Railroad, east of Monterey, Pa.

Both have large amygdules which are either oval or of irregular shape, and filled with different minerals.

c) *Pyroclastic deposits, tuffs and breccias.*—As is generally the case with large accumulations of surface eruptions, the South Mountain lavas are accompanied by extensive deposits of pyroclastic material. This includes coarse flow- and tuff-breccias, pumiceous bombs, and banded accumulations of fine volcanic ash. Like the massive rocks, this fragmental matter is both acid and basic in composition.

The most striking and important area of acid tuffs covers about a square mile in the Buchanan valley, at the eastern base of Piney Mountain, two miles north of the Chambersburg turnpike. Here the rock is a breccia whose component fragments vary from two or three feet in diameter to the finest ash. All sizes, shapes, and colors are heterogeneously mingled, and the result bears a superficial resemblance to the well-known triassic breccia ("Potomac marble," "calico rock") of the Frederick valley. The material in this case, instead of being limestone, is entirely rhyolite, and exhibits remarkable variety of structures and colors. Both flow- and tuff-breccias occur here, while a portion of the mass has been sheared into a quite fissile slate. Similar acid tuffs, though of less striking appearance, occur at many other points (Raccoon Creek, Monterey, old Furnace road, etc.), and will doubtless continue to be discovered as the examination of the region proceeds.

Fragmental deposits consisting wholly of basaltic material abound along the Western Maryland railroad near Monterey, and farther south. The finer cementing material is in these almost always altered to epidote. It is also not uncommon to find coarse breccias consisting of both the acid and basic types of rock, but a careful search has thus far failed to discover any fragments of sandstone in these pyroclastic beds

4. *Geological occurrence and relations to the Sandstone.*—No evidence is necessary, beyond the petrographical characters above described, to establish the igneous and volcanic nature of the South Mountain rocks. Additional evidence of a purely geological kind is not, however, wanting. The vicissitudes through which these ancient rocks have passed, and their present inadequate exposure, tend to obscure their original relationships. Nevertheless dykes may be seen at various points, especially at the western end of the railroad tunnel on Jack's Mountain, where an amygdaloidal red felsite cuts the massive and schistose greenstones. Further exploration will doubtless bring to light many similar occurrences. Successive flows are not now easy to separate, but the amygdaloidal and fluidal structure of the rocks indicates that they must have been extruded in this form.

The age of the South Mountain volcanics and their relations to the sandstone in which Mr. Walcott has recently identified the lower Cambrian fauna, are points of great interest. The hypothesis of the Pennsylvania geologists that the greenstones and felsites lie above the sandstone is evidently incorrect. It may, however, be regarded as an open question whether the volcanic rocks represent a much older horizon, which was already eroded before the sandstone was deposited, or whether they were, in part at least, contemporaneous with the sandstones.

The entire absence of sandstone as inclusions in the lavas, as well as in all the accumulations of pyroclastic material; the observations of Keith, Geiger* and Walcott,† that the

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* Bull. Geol. Soc. America, vol. ii, p. 155; plates 4 and 5.

† This number of this Journal.

sandstone lies flat or in synclinals; and the sections made by Miss Bascom across Monterey Peak, Pine Mountain, Jack's Mountain, and Haycock near Monterey, all indicate that the sandstone is altogether above the volcanic rocks, and that it has been only sporadically left by erosion on the east side of the mountain in Pennsylvania. In Maryland the volcanic rocks are flanked both on the east and west by sandstone (see map). No alternations of relatively thin beds of sandstone and lava have thus far been observed. The contacts of the sandstone above the porphyry on the old tapeworm railroad southwest of Maria's Furnace, and above the greenstone in the Jack's Mountain railroad tunnel are both admirable exposures, but both seem to be thrust-planes and are not contacts of original deposition.

The South Mountain volcanic rocks therefore become, not merely in their petrographical character and richness in metallic copper, but also in their stratigraphical position, comparable with the Keewenawan or Nipigon series of Lake Superior.

5. *Chemical Alteration and Metamorphism.*—Extensive chemical changes, involving devitrification and the formation of new minerals, have gone on in all the volcanic rocks of South Mountain without destroying the original structures. In other cases, where there has been movement and shearing, the same rocks have lost both their original minerals and structures by a process of complete metamorphism. The results are more or less perfectly foliated schists and slates, whose origin can be positively traced to the volcanic rocks, and whose present form can be shown to depend upon the intensity of the dislocation to which they have been subjected.

The chemical changes which have not affected the massive character of the rocks consist of the formation of new minerals to accord with the altered physical conditions. These have, as a rule, merely replaced the former minerals so as to leave the original structure of the rock intact. In the basic rocks the new minerals are epidote, fibrous green hornblende, chlorite, serpentine, iron oxide, and, to less extent, calcite and quartz. Of these by far the most important is epidote. Indeed the conditions for the formation of this substance must have been exceptionally favorable, as it has everywhere been produced in great abundance. Some of the finer material, like volcanic ash or breccia cement, is wholly altered to this mineral. It is also the most common filling of the amygdules.

In the acid rocks there has been a complete recrystallization of all glass into a fine quartz-feldspar mosaic, which, however, still exhibits the original structures. The conditions favorable to epidote formation are manifest in these rocks in the presence of large amounts of the manganese epidote (piedmontite).

This rare mineral is so abundant and occurs in such interesting relations that it will soon be made the subject of a special communication.

The manner in which these compact, fine-grained rocks have been reduced along lines of shearing into fissile slates is most instructive. This is accompanied by the abundant production of sericite in the acid, and of chlorite in the basic rocks, while the phenocrysts and all original structures are obliterated. Amygdules, where present, usually remain as flattened spots, either lighter or darker than the rock. Several suites of specimens have been collected to illustrate this process, but the account of its details must be reserved for a future paper.

That the large area of fissile, pale green schists occurring between Pine Grove Furnace and Laurel Forge consists of sheared felsite may be seen from the following analysis, made for commercial purposes by A. S. McCreath. This rock, which is locally known as "soapstone," is extensively used at Pine Grove Furnace in the manufacture of brick. Its alkalies were not determined.

SiO_2	74·970
Al_2O_3	13·860
FeO	2·700
CaO	0·220
MgO	1·230
Alkalies	?
Ign.	2·058
Total	95·038

6. *Comparison with other regions.*—The comparative rarity of very ancient volcanic rocks in America as compared with Great Britain* and other parts of Europe is doubtless due to their not having been recognized, rather than to their actual absence. The opinions entertained by Hunt of rocks like those of South Mountain have greatly retarded, in this country, the appreciation of their true character. Still they are well known on Lake Superior and in Missouri through the writings of Irving† and E. Haworth;‡ Wadsworth§ and Diller‖ have described them in eastern Massachusetts, Shaler¶ in Maine, and the northern continuation of this same belt has been made

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* Sir A. Geikie: Anniversary Address, Quart. Jour. Geol. Soc, vols. xlvii and xlviii, 1891–1892.

† Monographs U. S. Geol. Survey, v, 1883; and Bulletin, No. 62, 1890.

‡ Am. Geologist, vol. i, p. 280, 1888, and Bull. Missouri Geol. Survey, No. 5.

§ Bull. Mus. Compar. Zool Cambridge, vol. v, No. 13, p. 282.

‖ Ibid., vol. vii. No. 2, 1881.

¶ This Journal (III), vol. xxxii, p. 40, 1886. Ann. Rep. U. S. Geol. Surv., vol. viii, p. 1043, 1889.

known by the Canadian geologists, Bailey, Matthew and Ells, in New Brunswick.* Bell has also recently described similar rocks in the Sudbury region.†

Similar areas are easily recognizable in Canada and Maine from the writings of Hunt, Jackson and Hitchcock, in spite of the fact that they are not properly interpreted. Volcanic rocks have not before been clearly identified in the Appalachians, but if attention is called to them they will doubtless be recognized at many other points.

