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CONTENTS OF VOLUME XLV.

Number 265.

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Influence of Foreign substances on the Form, the Size and the Purity of Crystals separating from a solution, RETGERS, 65.—Resolution of Lactic Acid into Optically active Constituents, PURDIE and WALKER: New element Masrium, RICHMOND and OFF, 66.—Freezing points of very dilute Solutions, RAOULT, 67.—Chemical Lecture Experiments, G. S. NEWTH: Color Photography, M. G. LIPPMAN: Infra red spectra of the Alkali Metals, B. W. SNOW, 68.—Magnetic effect of the Sun upon the Earth, W. THOMSON: Sound and Music, J. A. ZAHM, 69.

Geology and Mineralogy—View of the Ice Age as One Glacial Epoch, 70.—Pleistocene History of Northeastern Iowa, W. J. McGEE, 71.—Note on the paper in the November No. of this Journal on "A New Oriskany Fauna in New York," S. T. BARRETT: Subdivisions of the Azoic or Archæan in Northern Michigan, M. E. WADSWORTH, 72.—Geological and Natural History Survey of Minnesota, N. H. WINCHELL: Final Report of the Pennsylvania Geological Survey, LESLEY: Arkansas Geological Survey: Geological Map of Baltimore and its Vicinity: Devonian Fishes of Canada, A. S. WOODWARD, 73.—Nepheline Rocks in Brazil, O. A. DERBY: Panama Geology, M. DOUVILLÉ: Geological Map of Scotland, A. GEIKIE: Quaternary Carnivores found on the island of Malta: Excavation by Glaciers: Chamberlin on the Glacial period, 74.—Mikroskopische Physiographie der petrographisch wichtigen Mineralien, von H. ROSENBUSCH: Gesteine de Ecuatonanische West Cordillere, M. BELOWSKY: Chemical Contributions to the Geology of Canada G. C. HOFFMANN, 75.—Presence of Magnetite in certain Minerals and Rocks. LIVERSIDGE: Manual of Qualitative Blowpipe Analysis and Determinative Mineralogy, F. M. ENDLICH, 76.

Miscellaneous Scientific Intelligence—Geminid Meteors of Dec. 11, 1892: La Planète Mars et ses Conditions d'Habitabilité, CAMILLE FLAMMARION, 77.—Investigation of the Coral Reefs of the West Indies, A. AGASSIZ: Gelatine slides for lantern projection, W. J. WAGGENER: Transactions of the Texas Academy of Science: Die Klassiker der exakten Wissenschaften, W. OSTWALD, 78.—Royal Society of London, 79.

Obituary—JOHN STRONG NEWBERRY, 79.—SIR RICHARD OWEN, 80.

Number 266.

SCIENTIFIC INTELLIGENCE.

Number 267.

SCIENTIFIC INTELLIGENCE.

Number 268.

SCIENTIFIC INTELLIGENCE.

Number 269.

SCIENTIFIC INTELLIGENCE.

Number 270.

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[THIRD SERIES.]

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ART. I.—*The Age of the Earth;* by CLARENCE KING. With
Plates I and II.

AMONG the various attempts to estimate geological time
none has offered a more attractive field for further develop-
ment than Lord Kelvin's mode of limiting the earth's age
from considerations of its probable rate of refrigeration,
published in 1862.* At that time the consequences of his
physical reasoning could not be fully applied to the condi-
tions within the earth, so as to test the probability of his
hypothetical case, for want of positive knowledge of certain
properties of rocks, particularly the volume changes of melted
rock in approaching and experiencing congelation, and the
qualitative and quantitative effects of pressure upon the fusion
and freezing points. Data then lacking are for the first time
available, and with them it is proposed to apply a new crite-
rion to the gradient of Lord Kelvin and to compare with
it other cases of more probable earth-temperature distribution,
which should have the effect of advancing his method of
determining the earth's age to a further order of importance.

Accepting the hitherto unshaken results of Kelvin and G.
H. Darwin, as to the tidal effective rigidity of the earth, and
the further argument for rigidity advanced by Prof. S. New-
comb† from the data of the lately ascertained periodic variation
of terrestrial latitude, as together warranting a firm belief in the
rigid earth, it follows that solidity may be used as a criterion

* Treatise on Natural Philosophy, Thomson and Tait, Part 2, Appendix D.
† Monthly Notices of the Royal Astronomical Society, vol. lii, No. 5, 1892.

to test the probable truth of many cases of earth-temperature distribution; at least so far as to justify the rejection of such as involve considerable liquidity of the upper couches. In an earth of which the superficial quarter of radius is composed of materials that contract from the fluid condition toward and in the act of congelation, any temperature gradient in which the downward heat augmentation exceeds the rate by which advancing pressure raises the fusion point, would obviously reach a fused couche, and all such distributions may be rejected as violating the requirements of rigidity.

A recent investigation of the rock diabase in its relations to heat and pressure offers the formerly lacking means of testing the admissibility of many cases of earth-temperature distribution from the point of view of solidity. Ten years ago in a laboratory established by me in connection with the United States Geological Survey, Dr. Carl Barus began a series of experimental researches tending toward the solution of some of the unknown but important points of geological physics. It has been my privilege to indicate the direction of much of the inquiry. The understanding between us maintained his entire independence in the mode and prosecution of the investigations and secured for him the fullest responsibility and credit for the purely physical results, many of which have at intervals appeared in this and other journals. For myself was reserved the privilege of making geological applications of the laboratory results. One of the most important of these is Dr. Barus's lately completed determination of the latent heat of fusion, specific heats melted and solid, and volume expansion between the solid and melted state, of the rock diabase.* To him I am also very generally indebted for aid in considering the present problem.

Diabase was chosen by me as fairly illustrative of the probable density and composition of the surface ·03 or ·04 of the earth's radius. For Laplace's law of distribution, density at the surface is taken at 2·75 and down one-tenth of radius at 3·88, yielding a mean density of the whole tenth of 3·33 and for the upper five-hundredths of about 3. For the whole tenth a rock like the extremely heavy basalt of Barenstein† (sp. gr. 3·35) would approach closely a fair mean expression of density. Typical hornblende-andesite comes closest to the average density at the surface, but diabase (sp. gr. 2·8 to 3·), nearly enough fills the conditions of the shell which this study seeks to investigate. The particular diabase under examination came from Jersey City, and was taken from the immediate vicinity of the Pennsylvania R. R. cut.

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* This Journal, Dec., 1891, and Jan., 1892.
† J. Roth, Gesteins-Analysen, 1861, p. 46.

The following analysis is by G. W. Hawes :[*]

Silica	53·13
Alumina	13·74
Ferrous oxide	9·10
Ferric oxide	1·08
Manganous oxide	0·43
Lime	9·47
Magnesia	8·58
Soda	2·30
Potash	1·03
Ignition	0·90
	99·76

Astronomical and geodetic requirements make necessary that density should proceed downward in shells of successively greater value, but the surface density is 2·75 and the mean density of the whole earth is not twice that of diabase, whence it appears that no probable chemical distribution of material could result in a surface couche of ·05 of radius having a greater specific gravity than 3· to 3·3.

Waltershausen[†] in his interesting scheme of chemical distribution attempts to account for the augmentation of density chiefly by the increase of the heavy bases, but leaves the whole surface tenth of radius in silicates. Eruptions of alkaline earths or metals are unknown, in fact, with the exception of carbonates of superficial origin the whole visible body of the crust is of silicates, and the earliest rocks are seen to be made of the debris of still older ones. All that can be said is that there is absolutely no known reason why the surface tenth of radius may not be of silicates, nor why specific material of widely different thermal properties from diabase should be postulated.

The two principal conditions within the interior of the earth upon which physical state and all purely physical reactions of the specific materials depend, are the distributions from center to surface of pressure and heat. Secular or sudden variations of either or both have the power, if carried sufficiently far, to disturb chemical and physical equilibrium and produce changes of volume, rigidity, viscosity, and conductivity, as well as changes of state from liquidity to solidity, and the reverse. Before proceeding to consider in detail some of the results of heat and pressure as existing in the surface ·05 of radius, it is desirable to glance at the relations of these two great antagonistic

[*] This Journal, III, vol. ix.
[†] " Rocks of Sicily and Iceland."

energies in the whole radius. Plate I gives earth-pressures from Laplace's law expressed in a gradient of which the ordinates are 100,000 atm. (larger divisions 1,000,000 atm.) and the abscissæ tenths of radius. Upon the same diagram are delineated two hypothetical cases of earth-temperature, the abscissæ remaining as for the pressure line, tenths of radius, and the ordinates corresponding in interval to the 100,000 atm. lines, are taken as each 1,000° C. The left vertical boundary of the plate represents the center of the earth and the right one the surface. The upper heat gradient corresponding to a temperature of 3,900° C. at the earth's center is the 100x10⁶ curve of Kelvin. The lower is computed for a central temperature of 1,741° C., about the melting point of platinum, and a secular cooling in 20x10⁶ years. Data for the construction of these gradients are given in the tables a few paragraphs later. The feature here called attention to is the exceedingly slight change of temperature from very near the surface downward to the center. In the Kelvin gradient even after the lapse of 100x10⁶ years the original maximum temperature is reached within ·05 of radius and remains thence unchanged to the center. Pressure, on the other hand, augments with one downward sweep through the entire radius. On Plate I its line is seen cutting both temperature gradients near the surface, passing the 1,741° C. line at a pressure of 175,000 atm., and the Kelvin line at 390,000 atm.; thence steadily augmenting until at the center it reaches the impressive figure of 3,018,000 atmospheres.

Since we are to look to heat and pressure for the keys to the physical condition of the matter of the earth, it is important to realize from the relation of these gradients, first, that the great effect of heat in opposing and overcoming the results of pressure must be limited to superficial earth-depths not exceeding 200 miles for an earth of the Kelvin assumptions; secondly, that below this depth and onward to the center there is a complete reversal of relations and a great and continual increase of pressure available to oppose and destroy the volumetric and other molecular effects of a temperature which has ceased to increase. The empire of heat over pressure is thus seen to be purely superficial, while that of pressure over heat begins not far below the surface and extends more and more powerfully to the center. This is obviously true only for such moderate assumptions of heat and time as are given in the gradients on Plate I, but it will be shown later that these figures are, upon the criterion of solidity, far more probable than very hot or very old earths.

Out of the infinite number of possible earth-temperature gradients, to discriminate the probably true case, is of critical

importance in any attempt to determine the earth's thermal age or to delimit the period of active geological dynamics.

Pressure and Temperature Tables.

The following tables offer figures for the construction of the pressure and some of the temperature gradients on both Plates I and II. Data for the distribution of earth-pressure may be obtained either from the formula of Laplace or that of G. H. Darwin for radial earth density, combined with the known decrease of terrestrial gravitation from center to surface.

In table 1, Laplace's law is used as giving the most conservative values of density at great depths. For the superficial ·2 of radius, however, the two density laws are near together, and as the thermal phenomena which determine the earth's age are probably wholly in the surface tenth, either law might be applicable to the present purpose. As, however, Darwin's law requires a surface density of 3·7, while Laplace only 2·75, the latter accords better with the average specific gravity of superficial rocks and is, therefore, here preferred.

Tables 2, 3 and 4 give data for three temperature gradients derived by mechanical quadrature from the well known Fourier equation in the manner given by Lord Kelvin, and are considered as sufficient in number and variety to indicate the character of the data ; figures for the other gradients shown on Plate II are therefore omitted.

Table 2 presents data for the Kelvin gradient, 3,900° C. initial excess, surface rate ·03600 in degrees Centigrade per meter of depth, and secular cooling 100×10^6 years. Earth temperatures in ° C. are given for depths that are expressed both in miles and fractions of radius and extend to 250 miles or about ·06 of radius. Surface rate appears both in ° Fahr. and feet, and ° C. and meters. Tables 3 and 4 exhibit similar data for earths of lower initial excess and shorter periods of secular cooling. Table 3 is computed for an earth of 1,740° C., 20×10^6 secular cooling, and table 4 for 1,230° C., 10×10^6 cooling.

TABLE No. 1.

Estimated Earth Pressures (Laplace's densities) n being radial distances from the center of the earth and p being the pressure corresponding to n expressed in atmospheres.

n. Earth Rad.	p. Atm.	n. Earth Rad.	p. Atm.	n. Earth Rad.	p. Atm.
1·000	0	·94	116000	·5	1680000
·995	8600	·92	162000	·4	2100000
·990	17400	·90	199000	·3	2470000
·985	26400	·80	497000	·2	2770000
·980	35600	·70	852000	·1	2950000
·960	74500	·60	1260000	0	3020000

TABLE NO. 2.

Estimated Earth Temperatures.   Initial excess of 3900° C.   100 millions of years
secular cooling with surface rate of 1° F. for 50·6 feet of depth.
Thermal conduction 400 ft²/year (Lord Kelvin's case).

Miles deep.	Rate in ° F and ft.	Rate in ° C and meters.	Temperature in ° C.	Depth in earth radius.
0	·01977	·03600	0	·00000
12	·01924	·03510	726	·00312
25	·01773	·03230	1412	·00625
50	·01279	·02330	2543	·01250
75	·00742	·01350	3275	·01875
100	·00346	·00630	3658	·02500
125	·00129	·00236	3825	·03125
150	·00039	·00071	3881	·03750
175	·00009	·00017	3897	·04375
200	·00002	·00003	3901	·05000
225	·00000	·00001	3902	·05625
250	·00000	·00000	3902	·06250

TABLE NO. 3.

Estimated Earth Temperatures.   Initial excess 1741° C. (about melting point of
platinum) 20 millions of years secular cooling with surface rate of
1° F. to 50·6 feet of depth.   Thermal conduction 400 ft²/year.

Miles deep.	Rate ° F and feet.	Temperature ° C.	Depth in earth radius.
0	·01977	0	·00000
6	- - - - -	359	·00156
12	·01726	693	·00312
25	·01147	1218	·00625
37	·00581	1534	·00937
50	·00224	1675	·01250
62	·00066	1725	·01562
75	·00015	1738	·01875
87	·00002	1741	·02187
100	·00000	1741	·02500

TABLE NO. 4.

Estimated Earth Temperatures.   Initial excess 1230° C., 10 millions of years
secular cooling with surface rate of 1° F. to 50·6 feet of depth.
Thermal conduction 400 ft²/year.

Miles deep.	Rate ° F. and feet.	Temperature ° C.	Depth in earth radius.
0	·01977	0	·00000
12	·01506	662	·00312
25	·00665	1063	·00625
37	·00171	1198	·00937
50	·00025	1227	·01250
62	·00002	1230	·01562
75	0	1231	·01875
87	0	1231	·02187
100	0	1231	·02500

TABLE No. 5.

Estimated Melting Point and Depth for the rock Diabase expressed in radial earth
distance, pressure and melting temperature.

$n.$ Earth Rad.	$p.$ Atm.	$\theta_m.$ ° C.	$n.$ Earth Rad.	$p.$ Atm.	$\theta_m.$ ° C.
1·000	0	1170	·920	162000	5210
·995	8600	1380	·900	199000	6100
·990	17400	1600	·8	497000	14000
·985	26400	1830	·6	1260000	33000
·980	35600	2060	·4	2100000	54000
·960	74500	3030	·2	2770000	71000
·940	116400	4080	·0	3020000	76000

Table 5 contains a prolongation of Barus's line of melting
point and depth for the rock diabase, expressed in radial earth
distance n, pressure p (Laplace's densities), and melting tem-
peratures, θ_m.

The Chart.

The chart constituting Plate II is constructed to present the
passage of certain hypothetical temperature gradients through
the uppermost ·08 of the earth's radius, and the position in the
same field of Barus's line marking the melting point in depth of
diabase, thus defining the relations of the various distributions
of earth-temperature to liquidity. The value of the ordinates is
each one thousand degrees Centigrade ; the abscissæ, which are
platted as equal in length to the ordinates, represent hun-
dredths of radius counting downwards from the surface which
is indicated by the right vertical boundary of the chart.

Kelvin's application of the Fourier equation involves an
assumed initial excess of temperature, an assigned value of rock
conductivity, a given period of secular cooling and the sur-
face rate of augmentation of earth-temperature.   As thus
applied to the case of the cooling earth, it is obvious that
while the body was of uniform initial heat there would
be no augmentation of temperature from the surface down-
ward, or otherwise expressed, the surface rate would be ∞ ;
but the moment refrigeration began a finite rate of downward
increment would be established. Since the earth's surface is
represented on the chart by the right vertical boundary, that
line would be the thermal distribution for the rate ∞. A com-
plete process of refrigeration would cause the rate to decline
until the earth reaches the temperature of space and the
line of initial tangency coincides with radius, and the rate
0. The angular relation of the initial tangent of the present as
compared with that of the rate ∞ is determined from ob-
served surface augmentation.

The value of the integral and the surface rate for any gradient does not change if conductivity and age vary reciprocally, and the surface rate does not change if the initial excess of temperature varies at the same rate as the square root of the product of conductivity and the time of secular cooling. If the square root of the product of conductivity and age be increased any number of times and the depth also be increased the same number of times, temperature remains unchanged if the initial excess is unchanged, but if the initial excess changes, temperature will change in the same ratio.

Upon the chart are delineated two families of temperature distributions. Those in continuous lines, lettered *a* to *f*, are calculated in accordance with the maximum surface rate of 50·6 ft. to 1° Fahr., being the generally accepted rate at the time Kelvin's curve was published. Those in dotted line and lettered *g* to *i*, are constructed for the rate of 75 ft. to 1° Fahr. the smallest of the observed inland rates. It is the value given by Hallock* for the recently completed boring near Wheeling, W. Va. The last published value as reduced from all available data by the B. A. committee is 64 feet to 1° Fahr. It is, therefore, extremely probable that unless some general but unrecognized cause, like a variation of temperature due to the chemical action of hot water and progressive downward either with heat or pressure, tends to raise or lower the mean rate, the true surface distribution falls between the values of 50·6 and 75 ft. per ° Fahr. upon which the two families of gradients are based.

The diabase line for melting temperature and depth D D is traced from its superficial fusion point, 1,170° C., downward according to the law established by Dr. Barus and expressed in table 5. This is the special point of interest in the chart and in the conclusions to which it gives rise. In passing from this surface value of 1,170° C. through ·1 of the radius, the fusion temperature is raised to 6,139° C.; continuing thence to the center of the earth it reaches the surprising value of 76,200° C. In consequence in an earth all of diabase any temperature gradient having an initial excess of less than the above central value must in reaching the surface either intersect the line D D twice or fall wholly beneath it. Since this line represents melting temperature, any point vertically above it in the chart is necessarily more highly heated than the melting temperature for the same depth, and hence in fusion. Conversely, any point below the diabase line being below the melting temperature for that pressure and depth, falls into solidity. Thus

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* This Journal, vol. xliii, p. 234, 1892.

the chart is divided into two areas by the line, that above it representing fluidity, and that below, solidity. For a diabase earth to have been wholly melted an initial excess of 76,200° C. would be required. Obviously any earth having an initial excess of less than the surface melting point 1,170° C. would have been always completely solid. Any initial excess above that figure and below 76,200° C. requires at the moment before refrigeration began, a solid nucleus and a fused zone above it extending to the surface, and the lower the initial excess the larger the solid nucleus of compression and shallower the initial couche of surface fusion. Knowing the law of the rise of the fusion-point it is a simple matter of computation to determine, for any assumed initial excess, exactly the radial value of the original solid nucleus and of the original supernatant fluid couche. For the region covered by the chart these values may be directly scaled off.

Fourier's equation enables us to go further and assuming that refrigeration is the result of conduction alone to determine the temperature distribution for any given period of refrigeration, and what is of particular geological interest the rate at which the fused couche is encroached upon by an overlying superficial crust of congelation, and the existence, depth, temperature and pressure differences of any residual fluid couche between the upper and lower solids. The relation, therefore, of any temperature gradient to the diabase line offers an immediate test of its admissibility as a probable case. Any temperature gradient that in passing across the area of the chart from below to the surface intersects the diabase line must in reaching the low temperatures of the surface intersect it again, and the zone included between the pair of points of intersection being above the line, and hence for that interval of radius above the fusion temperatures, must be a melted shell, and as on the criterion of solidity the existence of any considerable fusion is precluded, such a case of temperature distribution may be rejected.