Petrographical Laboratory,
Johns Hopkins University, Nov. 1, 1892.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Temperature of Steam from Boiling Salt-solutions.* Considerable diversity of opinion exists on the question of the temperature of the vapor arising from boiling salt-solutions. Certain observers, as Faraday, Wüllner and Magnus, maintain that this temperature is the same as that of the solution, while others, as Rudberg and Müller, hold the opinion that it is practically the same as that arising from water, boiling under the same pressure. In order to settle the question Sakurai has made a series of experiments in which certain sources of error incident to previous methods of investigation were avoided. His apparatus consisted of a long necked flask containing the solution, through the stopper of which two thermometers passed, one with its bulb in the solution the other with its bulb in the vapor above it. The neck of this flask was surrounded with a jacket, into which vapor could be passed from a boiler, and which was connected with a condenser. A third thermometer indicated the temperature in the jacket. Through a tubulure in the side of the flask, steam was blown in order to supply sufficient vapor to maintain the temperature in the neck, the excess of vapor passing off through a tube in the stopper. The solution to be examined was placed in the flask without soiling the neck, the stopper was inserted, a solution of acetic acid boiling at a slightly lower temperature than the solution was placed in the boiler and made to boil, and the gas was lighted under the flask. When the solution was heated to boiling, steam was admitted through the lateral tubulure and the whole being in equilibrium, the temperature of the thermometer was read. With a dilute solution of calcium chloride, the temperature of the solution varied from 112·5° to 113·3°, that of the jacket from 110·8° to 111·9° and that of the vapor from 111·2° to

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* Ann. Rep. Can. Geol. Surv., 1877–8 DD, and 1879–80 D.

† Ibid., for 1889–90 F, 1891.

113·3°; the difference between the temperature of the vapor and that of the solution, in eight experiments, being as much as one degree in a single case only. Solutions of potassium nitrate and of sodium nitrate gave similar results. "The experiments above described prove beyond any possible doubt," says the author, "that the temperature of the steam escaping from a boiling salt-solution is exactly the same as that of the solution. This I believe is the first occasion on which the above important fact has been experimentally established."—*J. Chem. Soc.*, lxi, 495, June, 1892. G. F. B.

2. *On the Allotropism of Amorphous Carbon.*—A graphitite has been investigated by LUZI, obtained from the chalk at Wunsiedel in the Fichtelgebirge, which was pronounced by both Fuchs and by Sandberger to be amorphous carbon, the latter considering it identical with the graphitoid or schungite of Lauer and Inostranzeff. A similar graphitite, occurring at Storgård in Finnland, has also been examined by Luzi. It occurs in the form of dark gray nodules which mark paper like graphite, have a conchoidal fracture but no cleavage. Its density is 2·255–2·26 at 17·5°, and on combustion in oxygen it leaves 0·67 per cent of a light yellow ash. The Wunsiedel mineral has a density of 2·207, and is also entirely amorphous. It is free from hydrogen and nitrogen, and on oxidation with potassium chlorate and nitric acid, gives, after five successive treatments, an orange-yellow substance, becoming brown on drying and insoluble in water and nitric acid. On heating, it is decomposed with a hissing sound, and glows, leaving behind a black powder. Under the microscope it appears to consist of minute irregularly rounded plates, which are doubly refracting. On analysis it gave 57·99 per cent of carbon, 1·93 per cent of hydrogen and 46·08 per cent of oxygen. Since ordinary amorphous carbon is completely oxidized by treatment with potassium chlorate and nitric acid, as is also schungite, and since graphite is converted into graphitic oxide by this treatment, the author considers this a new variety of amorphous carbon resembling graphite in the products of its oxidation. Indeed it appears to resemble closely graphitite produced in arc-light carbons, the oxidation-product of which gave Berthelot C 51·95, H 1·55 and O 46·50. This product the author calls graphititic oxide.—*Ber. Berl. Chem. Ges.*, xxv, 1378, April, 1892. G. F. B.

3. *On amorphous Boron.*—MOISSAN has prepared the so-called amorphous boron by the various methods described and has analyzed the products. By the method of Gay Lussac and Thenard, acting on boric oxide with potassium, using a copper tube, the product contained 44·1 per cent of boron. By acting on boric oxide with sodium in presence of sodium chloride, the method of Deville and Wöhler, a product containing 62·50 per cent of boron was obtained. By acting on potassium borofluoride with potassium, method of Berzelius, the product contained 51·15 of boron. On extracting the second product with boiling hydrochloric acid, the quantity of boron was raised to 71·97 per cent; extraction

with water lowering it to 32·38 per cent. In consequence the author first attempted to prepare boron electrolytically. When a current of 35 amperes is passed through boric oxide mixed with one fifth of its mass of sodium borate and heated to 1200°, boron is set free but at once burns to oxide. He then tried reduction by means of magnesium, mixing 70 grams of finely powdered magnesium with 210 grams of recently fused boric oxide, and heating the mixture to bright redness in a clay crucible. After the action was over, the mass was treated with water acidulated with hydrochloric acid, then with boiling strong hydrochloric acid, then with alcoholic potash and finally with hydrofluoric acid. The product was a light maroon powder, containing 94 or 95 per cent of boron. If this be fused with 50 times its weight of boric oxide and again treated with magnesium a product is obtained containing 98·3 per cent of boron. And if the reduction be effected in a crucible brasqued with titanic oxide and carbon, the percentage of boron may reach 99·2.—*C. R.*, cxiv, 319, 392; *J. Chem. Soc.*, lxii, 681, 682, June, 1892. G. F. B.

4. *On the Atomic Mass of Boron.*—ABRAHALL has determined in Dixon's laboratory the atomic mass of boron by titrating boron bromide by means of silver nitrate. The mean of five accordant determinations gave 10·825.—*J. Chem. Soc.*, lxi, 650, Aug., 1892. G. F. B.

5. *Absorption power of metals for the Energy of Electrical waves.*—Hertz concluded from his experiments that the production of resonance and the period of oscillation in resonators are not affected by the specific resistance or the magnetic properties of the secondary conductor. BJERKNES of the University of Christiana has examined this subject using an electrometer and finds that copper, brass, german silver, platinum, nickel and iron show different absorptive powers. The rate of absorption increases with the resistance and the magnetization of the metal. Iron and nickel showed a marked damping effect. Their magnetization however could be reversed one hundred million times per second. Bjernkes makes no reference to earlier papers of John Trowbridge and also of Professor Thomson of Cambridge, England, on this subject. *Ann. der Physik und Chemie*, 1892, No. 9, pp. 69–76. J. T.

6. *Electrical Oscillations.*—M. ZEHNDER exhibits to a large audience Hertz's oscillations by placing the conducting rods in the focal line of a concave mirror. These rods are connected with a Geissler tube within which the ends are placed very close together so that a general luminosity is produced inside the tube. The effects are augmented by a species of relay. On either side of the terminals of the resonator are two other terminals from a circuit of 600 Planté cells of small size, which are regulated so that the current is just able to pass between the terminals. When the resonator responds to the electric oscillations the discharge from the cells is augmented. It is also possible to work with another Ruhmkorff coil instead of with the secondary battery. *Ann. der Physik und Chemie*, 1892, No. 9, pp. 77–92. J. T.

7. *On Joints in Magnetic Circuits.*—Prof. Ewing shows the great effect of joints in reducing the residual magnetism of iron. The division of a ring 30^{cm} long into two half rings abutting against each other with the smoothest possible joints has the effect of reducing the residual magnetism from 9,000 to 6,000. "A similar reduction occurs in magnetic tests of bars when these are made to form part of a magnetic circuit by the addition of a marine iron yoke."—*Phil. Mag.*, Oct., 1892, pp. 320–326. J. T.

8. *Measurement of high temperatures.*—Ludwig Holborn and Willy Wien discuss the electrical methods of measuring high temperatures and give results obtained by the use of a thermo-element of platinum and platinum-rhodium. This method appears to be preferable to Siemens's method of observing change in electrical resistance. The authors obtain concordant results for the melting point of gold, silver and copper.—*Ann. der Physik und Chemie*, 1892, No. 9, pp. 107–134. J. T.

9. *Color Photography.*—Lippmann by the aid of a very sensitive bromide of silver albumen plate, made orthochromatic by a solution of azalin and cyanine has succeeded in photographing the solar spectrum. Also a colored church window, a parrot, and other colored objects. The time of exposure with sunlight and the electric light varied from five to ten minutes. With diffuse light an exposure of several hours was necessary.—*Comptes Rendus*, cxiv, p. 961, 962, 1892. J. T.

10. *Electrical Resistance of Metals at Low Temperatures.*—Prof. Dewar and Prof. Fleming have studied the electrical resistance of metals at the temperature of boiling oxygen, —197° C., and find an enormous decrease in the specific resistance of perfectly pure metals. Pure iron at —197° C. has $\frac{1}{23}$ of its resistance at 100° C. and pure copper $\frac{1}{11}$. The smallest impurity affects the results to a remarkable degree. A carbon filament such as is used in an incandescent lamp continually increased in resistance as the temperature was lowered. Carbon thus acts just the reverse of metals. Iron and nickel change most. Pure iron at the temperature of boiling oxygen, —197° C., conducts better than electrolytic copper at ordinary temperatures.—*Phil. Mag.*, Oct., 1892, pp. 326–337. J. T.

II. Geology and Natural History.

1. *Les Régions Invisibles du Globe et des Espaces célestes: Eaux Souterraines, Tremblements de Terre, Météorites;* par A. Daubrée, Membre de l' Institut. 240 pp. 8vo. 1892.—This volume is one of the series entitled "Bibliothèque Scientifique Internationale," published at Paris under the direction of Ém. Alglave. Prof. Daubrée has here brought together some of his very valuable papers illustrating geological principles by experimental researches. The papers included are the following: I. The work of subterranean waters at the present time; II. The part they have taken as mineralizers during geological time; III. Earth-

quakes; IV. The geological work of subterranean gases; V. Meteorites, and the constitution of the globe. It is greatly to the advantage of the science that Prof. Daubrée has made his important memoirs so conveniently accessible to those interested in the subject. This second edition contains several new figures.

2. *The Pleistocene History of Northeastern Iowa*; by W. J. McGee; pages 189 to 577 of the eleventh annual report of the director of the U. S. Geological Survey for 1889–90. A notice of this very complete memoir on northeastern Iowa is deferred to another number.

3. *Geological Survey of Iowa.*—A bill for a new geological survey of Iowa passed the legislature of the State last winter. The appointments made for the Survey are Prof. S. Calvin, Geologist, Charles R. Keyes, Assistant Geologist, and G. E. Patrick, Chemist.

4. *Tiefencontacte an den intrusiven Diabasen von New Jersey.* A. Andreae and A. Osann. (Verhandlungen des Naturhist.-Med. Vereins zu Heidelberg).—The locality which was personally studied by the writers is that at Jersey City and the diabase that of the well known Palisades. The contact of this diabase with the Newark shales is remarkable in that in extent and character it resembles that of the coarse granular abyssal rocks and not the ordinary diabase contact. The shales and arkose are completely changed to silicate hornstones, of which several varieties, one rich in tourmaline, are described. Thus the opinion that this diabase is intrusive receives strong support. L. V. P.

5. *Eleolite-Syenite of Litchfield, Me. and Red Hill, N. H.* W. S. Bayley (Bull. Geolog. Soc. Am., vol. iii, pp. 231–252).—This paper gives a careful and minute petrographical and chemical study of two varieties of eleolite-syenite. The occurrence at Red Hill, N. H., had been previously described by Hawes in his Lithology of New Hampshire as a hornblende syenite, the nephelite having been overlooked. It consists of augite, hornblende, biotite, sodalite, nephelite, albite, orthoclase and sphene. The study was made on hand specimens and nothing is yet known of its geological occurrence and connections. The same may be said of the rock from Litchfield, search in the field not yet having shown the source of the bowlders in which it occurs. This latter is shown to be a new variety of eleolite syenite in that the alkali feldspar is chiefly albite, not orthoclase. Hence regarding the albite as the most acid of the plagioclases, by a strict interpretation of Rosenbusch's system of classification, the rock would fall among the theralites and to avoid this difficulty the author proposes to distinguish the variety by the name of "Litchfieldite." This shows the rather unfortunate result of attempting to classify rocks by set schemes as if they were species. If we accept the conception held by most petrographers that eleolite-syenite is an alkali magma—rich in alumina, moderate in amount of silica, poor in ferro-magnesia and lime—crystallizing into a granular rock composed essentially of nephelite and alkali feldspar with

one or more members of the amphibole, augite or mica families present, and not according to the crystallographic nature of the essential feldspar, the name proposed seems hardly necessary.

L. V. P.

6. *The Gems and Precious Stones of North America;* by GEORGE F. KUNZ.—An Appendix to this fine work, making pages 337–367, has recently been issued. It gives much interesting matter, supplementary to the main volume, chiefly that which mineralogical investigation has brought out in the past two years.

7. *Muciferous System of Laminariaceæ*, by GUIGNARD (Annales des Sciences Naturelles, 15, I).—This study proves that certain genera of *Laminariaceæ*, such as *Lessonia* and *Alaria*, can comprise species which have no muciferous canals, while others possess them. We therefore must conclude that their presence or absence cannot offer any specific character. G. L. G.

8. *Researches on Multiple Buds*, by W. RUSSELL (Annales des Sciences Naturelles).—The principal conclusions which these researches have led the author to are:

(1) Lateral buds can be produced at the expense of the constituent parts of the foliar axil, either at the expense of the stem alone, or more rarely, that of the leaf. In the inflorescence of the Linden, Cactaceæ, and so on, their appearance can take place upon the summit at the same time as that of the axillary leaf.

(2) Every bud has at the commencement a double growth,—a proper growth, or one peculiar to itself, and a growth in common with the organs which have formed it. The latter is in general much more rapid than the former, at least at the outset.

(3) The majority of leafy buds, and numerous flower-buds, can send out branches at their base.

(4) These buds are the origin of successive ramifications which accompany the bud of the first generation, and sometimes these possess no axillary leaves at all.

(5) These successive ramifications, which are ordinarily designated as accessory buds or multiple buds, behave at the outset just as axillary buds themselves.

(6) The disposition of these buds always obeys the laws of phyllotaxy.

(7) The basal ramifications have a well-defined biological rôle. It is from these that many thorns and tendrils are produced, or modifications of inflorescence.

(8) In the majority of cases these buds remain in the state of dormant buds, and are the origin of distortions which appear under certain circumstances in woody plants. Sometimes upon annuals they play the rôle of hibernating buds, and permit the plant to grow from one year to another. They can develop in the same year that they form, or in the following year, coincidental with the bud of the first generation.

(9) We can show experimentally that the formation of these buds can continue throughout the whole life of the plant. This is well illustrated by *Convolvulus*, for example.

The principal results of these researches can be condensed into a single statement: the law of the unity of the axillary bud has absolutely no exception. G. L. G.

9. *Artificial intracellular Crystallization;* E. BELZUNG.—The author has shown conclusively that within the cell it is possible to produce artificial crystals of considerable size. His résumé, stated at considerable length by him, is condensed in the following shorter statement:

(1) All these crystallizations can be produced by the simple means of placing living tissues in pure glycerine. This reagent produces an exosmosis more rapid than that of the crystallizable substance dissolved in the water. From this process the sap is carried to the point of saturation and must undergo an intracellular precipitation.

(2) The most abundant principles which are contained in young plants which he has studied are asparagine, leucine, and neutral sulphate of potassium. The two amides crystallize in the cells simultaneously with the greatest facility. In *Lupinus luteus*, asparagine, tyrosine, and sulphate of calcium are produced. The gypsum crystallizes in the tissues, for Cicer, xanthine and calcium sulphate. Xanthine has been hitherto unknown as a product of the normal activity of the plant. It crystallizes clearly in the cells, in very delicate filamentous forms. In *Cucurbita pepo*, asparagine and potassium nitrate, can be very easily made to crystallize in all these cases.