I will now trace the several temperature distributions upon the chart, and note their relations to time and solidity, beginning with the family delineated in continuous lines (surface rate 50·6 ft. to 1° Fahr.). Line b, the gradient of Kelvin, 3,900° C. initial excess, 100×10^6 years secular cooling, is seen to enter the chart from the lower regions, maintaining even to the shallow depth of 226 miles from the surface, practically, its original maximum temperature. From the center of the earth up to this point it has remained in the initial solid of compression. At the depth noted it intersects the diabase line and passes into fusion. Since almost the full initial temperature is maintained up to its intersection,

it follows that that depth nearly marks the original surface of the solid nucleus and that the distance of 226 miles thence to the surface measures the depth of the original couche of fusion. Following the gradient toward the surface it is seen after describing its great convexity in the fluid region to intersect the diabase line a second time and enter a congealed shell or crust formed by cooling a surface portion of the initial fused couche, and leaving between the nucleus and crust, a residual present shell of fusion of 200 miles from top to bottom. The obvious tidal instability of a 26-mile crust resting upon 200 miles of truly fluid magma is sufficient basis for the rejection of this particular case of temperature distribution. To fulfill the requirements of rigidity either the time of cooling must be vastly greater to admit of entire congelation, or the initial excess materially less.

As an illustration of the first of these alternatives, gradient c with the same initial excess as b (3900° C.) has been developed to complete solidity which on computation proves to have required about 600×10^6 years, at which time it has but just reached tangency with the diabase line. Yet we are absolutely precluded from accepting it as a probable case and assigning 600×10^6 years as the age of the earth, because the temperature values of its emergence at the surface fall below even the 75 feet to 1° Fahr. surface rate. Its emergence is at a rate of ·0081° Fahr. per ft. (124 ft. per ° Fahr.) which is far less than the (Hallock) rate used in the dotted gradients, itself much less than the accepted mean rate of the British Association Committee.

Gradient d, 1,950° C. initial excess, and 15×10^6 years secular cooling, falls still some millions of years short of solidity. The initially fused surface couche was about 66 miles in depth, the present crust 33 miles thick and the present residual fluidity of 33 miles depth from top to bottom. Here again the liquid zone involves tidal instability and requires the rejection of the line.

Gradient e offers more satisfactory conditions: with an initial excess of 1,750° C., about the normal melting point of platinum, and an age of 20×10^6 years, a condition is reached which throws the convexity of the gradient below the diabase line in complete solidity and fulfills all the conditions. Here then is a possible age for an earth of diabase. Its initial surface couche of fusion would have been about 53 miles and is now wholly cooled into solid crust and united with the original solid nucleus of compression.

Gradient f, initial excess 1,230° C. and 10×10^6 years secular cooling, would in its first stage have shown only about five or six miles of surface fusion which would very shortly have cooled into solidity.

For those whose interest centers in earths of great age and high temperature, gradient *a* is given, initial excess 7,800° C. and 400x10^{6} years secular cooling. This has not been projected to the deep, but would not reach solidity until over 1,500x10^{6} years, a truly uniformitarian specimen.

Turning now to the family of three gradients in dotted line, computed to conform to the surface rate of 75 feet to 1° Fahr., the first, *g* is seen to be of the same initial excess as the Kelvin 3,900° C. line. In spite of its long cooling even after 237x10^{6} years it is still very far from solidity. Of the original fluid couche of 226 miles, only about 60 miles has been congealed into crust, 166 miles remaining fused.

Gradient *h*, initial excess 2,560° C., and a 100x10^{6} years refrigeration has an original fluid couche of 120 miles with a present crust of 56 miles and an existing residual couche of fusion of 64 miles, a case also inadmissible from the point of view of instability.

Gradient *i*, initial excess 1,760° C. (platinum melting point), and 46x10^{6} years of cooling, had originally a 53-mile surface couche of fusion which has long since passed into solidity. The following table sums up the condition of all the gradients as to initial excess, initial depth of surface fusion, time of cooling, thickness of crust congealed and present residual couche of fusion.

TABLE 6.—LIQUID SOLID CONDITIONS FOR DIABASE EARTH.

A.—Gradients having the surface rate of 50·6 to 1° Fahr.

Initial excess. ° C.	Initial depth of surface fusion. Miles.	Time of cooling. Years.	Thickness of crust congealed. Miles.	Residual couche of fusion. Miles.
3900	226	100x10^{6}	26	200 .
1950	66	15x10^{6}	32	33
1741	53	20x10^{6}	crust and nucleus united	0
1230	6	10x10^{6}	" "	0

B.—Gradients having the surface rate of 75 feet to 1° Fahr.

3900	226	237x10^{6}	50	166
2560	120	100x10^{6}	56	64
1741	53	46x10^{6}	crust and nucleus united	0

Comparison of gradients of equal initial excess and successively longer periods of secular cooling shows the ratio of their retreat from right to left across the chart or from lower to higher values of depth and time.

With each augmentation of age the initial tangent defining the surface rate is seen to have declined further and further from the original rate $\propto$, coinciding with and passing first

the maximum, then the minimum rate thence declining into
the region of inadmissible rates.

The probable conditions of the true gradient are as to initial
excess and age such as fall below the diabase line into solidity
and emerge at the surface with a rate which has not declined
below the mean (B A) rate of 64 ft. to 1° F.   From the point
of view of solidity no gradient of initial excess above 2,000° C.
is admissible : that of 2,560° C., even after 100×10^6 years cool-
ing still shows a deep shell of fusion (sixty-four miles from top
to bottom), and since it emerges on the minimum rate it has
already fallen below the admissible tangent.

Gradient d, 1,950° C. and 15×10^6 years, just cooled to the
maximum surface rate has still an inadmissible fluid shell, but
if refrigeration had been continued for 7×10^6 to 9×10^6 years
more the line would have fallen below the solidity line and
its surface rate would not have passed the mean value.   Hence
a 1,950° 24×10^6 year earth is possible and marks about the
superior limit admissible for initial excess.

From the point of view of age no greater time of cooling is
allowable than enough to bring the gradient for any initial
excess to the mean surface rate.   Thus the condition for
excess and age exclude a line of over 2,000° C. and 24×10^6
years.   Conductivity remaining of the value used, any higher
excess involves fluidity, and any greater age an inadmissible
surface rate.

To the extent, therefore, that solidity is a valid criterion
and so far as the melting temperature of diabase may be
supposed to apply to the depth examined, there is no escape
from an earth of the low age and temperature given except by
impugning the rate of surface augmentation and the value
of rock conductivity here employed.

Whoever has examined the B. A. committee's reports and
summaries on underground temperatures must have realized
the obstacles to the evaluation of a true mean rate.   The
range of observations is wide, from high rates due to residual
vulcanism to low ones produced by neighboring bodies of cold
water, such as are described by Wheeler from mines near
Lake Superior.*   It is not, however, likely that by rejecting
anomalies and assigning probable weight to further observa-
tions the present value will be moved to an important extent.

We have seen that all probable distributions of earth-tem-
perature involve in the initial stage a great solid nucleus,
practically the whole body of the earth, with a shallow surface
shell of fusion.   In the case of the 1,741° C., 20×10^6 year
earth there was an initial melted shell of 53 miles.   Obvi-

* This Journal, vol. xxxii, 1886.

ously it cannot be correct to apply the rock-conductivity value obtained at air temperatures and normal pressure to even so young and cool an earth with its couche of an initial temperature of 1,741° C. and a pressure difference between the top and bottom of 22,000 atm. The probable method of cooling the couche into solidity, involves three corrections of the accepted rate of refrigeration : *a*, acceleration of the process by possible convection ; *b*, the direct effect of heat and pressure upon conductivity, and *c*, the relative conductivity of matter at the same temperature, liquid and solid.

a. Convection. Leaving out of present consideration possible polymerization of the magma, or the descent of solid bodies of crust, vertical transfers of the liquid matter in the fused couche depend upon differences of density and this upon the ratio of the rates at which density is raised by pressure and lowered by heat. Isometrics of melted rock under high pressure are of course beyond the reach of experimentation, hence we are forced to look to those of the available materials. Isometrics from high pressure observations have been found to slope as follows :

Ether	8·7 atm. per ° C.		
Alcohol	10·5	"	"
Thymol	13·9	"	"
Dyphenylamine	15·4	"	"
Paratoluidine	13·9	"	"
Glass, computed	10·0	"	"

Since ether boils at 34° C. and dyphenylamine at 310° C., the range here given is wide. It is reasonable, therefore, to take the mean value, 12·5 atm. per ° C., as an index of the slope sought for. In the Kelvin earth this rate occurs between ·010 and ·015 of radius, the crust being ·0065 of radius thick. In so far, therefore, as the isometrics can be regarded as parallel straight lines with a slope of the order of the value given above, convection can only have taken place in the first 52 miles of the initial couche of fusion and in the present residual couche of 200 miles only the upper 26 miles would be subject to convection. In younger earths the above value per ° C. will be found much nearer the surface so that in them convection would be confined to a shell which is shallow in proportion as the earth is young. Initially when the whole earth was at one temperature there could have been no convection, since the change of temperature in depth was *nil*, but the change of density due to pressure was always pronounced. In the case of the 1,741° C. earth the zone of convection would have early been covered and extinguished

by the thickening crust and therefore would have played no very important part in accelerating the loss of heat, and thus for this particular initial excess is of small effect in shortening the estimate of earth's age.

b. The direct effects of heat and pressure upon the conductivity of matter under such high temperatures and pressures are also beyond laboratory investigation, and again we are driven to use the determined conductivity value unmodified, or seek for some other property which may be considered as its approximate measure. Such an index is found in viscosity which if not of high quantitative significance in defining the changing values of terrestrial conductivity in depth, nevertheless affords data applicable at least for determining the sign of an important correction.

Dr. Barus has lately determined that at least 200 atmospheres of pressure are required per one degree Centigrade in order that viscosity may remain constant. Examining several temperature distributions of the chart and applying the computed augmentation of earth-pressure, it appears that the required relation (200 atm. to 1° C.) is found at successively lower depths for successively higher values of initial excess and age. In the 1741° C. case the relation after 20×10^6 years' cooling is found at about ·016 of radius counting from the surface, where the vertical broken line *v. v.* of the chart intersects the gradient and marks the locus of stationary viscosity. As above this point temperature relatively to pressure has augmented more rapidly than the ratio required for constant viscosity it follows that viscosity has been diminished by temperature more than it has been raised by pressure. Below the stationary point, on the other hand, an excess of pressure above the required ratio is available for increase of viscosity.

For the gradient of 3900° C. excess the transitional depth is indicated by the intersection of the broken line V V. In both cases the transitional points occupy positions in their respective gradients not far below their full initial temperatures, and pressure having been most stationary the transitional points have moved but little during the whole period of secular cooling, and the earth shells passing through them have divided radius into a lower solid of higher viscosity and a surface couche, partly liquid partly solid of lower viscosity. So far therefore as viscosity indicates the behavior of conductivity, that also should have been systematically diminished (relatively to the surface value obtained at normal pressure and temperatures and used in the construction of the gradients) from the surface downward for a small fraction of radius, till at the appropriate depth for each excess and age of cooling, it reaches a transitional value and thence increases.

How this correction, of at present unknown value, affects the coördinates of a given gradient qualitatively, is shown by the following figure in which are given the diabase melting point and pressure line, D D, gradient b of 3900° C. excess and 100×10^6 year's cooling, with the viscosity transitional line V V intersecting it, also a dotted line c, indicating the position of the b gradient corrected for diminished conductivity (viscosity).

Lagging to the right of the uncorrected gradient obviously the dotted line would require longer refrigeration to reach the state of solidity, and it is equally important to note that its position requires its emergence at the surface with a higher rate than the uncorrected line and thus extends the time of cooling down to the mean rate which marks for all gradients the present limit of the process.
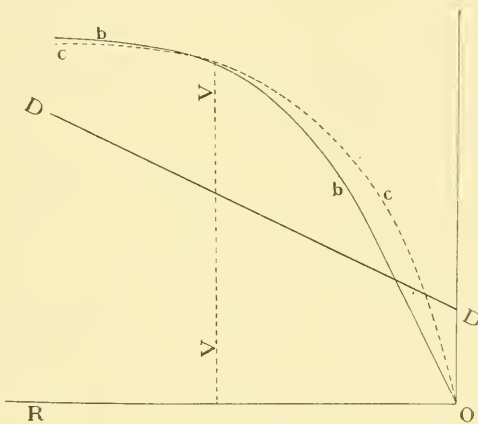
c. Liquid-solid conductivity. Closely involved in the above heat-pressure-viscosity correction is the change of conductivity on passing isothermally from solid to liquid. Here again the results of Dr. Barus* throw important light.

The relatively higher thermometric conductivity of the solid over the liquid of equal temperature indicates an additional plus correction for time values.

Both the minus correction due to convection, and the plus corrections based upon conductivity diminished below the Everett figures, sink in importance as we pass from earths of higher to those of lower initial excess, so that until some approximate quantitative values can be given them we have no warrant for extending the earth's age beyond 24 millions of years.

* The change of heat conductivity on passing isothermally from solid to liquid. C. Barus, this Journal, July, 1892.

That the application of the criterion of solidity here made to Kelvin's method is open to the objection of being based on the physical relations of an extremely superficial fraction of radius is obviously true.   Ignorance of the deeper, interior distribution of specific materials and of their relations to the degree of heat and the range of pressure to which they are subjected, forbids the construction of a generalized line of melting temperatures for the whole of radius.

It might, therefore, be contended that a reversal of the diabase conditions is possible, and the deeper materials may possess the property of ice-fusion; their melting temperatures suffering depression instead of elevation.   The high densities required in lower earth-depths have constantly suggested the concentration there of heavy metals and the examples of meteorites has further influenced the idea of a metallic nucleus chiefly of iron.   And as iron at normal pressure unmistakably exhibits ice-fusion, any great iron mass at the center might be supposed to exist as a liquid in spite of the enormous pressure there exerted.

The distribution of materials and of " state " under this assumption involves a metallic (iron) nucleus, liquid from ice-fusion, overlaid by less dense couches which at some unassignable depth pass into silicates of the diabase type, solid from compression under the law shown for diabase, and solid to the surface as required by tidal effective rigidity.

Ice-fusion, however, is an exceptional phenomenon, nor have we any but the most limited data as to its range as regards temperature and pressure.   Iron is conceded to contract in the act of fusion, but cold iron is more dense than the substance either just above or just below the fusion point.   It is not beyond the range of probability that excessive pressures might bring about the same density in iron that cooling does, and thus isothermally convert ice-fusion into the normal type and produce a solid nucleus.   However that may be, tidal effective rigidity excludes fusion of either type for at least ·2 of radius.

Other methods have been used for obtaining a measure of the earth's age or for some definite portion of geological time.

Earth-Age from Tidal Retardation.

Kelvin's comparison of the earth's present figure with that of a thousand millions of years ago when the terrestrial day would have been only half its present length is one of the most interesting.   The earth, if then plastic, would have yielded to four times the present centrifugal force at the equator and shown a correspondingly greater flattening at the poles

and bulging at the equator and "therefore" (as Tait expresses it) "as its rate of rotation is undoubtedly becoming slower and slower it cannot have been many millions of years back when it became solid, else it would have solidified very much flatter than we find it." This implies that because a computed earlier and greater value of ellipticity does not now exist it could never have existed, in other words, that terrestrial rigidity has been and is of such value that a form taken in the remote past by the solid earth would not be modified by the tidal retardation of rotation and its attendant change of centrifugal force.

There is in modern geology a growing body of evidence which is believed to prove the very general plasticity of the lithosphere, by which it may experience important deformations from very *slowly* applied stresses. So strongly has this belief taken root that many American geologists accept "isostasy" and consider it to be an expression of a fluid equilibrium for the earth.

From abundant geological observation plasticity must be admitted for slow deformations enormously in excess of the small change of figure which the stress of tidal attraction would produce but for elastic resistance.

Although rigidity prevents a sudden tidal deformation of five feet it does not prevent a slow radial deformation of five miles of the surface matter. How then can it be supposed to resist the slow change of stress due to tidal retardation of rotation? The excess of the equatorial over the polar axis is now roughly 25 miles while the radial range of surface inequalities of the lithosphere is about 12 miles, of which a large part dates from this side of the beginning of Tertiary time. If past plasticity equals present values, the earth's figure could never have been a survival from some assumed earlier epoch when centrifugal force was greater, but must always have been a function of the slowly diminishing rate of rotation.

If the conclusions of the earlier portion of this paper are true they go further and exclude the idea of a formerly fluid earth and *any* epoch of solidification. With any admissible assumption of initial excess nearly the whole earth must have been solid from the date of the first collocation of its matter.

To whatever radial depth plasticity may descend, what is enough for geologically recent superficial inequalities is sufficient for adjusting the figure of the earth to existing forces of rotation.

The same coast lines which remain stationary under tidal stress are slowly rising and falling in a hundred places under the slow application of subterranean energy.

It therefore appears that no time measure can be deduced from the supposed fixing of the present ellipticity at some past date.

Astronomical Measure of Earth-Time.

Croll's hypothesis from which it was proposed to fix dates by secular variations of eccentricity and to correlate the *climatic* effects of those variations with geological operations and thus measure certain intervals of geological time, required so much questionable physical geography and left so many physical doubts that few have been found to accept the excessively complex chain of effects lying between eccentricity data and geological facts. The objections of Professor Newcomb, noticed rather than answered, left Croll's doctrine where it was permissible to believe that there was *something* in it, but not necessarily that definite sequence of climates which is the core of the idea.

The gap in Croll's scheme seems to have been successfully stopped by Sir Robert Ball whose interesting proof of the seasonal inequality of the thermal element in climate due to position of the equinoxes, and its intensification in periods of high eccentricity offers a new hope for the accurate dating of at least very modern geological climates. From this point of view late geological history requires reëxamination, and if it should appear that a sequence of climates has existed closely paralleling the thermal variations which the astronomical values seem to afford, an extremely probable case will have been made out. And this case would be practically substantiated if the hypothesis of H. Blytt should yield the confirmation for which he hopes. Blytt* proposes and has already attempted to correlate the secular *attractional* changes due to varying eccentricity and precession with the observed successive shifting of beach lines.

So far as he has proceeded it is of interest to note that his time estimates are more in harmony with the physical than the stratigraphical figures.

Periodic changes in the figure of the hydrosphere relatively to the solid earth, due to alterations of attraction, might be predicted with some confidence if it were clear that the lithosphere would under the slow stresses involved continue to exercise a degree of rigid resistance comparable with that it opposes to the tidal stress, but there is no proof that it would.

Since we find the solid earth undergoing slow deformations to-day which are relatively permanent, while its effective

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* The probable cause of the displacement of beach lines. H. Blytt—1889, Christiania Videnskabs Forhandlinger No. 1 — Additional note 1889 — second additional note 1889.

elastic resistance to tidal stress is sufficient to permit a water tide, it appears that either the purely telluric stresses are greater than the moon's attraction, or that there is for the time rate of application of equal stress, a transitional value above which the elastic resistance of the earth-solid is enough to conserve figure, and below which plastic deformation is easy; a relation of properties such as Kelvin suggests for ether. Under the former alternative, deformations due to purely telluric forces might by upheaval or subsidence at any time mask or counteract astronomical beach shifting. In the latter case to make use of the astronomical data for displacement of beaches, it is required to ascertain the time rate of terrestrial plasticity accurately enough to know that relatively to the duration of eccentricity and precession cycles and their correlative attractional variations, the reaction of the lithosphere would differ enough from that of the hydrosphere to allow of the beach shifting sought.

Beyond the most modern geological dates the grander earth deformations have carried ancient beach lines out of all recognizable radial relations with each other and the several oceans of which they mark the shores, or else as is frequently the case with rising continents they have been wholly effaced by erosion. Evidently the Croll-Blytt time measure, interesting as it may prove to be for recent dates, is at present inapplicable to any general determination of the earth's age.