(3) The metamorphosis of protein and saline matters under these conditions is almost exactly like that which takes place in the ripening of a seed, so that we have really artificial aleurone grains formed, much as in a ripened seed.

(4) What is the mechanism of the formation of these different products? Certain of the amides are produced from albuminoid matters by dilute acids or alkalies, as a consequence of the action of particular ferments, diastatic or peptonizing. So far as the mineral products, the nitrates and sulphates, are concerned, little can be said positively. The nitrates of germination, for example, are comparable with those salts of the same composition which result from bacterial fermentation of ammoniacal compounds, and the same remark applies to the sulphates of germination. G. L. G.

10. *On the Aeration of Solid Tissues;* HENRI DEVAUX.—(1) The internal atmosphere of all solid tissues contains a notable proportion of oxygen, in certain cases pretty nearly that which exists in pure air.

(2) The proportion of carbonic acid is in general feeble.

(3) The proportion of nitrogen is often different from that which exists in pure air, sometimes less, often more.

(4) The total pressure of the internal atmosphere differs from that of the exterior air, sometimes positively, more often negatively, and its ratio is always inverse to the proportion of nitrogen.

(5) We may consider tubers, tubercles, fleshy fruits, and most solid organs as formed of a mass very porous in its character,

which is enveloped by a thin and porous membrane, less permeable than itself. Sometimes this has no normal pores, for instance, in the apple, the orange.

(6) It is probable that a gas which traverses the envelope can penetrate to the deepest part of the tissue.

(7) The gas passes through the external envelope of solid masses, sometimes in the free state, and sometimes dissolved.

(8) The changes which are produced at the surface depend on the permeability and the porosity of the peridermic membrane.

(9) Oxygen tends to enter especially by the pores, while carbonic acid escapes from the whole surface of the membrane. There exists a veritable circulation of these gases, but the circulation is only partial in the majority of instances.

(10) Humidity acts in a very variable manner on the composition of the internal atmosphere, sometimes increasing permeability, sometimes diminishing it.

(11) Slow or rapid drying diminishes permeability and causes a greater and greater accumulation of carbonic acid.

(12) It is to these variations in the proportions of oxygen and carbonic acid in the internal atmosphere that we must attribute the different values of pressure in the internal atmosphere.

(13) According as the total pressure is stronger or weaker in the internal atmosphere, there is produced across the superficial pores an inward or an outward current. This gaseous current is purely mechanical, and can be regarded as a third series of exchanges.

(14) Nitrogen is passively held in this gaseous current.

(15) When the gas acquires a constant difference of pressure, in spite of the constant sweeping hither and thither, we must believe that the current is produced in some other way than by diffusion. A constant circulation of nitrogen exists in the aërial parts of plants, but the circulation is purely passive.

(16) Temperature increases or diminishes the intensity of respiration, and this modifies the composition of the internal atmosphere.

(17) Light acts wherever green matter exists, sometimes through chlorophylline assimilation, and sometimes by the withdrawal of water, thus influencing the permeability of the membranes.

The mechanism of exchange can be summed up in the following conclusion : Gaseous exchanges of all solid organs hitherto studied are produced in three different ways, which ordinarily coexist, but which act with a variable intensity. These are, Effusion; Dialysis; and a purely mechanical passage of a gaseous current.

Effusion. Diffusion of free gas across the pores of an envelope under the influence of differences of pressure proper to each gas.

Dialysis. Diffusion of gas, dissolved, across the membrane under the same influence.

Gaseous current. General displacement of the total mass of the mixed gases across the pores of the envelope under the influence of the difference of total pressure which exists between the interior and the exterior. G. L. G.

11. *Bibliotheca Zoologica*, II.—This valuable and exhaustive work, under the editorship of Dr. O. Taschenberg, giving the titles of works and articles on Zoology which appeared between 1861–1880, has reached its 10th Lieferung. This includes the last of the Mollusca and beginning of the Vertebrates, covering signatures 361 to 400, or pp. 2929 to 3248.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—At the meeting of the National Academy held in Baltimore, Nov. 1 to 4, 1892, the following papers were presented :

G. K. GILBERT: The Evolution of the Moon.

T. C. MENDENHALL: On the Observations for Latitude at Rockville. Md. On the Latitude Observations at Honolulu. The Use of Planes and Knife-edges in Pendulums.

THOMAS B. OSBORNE: Crystallized Vegetable Proteids. Proteids of the Flaxseed.

H. A. ROWLAND: A Spectroscopic Analysis of the Rare Earths. A Table of Standard Wave-lengths. On the Motion of a Sphere in a viscous Fluid.

G. H. WILLIAMS: Volcanic Rocks of South Mountain in Pennsylvania and Maryland.

IRA REMSEN: On Some Curious Double Halides. Study of the Action of Light on acids in Solutions containing a Salt of Uranium.

C. BARUS: On Isothermals and Isometrics of Viscosity.

W. K. BROOKS: Significance of the Follicle of Salpa. Biological Relations of the oldest Fossils.

E. D. COPE: On the Vertebrate Fauna of the Blanco Epoch.

S. C. CHANDLER: On the Motion of the Earth's Pole.

C. S. HASTINGS: Recent Improvements in Astronomical Telescope.

GEORGE E. HALE: Exhibition of Photographs illustrating new methods and results in Solar Physics.

GEORGE E. SQUIER and FRANK A. WOLFF, JR.: Some effects of Magnetism on Chemical Action.

Volume V of the Memoirs of the Academy, which has just appeared, is a large quarto of about 600 pages with many plates. The following are the papers it contains : On energy and vision by S. P. Langley ; Contributions to Meteorology by Elias Loomis ; Report of studies of atmospheric Electricity by T. C. Mendenhall ; Embryology and metamorphosis of the Macroura by W. K. Brooks and F. H. Herrick ; Application of interference methods to astronomical measurements by A. A. Michelson.

INDEX TO VOLUME XLIV.*

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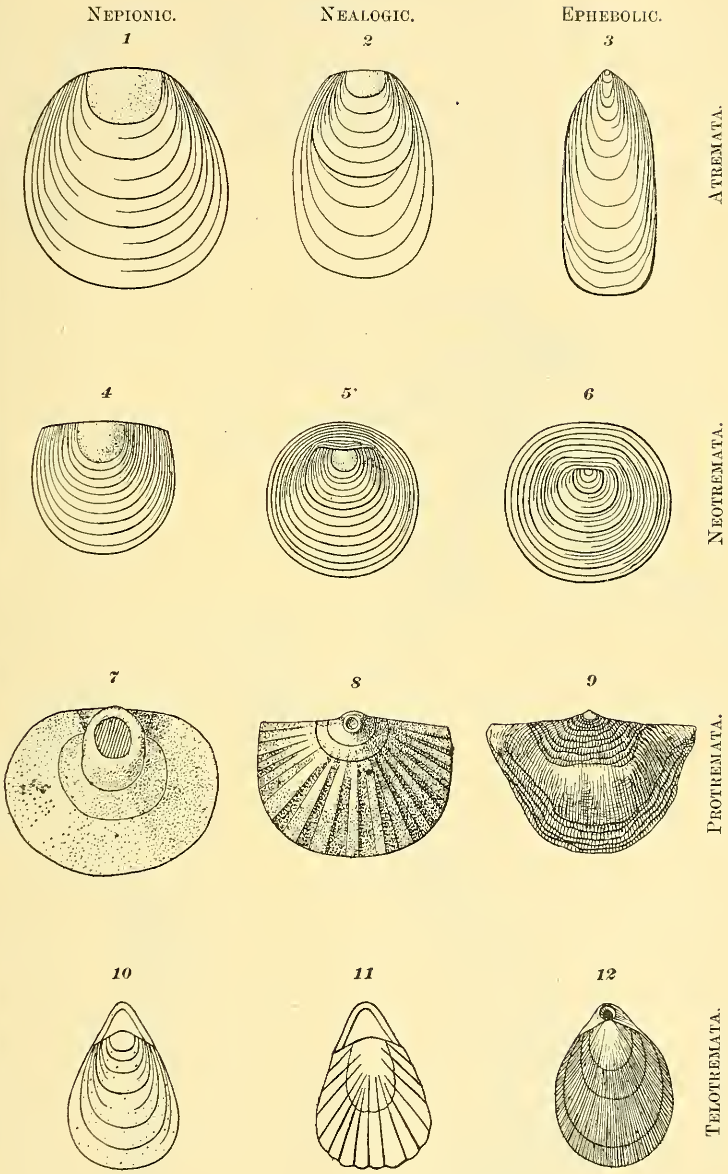
* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ROCKS, and under each the titles of Articles referring thereto are mentioned.