Earth-age measured by Sun-age.

Since the incrustment of the earth would be almost immediately followed by a climate controlled wholly by the sun's heat, redistribution of the crust by water necessitates a sun heat received upon the earth's surface sufficient at least to maintain the temperature above that of permanent freezing.

Newcomb* remarks :

"If we reflect that a diminution of the solar heat by less than one-fourth its amount would probably mean an earth so cold that all the water on its surface would freeze, while an increase of much more than one-half would probably boil all the water away, it must be admitted that the balance of cause which would result in the sun radiating heat just fast enough to preserve the earth in its present state has probably not existed more than 10,000,000 years."

All we know of the earlier strata indicates a water mechanism for the denudation, comminution and deposition of rock. Exactly the division of this work between tidal and river

* Popular Astronomy, p. 511.

forces we may never know, but all evidences confirm the con-
viction that life was continuous from its earliest, or at least
an early, appearance and hence climate must have been con-
tinuously suitable for the circulation of continental waters.
The range of temperature for the time since the beginning of
the Huronian must have been well within Newcomb's limits.
So that unless the selective absorption of either the sun's
atmosphere or the earth's or both have varied reciprocally or
concurrently with radiation, solar emission cannot have had a
wide range of either secular or paroxysmal change.

Nevertheless the age assigned to the sun by Helmholtz and
Kelvin (15×10^6 or 20×10^6 years) communicated a shock from
which geologists have never recovered. The thermodynamic
reasoning on which the brevity of the sun's life is reached
stands undisturbed, yet so powerful is the influence of the
old uniformation method of estimating the age of the total
stratified crust, that to many geologists it has seemed easier to
reject the physical conclusions than to seek a source of error
in our own very vulnerable methods.

If as I hold, Kelvin's suggestions as to ellipticity and tidal
retardation do not apply to an earth readily deformable by slow
stress as this one evidently is, there remain but three earth-ages
to be weighed—Kelvin's value from terrestrial refrigeration
which this paper seeks to advance to a new precision, Helmholtz
and Kelvin's age of the sun which must sharply limit the date
of the redistributed earth crust, and the old stratigraphical
method. From this point of view the conclusions of the
earlier part of this paper become of interest. The earth's age,
about twenty-four millions of years, accords with the fifteen
or twenty millions found for the sun.

In so far as future investigation shall prove a secular aug-
mentation of the sun's emission from early to present time in
conformity with Lane's law, his age may be lengthened, and
further study of terrestrial conductivity will probably extend
that of the earth.

Yet the concordance of results between the ages of sun and
earth, certainly strengthens the physical case and throws the
burden of proof upon those who hold to the vaguely vast age,
derived from sedimentary geology.

ART. II.—*The Tertiary Geology of Calvert Cliffs, Maryland ;* by GILBERT D. HARRIS, Washington, D. C.

(Communicated by permission of the Director of the U. S. Geological Survey.)

ON the Bay shore of Calvert county, Maryland, extends a long series of high cliffs, remarkable for their abruptness and continuity. Here and there, to be sure, occur narrow channels of bayward flowing streams, but extensive stretches of lowlands are wanting. It therefore becomes possible to trace every important stratum represented in these cliffs from its northernmost outcrop to where its southern dip carries it beneath tide level. This task has actually been attempted ; and the series of sections given in the map, p. 23, shows diagramatically some of the results obtained.

Herring bay, Section 1.—This locality is somewhat north of Calvert cliffs proper, and the horizon of its fossiliferous exposure has not been definitely correlated with those farther south ; yet on paleontologic grounds alone, it is safe to say that the lower portion of Section 1 is stratigraphically equivalent to, or somewhat below *Zone a* of Sections 2 and 3.

Conrad† mentions from this locality :

Bones of Cetacea, siliceous casts of marine shells, Ostrea percrassa, Pecten Humphreysii.

The present writer's list includes :

Ostrea percrassa, Pecten Humphreysii, Pecten madisonius, Striarca centenaria, Thracia Conradi ?, Carditamera arata, Lucina subplanata, Crassatella melina, Corbula elevata, Astarte varians, siliceous casts of a Turritella, probably T. Mortoni from neighboring Eocene deposits, Discina lugubris.

These fossils consist of casts only, and are found in the lower 10 feet of Section 1. The matrix is a bluish green sandy clay. Above lie variable thicknesses of diatomaceous earth, sand, and clay, all of a light yellowish hue, rarely containing molluscan remains, though small *Nuculidæ* were in one instance seen at an elevation of 30 feet above the level of the Bay.

Section 2.—About one mile south of Fishing creek the following section occurs :

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* The field observations upon which this essay is based were made under the auspices of the U. S. Geological Survey, April 23–30, 1891, and May 23–June 1, 1892. During the latter period, the writer was accompanied by Mr. Frank Burns, whose diligence and skill at collecting very materially aided in procuring the results here presented.

† Proceed. Nat. Inst., 2d Bull., 1842, p. 181.

No. 1. Light yellowish sand _____ 5 feet.
    2. Light clay, brownish above__ _____ 5 "
    3. Isocardia layer_____ 2 inches.
    4. Bluish clay with Lucina subplanata _____ 2 feet.
    5. Ostrea percrassa bed, greenish sand _____ 6 inches.
    6. Bluish sandy clay _____ 2 feet.

The beds here represented dip slightly to the north. They are cut off by Pleistocene deposits before reaching half way to Fishing creek, so that it is impossible to determine how far northward this abnormal dip extends.

Section 3.—This is the locality described by Conrad as "Colonel Blake's" in the Second Bulletin of the Proceedings of the National Institution, page 181. He says: "The cliff is at least one hundred and fifty feet high. At base we found a clay replete with a species of *Tellina*, probably new, and over this at about six feet elevation, a thin stratum of *Ostrea percrassa*. The upper portion of the cliff consists of sand and clay, and appears to be destitute of organic remains."

Conrad doubtless examined this locality somewhat hastily, insomuch as several fossiliferous beds occur in the sand and clay regarded by him as "destitute of organic remains."

The section stands thus :

No. 1. Light colored clayey sand_____ 25 feet.
    2. Sandstone ferruginous layer. (Fossiliferous ?)   4 "
    3. Blue clay ____ _____ ___ _____ 10 "
    4. Ferruginous sand. (Fossiliferous ?)_____ 3 "
    5. Blue clay _____ 20 "
    6. *Zone d ;* Isocardia bed ; ferruginous sand___ 5 "
    7. Bluish sandy clay_____ 15 "
    8. Ferruginous brownish sand _____ 4 "
    9. Blue clay _____ 8 "
    10. *Zone b ;* greenish gray fossiliferous sand. This stratum is overlaid by a line of concretions _____ 12 "
    11. Light bluish sandy clay ; Corbula layer 3 feet from base _____ 18 "
    12. *Zone a ;* Ostrea percrassa, in greenish sand__ 6 inches.
    13. Gray sandy clay to surface of water _____6–8 feet.

From *Zone b*, at this locality, Mr. Burns and the writer obtained the following species :

Pelecypoda.—Pecten madisonius, Arca subrostrata, Pectunculus parilis, Nucula sp. undt., Astarte varians, Crassatella melina, Lucina anodonta, Lucina Foremani, Lucina crenulata, Cardium leptopleura, Isocardia Markoei, Venus latilirata, Venus staminea, Cytherea marylandica var. ?, Tellina subreflexa, Corbula idonea, Corbula elevata, Panopæa porrecta ?

MAP
&
STRATIGRAPHY
OF
CALVERT CLIFFS.
Md

Statute Miles
1 2 3 4 5

Fairhaven
Herring Bay
ANN ARUNDEL COUNTY
1
Fishing Creek
2
"Col. Blakes" 3
4
5
Plum Pt.
Plum Pt Ldg
Capt Hances 6
7
Dares Ldg
Parkers Cr.
Jas Hance 8
9 Governors Run
10
Flag Pond 11
Pt of Rocks 12
Cove Pt.
13 Little Cove Pt
14
15
Drum Pt

CALVERT COUNTY

CHESAPEAKE BAY

PATUXENT RIVER
Jones Wharf
ST MARY'S CO.
Pt Patterce

Feet
100 90 80 70 60 50 40 30 20 10

Gastropoda.—Oliva sp. undt., Voluta typus, Fulgur coronatum, Turritella indenta, Turritella exaltata, Crucibulum contractum, Infundibulum perarmatum.

From *Zone d*, Isocardia n. sp. and Venus n. sp. were obtained.

Section 4.—The bluffs are much lower at this locality, *Zone d* being overlaid by only 10 feet of light barren sand. The southerly dip is here recognizable, but it becomes much greater a little farther south.

Section 5.—In this section, all but the basal three feet of *Zone b* has been removed by erosion, and the space refilled with Pleistocene sand and gravel. From the remnant of this zone the following species were obtained : *Pecten madisonius, Arca subrostrata, Astarte varians, Venus latilirata, Dosinia acetabula,* and a smooth *Dentalium.*

Section 6.—The next good exposure seen on the bay shore going south is about one mile below Plum point landing. This is the locality designated as " Captain Hance's " in Conrad's article referred to above. Fossils are here very abundant, but owing to their softness, it is difficult to obtain whole or perfect specimens. The species enumerated in the following table were all obtained from *Zone b* as it crops out along the base of low bluffs a few hundred yards north of Section 6.

Molluscan Species of Zone b, one mile south of Plum Point Landing, Calvert County, Maryland.

Pelecypoda.—Ostrea, sp., Anomia, young, Pecten Humphreysii, Pecten madisonius, Perna maxillata, Pinna muricata ?, Modiola, fragment, Arca subrostrata,* Byssoarca marylandica, Pectunculus parilis, Nucula sp. nov., Leda sp., Leda sp. nov., Cardita granulata, Astarte varians,* Astarte exaltata,* Astarte sp., Crassatella melina,* Lucina subplanata,* Lucina anodonta, Lucina Foremani,* Lucina crenulata,* Lucina sp., Chama congregata, Cardium leptopleura,* Isocardia Markoei,* Isocardia sp. nov., Venus Ducateli var. of mercenaria ?, Venus staminea,* Venus latilirata,* Cytherea marylandica var., Dosinia acetabula,* Tellina subreflexa, Tellina sp., Semele carinata, Mactra sp., Mactra (Schizoderma), Corbula cuneata, Corbula idonea,* Corbula elevata,* Saxicava sp. nov., Pholas ovalis, Panopæa goldfussii ?

Gastropoda.—Actæon fragment, Volvula iota ?, Cylichna sp., Terebra simplex, small var., Pleurotoma marylandica,* Pleurotoma calvertensis ?, Pleurotoma bella-crenata,* Pleurotoma parva, Pleurotoma sp., Cancellaria engonata,* Cancellaria sp., Oliva literata, small, Volutella sp. nov., Scaphella solitaria,* Scaphella typus, Fulgur coronatum, Fusus devexus, Fusus migrans, Ecphora

* Mentioned also by Conrad, pp. 181–182; 2d Bull. Proc. Nat. Inst., 1842.

quadricostata, Nassa peralta, small var., Scala pachypleura,* Niso lineata ?*, Pyrula sp. nov., Turritella indenta,* Turritella exaltata,* Turritella plebeia, Solarium trilineatum, Crucibulum constrictum, Crepidula, small sp., Natica heros, Natica duplicata, Sigaretus fragilis,* Calliostoma sp., Infundibulum perarmatum,* Fissurella marylandica.*

Brachiopoda.—Discina acetabula.

In addition to the above forms, Conrad mentions in the Proceedings of the National Institution, *Arca depleura, Pectunculus lentiformis, Lima papyria, Cancellaria biplicifera, Dentalium thalloides, Voluta mutabilis, Marginella perexigua,* and *Trochus peralveatus.* Of these, *Pectunculus lentiformis* and *Voluta mutabilis* were afterwards called by Conrad himself, *P. parilis,* and *V. typus.* The name *Dentalium thalloides* had been applied by this author nine years before to a characteristic Claiborne species.

Section 6, may be subdivided as follows:

No. 1. White sandy clay _____ 15 feet.
    2. Light clay with conchoidal fracture_____ 12 "
    3. Yellowish sandy clay _____ 16 "
    4. *Zone d ;* Isocardia bed ; Yellowish sands __ 8 "
    5. Bluish sandy clay _____ 14 "
    6. *Zone c ;* thin seam of Venus sp. nov. and sand _____ 6 inches.
    7. Clayey sand; bluish above, becoming brownish below _____ 15 feet.
    8. *Zone b ;* greenish gray sands_____ 8 "

The *Isocardia* of *Zone d* is quite different from *I. fraterna,* as well as from *I. rustica.* It is smaller, not so large posteriorly, and with differently formed teeth. The new species of *Venus* which characterizes *Zone c,* bears some resemblance to *V. penita.* The same, or a very closely allied species was found by the writer about 1½ miles southeast of Skipton, Talbot county, on the " Eastern shore " of Maryland.

Section 7.—This section presents no very remarkable features. As seen on map, p. 23, nearly all the component beds of Section 6 are found here from 5 to 8 feet nearer tide level than they are in that section. Before passing on to Section 8, however, it may be remarked that Conrad was doubtless somewhat mistaken in giving "Col. Beckett's" as the location of a fossiliferous outcrop; for the low bluffs all along the old Beckett farm (just above Dare's landing), are made up wholly of Pleistocene sands.

Section 8.—Just below Parker's creek, on land owned by James Hance, steep escarpments occur ranging in height from 40 to 70 feet. In these, *Zones c* and *d* are found much nearer

tide level than in Section 7, while at an elevation of 40 feet, a new fauna makes its appearance (*Zone e*).   Here the species of Barker's land on the Choptank, and Jones's wharf on the Patuxent river predominate to the exclusion of those mentioned on page 25 from *Zone b*, of Section 6.   Some of the fossils here recognized are: *Pecten madisonius, Perna maxillata, Mytiloconcha, Astarte obruta var., Crassatella turgidula, Cardium laqueatum, Venus mercenaria, Corbula idonea, Ecphora quadricostata, Turritella plebeia,* etc.   For several feet above, in the face of the cliff, no well preserved fossils are seen ; but in an old roadway, perhaps 200 yards back from the shore, at an elevation of from 60 to 77 feet Mr. Burns discovered a recurrence of this fauna in a friable, yellow sand matrix.   Its position is indicated in Section 8 by the letter *f.*   The more abundant and conspicuous fossils from this locality are :

Arca elevata, Carditamera protracta, Astarte obruta, Crassatella marylandica, Crassatella turgidula, Lucina contracta, Lucina anodonta, Mysia acclinis, Cardium laqueatum, Isocardia n. sp., Venus mercenaria var. mortoni, Cytherea marylandica, Dosinia acetabula, Corbula idonea, Panopæa americana, Natica duplicata.

South of Section 8, *Zone f* shows plainly in the face of the cliffs, but is too high to be reached.   Large masses, however, are often dislodged by atmospheric agencies and, in falling, crumble to pieces, and afford ample opportunity for examining their fossil contents.   In this way *Pecten madisonius, Perna maxillata, Cytherea sayana? Tellina biplicata,* and "*Petricola*" *centenaria* have been added to the faunal list of *Zone f.*

Section 9.—The following section was taken about two-fifths of a mile north of Governor's Run :

No. 1. Bluish and yellowish sandy clay _____   25 feet.
     2. Blue clay (base of Pleistocene ?) _____   5   "
     3. Yellow sand _____   0–3   "
     4. *Zone f ;* yellow fossiliferous sand _____   15   "
     5. Resembling No. 4, but with few small fossils   4   "
     6. Marly bluish sand _____   20   "
     7. *Zone e ;* Yellowish and grayish fossiliferous
          sand _____   4   "
     8. Yellow sand with blue clay bands _____   15   "
     9. Blue clay _____   8   "
   10. *Zone d ;* Isocardia bed ; _____   3   "
   11. Bluish clayey sand _____   3   "

Section 10.—The escarpments south of Governor's Run are for some distance obscured by the growth of trees, underbrush, and grasses; but at Section 10, about $2\frac{1}{4}$ miles south of this

place they are again barren and abrupt, though generally of a very moderate elevation. The beds here exposed are as follows:

No. 1. Pleistocene yellowish sand	30 feet.
2. *Zone e ;* fossiliferous grayish and yellowish sand	5 "
3. Bluish sandy clay	15 "

A large collection of the fossils of *Zone e* was here made by Mr. Burns. It includes:

Pelecypoda.—Pecten madisonius, Perna maxillata, Mytilus, large cast perhaps M. incurva, Arca elevata, Astarte obruta, var., Crassatella turgidula, Lucina anodonta, Lucina contracta, Mysia acclinis, Diplodonta sp., Cardium laqueatum, Isocardia rustica Con. (partim) non Sow., Venus mercenaria, var. mortoni, Cytherea marylandica, Dosinia acetabula, " Petricola " centenaria, Tellina biplicata, Corbula idonea, Panopæa porrecta, Panopæa americana.
Gastropoda.—Ecphora quadricostata, Turritella plebeia, Natica heros? Crucibulum sp.

Section 11.—Below Flag pond, high bluffs again set in, and present the following section:

No. 1. Light sands and clays	25 feet.
2. Band of Perna, Pecten, etc.	2 "
3. Bluish sandy clay	25 "
4. *Zone f ;* overlaid by a one foot band of very hard ferruginous fragmentary rock	5 "
5. Grayish sandy clay	20 "
6. *Zone e.*	5 "

Between this and the next section, *Zones e* and *f* are often wholly made up of huge, unshapely, hard rocks as described by Conrad on page 183 of his article already referred to.

Section 12.—This is the last exposure on the Bay shore before reaching Cove point. *Zone f* is here found at tide level, and is overlaid by about 15 feet of Pleistocene sand.

Section 13.—It is impossible at present to state the exact stratigraphic relations of the various fossiliferous zones occurring south of Cove point with those to the north. Yet the discrepancy here involved is in all probability a matter of not over ten or twenty feet. Above *Zone f* in Section 11 there are bluish clays whose equivalents farther south towards Section 12 become blackish and contain a few organic remains. Among these were noted *Solen ensiformis* a Mactroid shell like a small *Schizoderma delumbis,* and *Nassa peralta.* Section 13 is as follows:

No. 1. Sand .... 4 feet.
    2. Light yellowish sand .... 30 "
    3. Hard ferruginous sand stratum .... 8 "
    4. Bluish black efflorescent marl .... 8 "
    5. Light yellowish and bluish sandy clay...... 25 "
    6. Compact blue clay .... 9 "

It is believed that the lowest member of this section bears to the dark bluish or black clays above *Zone f*, between Sections 11 and 12 the stratigraphic relation indicated on the map.

After rounding Little Cove point, No. 6 becomes quite fossiliferous and so also does the basal portion of No. 5. Here the section presented is as follows:

No. 1. Pleistocene sand and gravel ....0-5 feet.
    2. Light yellowish sand .... 5 "
    3. *Zone g ;* light sands..................... 3 "
    4. Blue clay .... 5 "
    5. Fossiliferous sand........................ 1 foot.
    6. Blue clay .... 4 feet.
    7. Fossiliferous sands....................... 1 foot.
    8. Blue clay .... 3 feet.

No. 5 contains the following forms all more or less waterworn :

Pelecypoda.—Pecten madisonius, Arca idonea, Cardium laqueatum, Venus mercenaria, Dosinia acetabula, Corbula cuneata.
    Gastropoda.—Terebra simplex ?, young, Pleurotoma parva, Nassa peralta, Astyris communis, Natica duplicata, Turritella plebeia.

No. 3 or *Zone g* is not very fossiliferous at this particular locality but a few yards farther south is replete with :

Pelecypoda.—Pecten madisonius, Lucina crenulata, Venus mercenaria, small, Cytherea Sayana, Tellina biplicata, Mactra ponderosa, Mactra subcuneata, Solen ensiformis.
    Gastropoda.—Actæon ovoides, Terebra simplex, Pleurotoma communis, Nassa integra, Nassa peralta, Turritella plebeia, Pleurotoma parva, Fulgur coronatum, Ecphora quadricostata, Natica duplicata, Natica heros.

Section 14.—In going southward from Little Cove point, the fossiliferous layers exposed in the cliffs are observed to gradually rise and at Section 14 present the following appearance :

No. 1. Yellowish sand _____25-40 feet.
   2. Hard ferruginous layer_____ 5 "
   3. Yellowish sand _____ 15 "
   4. Ferruginous layer_____ 1 foot.
   5. Light and dark, yellow and blue sandy clay_ 15 feet.
   6. *Zone g ;* grayish sand_____ 4 "
   7. Blue clay_____ 4 "
   8. Fossiliferous sand_____ 1 foot.
   9. Bluish sandy clay_____ 15 feet.

Section 15.—At the southern terminus of the cliffs between Little Cove point and Drum point, *Zone g* is 10 feet above tide, and contains the same fauna as that last mentioned.

The following section is a generalization of all the foregoing sections, taken from 14 to 1 in a descending order. An attempt is moreover made to correlate as far as possible from personal observation the various fossiliferous zones here represented with those farther west on the Patuxent, and those of the " Eastern shore."

No. 1. Yellowish sand _____25-40 feet.
   2. Hard ferruginous layer. (Fossiliferous?)___ 5 "
   3. Yellowish, bluish, or even black sandy clay_ 33 "
   4. *Zone g* _____3-4 "
      This together with the two fossiliferous
      layers, Nos. 6 and 8, contain a typical
      St. Mary's Miocene fauna.
   5. Blue clay_____4-5 "
   6. Fossiliferous sand_____ 1 foot.
   7. Blue clay _____ 4 feet.
   8. Fossiliferous sand_____ 1 foot.
   9. Blue sandy clay _____ 12 feet +
  10. *Zone f;* yellow fossiliferous sand generally, 6-15 "
  11. Yellowish and grayish sand, few fossils___20-25 "
  12. *Zone e ;* yellowish or grayish sand_____4-8 "
      The substance of this bed as well as No. 10,
      is sometimes highly ferruginous and very
      hard. Nos. 10 and 12 are intimately re-
      lated, and represent one faunal horizon.
      This occurs also at Jones's wharf on the
      Patuxent, and at Barker's landing on the
      Choptank river, about five miles south-
      east of Easton, Md. At Greenborough,
      Caroline county, very nearly the same
      horizon is represented, though it may be
      slightly higher.
  13. Light bluish sand and clay, often weathered
      yellowish _____20-25 "
  14. *Zone d;* compact bluish or yellowish sandy
      clay _____3-5 " +

15. Bluish sandy clay _____14–17 feet.
16. *Zone c ;* thin seam of bluish compact sandy
     clay _____ _____ _____½–1 foot.
17. Bluish clay _____8–15 feet.
18. *Zone b ;* grayish sand_____8–12 "
     This horizon crosses the Patuxent near
        Benedict. On the "Eastern shore" it is
        well represented in marl pits about ¼
        mile south of Skipton.
19. Light bluish sandy clay, with thin layers of
        Corbula alta, and with casts of Tellina and
        Yoldia _____16–20 "
20. *Zone a ;* greenish gray sand, replete with
        Ostrea percrassa, together with a few
        specimens of Pecten madisonius and P.
        Humphreysii _____ 6 inches.
21. Bluish green sandy clay as at Fair Haven__ 15 feet +
                                        Total 203–263 feet +

In this section there are represented three fairly distinct and well defined faunas. These may be enumerated as follows:

1. *The St. Mary's fauna ;* characterized by such species as:

Arca idonea, Astarte perplana, Venus alveata, Mactra ponderosa, Mactra subnasuta, Solen ensiformis, Terebra simplex, Conus diluvianus, Pleurotoma communis, Fusus parilis, Fusus rusticus, Bulliopsis integra, Nassa peralta, Murex acuticostata, Scala expansa, Turritella variabilis.

2. *The Jones' wharf fauna ;* characterized by such species as:

Mytiloconcha incurva, Arca elevata, Carditamera producta, Astarte obruta, Crassatella turgidula, Mysia acclinis, Cytherea marylandica, Mya producta, Panopæa americana, Turritella terebriformis, Calliostoma Wagneri.

3. *The Plum Point fauna ;* characterized by such species as:

Pecten Humphreysi, Arca subrostrata, Byssoarca marylandica, Pectunculus parilis, Astarte varians, Astarte exaltata, Crassatella melina, Lucina Foremani, Cardium leptopleura, Corbula elevata, Isocardia Markoei, Venus staminea, Venus latilirata, Pleurotoma marylandica, Pleurotoma bellacrenata, Scala pachypleura, Turritella indenta, Turritella exaltata, Solarium trilineatum.

In concluding, it may be of interest to make a few brief comparisons between these observations and those of earlier writers.

Conrad,[*] in 1841, seemed not to detect the true stratigraphy of the fossiliferous deposits he noted along this shore, and strangely enough, apparently believed them to extend nearly horizontally from Fair Haven to Drum point.

In 1880, Heilprin[†] concluded from a study of the paleonto-logic literature on the subject, that there must be a southern dip along this shore in so much as two faunas, differing con-siderably in their relative proportions of recent and extinct species, are here represented. To the older fauna, the species occurring at Fair Haven, "Col. Blake's," "Capt. Hance's," and those from the base of the "Cliff near Beckett's," are referred; to the newer, those from the upper part of the last mentioned cliff as well as those from localities south of Cove point. Had Heilprin examined these sections personally, his conclusions would doubtless have been quite different. The three-foot fossiliferous layer in the upper part of Conrad's section at "Beckett's" is obviously the same as *Zone d* of the present essay, and not the Jones's wharf beds as Heilprin sup-posed. Nor is it this bed that furnishes the St. Mary's fauna below Cove point: between the two occur at least 70 feet of deposits bearing a well marked fauna.

In Darton's[‡] paper on the "Mesozoic and Cenozoic Forma-tions of Eastern Virginia and Maryland," published in 1891, he subdivides the "Chesapeake formation" into three parts, thus: "The lower beds consist mainly of dark-colored clays and fine, mealy sand containing the extensive and well-known diatomaceous deposits. These are succeeded by lighter colored clays and sands, with occasional local inclusions of blue marl. The upper beds are coarse-grained, and consist chiefly of white beach sands containing shells and deposits of shell fragments, and occasional argillaceous members." The outcrops at Her-ring bay are said to belong to the lower beds; those on the lower St. Mary's river to the medial; and "those along the lower Patuxent river and the adjoining shores of Chesapeake bay," to the upper beds.

[*] 2d Bull. Proc. Nat. Inst., 1842, p. 176.
[†] Proceed. Phila. Acad. Nat. Sc., 1880, pp. 23–30.
[‡] Bull. Geol. Soc. Am., vol. ii, p. 444.

ART. III.—*On the " Anglesite," associated with Boléite,*
No. 55; by F. A. GENTH.

MALLARD and Cumenge state in their interesting investiga-
tion on boléite[*] that anglesite, generally covered with a coat-
ing of gypsum, of variable thickness, is associated with the
boléite from Boléo, Lower California, Mexico.   These crystals
showed such a peculiar appearance that I thought they de-
served a fuller investigation, for which Mr. Clarence S. Bement
with his usual liberality, furnished me with excellent material.

The crystals, from 2 to 20^{mm} in size are often distorted, but
show generally a very common form of anglesite, the planes c,
m and l predominating.   They are opaque, and of a luster,
between vitreous and greasy, their color is from white to bluish
white, some show minute blue spots from a slight contamina-
tion with boléite.   Many crystals have a coating of gypsum or
minute scales of the latter implanted, while others are entirely
free from it.   Sp. gr. = 4·401.   The material for the analysis
was selected with great care and the purest that could be
obtained, it gave :

		Molecular ratio.	
$PbSO_4$	76·16	0·251	2
$CaSO_4$	17·31	0·127	1
H_2O	4·53	0·251	2
Boléite by diff.	2·00		
	100·00		

This gives the formula : $2PbSO_4 + CaSO_4 + 2H_2O$.   As it is not
very likely that 2 mol. of $PbSO_4$ should have crystallized with
one mol. of gypsum in exactly the same form as anglesite, we·
must come to the conclusion, that the so-called anglesite crys-
tals from Boléo are pseudomorphs after a mineral of the com-
position : $2PbSO_4 . CaSO_4$, which has not yet been observed in
its original condition, but only after the calcium sulphate in
it had taken up two molecules of water and changed into gyp-
sum which now forms a mechanical mixture with the remain-
ing anglesite, from which it can be completely extracted by
water.

The fine powder of two small crystals was treated with
water, as long as any precipitate of calcium oxalate could be
formed in the filtrate ; a small quantity of lead in the solution
was removed by hydrogen sulphide.

* Bull. Soc. Franc. de Mineralogie, December, 1891.

The analysis gave :

$$PbSO_4 \text{-----------------} 74\cdot76$$
$$CaSO_4 \text{-----------------} 19\cdot64$$
$$H_2O \text{ required to form gypsum} \text{--} 5\cdot20$$

$$99\cdot60$$

showing that these crystals had a considerable admixture of gypsum.

Chem. Laboratory. 111 S. 10th St.,
   Philadelphia, Nov. 22d, 1892.

ART. IV.—*Preliminary Account of the Iced Bar Base Apparatus of the U. S. Coast and Geodetic Survey ;** by R. S. WOODWARD.

Historical Note.—The use of ice in thermometry to furnish a standard temperature naturally suggests the availability of ice to fix the temperature of a standard of length when used in laboratory comparisons or in measuring base lines   It does not appear, however, that ice has been generally used even in laboratory work with standards of length,† and I am not aware that any attempt has been made hitherto to measure a base with a bar whose temperature is controlled by means of melting ice.   The feasibility of using such an apparatus in base measurement has, nevertheless, been suggested and maintained by several persons.   One of the first, if not the first, to outline a scheme for such an apparatus is, I believe, Mr. E. S. Wheeler, a former colleague on the U. S. Lake Survey.   Mr. Wheeler's plan is advocated by Professor T. W. Wright in his treatise on the Adjustment of Observations.‡   The late Captain C. O. Boutelle of the U. S. Coast and Geodetic Survey also advocated the use of such apparatus.

Soon after joining the U. S. Coast and Geodetic Survey in July, 1890, I was requested by Dr. Mendenhall, Superintendent, to devise means of testing in the most thorough way

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* Communicated by permission of the Superintendent of the Survey.   The substance of this paper was presented before Section A of the American Association for Advancement of Science, at the Rochester meeting, August, 1892.

† From published accounts it would appear that the most extensive series of laboratory comparisons of standards, wherein ice was used, are those of the U. S. Lake Survey, conducted under the superintendence of General C. B. Comstock, Corps Engineers, U. S. A.   In these comparisons ice was successfully used during several years.   See Professional Papers Corps Engineers, U. S. A , No. 24.

‡ D. Van Nostrand, New York, 1884.   See also this Journal, III, vol. xxviii, p. 479.

practicable the efficiency of the various forms of base apparatus used by the Survey and especially the efficiency of long steel tapes or wires. Accordingly, considerable study was given to this subject during the autumn of 1890 and the winter of 1890–1, and the plans and specifications for the iced bar apparatus considered in this paper were matured and approved early in the spring of 1891. It was constructed in Washington, partly by the machinists E. N. Gray and Co., and D. Ballauf, and partly by the Instrument Division of the Survey.

Before proceeding to a description of the apparatus I desire to acknowledge my indebtedness to colleagues of the Survey for valuable suggestions and criticism. I am specially indebted to Mr. John S. Siebert, who verified all of the preliminary calculations relative to the stability and efficiency of the apparatus, and who elaborated many of the designs and made most of the working drawings for its construction. I am particularly indebted also to Mr. E. G. Fischer, chief mechanician of the Survey, whose knowledge of and skill in mechanical appliances were frequently appealed to. Finally it affords me pleasure to state that my friend Mr. E. S. Wheeler, who has had extensive experience with base apparatus, happened to visit Washington about the time the plans for this apparatus were completed and gave me the benefit of his advice and criticism.

Description of Apparatus.

The measuring bar.—The measuring bar of this apparatus is a rectangular bar of tire steel. It was rolled in the steel works at Lancaster, Pa. It is $5 \cdot 02^m$ long, 8^{mm} thick and 32^{mm} deep. A cross-section is shown at A in the accompanying drawing.

The upper half of the bar is cut away for about 2^{cm} at either end to receive the graduation plugs of platinum-iridium, which are inserted so that their upper surfaces lie in the neutral surface of the bar. Three lines are ruled on each of these plugs, two in the direction of and one transverse to the length of the bar. These lines were ruled by Mr. Louis A. Fischer, Adjuster in the Weights and Measures Office. The longitudinal lines, which serve to limit the parts of the transverse lines used, are $0 \cdot 2^{mm}$ apart.

To secure alignment of the bar eleven German silver plugs of 5^{mm} diameter are inserted at intervals of 495^{mm} along the bar so that they project about 1^{mm} above its top surface. The upper surfaces of these plugs are all the same distance, within a few hundredths of a millimeter, from the neutral surface of

the bar On the top of each plug is ruled a fine line in the direction of the bar as shown at P in the drawing. The length of the bar as regards alignment is defined to be the distance between the transverse graduation marks when the upper surfaces of the alignment plugs are all in one plane and

CROSS SECTION.

Y-TROUGH.

Scale — ½

END OF BAR.
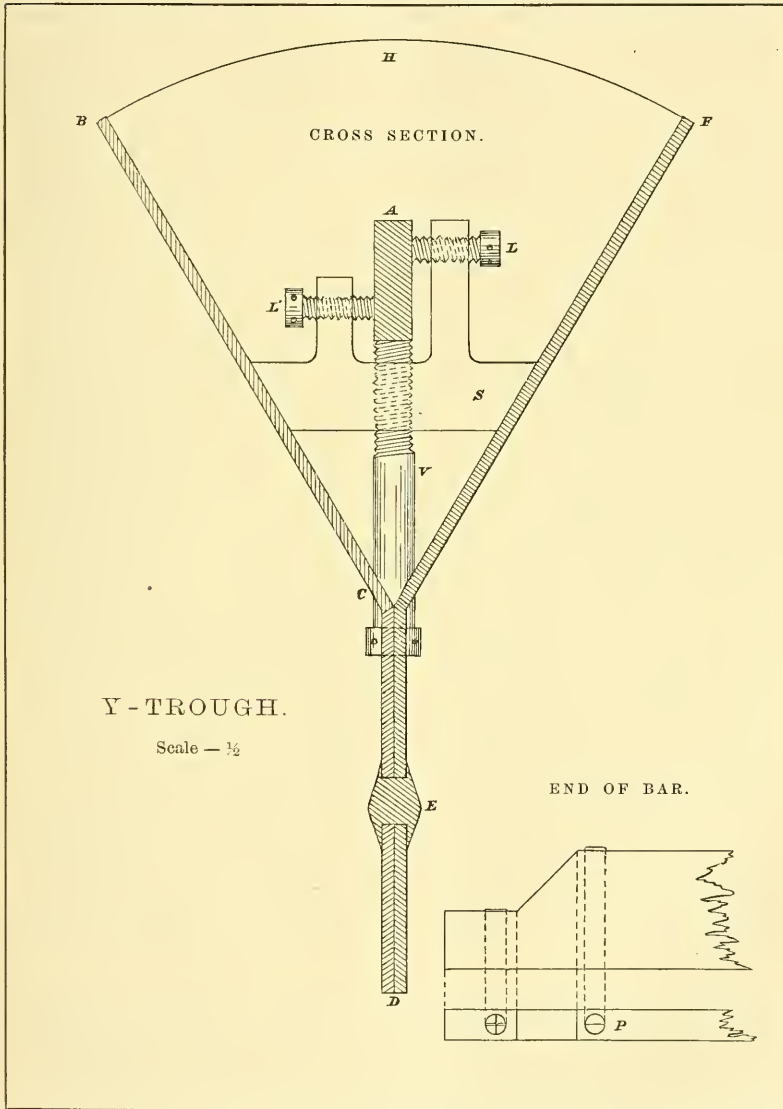
when the lines on these plugs are in one straight line. The means of securing these two adjustments are described below.*

The Y-Trough.—The most important and distinctive part of this apparatus is the trough which supports the bar, keeps it aligned, and carries the ice load essential to control the bar's temperature. This trough is called the Y-trough by reason of the resemblance of its cross-section to the letter Y. The drawing shows a cross-section of this trough. It is made of two steel plates $5 \cdot 14^m$ long $25 \cdot 5^{cm}$ wide and 3^{mm} thick. They are bent to the angle B C D of the figure and are riveted together as shown at E, thus making the angle of the trough B C F = 60°. The bar, shown in cross-section at A, is sup· ported at every half meter of its length by saddles, one of which is shown in the figure. These saddles are rigidly attached to the sides of the trough by screws at S, S. Each saddle carries one vertical and two lateral adjusting screws as shown at V, L, L'. These screws serve to fix the alignment of the bar. The lateral adjusting screws of the saddles at the ends of the bar are of the same height, which is equal to that of the lower screw L' of the diagram. The lateral adjusting screws of the intermediate saddles on either side of the bar are alternately high and low. The object of this disposition is two-fold, to wit: 1st, to prevent pinching the bar, which might more readily occur if the lateral screws were all opposite to one another; 2d, to afford means of rotating the bar slightly about its longitudinal axis, so that for a fixed and nearly vertical position of the trough the graduated surfaces of the bar may be made horizontal. The vertical adjusting screws of the saddles project, as shown in the diagram, below the vertex of the trough, and their capstan heads are accessible through slots cut in the web of the trough. These slots serve also as drainage-ways for the melted ice. To prevent circulation of air through them they are stuffed with cotton batting, through which the water percolates freely. The ends of the trough are closed with wooden V-shaped blocks.

The trough is very rigid in all directions and especially so with respect to vertical stresses. It weighs 82 kilograms exclusive of the bar and ice load. The whole trough is covered by a closely fitting jacket of heavy white cotton felt, which protects the trough and ice load alike from direct radiation.

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* The form of bar described is evidently not the best form. Theory and experience indicate that a bar having a Y-shaped cross section with metric subdivisions on its neutral surface would best meet the requirements However, the question which presented itself in planning the apparatus was not what is the best form of bar, but what is the most economical form possessing the requisite properties.

For measuring grade angles a sector reading by two opposite verniers to $10''$ is attached to one side of the trough near its middle point. Thus arranged this sector has great stability.

The ice load and ice crusher.—When the apparatus is in use the Y-trough is completely filled with pulverized ice, the upper surface of which is rounded to about the height shown by the curve B H F in the diagram. The amount of ice required for this purpose is about 40 kilograms, or 8 kilograms per meter of the bar's length. The ice, by reason of its weight and the sloping sides of the trough, is kept in close contact with the bar. This is especially the case when the apparatus is in use, for it is then trundled along on its cars with sufficient jarring to overcome any tendency of the ice to pack. For covering the ends of the bar a small quantity of ice is cut with a jack plane. Ice thus cut, like wet snow, packs well and permits making a small conical hole through it to the graduation plugs.

A very essential auxiliary to the use of the apparatus is an ice crusher to pulverize the ice. The machine used is a modification of the Creasey ice breaker manufactured at Philadelphia, Pa. It is a small light hand machine which, as modified, does its work very satisfactorily. With it 40 kilograms of ice may be pulverized in ten minutes or less. The particles of crushed ice vary in size from the smallest visible up to the bulk of a cubic centimeter; and this gradation in size appears to be advantageous as compared with uniformly finer particles like those of snow, since there is less liability of regelation and packing.

The cars and portable track.—The Y-trough is mounted on two cars, the saddles or bolsters of which are attached to the trough 40^{cm} from either end. Each saddle is attached rigidly to the trough above and to a jack screw below. The jack screw is attached to a slide rest which is connected rigidly with the base of the car. The slide rests are provided with screws to give slow motions in the direction of the trough's length and transverse to its length.

The jack screw cylinders have right and left handed threads at their respective ends and are turned by a short capstan bar. They give thus the rapid vertical motion to the trough essential in bringing the bar quickly to focus under the microscopes which define its position.