Nepionic.
Nealogic.
Ephebolic.
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Protremata.
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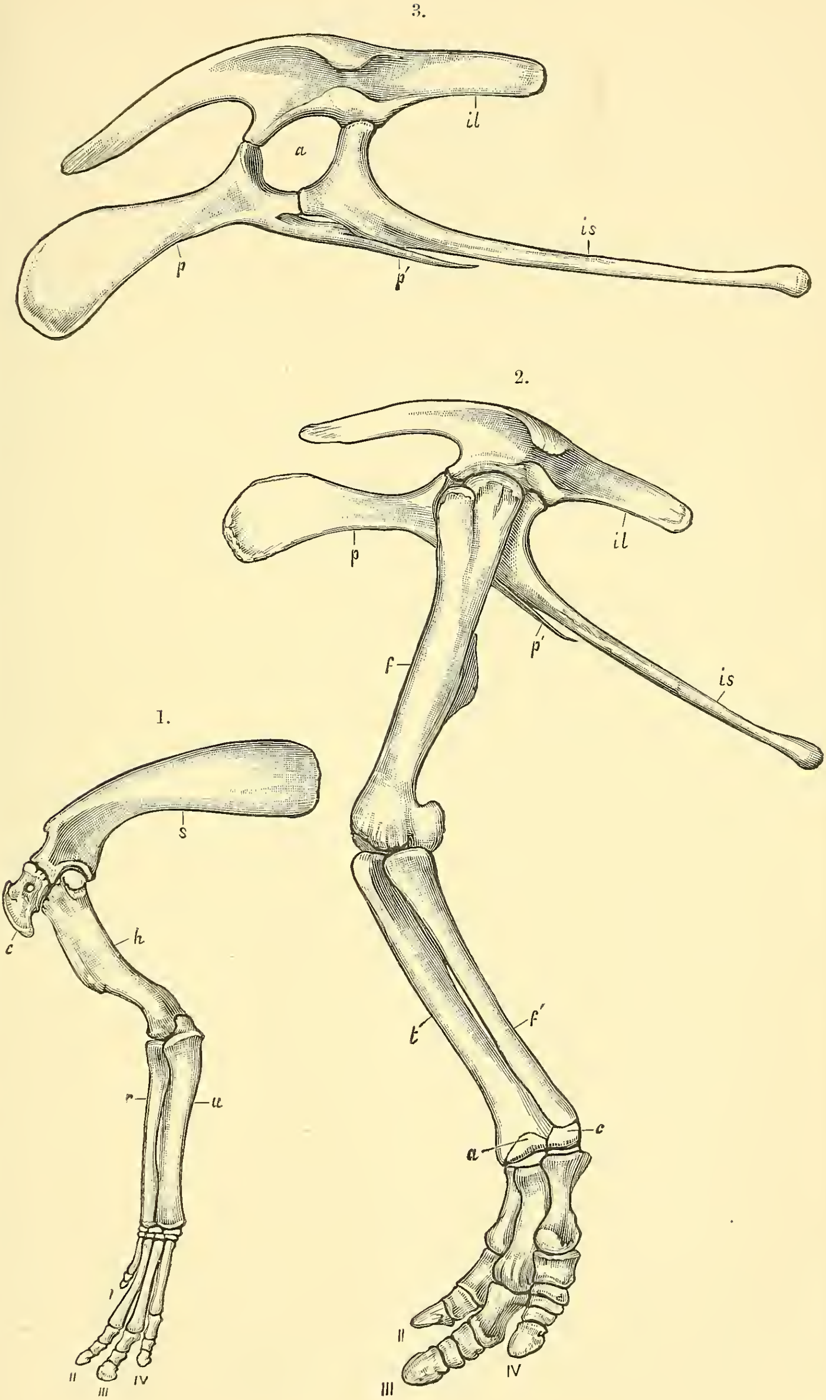
Telotremata.



Claosaurus annectens, Marsh. Cretaceous.

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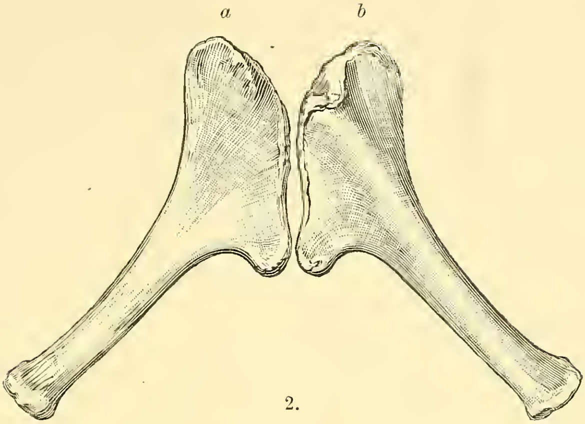

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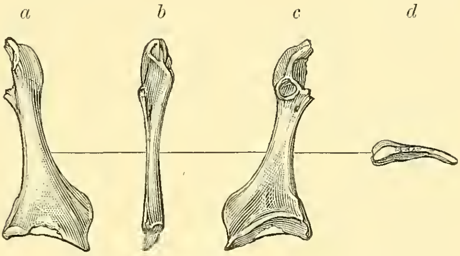

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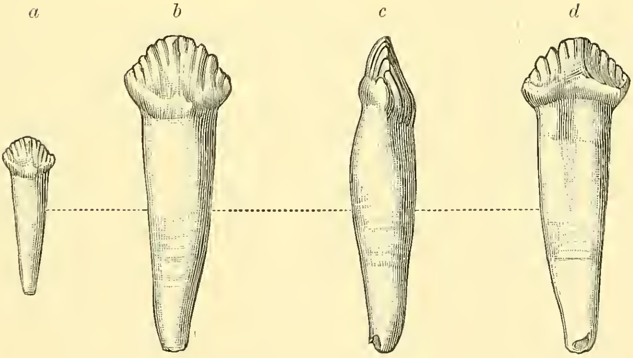

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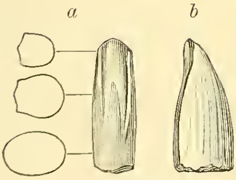

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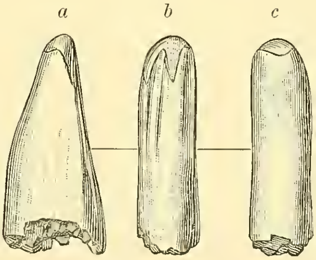

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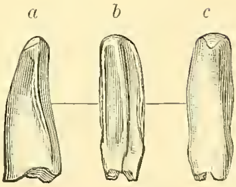
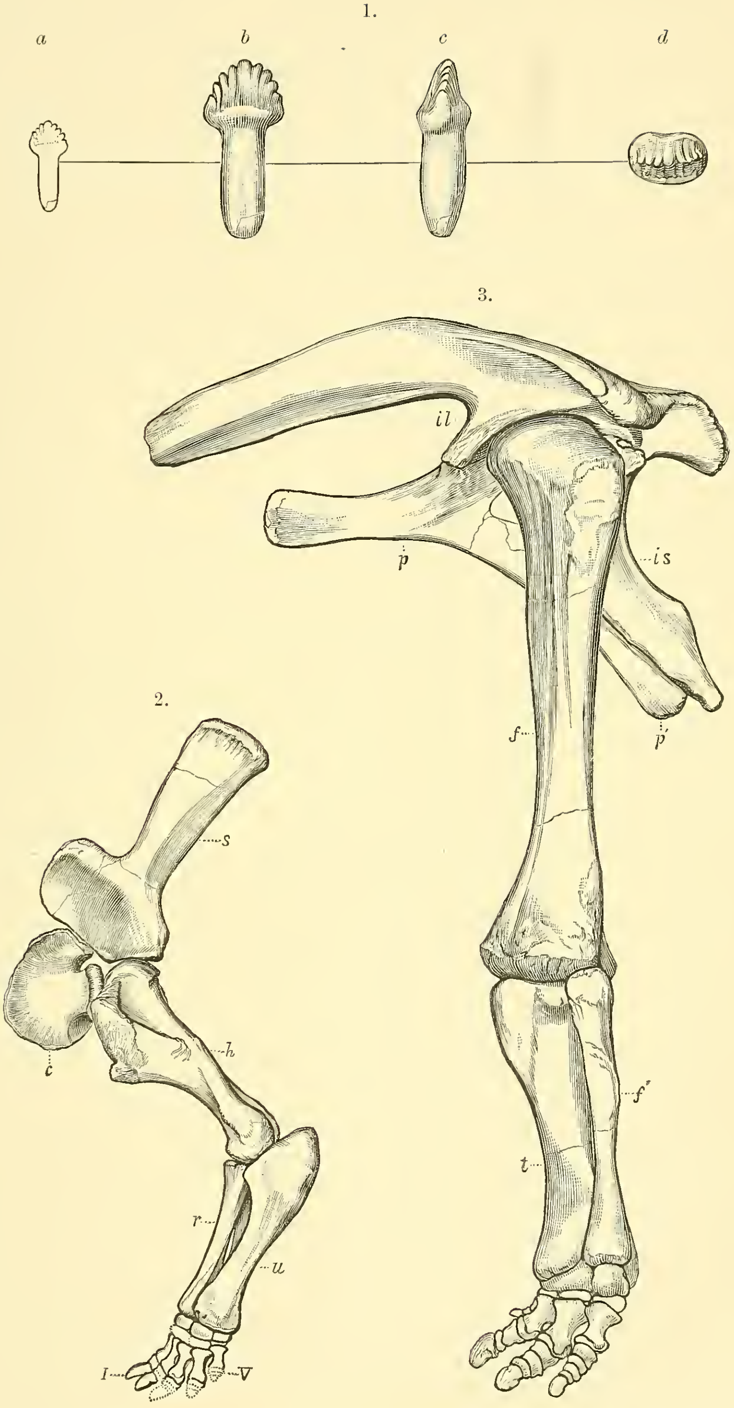
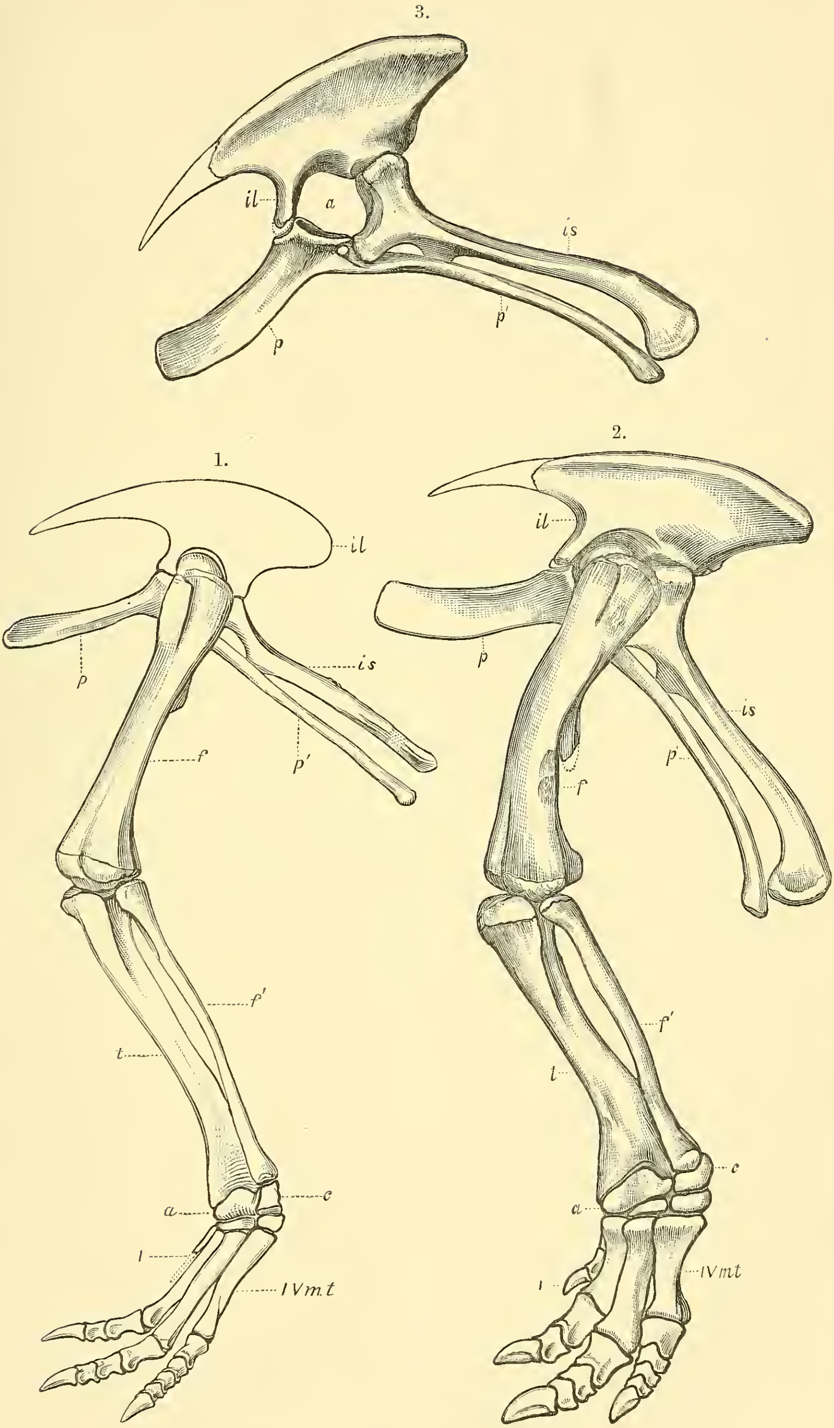