The cars have each three wheels and run on a portable track whose width is 30^{cm}. Three sections of this track, each 5^{m} long, are provided; and each section is carried forward as the cars are rolled along during the measurement of a line. It thus appears that instead of lifting up and carrying forward

the measuring bar as with most forms of apparatus, this rather delicate and difficult operation is supplanted by that of moving the portable tracks.

The micrometer microscopes.—To define the successive positions of the bar in measuring a line, micrometer-microscopes are used. Through the courtesy of General Casey, Chief of Engineers, U. S. A., the Survey was enabled to borrow the four microscopes and the cut-off cylinder of the Repsold base apparatus[*] used on the U. S. Lake Survey. These are especially well adapted for use with any line measure apparatus. As designed by the Repsolds and as used on the Lake Survey the microscopes were mounted on iron tripods. These latter having been destroyed by fire while stored at the Engineer depot at Willett's Point, N. Y., it was essential to replace them by some equivalent device. In view of the economic and other features of the special work contemplated with the iced bar apparatus it was decided to mount the microscopes on wooden posts set firmly in the ground. To connect the microscope with the post a cast-iron post cap is provided. It fits like a box cover on the end of the post and is clamped rigidly to it by means of a screw.

The microscopes are provided with levels and leveling screws so that their axes may be made vertical. They are mounted on slide rests which give a motion of 2^{cm} in the direction of the line measured or transverse to it. To secure additional displacement in the direction of the line a small rotary motion is provided for in the connection of the microscope with the post cap. The micrometer heads of the microscopes are divided to read microns directly, one revolution of the screws corresponding to $0\cdot1^{mm}$. When used in the field the microscopes are shaded from the sun by large umbrellas.

With this method of mounting the microscopes it is advantageous if not essential to set the microscope posts and those supporting the portable track before beginning measurement.

End marks and method of reference thereto.—The method of marking the end of a line is essentially that of the Repsolds and fully described in the Lake Survey Report referred to above. It consists in the use of a metallic bolt terminating in a spherical head, the bolt being embedded in a stone or other stable mass set in the ground. The center of the bolt head is the fiducial point. To refer to this point a cylinder called a cut-off cylinder is used. It terminates at one end with a conical hole which fits over the spherical head. The other end is provided with a transverse level and graduated scale. The scale is

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[*] Fully described in General Comstock's report referred to on page 33.

brought by a rack and pinion motion to focus under the micro-scope whose position relative to the fiducial point is sought. The scale and level, which are parallel to each other, are placed parallel to the line measured. With the cylinder thus disposed readings of the micrometer on the scale and of the position of the level bubble are made. The cylinder is then turned 180° in azimuth and the scale and level readings are again observed. From these observations and the height of the scale above the bolt head, the horizontal distance (in the direction of the line) between the micrometer zero and the fiducial point may be accurately determined.

Adjustments of apparatus.—The most important adjust-ment of the apparatus is the alignment of the bar in the Y-trough. This adjustment is made when the ice load is in the trough and after the latter has had time to assume a stable shape. This time does not exceed 15 minutes.

As already stated, the alignment of the bar requires that the upper surfaces of the alignment plugs be in one plane and that the lines on these plugs be in the same straight line. The former requisite is secured by a striding level whose feet are 99^{cm} apart, so that they reach from any plug to the second adjacent plug. Beginning at one end of the bar the plugs are numbered 1, 2, 3,—11. By placing the level feet in succes-sion on plugs 1 and 3, 3 and 5, etc., plugs 1, 3, 5,—11 are brought into the same plane by means of the corresponding vertical adjusting screws, the screws under plugs 2, 4,—10 being loosened if need be to secure this end. Having thus adjusted plugs 1, 3, 5,—11, the level is placed on plugs 2 and 4, 4 and 6, etc., and the vertical screws are brought up to contact with the bar but not raised enough to disturb the previous adjustment of 1, 3, 5—11, which are the principal defining plugs in this adjustment.

To place the lines on the plugs in the same straight line a sharp pointed plumb bob suspended from a fine brass wire stretched over the trough was originally used. This device with the aid of the lateral adjusting screws of the saddles per-mits placing the lines in proper position within 0·1^{mm} when the trough is fully loaded with ice. Experience with the appa-ratus, however, showed that the simpler method of stretching the wire, or better still, a fine thread, close over the plugs when the trough is about four-fifths loaded secures equally good results.

It was feared before using the apparatus that the daily tem-perature range might produce an appreciable effect on the length of the bar through change in curvature of the trough. Hence the accurate method of measuring such change by the striding level was provided. But experience shows that the

change in shape of the trough gives rise to quite insignificant changes in length of the bar. Indeed, the alignment of the bar may be maintained so perfectly that the correction for its curvature will not exceed a few tenths of a micron.

The grade sector of the apparatus is adjusted to zero when the graduated surfaces of the bar are in the same horizontal plane. To secure the latter condition an engineer's level is used; and with appropriate care the difference in height of the ends of the bar can be made zero with a probable error not exceeding $\pm 0\cdot1^{mm}$.

The microscopes are provided with fixed levels, which, when once adjusted, enable the operator to make the axes of the microscopes vertical. They are also provided with clamp screws so that they may be rigidly held in proper position.

When posts are used to support the microscopes, as has been the case with this apparatus thus far, they must be set in their proper positions within a centimeter or two. It is easy and convenient, however, to adjust their sides facing the line to be measured with much greater precision. When firmly set, a line parallel to the base may be deliberately ranged out with a theodolite of high magnifying power, and this line may be defined by suitable marks on each post. Then by simply noting the distance of the axis of the bar during measurement from this reference line an accurate correction for deviation of the bar from parallelism with the base may be obtained. This adjustment of the posts though not essential to the use of the apparatus has been followed.

Another convenient adjustment which the use of posts permits is that of making the tops of several or many posts conform to one grade. By this means, since the four microscopes used are closely alike, the grade angles for several or many bar lengths are nearly the same—a condition favorable to precision in determining grade corrections. As an additional precaution in the use of this apparatus the relative heights of the alternate post tops have been determined with an engineer's level.

Method of measurement.—To conduct the measurement of a line with this apparatus eight men are required, to wit: three observers; one recorder; one man to move the microscopes; and three men to move the car tracks, the microscope shades, and the ice and ice crusher.

The operation of measurement proceeds as follows: The position of the microscope relatively to the fiducial point at the end of the line having been observed as explained above, the rear end of the bar is brought to focus under that microscope by the rear end observer. By means of a lever which grips into the track and hinges on the car, the latter observer

holds the bar near to bisection under the microscope while the
front end observer brings his microscope into position over
the front end of the bar; to do which he can make use of the
lateral motion of the trough, of the microscope, or both.
When the bar is adjusted at both ends the rear observer brings
the rear end graduation accurately to bisection between the
micrometer wires by use of his lever without turning the
micrometer screw. Simultaneously he gives the signal " read "
to the front observer, who brings his micrometer wires to
bisect the front end graduation mark by moving the micro-
scope, the micrometer wires, or both. The observers then
read their micrometers and the recorder notes them down in
his book, after which the rear observer turns his micrometer
screw a half revolution or less backwards. The observers
then exchange positions. The rear observer carrying with
him his lever applies it to the front car and brings the front
end graduation to bisection without disturbing the micrometer
threads from their previous position; while at the signal
" read " the front observer bisects the rear end graduation by
moving the threads with the micrometer screw. They then
announce the readings as before and the recorder jots them
down, notifying the observers at the time if the screw revolu-
tions differ from their previous values. This process eliminates
the relative personal equation of the observers, and checks any
blunders of whole revolutions in reading the microscopes, each
of them being read four times, and the four readings being the
same within a few microns. The probable error of a bisec-
tion is less than $\pm 1^{\mu}$.

While the bar is in position under the microscopes, the third
observer measures the distance of the front end (and the rear
end at starting) of the axis of the bar from the reference line,
and adjusts the sector level bubble to center, taking care at
the same time to keep away from the microscope posts when
the bar is observed. The grade sector reading is then made
and recorded, and the bar is rolled rapidly forward to a new
position.

As soon as the rear end of the bar is brought safely to posi-
tion under a microscope the one previously at the rear end is
taken up and carried forward by the microscope porter who
clamps and adjusts it on a new post. Likewise, as soon as a
section of track is passed over it is carried forward to a new
position.

The observers stand on platforms which rest at their ends
on the ground at a distance of about one meter on either side
of a microscope post.

At intervals of 20 to 40 minutes fresh ice is supplied, the
trough being run to the rear of or ahead of the two micro-

scopes which were last used. The trough is completely un-
covered in this operation and the ice stirred up and supple-
mented by the amount requisite to replace the waste. This
amount is usually 3 to 5 kilograms.

The speed of measurement has varied somewhat with cir-
cumstances. It has usually been about 100^m per hour. 750^m
were measured in 7 hours on two different dates; and a kilo-
meter would not be an excessive day's work.

The Efficiency of the Apparatus.

Plan of operations with apparatus in 1891.—The plan sub-
mitted by me to the Superintendent of the Survey for the use
of this apparatus on the Holton Base, of the transcontinental
triangulation in Indiana, contained the following recommenda-
tions which were approved and carried out during the summer
of 1891 : (*a*) To construct a 100-meter comparator near the
Holton Base ; to standardize this comparator by repeated
measurements with the iced bar ; and to use this comparator
in turn to standardize and study the behavior of 100^m tapes or
those of less length, or any other form of base apparatus. (*b*)
To use the iced bar in addition to make several measures of a
kilometer at least of the base line ; so that the efficiency of
the different forms of apparatus used in measuring the whole
base could be tested on the actual ground over which they were
applied.

The plan also contemplated making a determination of the
length of the steel bar of the apparatus in terms of one of the
International Prototype Meters. This was done, but owing to
the small amount of time available before going to the field it
was impossible to reach anything better than a tentative value.

Before giving the results of the measures made with the
iced bar it is proper to give a brief description of the long
comparator and of the kilometer whereon the apparatus was
used.

The 100-meter comparator.—The 100-meter comparator of
the Holton Base was a line 100^m long fitted for measurement
with the iced bar apparatus. Twenty-one beech wood micro-
scope posts 1·8^m long and 15^{cm}×15^{cm} in cross section were set
firmly in the ground 5^m apart on a level plat near the north
end of the Base. Alongside of the posts a stationary railway
track was laid, the support posts of which were half way be-
tween the microscope posts. The ends of the line were
marked by brass, spherical headed bolts cemented into the
upper ends of stone posts, which latter were well set in beds
of concrete. The comparator was covered by a shed 110^m
long by 3^m wide. Its length extended nearly east and west.
It was covered at the ends and on the south side as well as

overhead, but the north side was left open in order to permit
free access of daylight and air.

This comparator was built by Assistant A. T. Mosman after
plans drawn up by Mr. Siebert. It answered its purpose very
satisfactorily. An efficient auxiliary applied by Assistant
Mosman was a sawdust covering to the ground along the com-
parator. This covering absorbed dust and moisture, and pre-
vented the transmission of disturbances through the ground to
the microscope posts. The stability of these posts may be
inferred from the measures of the comparator interval given
below.

The standard kilometer.—A nearly level portion one kilo-
meter in length of the Holton Base was selected by Assistant
Mosman for measurement with the iced bar apparatus. The
base line, whose entire length is 5·5 kilometers, runs in a
nearly north and south direction across the Crawfish Flats of
southern Indiana. The portion selected for the iced bar
measures passes for 600^m of its length through a dense forest
growth, leaving about 200^m at either end in open fields. The
whole kilometer is on low ground and the part within the
forest is, in a wet season, subject to partial inundation. The
soil along the kilometer is a stiff clay which is very firm when
dry but which assumes a jelly-like mobility and elasticity
when saturated with water.

The way through the forest was cleared and the end stones
of the kilometer were set under the direction of Assistant
Mosman during May and June, 1891. During the latter half
of the following August and early September the microscope
and track posts were set along the line. Owing to frequent
and heavy rains this was a tedious operation. Many of the
posts were set in the water which filled the post holes as fast
as they were dug. It is impossible, therefore, to present any
statistics as to the speed with which this work can be done
under usually favorable circumstances. It may be remarked,
however, that it is a work which requires but little skilled
labor. In addition, it should be said that the microscope posts
were set with considerable precision. Accurate spacing of the
posts to 5^m apart was secured by means of 100^m and shorter
steel tapes; while the posts were aligned by means of a
theodolite. The probable error in position of a post face with
respect to the kilometer line does not, I think, exceed $\pm 3^{mm}$;
while the probable error of the reference line fixed on the
posts as explained above does not exceed $\pm 1^{mm}$.

The bolts marking the termini of the kilometer were
cemented in the end stones by Assistant Mosman early in
August, after their proper relative positions had been deter-
mined by Assistant O. H. Tittmann with the Survey secondary

apparatus.* Intermediate stones dividing the kilometer into four nearly equal sections were set on September 7, 1891. Each of them consisted of a half cubic meter of concrete set in the ground so that its upper surface was about even with the ground surface. On the top of each stone was cemented one of the Repsold cut-off plates which are provided with spherical headed bolts for use with the cut-off cylinder previously described.

When these intermediate stones were set, the ground along the line was so wet that it was a matter of difficulty to keep the water out of the excavations while the concrete was being rammed into place. These stones did not become dry and hard until deep trenches were dug about them on September 18, 1891. For this reason it is probable that these stones were much less stable during the first two measures of the kilometer (Sept. 10–15) than during the last two measures (Sept. 26–30).

Results of measures of 100ᵐ comparator interval.—The earliest experience with the iced bar apparatus showed that the personal equation of the observers may cause appreciable constant error, and hence the method of interchange of the observers already explained was adopted. The first five measures of the comparator interval, however, were made without interchange of the observers. In place of such interchange direct observations for relative personal equation were made on the bar.

The greater part of the measures of the comparator interval were made by starting at the west end and moving the bar toward the east. Some of the later measures were made in the opposite direction and they disclose, apparently, a systematic error depending on the direction of measure. The same kind of systematic error is indicated also by the measures of the kilometer referred to below.

In order to explain the data of the comparator measures clearly and fully let

D = distance between spheres of comparator
= $100^m + 39 \cdot 5^{mm}$ approximately,
B_{17} = length of 5^m steel bar No. 17 in ice,
x = the relative personal equation of the two observers on the bar,
Q = quantity measured on cut-off scale,
v = the most probable correction to Q.†

Then, for one position of the observers a measure of the comparator interval gives an observation equation of the form

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* This is an end measure apparatus consisting of two steel rods encased in wood, with mercurial thermometers to give their temperatures.

† The quantity Q involves the error of measuring the line as well as the errors in position of the first and last microscope with respect to the fiducial points.

$$D + 20x - 20B_{17} - Q = v,$$

while for the reverse position the equation is

$$D - 20x - 20B_{17} - Q = v.$$

The following table gives the data furnished by the first group of measures of the comparator. These data include the observations for personal equation, which give rise to observation equations involving the quantity x only. Although the latter equations should have somewhat greater weight than the others they are all treated as of equal weight in this purely preliminary statement.

Data for length of 100^m comparator.

Date 1891.	Direction of Measure.	Observation Equations.
July 30	W to E	$D + 20x - 20B_{17} - 39{\cdot}532 = + 0{\cdot}052$
30	W to E	$D + 20x - 20B_{17} - 39{\cdot}574 = + \ \cdot010$
30	W to E	$D + 20x - 20B_{17} - 39{\cdot}660 = - \ \cdot076$
30	....	$+ 20x \quad .... - 0{\cdot}049 = + \ \cdot013$
31	W to E	$D + 20x - 20B_{17} - 39{\cdot}548 = + \ \cdot036$
31	....	$+ 10x \quad .... - 0{\cdot}040 = - \ \cdot008$
Aug. 3	W to E	$D + 20x - 20B_{17} - 39{\cdot}643 = - \ \cdot059$
3	....	$+ 10x \quad .... - 0{\cdot}061 = - \ \cdot029$
4	W to E	$D + 20x - 20B_{17} - 39{\cdot}624 = - \ \cdot040$
4	W to E	$D - 20x - 20B_{17} - 39{\cdot}476 = - \ \cdot016$
4	....	$+ 20x \quad .... - 0{\cdot}022 = + \ \cdot040$
7	W to E	$D + 20x - 20B_{17} - 39{\cdot}528 = + \ \cdot056$
7	W to E	$D - 20x - 20B_{17} - 39{\cdot}424 = + \ \cdot036$

The resulting normal equations are :

$$9D + \ \ 100x = \ \ \ 9(20B_{17} + 39^{mm}) + \ \ 5{\cdot}009,$$
$$100 + 4600 \ \ = 100(20B_{17} + 39^{mm}) + 66{\cdot}610 ;$$

whence

$$D = 20B_{17} + 39{\cdot}522^{mm} \pm 0{\cdot}011^{mm},$$
$$x = +3^{\mu}{\cdot}1 \pm 0^{\mu}{\cdot}5.$$

The probable error of an observed quantity of weight 1, or of a single measure of the comparator without interchange of observers to eliminate personal equation, is $\pm 30^{\mu}$.

Later in the season (Sept. 24 to Oct. 6) a second set of measures of the comparator interval was made. In each of these measures the observers interchanged positions, and on two dates the interval was measured in the direction east to west as well as in the direction west to east. The results of these measures are given in the following table which is arranged in the same form as the preceding table.

Data for length of 100ᵐ comparator.

Date 1891.	Direction of measure.	Observation equations.
Sept. 24	W to E	$D + 20x - 20B_{17} - 39 \cdot 272 = + 0 \cdot 134$
24	W to E	$D - 20x - 20B_{17} - 39 \cdot 191 = + \cdot 149$
Oct. 2	W to E	$D + 20x - 20B_{17} - 39 \cdot 394 = + \cdot 012$
2	W to E	$D - 20x - 20B_{17} - 39 \cdot 320 = + \cdot 020$
2	E to W	$D + 20x - 20B_{17} - 39 \cdot 432 = - \cdot 026$
2	E to W	$D - 20x - 20B_{17} - 39 \cdot 369 = - \cdot 029$
6	W to E	$D + 20x - 20B_{17} - 39 \cdot 422 = - \cdot 016$
6	W to E	$D - 20x - 20B_{17} - 39 \cdot 370 = - \cdot 030$
6	E to W	$D + 20x - 20B_{17} - 39 \cdot 512 = - \cdot 106$
6	E to W	$D - 20x - 20B_{17} - 39 \cdot 449 = - \cdot 109$

The normal equations from this group are :

$$10D + \quad 0x = 10(20B_{17} + 39) + 3 \cdot 731,$$
$$0 \ + 4000 \ = \qquad\qquad\qquad + 6\,660 ;$$

whence

$$D = 20B_{17} + 39 \cdot 373 \pm 0 \cdot 019,$$
$$x = \quad 1^{\mu} \cdot 7 \pm 1^{\mu} \cdot 0.$$

The probable error of an observed quantity of weight 1, or the probable error of one measure without interchange of observers, is $\pm 61^{\mu}$.

The values of D resulting as above from the two groups of determinations differ by $0 \cdot 149^{mm}$, a quantity which is about ten times the average of the probable errors of the separate values. It seems most probable, in view of our experience on the standard kilometer, that this difference is due to a movement of the end marking stones of the comparator. The residuals of the second group of measures indicate a progressive change of this sort.

The data of Oct. 2 and 6 indicate that measures made in the direction west to east give smaller lengths than measures in the opposite direction. Thus the lengths for Oct. 2 are :—

$$\text{Direction W to E} \qquad 20B_{17} + 39 \cdot 357,$$
$$\text{`` \quad E to W} \qquad 20B_{17} + 39 \cdot 400,$$

Their difference is 43^{μ} and the corresponding difference for Oct. 7 is 84^{μ}. They show an average difference of 64^{μ}, which is equivalent to an error of $1^{\mu} \cdot 6$ per bar length relatively to the mean of a forward and backward measure of a line.

Results of measures of standard kilometer.—In the measures of the kilometer the observers always interchanged positions in reading on the bar. The results may then be regarded as free from personal equation except so far as such equation

may differ for the two ends of the bar. Each section of the kilometer was measured in both directions. The bar was kept in the same position, relatively to the Y-trough, it had when used on the comparator. A measure from west to east on the comparator corresponds then to a measure from north to south on the kilometer.

Two series of measures of the kilometer were made; one immediately after the intermediate section stones were set and while the ground was very unstable, and one after the ground was dry and very stable. In addition to errors arising from unstable ground the first measures were subject to some errors arising from delay and temporary stops, which were avoided in the second measnres. Accordingly, the first series of measures must be regarded as much less precise than the second.

The following table gives the results of these two series of measures. The numerical quantities given are the excesses measured with the cut-off scale over a round number of bar lengths, the number of bar lengths being fifty for each section and two hundred for the whole kilometer. The first measures were made on Sept. 10 to 15 and the second on Sept. 26 to 30.

Results of measures of kilometer.

1st series, Sept. 10 to 15, 1891.

No. of meas-ures.	Direction of measure.	Section 0^m to 250^m.	Section 250^m to 500^m.	Section 500^m to 750^m.	Section 750^m to 1000^m.	$0^m - 1000^m$.
		mm	mm	mm	mm	mm
1	N to S	+6·35	−5·43	+19·08	−20·56	−0·56
2	S to N	+6·52	−4·55	+19·37	−19·28	+2·06
1−2		−0·17	−0·88	− 0·29	− 1·28	−2·62

2d series, Sept. 26 to 30, 1891.

3	N to S	+6·97	−5·50	+19·67	−21·28	− 0·14
4	S to N	+7·07	−5·60	+19·76	−21·19	+0·04
3−4		−0·10	+0·10	− 0·09	− 0·09	−0·18

Without attempting to discuss these results here, it may be pointed out that they indicate systematic differences depending on the direction of measurement. These differences agree in sign with those developed in the forward and backward measures of the 100^m comparator as explained above. It may be remarked also that the largest differences in the first series are found in the measures of the second and fourth sections where the ground was least stable.

From the differences (1–2) and (3–4) of the table it appears that the probable error of one measure of a kilometer is $\pm0\cdot76^{mm}$ from the first series and $\pm0\cdot09^{mm}$ from the second series. The second of these probable errors, it may be remarked, agrees well with the corresponding value deduced from the measures on the 100^m comparator, to wit, using the average value for the probable error of one measure of the comparator interval :

$$\pm \tfrac{1}{2}\frac{(30^\mu+61^\mu)}{\sqrt{2}}\sqrt{10} = \pm 0\cdot10^{mm}$$

It will be of interest in this connection to compare these probable errors of measurement with those obtained with other micrometer microscope apparatus. The apparatus most nearly comparable in this respect with the iced bar apparatus are the Repsold bimetallic (zinc and steel) of the U. S. Lake Survey and the Brunner bimetallic (copper and platinum) used recently by French geodesists. The best work with the Repsold apparatus, on the Olney base 1879, shows a probable error of $\pm0\cdot40^{mm}$ for one measure of a kilometer.* The work of the French on the Paris and Perpignan bases, 1890, 1891, shows $\pm0\cdot67^{mm}$ for one measure of a kilometer.† These larger values are due probably to imperfect temperature indications of the bimetallic apparatus rather than to any material differences of manipulation.

An idea of the stability of the end and section marks of the kilometer may be gained from the above table by computing the differences between the mean lengths of the several sections resulting from the first pair and second pair of measures. Thus we have :

Mean of first pair *minus* mean of second pair of measures.

Section			
Section	0^m to	250^m	$-0\cdot58^{mm}$
"	250 "	500	$+0\cdot56$
"	500 "	750	$-0\cdot50$
"	750 "	1000	$+1\cdot32$

These figures indicate considerable movements of the marking stones; and it seems not improbable that movements of such magnitude did actually occur, since the stones rose to the surface of the ground and the moisture in the ground varied from the extreme of saturation to the extreme of dryness during the interval which elapsed between the two sets of measures.

* Professional Papers Corps Engineers U. S. A., No. 24, p. 303.
† Comptes-Rendus des séances de L'Association Géodésique International du 8 au 17 Octobre, 1891, p. 182.

Length of measuring bar.—The most important and diffi-cult operation attending the use of the iced bar apparatus is that of deriving the bar's length in terms of one of the Inter-national Prototype Meters. As already stated, a preliminary determination of this length was made in July, 1891, just previous to shipping the apparatus to Holton Base, Indiana. The method adopted in this and in most subsequent determi-nations may be briefly described as follows : Six micrometer microscopes were mounted in a straight line at intervals of one meter. The 5^m distance between the two extreme microscopes was measured with Prototype Meter, No. 21, and this distance transferred from the extreme microscopes to the 5^m steel bar No. 17. All comparisons of this kind were made with both the meter and 5^m bars in melting ice. The 5^m bar was mounted in its Y-trough and the meter bar in a wooden box. 40 to 45 kilograms of ice were used for the 5^m bar and 10 to 12 kilo-grams for the meter.

Assuming constancy of temperature of the bars under com-parison the precision of the method just outlined evidently depends on the stability of the microscopes used. The first series of comparisons of July, 1891, and several series of February to May, 1892, were made on the office comparator. This comparator was not designed to meet the special require-ments of the case and it did not meet them satisfactorily. The microscopes were too unstable. Their instability was due primarily to the manner of mounting them. They were each suspended by a cast iron bracket from a wrought iron I-beam about 6^m long which is supported at its ends on brick piers. The focal planes of the microscopes fell about $0 \cdot 5^m$ below the beam. The beam was wrapped with cotton batting and cov-ered with a wooden casing to prevent rapid temperature changes. Resting as the beam does by friction on the piers, it is in general in a state of longitudinal stress, which is fre-quently relieved by vibrations communicated to the piers by vehicles passing in the adjacent street. Changes in this stress produce changes in the curvature of the beam and entail exag-gerated motions in the microscopes. The temperature of the comparing room (which is underground) changes very slowly from day to day when not occupied long by observers or when lighted for short periods. The comparisons in question, how-ever, required occupying the room for some hours per day, and the heat from the observers and the electric lights caused notable changes in the temperature of the beam as well as of the air in the room. These changes no doubt caused more or less irregular displacements of the microscopes.

The observations were so arranged as to eliminate the effects of uniform motions of the microscopes. Thus in the first series of determinations the following program was adhered to :

1. Measure of distance between end microscopes with meter,
2.   "   "   "   "   "   with 5^m bar.,
3.   "   "   "   "   "   "   meter;

the second measure with the meter being made in a direction opposite to that of the first. In later measures on this comparator the above program was supplemented by an initial and final measure with the 5^m bar.

The observations were made by two persons observing simultaneously at the respective ends of either bar. The observers also exchanged positions in all cases to eliminate personal equation.

The determinations made in the manner just described showed large ranges, amounting to 1/200000th part at the maximum ; and with the hope of overcoming the effects of the irregular motions of the microscopes a different method was tried with the same comparator. The essential feature of this method consists in the use of an intermediary 5^m steel bar subdivided into meter spaces. This bar, known as No. 18, is similar in form to No. 17, except that it is cut down to the mid depth at four intermediate places as well as at its ends. The lines subdividing the bar into meter spaces are ruled on platinum iridium plugs. This bar was mounted in the steel Y-trough where its flexure could be controlled in the same way as that of bar No. 17. The sub-spaces of No. 18 when packed in melting ice were determined by direct comparisons with Prototype Meter No. 21. Three series of six measures each of the sub-spaces, and hence of the whole length of the bar, were made. In the intervals between the first and second and the second and third series, bars 17 and 18 were compared. For this purpose No. 17 was mounted in an auxiliary wooden trough similar to the Y-trough. Notwithstanding the diminished time-interval during which dependence on the stability of the microscopes was required by this process, the results attained were still too erratic to give confidence. The range in values for the metric sub-spaces of No. 18 rose to 1/200000th part and in the values for the whole length, or sum of these spaces, to 1/300000th part ; and these ranges appeared to be directly referable to the large progressive, and frequently large sudden, movements of the microscopes.

Such being the unsatisfactory quality of the results attained on the office comparator, it was determined in June, 1892, to build a new comparator designed more especially to meet the

requirements of the iced bar apparatus. This comparator was constructed in a lot adjacent to the Survey Office. Briefly described it consists of six brick piers resting at intervals of a meter on a foundation of six cubic meters of well rammed concrete. The foundation and the piers are set in Portland cement and weigh about twelve tons. The foundation, which rises to near the ground surface, is covered to the depth of a decimeter with sawdust. Each pier carries a micrometer microscope. The latter and their connections with the piers are wrapped heavily with cotton batting. The meter and 5^m bars were moved under the microscopes on portable tracks supported on posts isolated from the piers. The track for the 5^m bar was that used in the field, and the mode of handling this bar was precisely the same in all respects as that followed in measuring a line.

The microscopes as mounted on this comparator proved to be very stable notwithstanding the fact that they were subject to the daily range in air temperature except so far as they were protected by cotton batting wrappings. The effect of the observers' presence near the comparator was undoubtedly less than in the office comparing room, and the use of artificial light was avoided entirely.

The program followed in the use of the new comparator comprised three measures of the distance between the end microscopes with the meter and two measures with the 5^m bar in each set of observations. The measures with the meter were made in opposite directions alternately along the comparator. Twenty sets of observations were made with the 5^m bar in each of its two orientations relatively to the Y-trough and microscopes. The consistency of the results attained leaves little to be desired. The probable error of a single determination of the length of the 5^m bar in terms of the Prototype is $\pm 1^{\mu}\!\cdot\!8$ from one group of measures and $\pm 1^{\mu}\!\cdot\!7$ from the other. The range in the one case is $12^{\mu}\!\cdot\!3$ and in the other $8^{\mu}\!\cdot\!5$.

The following table gives an abstract of the results obtained in the manner described above for the length of the 5^m bar. The values given are subject to corrections for flexure of the 5^m bar, which, however, cannot exceed a few tenths of a micron. The probable errors are those which come from the discrepancies between the individual and mean results of a group of determinations. Each result is derived from an equal number of measures with the meter and 5^m bars in their two different orientations. The first, second, and third results were obtained from the Office comparator, the third one depending on the method wherein the auxiliary bar, No. 18, was used. The fourth result was obtained from the new comparator.

Summary of results for length of B_{17}.

Date.	No. of Measures.	Mean length of bar.
July, 1891	10	$5^m - 11^\mu \cdot 0 \pm 1^\mu \cdot 4$
Feb. and March, 1892	20	$5 \ -15 \ \cdot 2 \pm 0 \ \cdot 6$
April and May, 1892.......	18	$5 \ -11 \ \cdot 7 \pm 1 \ \cdot 6$
July and August, 1892 ...	20	$5 \ -16 \ \cdot 8 \pm 0 \ \cdot 3$

Without desiring to discuss these data here, it may be said that so far as is known at present the probable errors are fairly trustworthy indices of the precision of the several results. The range among them is but little in excess of the millionth part of the bar's length, and is no greater than the probable errors would lead one to expect.

It may be stated also that the external air temperature varied for the different groups of comparison from 5° to 40° C. The average air temperatures for the two most important groups, namely, those of February and March, 1892, and July and August, 1892, were about 5° C. and 35° C. respectively. Hence it does not appear that the bars in ice were affected appreciably by the external air temperature. Finally, it should be said that a systematic difference in the length of the bar, according as the one or the other of its ends is to the right in the Y-trough, is indicated by each group of comparisons. This difference appears to be an inequality of relative personal equation of the observers at the two ends of the bar, and may be due to the considerable inequality in widths of the terminal graduation lines.

Concluding remarks.—The question may be asked, does the bar take the temperature of melting ice when fully packed in it? I am unable to give a decisive answer to this question at present, but there appears to be no reason to suppose that it takes a materially different temperature. Repeated observations on mercurial thermometers placed in the ice alongside the bar show that they read zero within the unavoidable errors of a few hundredths of a degree. That the bar assumes a fixed length within very narrow limits is, it would seem, demonstrated by the small range among the measures of the 100^m comparator and the kilometer sections referred to above, and especially by the recent work on the new comparator. This latter work appears to justify the conclusion that the mean of four determinations of the bar's length in terms of the Prototype meter, made in the manner described above, cannot have a greater probable error than one micron. It is evident therefore, in view of the unavoidable errors of observation in such work, and in view of the fact that the bar's expansion is about 55$^\mu$ per degree Centigrade, that there is a very small margin for change in the bar's length.

The time required for the bar to acquire a sensibly stable length is less than ten minutes. The rate of temperature-change is so great in the early stages of freezing that ninety per cent or more of the contraction of the bar occurs within a minute after it is well surrounded by ice. The corresponding time required by the Prototype meter to reach a stable length appears to be less than five minutes, which is less than the time essential to properly pack it in ice.

A query may also arise as to whether the bar, resting as it does with considerable friction on the vertical adjusting screws of the Y-trough, may not change length by reason of longitudinal stress communicated by the trough. In answer to this query it may be said that the experiment of putting the trough alternately under tension and compression in quick succession has been tried on several occasions without disclosing any effect on the bar.

With regard to the precision attainable in the measurement of a line with this apparatus, it would appear that the error of operation may be rendered insignificant in the mean of a few measures of a line, so that the probable error of the mean length may be diminished to that of the bar when expressed as a fraction of its length. It appears practicable to determine that length with a probable error not exceeding 1/5000000th part, and this, therefore, would appear to be an attainable precision in the measurement of a line with the apparatus.

Although the use of this or similar apparatus is not to be recommended for primary bases in general, since it gives a needless precision, it will compare favorably I think on the score of economy with any of the earlier forms of apparatus which have given a precision approaching the millionth part of a measured line. The proper function, however, of the iced bar apparatus appears to be that of an intermediary between the lighter and cheaper forms of base apparatus and the standard meter. By means of this bar it appears practicable to standardize long steel tapes so accurately that they will give all needful precision for bases in general at much less cost than other forms of apparatus.*

Office Coast and Geodetic Survey, Sept. 15, 1892.

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* Experience of the author in the use of 100^m steel tapes with mercurial thermometers to give temperature, on the Holton Base, 1891, shows that the length of such a tape can be determined with a probable error not exceeding 1/2000000th part, and that the probable error due to errors of operation and temperature in the mean of n measures of a line k kilometers long need not exceed

$$\pm 2^{mm}\sqrt{\frac{k}{n}}.$$

ART. V.—*Some Experiments with an Artificial Geyser;*
by JAMES C. GRAHAM.

As a result of observations during his travels in Iceland in
the summer of 1846, Professor Bunsen advanced the explana-
tion[*] of the eruptions of the Great Geyser which has been
almost universally accepted since then.   In 1847,[+] there ap-
peared an article in which Professor Bunsen's views were dis-
puted and it was in answer to this article that Professor
Müller published in 1850 the first account of which I can find
any record, of experiments with an artificial geyser.[‡]   Since
that date artificial geysers have been often
constructed and exhibited, the most com-
plete descriptions in English of such gey-
sers, being found in Professor Tyndall's
" Heat as a mode of Motion " (Appleton,
1865, p. 139) and in a description of
Müller's experiments in Hayden's Report
for 1878 of the U. S. Geological Survey
(p. 420).
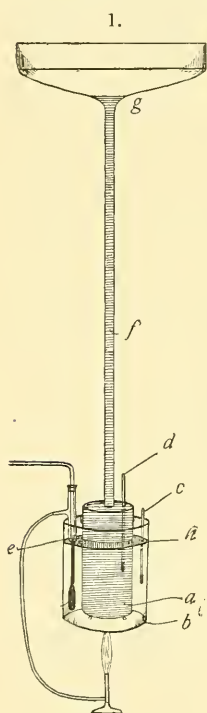
In all of these experiments, however,
the artificial geyser has not been con-
structed to explain geyser phenomena in
general but has been restricted to an
imitation of the Great Geyser of Iceland.
This geyser is peculiar in having the boil-
ing point reached first, not at the base
of the tube or throat, but at a position
considerably above this.   It is doubtful if
this peculiarity has been repeated in any
geyser which has been elsewhere studied.
In my work, therefore, I have not applied
heat at an intermediate point of the tube,
but only at the base.   The description of
my apparatus is as follows:

It consists (fig. 1) of a glass tube, f,
surmounted by a funnel, g, and terminat-
ing in an iron cylinder, a.   This cylinder
is immersed (to the line h) in a bath of mercury contained
in another iron cylinder, b; c and d are thermometers, regis-
tering the temperature of the mercury and of the geyser fluid
respectively; e is a mercury gas-cock, so arranged that an

1.

* Poggendorff, vol. lxxii, p. 159.
† Die Fortschritten der Physik im Jahre, 1847, dargestellt von der physikal-
ischen Gesellschaft zu Berlin, p. 92.
‡ Poggendorff, vol. lxxix, p. 350, 1850.

increase of heat causes an expansion of mercury in the bulb below, thereby decreasing the heat by cutting off the gas. The object of this device is to maintain, as nearly as practicable, a constant temperature in the mercury. The whole is supported upon a frame not shown in the figure.

The important dimensions of the apparatus are :

Internal diameter of inner cylinder	0.089^m
" height " "	0.136^m
" diameter of tube	0.021^m
Height of tube	1.44^m
Height to which cone is filled	0.035^m
Total height of fluid column	1.611^m

With this apparatus we are enabled to get not only qualitative but quantitative results to a large extent, for all the factors are nearly constant, and where variable, the amount of variation can be detected.

The object of my experiment was to see if any light could be thrown upon the subject of "soaping geysers" by the study of an artificial one. But before considering this subject, I wish to mention an observation which seems to me to give a criterion, judged by which certain geysers can be proven not to operate upon the McKenzie principle.

It will be recalled that Sir George in explaining the phenomenon of an eruption supposed a tube communicating with a subterranean cavern in the way indicated in the accompanying sketch, fig. 2.

2.
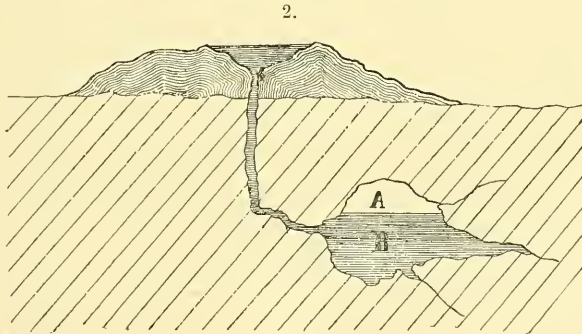
The water is kept in the tube at the level indicated, by the steam pressure in A, arising from the heated water B. An eruption takes place when the pressure in the cavity becomes great enough to lift the column in the tube sufficiently to cause an overflow and thus to lessen the pressure of the column. By forcing the tube of my artificial geyser part way

down into the iron cylinder, a geyser is formed of practically the same type that Sir George's theory requires.   When this is done, this change is at once observable in the eruption. *They are unpreceded by steam bubbles.*   It is evident that this must be so; for the peculiar form of the tube and chamber are of no avail in Sir George's theory unless the temperature of the water reaches the boiling point before the water-level in the subterranean chamber has been forced down to the opening of the tube into the cavity.   And until this level is reached no steam bubbles of any consequence can escape.   The conclusion which I would draw would be that those geysers in which the eruptions are markedly preceded by bubbles can-not be classed as " McKenzie's."

To turn now to the main subject of this paper, that is the effect of soaping geysers.

It has long been thought that by throwing stones or putting soap into a geyser, a premature eruption could be brought on in the cases of geysers erupting periodically, and that in some cases, hot springs, not known to be active, have by this means been caused to throw out the water in their basins in geyser-spouts.   It is evident, however, that this matter is not capable of absolute proof ; for, as none of the geysers are perfect in regard to the equality of their periods, we can never say posi-tively that the geyser would not have erupted when it did if it had not been soaped.   Or, in the case of forced eruptions of hot springs, it might be considered that these springs were geysers with periods so long that the nature of the spring was now for the first time revealed.   To be sure that such would be the case in many instances is improbable but not impos-sible, especially as but comparatively few springs have been successfully experimented upon.   If now, in the artificial geyser, it can be shown that with the same conditions as to the amount of fluid, heat, barometric pressure, etc., the periods of eruption are shorter when the soapy fluid is used than when the fluid is simply water, it will then be conclusively proven that the soap does cause a premature eruption.   The question of why it so acts, may then be attacked.