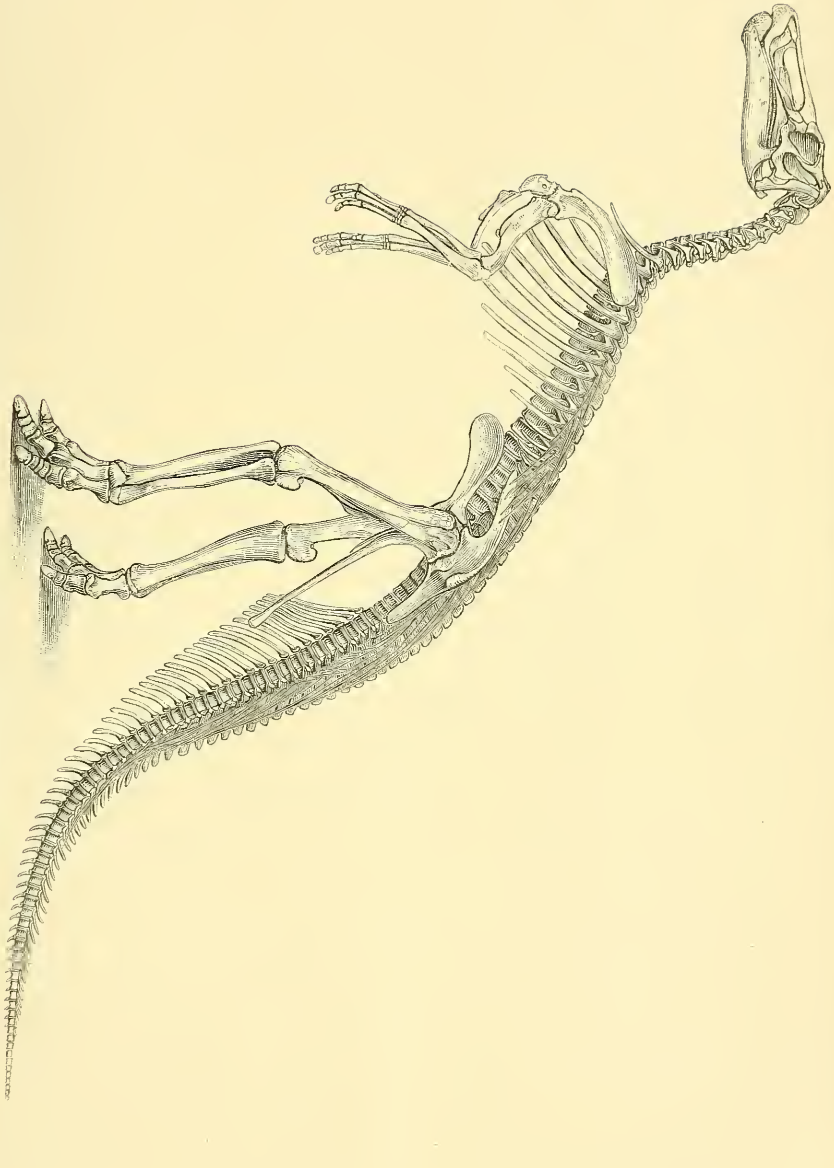
1. CLAOSAURUS. 2. CIMOLOPTERYX. 3. PALÆOSCINCUS. 4–6. AUBLYSODON. Cretaceous.



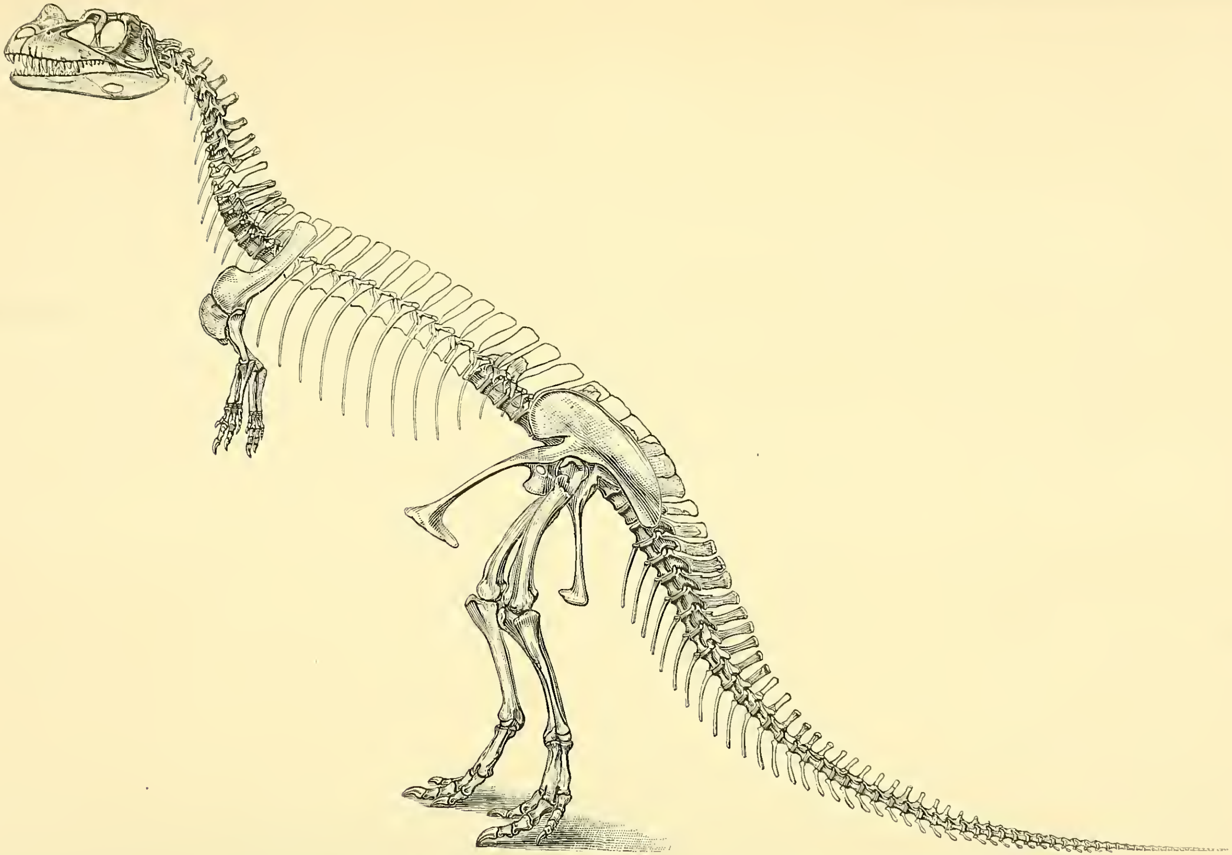
Stegosaurus ungulatus, Marsh. Jurassic.



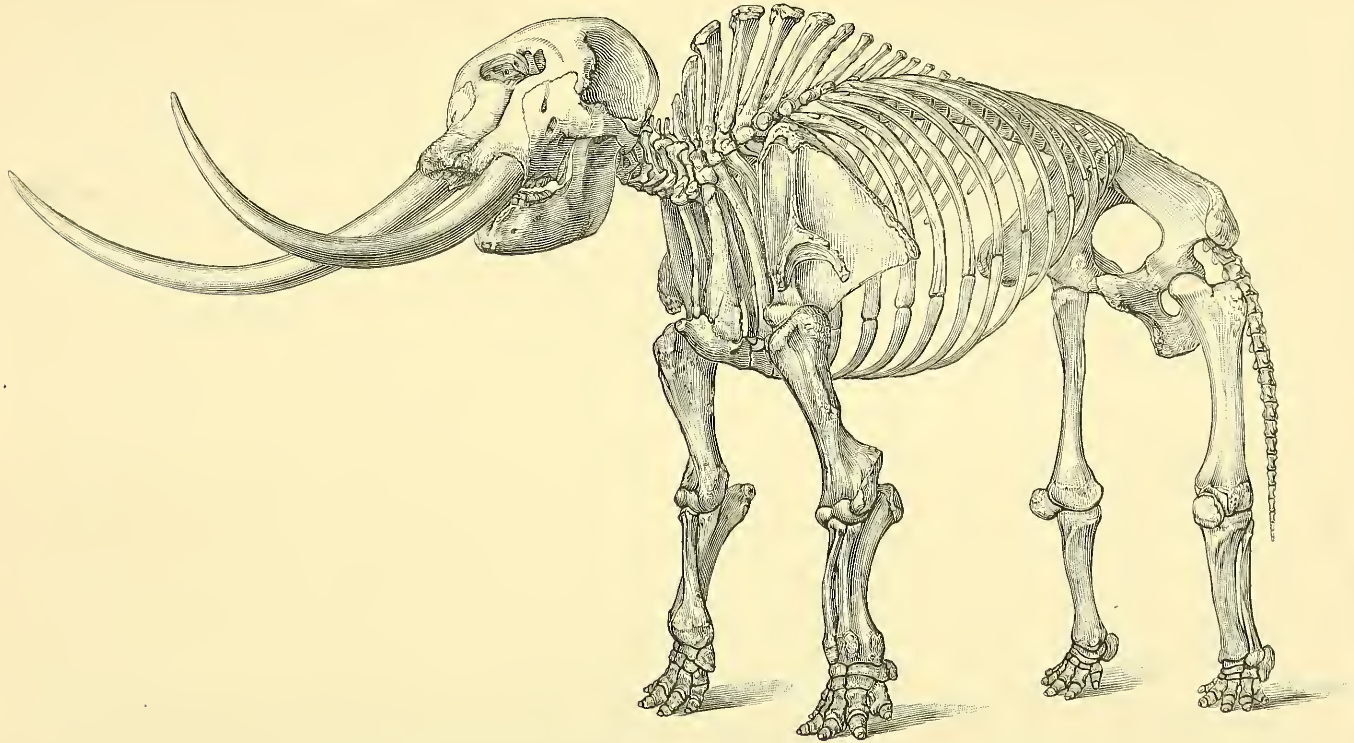
1. Laosaurus. 2 and 3. Camptosaurus. Jurassic.



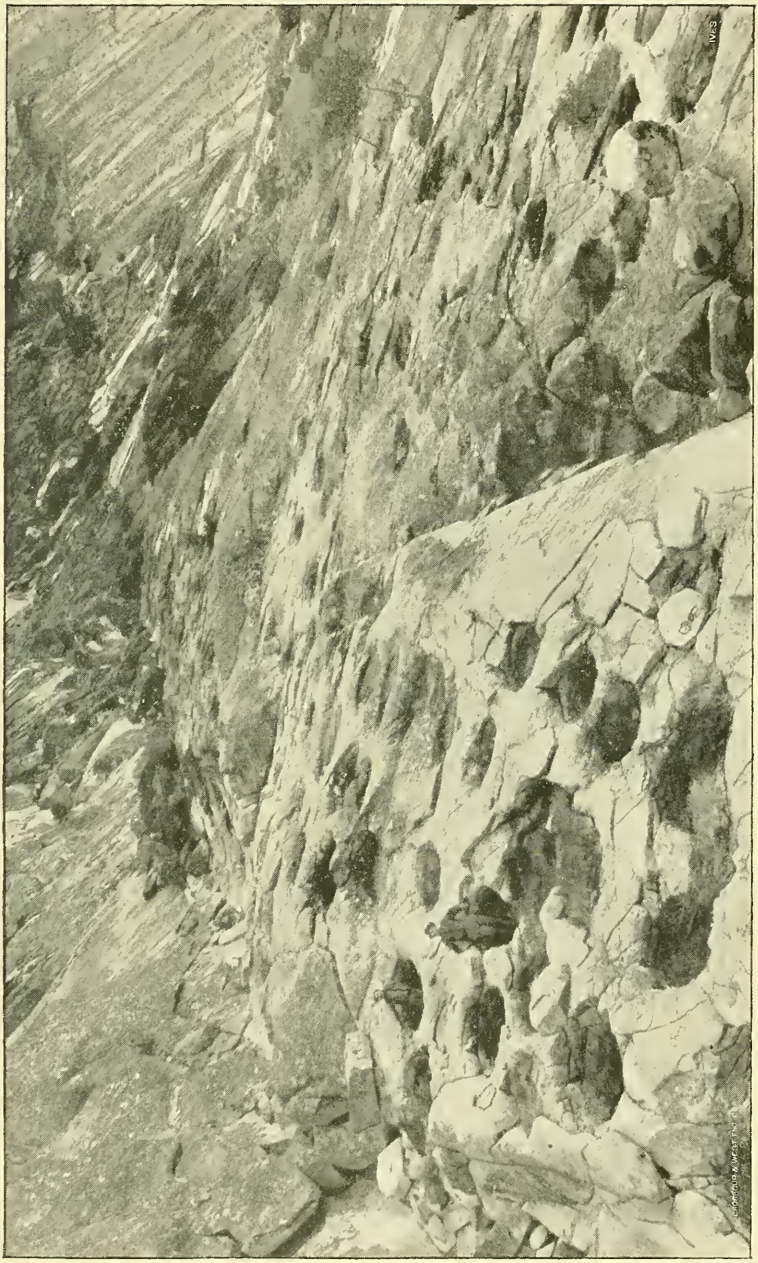
Restoration of CLAOSAURUS ANNECTENS, Marsh. One-fortieth natural size.



Restoration of CERATOSAURUS NASICORNIS, Marsh. One-thirtieth natural size.



Restoration of MASTODON AMERICANUS, Cuvier. One thirty-second natural size.



Pot-holes in Mokelumne River Cañon, California.

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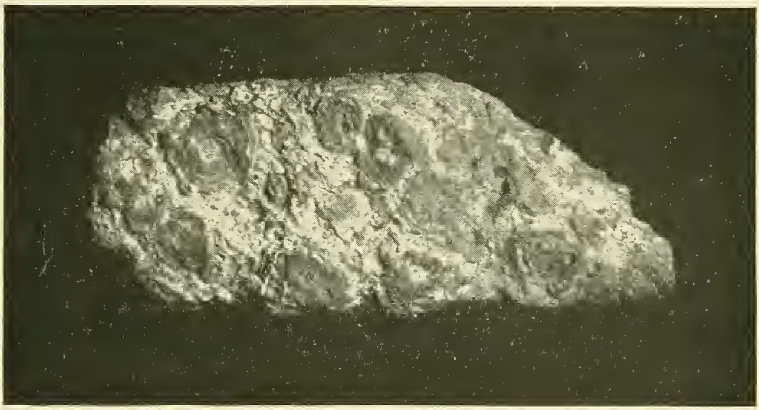

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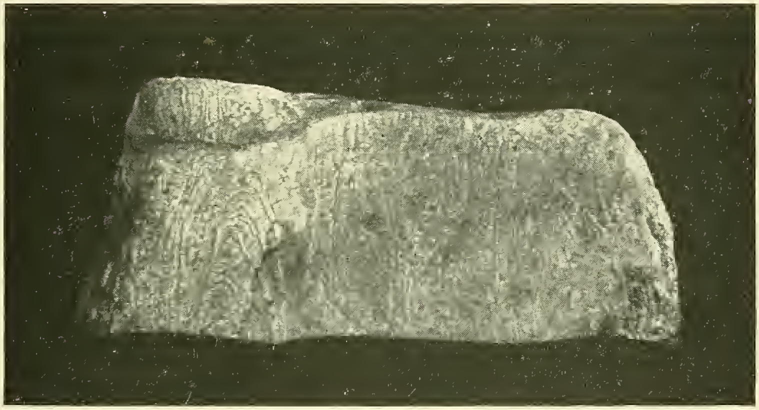

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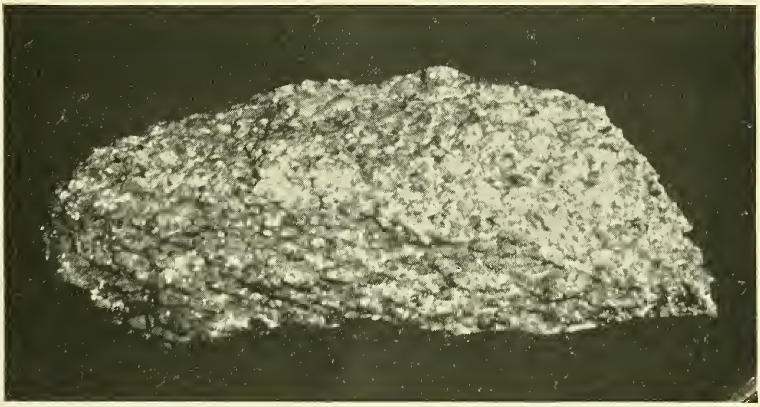

South Mountain Rhyolites.

1.—Lithophysae, Raccoon Creek. 2.—Flowstructure, Raccoon Creek.
3.—Spherulites, North of Tom's Creek.
(All reduced about one-half.)

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CONTENTS.

SCIENTIFIC INTELLIGENCE.

ERRATUM.—Page 468, line 11 should read: difficultly soluble or insoluble, etc.