There are many difficulties in the way of making these seemingly simple observations.

It is necessary that the amount of fluid in the geyser should be the same in all observations ; but owing to splashing and evaporation, this has a constant tendency to vary.   The splashing was provided against by filling the geyser not sim-ply to the top of the tube, but part way (3.5^{cm}) up the funnel as well, which had the effect of deadening the eruption.   The error due to evaporation was provided against by adding a determined amount of fluid at the end of each eruption.   By

this means the error is made a nearly constant one, and the height of the column is not affected.

The question of a constant supply of heat cannot be entirely solved, or at least could not be with the apparatus at my control. But by the aid of the self-regulating gas-cock I was able to keep the supply nearly constant, and by means of many readings of the thermometer immersed in the mercury bath, a comparison could be made in the cases of different eruptions which I think are sufficiently accurate and definite.

The error of barometric pressure variations was overcome by making observations on various days and comparing those in which the heights of the mercury columns were nearly the same.

There were also many minor factors, such as the temperature of the room in which the observations were made, which had to be taken into account and eliminated when possible.

In making the statement of the results of these experiments, only a few from several hundred observations will be given; those in which the various conditions were most favorable to accurate determinations. In Tables I and III the fluid used was ordinary water from the city reservoir. In Tables II and IV it was a solution of Ivory soap in water, of such strength that it was of a molasses-like consistency when cold, but of course much more fluid when warm.

Tempera-ture of room.	Temp. Hg. at erupt.	Temp. Hg. after erupt.	Temp. aq at erupt.	Temp. aq. after erupt.	Time of erupt. H. M. S.	Period between erupts.
Water.				I.	Barom. 30·24 in.	
21·5°	107·5°	104·5°	103·2°	94°	11 35−25	6−30
21·5	107·5	104 8	103·2	94	40−25	5−25
21·5	107·2	104·5	103·2	95	46−30	·6−05
21 5	107·2	104·5	103·2	95	52−50	6−20
21 5	107·2	104·3	103 2	94	59−15	6−25
Soap and Water.				II.	Barom. 30·2	
22	107 5	104·7	103	91·5	14−	5−15
22 5	107	104·7	103	91·5	19−10	5−10
22·5	107	104·6	103	91·5	24−20	5−10
22·5	107	104·7	103	91·5	24−55	5−35
22	107	104·6	103	91·5	35−10	5−15
22	107	104+	103	91·5	40−20	5−10
Water.				III.	Barom. 29·74	
22	106·5	103·8	103·1	94	10 21−05	7−50
22	106·5	103·5	103	93	29	7−55
22	106·5	103·8	103	94	37−10	8−10
22	106·5	103·8	103	94	44−40	7−30
22	106·5	103·7	103	94	52−35	7−55
22	106·5	?	103	94	0−05	7−30
Soap and Water.				IV.	Barom. 30·8	
21·5	106·5	103·5	103·1	92	9 52−20	6−10
21·5	106·5	103·7	103·1	91	· 58−15	5−55
21·5	106·5	103·5	103·1	91	10 4−25	6−10
21·5	106 5	103·5	103·1	91	10−15	5−50

In these tables although the conditions are not precisely the same, it is evident that in those cases in which the soap was used, the periods between the eruptions were much shortened. The differences in the temperature of the room and mercury, and the changes in barometric pressure, are so slight as to be unworthy of notice, or in a direction contrary to produce the obtained result. It is also noticeable that the soap solution is cooled much more after each eruption than is the case with pure water. This is due to the fact that as the periods are shorter, convection and other causes, could not operate so completely to heat the water in the geyser throat, and this cooler water in rushing down at the end of the eruption, lowers the general temperature. This factor also acts against the tendency of the soap solutions having shorter periods, as it requires a greater elevation of temperature at each eruption than is required in the case of pure water.

I think that these observations show conclusively that soaping geysers does have a tendency to shorten their periods. The question which now confronts us is : How does it produce this effect ? I will confess at once that I have not solved this problem very satisfactorily ; but I have at least shown that some theories which have been advanced as to the *modus operandi*, cannot hold.

It is evident that to bring about an eruption, what must be done is to cause the water to boil at some point in the tube ; and *any* effect which the soap has upon the boiling of the geyser water may be a factor in the solution of the problem, provided only the effect is in a positive direction. By being in a positive direction, I mean having a tendency to hasten, rather than to retard, the boiling. What these various effects are, I will now proceed to consider.

First. as to the weight of the column. If the specific gravity of the soapy water were much less than that of the water alone this would lessen the pressure and so lower the boiling point for any given depth. By determination, I found that considering the water used of a specific gravity of 1, the specific gravity of the soap solution was 1·00454. The determinations were in both cases at a temperature just below the boiling point and the fluids were those actually used in operating the geyser. The effect of the difference of specific gravities would therefore be negative as regards hastening an eruption.

Second, as to the boiling point itself. In this respect there was no difference, it being 99° C. for both. These observations were made at the same time and with the same thermometer, etc., to avoid all chances of error.

Third, as to the specific heat. If the specific heat of the soap solution were less than that of the water, less heat would be required to bring a given amount to the boiling point, and with a constant supply of heat, less time would be required. This observation it was impossible for me to make with any great accuracy, but from the results of my experiments, I should say that there was no appreciable difference between the two specific heats.

Fourth, as to the retention of heat. In the tables concerning the periods of eruption, it was noticed that the temperature was lowered more after an eruption in the case of the soap and water than in the case of the pure water. As the boiling point was the same in both cases (compare Tables III and IV) it was considered that this was due to the columns above being less heated in one case than in the other. This at once suggests a possible explanation. The heat is retained in the lower part of the tube where it can be utilized in causing the fluid to reach the boiling point, and so not wasted in raising the temperature of the whole column. How, then, is this heat retained, or conversely, how is the heat lost in the case of the water geyser?

Convection is, of course, the principal method by which heat is conveyed from the lower part of the tube to the upper portion. If the viscosity of the fluid retards convection, this then would cause the heat to be retained below. To test this matter, I constructed a piece of apparatus by which a column of water was heated at the base only, and the temperature attained by the water in the upper part of the tube could be read at given intervals of time. By changing the fluid to soap and water, the influence of the viscosity upon convection, at least as far as it affected my problem, could be determined. After a number of experiments with the fluids at high temperatures, I was somewhat surprised to find that the thermometer in the soap solution showed in every case, a slightly greater degree of heat than in the case of the water. That is, viscosity did not seem to retard the escape of heat by convection. Hence convection cannot be the factor sought.

In all eruptions of the geyser the final out-rush of the water is preceded by the rise of bubbles of steam (and of air, possibly, to some extent), through the column of water. If these bubbles are retarded in their ascent by the viscosity of the fluid, they will give out more heat in the lower part of the tube and so carry less to the upper. Accordingly, I devised an apparatus to measure by the chronograph, the time required for the bubbles to pass a given distance through the different liquids against the force of gravity. The average of about twenty five readings in each fluid showed that the time re-

quired was the same in both cases to the hundredth of a second.

From these experiments I am forced to the conclusion of Mr. Arnold Hague, which he states in his paper entitled " Soaping Geysers," read before the New York meeting of the American Institute of Mining Engineers in February, 1889. " Viscosity must tend to the retention of steam within the basin, and, as is the case of superheated waters, where the temperature stands at or above the boiling point, explosive liberation must follow.   All alkaline solutions, whether in the laboratory or in nature, exhibit, by reason of this viscosity, a tendency to bump and boil irregularly.   Viscosity in these hot springs must also tend to the formation of bubbles and foam when the steam rises to the surface, and this mixture aids to bring about the explosive action, followed by a relief of pressure, and this to hasten the final and more powerful display."   The retention of steam referred to in the above quotation is an entirely distinct phenomenon from that of the interference in the rise of steam bubbles investigated in my experiments.   It is an interference with the actual formation of the bubbles rather than with the rise of them after formation.   That such an interference does actually take place is also shown by the fact that the bubbles liberated in the soap geyser are far less numerous than in the case of the water geyser.   Also, when they occur in the case of the soap geyser, they are large and of sudden formation, which would tend to cause an overflow of the basin and thus to relieve the pressure.

In these facts then in regard to the formation of the steam bubbles, I take to lie the main explanation of the phenomenon, believing the surface bubbles to be a much less important factor.

Physical Laboratory of Wesleyan University,
      Middletown, Conn., Oct. 12, 1892.

ART. VI.—*Observations of the Andromed Meteors of November 23d and 27th, 1892;* collected by H. A. NEWTON.

ON the evening of Nov. 23d there were seen at various places in the United States shooting stars which radiated from Andromeda, and which were apparently fragments from the Biela Comet.

At New Haven, Conn.—Dr. Elkin was in the open air for some minutes about seven o'clock on the evening of Nov. 23d. The sky was clear and he feels confident that if there had been a great number of shooting stars, he would have certainly seen them. About a quarter past ten o'clock he was informed by Mr. Chase that the meteors were coming in unusual numbers. For a time they came so as to furnish about ten per minute visible by one observer. Only a part of the sky was clear. Most of the trains were short, not exceeding four degrees in length. Very few were as bright as stars of the first magnitude.

Dr. Chase of the Yale Observatory was walking across the Observatory grounds between ten o'clock and a quarter past ten and in seven minutes counted 16 meteors. In the twenty minutes following he saw enough more to make in all more than 100 flights, that is, in 20 minutes he saw more than 84 meteors. Most of them were faint and had short tracks. Very few left trails. One however left a trail that was visible during 15 seconds. The radiant was very close to Gamma Andromedæ. About $10^h 35^m$ he and Dr. Elkin gave up counting, as the sky was nearly overcast and therefore the counts were unsatisfactory.

Mr. Van Name, the University Librarian, counted 50 in five minutes between $10^h 50^m$ and $10^h 55^m$. He was looking southeast. The direction was almost straight down. There were no very bright ones, though the train of one lasted a second.

Observations of Meteors at 1905 N St., Washington, D. C.—Prof. J. R. Eastman writes : While crossing the street at the corner of N and 19th sts., I saw a meteor near α Cassiopeæ, quickly followed by two more. In a short time I counted 15 and from $10^h 24^m$ to $10^h 43^m$ I counted 102 meteors. From $10^h 59^m$ to $11^h 11^m$, 111 were counted, and from $11^h 19^m$ to $11^h 41^m$ I counted 114, or, in all, 327 meteors in 53 minutes by one observer. They were scattered all over the sky wherever I could see, but in a general way they seemed to diverge from a point about half way between γ Andromedæ and γ Cassiopeæ and near φ Persei. The coördinates of this radiant

would be about 1^h 35^m and $+51°$. Owing to the wide disper-
sion of the bodies the location of the radiant was very difficult
and, at best, could be only approximate.   Several meteors
were quite bright, and one left a bright train showing brilliant
red and green tints.   The behavior of several meteors gave
the impression that they were not more than 100 yards from
the observer; I observed this peculiarity in several instances
in the shower of Nov. 27, 1872.

Prof. Eastman also communicates the following notes by
Mr. D. Horigan, watchman at the new Naval Observatory:

Some meteors appeared soon after dark.   At 7^h were quite
numerous.   At 8^h, increasing in number.   At 9^h, still increas-
ing, several seen at once. 9^h 30^m, still increasing, some leav-
ing trains of red and orange tints. 9^h 40^m, too numerous to
count.   Radiant apparently east of " chair of Cassiopeæ."
10^h 0^m to 10^h 45^m still increasing.   Began to decrease some-
what after 11^h 25^m.   About 11^h 25^m quite a cluster fell from
about 15° below Polaris to the horizon.

At midnight many visible but apparently growing fainter.
0^h 20^m, reduced to counting scale but rather late to begin now.
1^h 0^m, many still falling, but number decreasing. 3^h 0^m, some
to be seen yet.   After 3^h 0^m A. M. on the 24th made several
observations and found more or less falling till daylight.

At Griswold, Conn.—Prof. A. W. Phillips was on the even-
ing of Nov. 23d riding in an open carriage in Griswold.
Between 8^h 15^m and 8^h 50^m he counted nearly 200 shooting
stars.   Most of them were faint and had short paths ; a few
were brilliant.   The radiant was in Andromeda, but was not
accurately located by him in the constellation.   At times they
came in rapid succession, then frequently a lull.   After reach-
ing home (8^h 50^m) he saw through a window that the display
continued.   About 9^h 10^m it became cloudy, and after that
more were seen by him.

At Meriden, Conn.—Mr. E. W. Abell reports that he and
his two sisters were at ten minutes past eight looking atten-
tively at Jupiter for at least three-quarters of a minute and if
there had been an unusual display at that time they would
certainly have seen it.   At 9^h 26^m he and his mother went out
upon an errand and at once saw the shooting stars " falling
quite rapidly, sometimes almost as fast as we could count."   A
regular watch was shortly afterwards arranged for, four per-
sons watching each a quarter of the heavens, and counting
aloud to prevent duplication.   In the five minutes between
10^h 7^m 30^s and 10^h 12^m 30^s there were seen to the south 29, to
the west 18, to the north 35, and to the east 52 meteors; in
all 134.   A few minutes later two of the party looking to the

east counted in five minutes (beginning about $10^h 20^m$) 71 meteors. Mr. Abell then began to locate the radiant. It was between Aries and Andromeda but the meteors did not fall so numerously as before and it took five or ten minutes to see three or four start near enough to the radiant to locate it approximately,—a little to the north of the triangle,—between Aries and Andromeda. A sketch of the stars made by Mr. Abell places the radiant near R. A. $1^h 40^m$ and Dec. $+ 35°$. The sky was very clear all the time.

At Albuquerque, N. M.—Rev. M. R. Gaines writes that at a little before ten o'clock (presumably by time seven hours from Greenwich) the meteors were quite frequent, — he " counted 100 in a few minutes, as many as three at a time being visible." No very large ones, and none with trains of any great durability were noticed. He was told that the shower was noticed two hours earlier than the time when he first saw it. At eleven o'clock the rate was somewhat less than when first noticed, but meteors were still frequent at that hour.

At other places.—From the newspapers we learn that Profs. Young, Rees, Davidson, and Hale, and others observed the display. It seems better to wait for their responsible accounts than to incur the risk of perpetuating the unavoidable errors of newspaper reports.

This display seems to me to be the successor of the sprinkle observed at New Haven and Germantown on the 24th of November, 1872 (this Journal, II, vol. v, p. 53) rather than of the more brilliant display seen in Europe three days later, that is Nov. 27th, 1872.

There were no Andromed meteors seen so far as I know on evenings of the 24th, 25th or 26th, though in New Haven, and generally in the eastern part of the United States the skies were clear. On the night following Nov. 27th it was generally cloudy in the United States.

Shooting Stars in Mexico, Nov. 27th.—Mr. A. J. Newton and Mrs. A. G. Dana left Torreon in the afternoon of Nov. 27th en route for New Orleans. Between eight and eleven o'clock they saw through the windows of the car (single thickness of plate glass) a large number of shooting stars. It seemed hopeless, says Mrs. Dana, to count them. They came two and more at a time, and they formed a continual display of celestial fireworks.

Art. VII.—*Preliminary Notice of a Meteoric Stone seen to fall at Bath, South Dakota;* by A. E. Foote.[*] With Plate III.

On the 29th day of August, 1892, about four o'clock in the afternoon, while Mr. Lawrence Freeman and his son were stacking upon his farm two miles south of Bath, they were alarmed by a series of heavy explosions. On looking up they saw a meteoric stone flying through the air followed by a cloud of smoke. Its course was easily traced to the point where it fell within about twenty rods from where they were standing. The stone penetrated the hardened prairie to a depth of about sixteen inches and when reached it was found to be so warm that gloves had to used in handling it. Three small pieces of an ounce or two each had apparently been blown off by the explosions, but the stone still weighed 46¾ lbs. One of these small pieces was found by some men not far distant and was broken up and distributed among them. The explosions were plainly heard by a large number of people at Bath, two miles away, and at Aberdeen, nine miles away, it sounded like distant cannonading. The exterior of the stone presents the usual smooth black crust. The interior is quite close-grained resembling in texture the stones from Möcs. The iron is abundantly disseminated through the mass, and although the grains are small they are easily distinguished and separated on pulverizing.

Preliminary tests made by Mr. Amos P. Brown of the mineralogical department of the University of Pennsylvania prove the presence of nickel and cobalt in considerable quantity. Plate III shows the form of the stone and the size is indicated by the metric scale at the side. An affidavit signed by Charles Freeman (before H. T. Root, Notary Public) stating the facts of the fall, is in the hands of the writer to whom the stone was sent.

[*] A verbal communication on the above was made before the Academy of Natural Sciences of Philadelphia (November 23, 1892.)

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Influence of Foreign substances on the Form, the Size and the Purity of Crystals separating from a solution.*—In continuation of his investigations on isomorphism, Retgers has studied the influence, in a solution from which crystals are separating, of the presence of foreign substances upon the form, the size and the purity of these crystals. It is well known for example that sodium chloride, which crystallizes in cubes from solution in pure water, separates in octahedrons if urea be present. Lead nitrate which separates from an aqueous solution in white porcelain-like crystals, appears in perfectly clear, transparent crystals if nitric acid be added to the solution. Ammonium chloride which is deposited from solution in water in insignificant grains and skeleton-like crystals, separates in crystals a centimeter long if the solution contain some ferric chloride. If a cubo-octahedron of sodium chloride be placed in a concentrated aqueous solution of salt, the author observes that the cubic faces grow faster than the octahedral, and so produce finally a cube; while a similar cubo-octahedron placed in a solution containing urea, becomes finally an octahedron by the more rapid growth of the octahedral faces. The cause of this difference lies evidently in a contact difference in the two cases between the crystal-faces and the liquid; a change in fact in the capillary attraction. Adhesion depends upon the nature of the liquid as well as upon that of the solid, the same liquid acting very differently upon different solids. Moreover the cubic and the octahedral faces of the cubo-octahedron are physically quite different; this difference being often evident in their difference of luster. Sodium chloride gives cubes in pure water, or in water containing ferric chloride or a lead halide; but it yields octahedrons in water containing urea or chromium chloride. The potassium halides give cubes in all these cases, except where the solution contains a lead halide, when the crystals are octahedrons. Potassium chloride however, which generally crystallizes in cubes, gives cubo-octahedrons if the solution contains urea. Ammonium chloride and bromide, which separate in trapezohedrons from an aqueous solution, crystallize in cubes if the solution contains urea or chromium chloride; while if it contains ferric chloride, the ammonium chloride separates in cubes and the bromide in trapezohedrons; the reverse being the case when the solution contains a lead halide. Ammonium iodide crystallizes in cubes from aqueous solutions and from those containing urea, while the crystals are octahedrons if the solution contains chromium or ferric chloride or a lead halide. As to the size of crystals, the author concludes that every crystal has a maximum limit, beyond which there is no further growth. This

maximum is variable somewhat with the conditions, the volume of the solution affecting the result, up to a certain point. In proof of this he exposed crystals of alum and of magnesium sulphate, after they had reached this maximum size, to strongly supersaturated solutions for several days, without any result. This maximum size of a crystal, however, depends upon the presence of foreign substances in the solution, a crystal of salt being larger when obtained from a solution containing cupric chloride. —*Zeitschr. physikal. Chem.*, ix, 267, April, 1892. G. F. B.

2. *On the Resolution of Lactic Acid into Optically active Constituents.*—Although the asymmetric carbon theory of Van't Hoff was suggested to him by the isomerism of lactic and sarcolactic acids, no experimental proof has until now been given that inactive lactic acid is actually composed of two optically active lactic acids. This proof is furnished by PURDIE and WALKER, who have effected the resolution of lactic acid by fractional crystallization of the strychnine salt. Commercial lactic acid was diluted and boiled with water to convert the anhydride present —about 31 per cent—into acid. In the calculated quantity of this acid 460 grams of strychnine were dissolved, and the neutral solution thus obtained was submitted to fractional crystallization. Three crops of crystals were obtained which were dissolved separately in water and treated with ammonia in slight excess. The filtered solution made up to the same concentration gave rotations in a 200^{mm} tube of $+ 5\cdot46°$, $+4\cdot83°$ and $-1\cdot33°$. The first solution was boiled with zinc oxide and fractionally crystallized. The first crop of crystals proved to be the pure zinc salt of lævo-lactic acid, and gave a specific rotation $[\alpha]_D = + 5\cdot63$. The rotation of the acid is opposite in direction to that of its salts. The mother liquors were converted into zinc salts, and by successive crystallization pure zinc dextrolactate was obtained having a specific rotation $[\alpha]_D = - 5\cdot71°$. By mixing equal weights of the solutions of these two zinc salts, the authors obtained a solution which was optically inactive and which deposited crystals of ordinary zinc lactate.—*J. Chem. Soc.*, lxi, 754, Aug. 1892.

G. F. B.

3. *On the new element Masrium.*—In examining a native fibrous alum from Egypt, RICHMOND and OFF have detected what appears to be a new element. The alum also contained from 1·02 to 3·63 per cent of cobalt. To extract the new substance, 100 kilograms of the mineral were dissolved in water, acetic acid and sodium acetate were added, and hydrogen sulphide was passed through the solution. A white precipitate was thrown down, which was filtered off, well washed, extracted with dilute hydrogen chloride, boiled with aqua regia, diluted and filtered. On cooling a little calcium sulphate separated. This was removed and the solution was evaporated to dryness, taken up with dilute hydrogen chloride and precipitated with ammonia. The washed precipitate was dissolved in sulphuric acid and crystallized from 50 per cent alcohol. A second crystallization gave a

nearly white sulphate. This was dissolved in water and precipitated by caustic soda, in excess of which the precipitate was soluble. On adding ammonia a white precipitate came down which was dissolved in hydrogen chloride. After repeating the operation, the precipitate, on dissolving it to saturation in hydrogen chloride, gave a solution acid to litmus but absolutely neutral to methyl-orange. A portion of the solution was precipitated with ammonium oxalate and the precipitate ignited. On repeating the operation, the oxalate gave of white oxide 55·70 per cent, of oxalic oxide 15·85 and of water 31·27. Hence the authors calculate an equivalent of 122 for the oxide and of 114 for the metal; which supposing it bivalent gives an atomic mass of 228. The periodic law supposes an element of atomic mass 225 in the beryllium, calcium, strontium and barium group. The new element appears to resemble beryllium in many of its properties, zinc in others and calcium in its oxalate. Caustic soda gives a white precipitate soluble in excess, while the ammonia precipitate is insoluble in excess. Hydrogen sulphide in an acid or neutral solution of the chloride gives nothing; but in an acetic solution it gives a white gelatinous precipitate soluble readily in hydrogen chloride. Potassium chromate gives a yellow precipitate soluble in excess of the chloride, insoluble in excess of the precipitant. Sodium-potassium tartrate gives a white precipitate soluble in excess. Potassium sulphate added to a strong hot solution gives a white precipitate. Heated with cobalt nitrate the oxide gives a feeble blue color. The chloride does not crystallize. The authors have given the name Masrium to the new element, from Masr the Arabic name of Egypt. The mineral they call masrite.—*J. Chem. Soc.*, lxi, 491, June, 1892.   G. F. B.

4. *On the Freezing points of very dilute Solutions.*—By the method described by him in 1884, Raoult was able to obtain the solidifying point of ordinary solutions within one or two hundredths of a degree. To-day a greater exactness being demanded Raoult has secured it by modifying his earlier method, with regard (1) to the mode of cooling the solution and (2) to the mode of stirring it. The beaker containing the solution, previously cooled to 0°, is immersed in a 40 per cent glycerin solution, containing a spiral tube of copper, connected at each end with a vessel filled with ice and salt. The salt solution from these vessels has a temperature of — 10°; and by regulating their relative heights, the rapidity of flow and the temperature of the glycerin solution can be regulated at will. This solution is maintained about 3° below the solidifying temperature of the liquid to be examined, so that the latter requires about 20 minutes to cool 1°. The stirrer consists of a small propeller of platinum gauze attached to the bulb of the thermometer and rotating with it. Moreover, the point of surfusion is never allowed to exceed 0·5°. As a proof of the exactness of the modified method, the author states that he finds the solidifying point of water to agree with the fusing point of ice within ·002 of one degree. Applying the new method to very

dilute solutions of cane sugar containing 0·683 parts in 100 parts of water the reduction of the freezing point is 0·042 and the molecular depression is 20·9; calling the molecular mass of the sugar 342. If the solution contains 2·848 parts of sugar, the freezing point is lowered 0·168 and the molecular depression is 20·1. For 7·297 parts in 100, the lowering of the freezing point is 0·422 and the molecular depression 19·8. For a solution of 39·040 parts, the freezing point is lowered 2·474 and the molecular depression is 21·6. Plotting the lowering of the freezing point as the abscissa and the molecular depression as the ordinate, a curve is obtained coinciding substantially, except at the origin, with one given by the author in 1886 and criticised by Arrhenius, as to the portion relating to very dilute solutions; thus confirming the original statement of the author, that when the dilution exceeds certain limits, the molecular depression of cane sugar, like that of other substances, suffers an increase. This increase is so small, however, that it appears to confirm the opinion of the Swedish chemist. These results show the advantages of the new method.— *C. R.*, cxiv, 114; *Zeitschr. physikal. Chem.*, ix, 343, April, 1892.   G. F. B.

5. *Chemical Lecture Experiments. Non-metallic Elements*, by G. S. Newth. 323 pp., 8vo. London, 1892 (Longmans, Green & Co.).—The chemical lecturer will find a valuable companion in this volume, for it describes for him, clearly and with sufficient detail as to manipulation, such experiments as he is likely to need to present to his audience. For the student it is also of hardly less value, since it can be used by him in connection with the lectures which he is attending as supplementary and explanatory to them. The experiments are well chosen and cover the important properties of the non-metallic elements, including also some related physical phenomena, as the liquefaction of gases. The closing chapter is devoted to lantern illustrations, and an appendix gives a series of useful tables of chemical data.

6. *Color Photography.*—M. G. Lippman states that albumenized and gelatinized plates soaked in bichromate of potash may be employed for photographing in colors. They are used like silver salt plates. The colors appear after immersion in water which develops and fixes the image. The latter disappears on drying, but reappears when the plate is soaked. The colors are very brilliant, and are produced by the interference of hygroscopic and non-hygroscopic layers with variable refractive indices.— *Comptes Rendus*, Oct. 24, 1892.   J. T.

7. *Infra red spectra of the Alkali Metals.*—Mr. Benjamin W. Snow in studying this subject has employed the bolometer with a very delicate galvanometer. The needle of the latter was suspended by a quartz fiber 40^{cm} long. With a scale distance of 3^m a deflection of 1^{mm} corresponded to a current of $1·5 \times 10^{-11}$ amperes. A silicate-flint prism was employed to avoid the overlapping of diffraction-grating spectra. An arc light was used and a hole having been bored through the center of the carbon a

wick of the compressed salt was placed in it. The bolometer consisted of two platinum resistances. These were formed from platinum wire embedded in silver and hammered flat so as to have a breadth of 0.05^{mm} and a thickness of 0.00036^{mm}. Two of these resistances were placed side by side on a mica frame, one was blackened and exposed to the light, the other was covered. It was found that a standard candle at a distance of 1^m gave a throw of 150^{mm}. A large number of carbon bands were discovered extending to wave length 20620. Sodium showed maxima at 8180, 11270, 12400 and 18360. Potassium at 7670, 10820, 11580, 12250 and 14610; lithium at 8070; rubidium at 7910, 9980, 13120 and 14760; cæsium at 8380, a large one at 8820 and other lines at 9980, 13270 and 14530.

Kayser and Runge's empirical law was confirmed for the infra red of lithium and sodium, but not for the other metals examined. —*Ann. der Physik und Chemie*, No. 10, 1892.   J. T.

8. *The Magnetic effect of the Sun upon the Earth.*—Sir WILLIAM THOMSON, in his address at the anniversary of the Royal Society, spoke of the hypothesis that terrestrial magnetic storms are due to electro-magnetic waves emanating from the sun. The primary difficulty is to imagine the sun a permanent magnet or an electro-magnet, sufficiently powerful to produce on the earth changes of magnetic force amounting in extreme cases to $\frac{1}{20}$ or $\frac{1}{30}$ of the earth's terrestrial magnetic force, and in ordinary magnetic storms to $\frac{1}{400}$. The sun must be as a magnet at least 12000 times the average intensity of the earth's magnetism to produce by direct action, simply as a magnet, any disturbances of terrestrial magnetism sensible to the magnetic instruments in our observatories. To produce the magnetic storm of June 25, 1885, the sun must have worked at something like 12×10^{35} ergs per second, which is about 364 times the total horse power (3.3×10^{32} ergs per second) of the solar radiation. Thus during the eight hours of a not very severe magnetic storm, the sun was doing as much work in sending forth magnetic waves through space as he actually does in four months of his regular light and heat. To Sir William Thomson's mind, this result is conclusive against the supposition that terrestrial magnetic storms are due to magnetic action of the sun; or to any kind of dynamical action taking place within the sun, or in connection with hurricanes in his atmosphere. We are forced to conclude that the supposed connection between magnetic storms and sun spots is unreal, and that the seeming agreement between the periods has been a mere coincidence.—*Nature*, Dec. 1, 1892.   J. T.

9. *Sound and Music;* by the Rev. J. A. ZAHM, Professor of Physics in the University of Notre Dame. 452 pp. 8vo. Chicago, 1892 (A. C. McClurg and Co.)—This is an excellent book, presenting a subject which is always full of interest in such a way as to make it doubly attractive. While accurate and scientific in its statement of the laws and phenomena of Sound, it is eminently popular, in the better sense of the word, in style and method, and

the reader is thus carried through from one chapter to the next
with unflagging interest. Developed from a series of lectures
delivered in Washington, in 1891, the author has retained the
lecture room form, which brings him at once into close contact
with his larger audience and makes them feel and share his inter-
est and enthusiasm. The book is fresh in matter throughout,
and while not aiming at originality, it gives with fullness the
results particularly of recent investigations in this department;
as, for example, the well-known work of Kœnig on beats and
beat-tones produced by the simple notes of tuning forks, also the
proof of the influence of difference of phase upon the quality of a
compound musical note. It is a book which every practical
musician can read and study with much profit, and which may
be used advantageously by students who are approaching the
subject of acoustics from a more theoretical side.

II. Geology and Mineralogy.

1. *View of the Ice Age as One Glacial Epoch.*—Mr. Upham
closes an important paper on the " Accumulation of Drumlins " in
the American Naturalist for December, with the following para-
graphs. :

"In conclusion, I deem it a duty to state that this reference of
the drumlins, terminal moraines, kames, and eskers, to rapid ac-
cumulation from previously englacial drift during the departure
of the ice, seems to me better accordant with the view that the
Ice age comprised only one great epoch of glaciation, attended by
oscillations of the ice-border, than with the alternative view which
supposes the ice-sheets to have been at least once and perhaps
several times almost entirely melted away, afterward being
restored by recurrent glacial epochs. This belief in the unity of
our glaciation I held during my work on the New Hampshire
Geological Survey in the years 1874 to 1878; but in my ensuing
work on the survey of Minnesota, the peat and forest beds
enclosed between deposits of till in that region led me to accept the
duality or plurality of glacial epochs as taught by Croll, James
Geikie, N. H. Winchell, Chamberlin, Shaler, McGee, Salisbury,
and at present by most American glacialists. The recent state-
ment by Prof. G. F. Wright of the evidence for the unity of
Quaternary glaciation as the more probable view,* expresses a
similar opinion with that to which I have been gradually return-
ing, during the past year or longer, through the guidance of my
investigations in this field. Moraines and drumlins are effects of
secular vicissitudes of climate on the border of the departing ice-
sheet. The ice-sheet, I think, owed its existence to great altitude
of the land at the beginning of the Glacial period, to have been
attended when at its maximum extension and volume by depres-

* "Unity of the Glacial Epoch," this Journal, III, vol. xliv, pp. 351–373, Nov.,
1892.

sion of the land on which it lay, and to have witnessed, during
the retreat and removal of its load, a progressive re-elevation of
the same area to its present height.

"For Europe, also, after reading the recent very ably written
article by Prof. James Geikie,* in which he argues for five dis-
tinct epochs for glaciation, I think that there, as here, it is more
reasonable to refer the whole of the glacial drift to a single glacial
epoch, with moderate fluctuations in the extent of the ice-sheets
and glaciers. In thus differing from this eminent glacialist and
from Wahnschaffe in Germany, Penck in Austria, and DeGeer
in Sweden, who are of the same opinion with Geikie, that there
were long mild interglacial epochs in Europe, I come into agree-
ment, on this question, with other distinguished European glacial-
ists, as Lamplugh in England, Falsan in France, and Holst in
Sweden, who hold that the Quaternary reign of ice was essentially
a unit. But this present state of our division under the two
opinions surely calls for much further observation and candid
study that ultimately the truth may be confidently known, on
whichever side it may be."

2. *The Pleistocene History of Northeastern Iowa*, by W. J.
McGEE, pp. 189–757 of the 11th Report of the Director of the
U. S. Geological Survey for 1889–90.—This paper by Mr. McGee
consists of a very comprehensive discussion of the topography,
soils, rivers, glacial deposits, and glacial history of northeastern
Iowa. The author has presented his views in former volumes of
this Journal, the latest in volume xxxv (1888). The present
report gives his final results in detail and with numerous illustrat-
ing plates and maps. His general conclusions as to the glacia
invasions are as follows: Over about half of Northeastern Iowa
16,500 square miles in area, there are two well-defined moraine
deposits, indicative of two ice-invasions; through nearly half of
the rest, lœss overlies the *two* deposits, and in a small area, only
one of the two, and occurs over the driftless area on the borders
of Wisconsin, and along the borders of the Mississippi farther
south. Above the lower or older moraine deposit there is gene-
rally a bed of soil abounding in sticks, stems and other remains
of trees, indicating that a forest growth covered much of the
region of the lower moraine before the deposition of the upper;
and besides the soils, there are locally stratified beds of sand.
The two lobes of ice which moved southwestward either side of
the driftless area during the second invasion, are stated to have
occasioned, by their junction below, a large ice-bound lake—
Lake Hennepin as named by the author; and within this lake
most of the lœss of Iowa was deposited. The lœss contains
freshwater and land shells, as elsewhere, and makes the most
fertile land of the region. But the shells are much less than their
normal size, owing, it is observed, to the coldness of the
waters. "'The third invasion by the ice fell short of this terri-
tory."

* "On the Glacial Succession in Europe," Trans. Royal Society of Edinburgh,
vol. xxxvii, pp. 127–149, with map, May, 1892.

3. *Note on the paper in the November No. of this Journal on
" A New Oriskany Fauna in Columbia Co., N. Y.,"* by S. T.
BARRETT. (Communicated).—The paper entitled " Notice of a
New Oriskany Fauna in Columbia Co., N. Y., with List of Fos-
sils" by Messrs. Beecher and Clarke, containing occasional refer-
ences to rocks of similar horizon near Port Jervis, N. Y., seems
to me to remove much of the difficulty in the classification and
division, upon faunal grounds, of the rocks in this vicinity.

If one includes the *Dalmanites dentatus* layer in the Lower
Helderberg group he finds himself confronted with the difficulty
amounting, I think, to an impossibility of running any dividing
line at all upon grounds of faunal relationship between that layer
and the strata lying above it and below the Cauda Galli Grit
and there is no Oriskany.

The relations of the *D. dentatus* layer seem to be more with
the rocks above than those below it. Include it, and the 100 feet
of shale lying below it and above the Gray Limestone, No. 5, of
my paper,* with the 50 feet extending upwards above it to the
base of the Cauda Galli in the Oriskany group, and we have not
only easily found boundaries, but a thickness of about 150 feet
containing a fauna strongly individualized and peculiar.

The Oriskany series, thus extended from Gray Limestone to
Cauda Galli, presents a fauna into which many Lower Helderberg
species persist along with characteristic Oriskany species, several
new to paleontology and others, according to Profs. Beecher and
Clarke, which originating in the Oriskany are continued up into
and reach a fuller stage of development in rocks of Lower De-
vonian age.

Port Jervis, N. Y., Dec., 1892.

4. *Subdivisions of the Azoic or Archœan in Northern Michi-
gan;* by M. E. WADSWORTH. (Communicated.)—The work of
the Michigan Geological Survey in 1890 made it clear that the
Azoic System of the Lake Superior district of Northern Michi-
gan was composed of at least three unconformable formations.
This conclusion was published by me early in 1891, in an article
entitled " A Sketch of the Geology of the Marquette and Ke-
weenawan Districts," which was appended to a pamphlet called
" Lake Superior along the South Shore." New York, 1891.

These general conclusions have been confirmed by the work of
the two subsequent seasons, and two other unconformable forma-
tions rendered probable, although not yet proved conclusively.
A discussion of these points will subsequently be given in detail
in the reports of the State Geologist. The following are the
formations as made out and named from prominent localities, by
the Michigan Survey, commencing with the oldest.

There are given with this, the formations as determined by the
United States Geological Survey showing their supposed equiva-
lency.

* This Journal, vol. xiii, p. 385, 1877.

Michigan Geological Survey.	U. S. Geological Survey.
Cascade Formation.	Fundamental Complex.
Republic Formation. Mesnard Formation.	} Lower Marquette Series.
Holyoke Formation. Negaunee Formation.	} Upper Marquette Series.

Office of the State Geological Survey, Michigan Mining School,
Houghton, Michigan, October 20th, 1892.

5. *Geological and Natural History Survey of Minnesota*, Annual Report for 1890, N. H. Winchell, State Geologist. 255 pp. 8vo. Minneapolis, 1892.—This report consists of a translation of a memoir by Boricky on the Micro-chemical examination of minerals and rocks (80 pages), and of a paper by J. H. Kloos on Geognostic and Geographical observations in Minnesota; also a chemical report by J. A. Dodge; a report on the woods of Minnesota by H. B. Ayres; on the petrography of the Akeley Lake region by W. S. Bayley; and on the Lamellibranchs of the Lower Silurian by E. O. Ulrich.

6. *Final Report of the Pennsylvania Geological Survey*, by the State Geologist, Prof. Lesley, vol. ii, pp. 721–1628, 8vo. Harrisburg, 1892.—The second volume of this very convenient Summary Description of the Geology of Pennsylvania, treats of the Upper Silurian and Devonian formations, and is illustrated by maps, sections, and many figures of fossils.

7. *Arkansas Geological Survey.* Annual Report for 1891, Vol. I, 144 pp. 8vo. Little Rock, 1892.—This small volume by Prof. Branner treats of the mineral waters of Arkansas.

8. *Geological Map of Baltimore and its Vicinity.* Published by the Johns Hopkins University.—This map is based mainly on materials belonging to the U. S. Geological Survey and especially for the outlines of the sedimentary formations, on the work of N. H. Darton. It has been prepared by Prof. George H. Williams, who has shown excellent judgment in the selection of colors and in the various details. It is a beautiful and highly instructive map.

9. *Devonian Fishes of Canada.*—A. S. Woodward describes, in the Geological Magazine for January and November, 1892, and illustrates by figures, Lower Devonian fishes from Campbellton, New Brunswick. The species pertain to the genera *Protodus, Diplodus, Gyracanthus, Climatius* and *Acanthodes* among Elasmobranchs; *Cephalaspis;* and the Dipnoan genus *Phlyctænaspis* of Traquair. Two of the species had been previously described by Traquair and two others by Whiteaves. The author also describes, in the November number, Upper Devonian species, from Scaumenac Bay of the genera *Diplacanthus* and *Coccosteus,* with remarks on certain plates of a *Bothriolepis* of the same locality.

10. *Nepheline Rocks in Brazil.*—A paper by ORVILLE A. DERBY, on the Nepheline Rocks of Brazil is contained in the Quarterly Journal of the Geological Society for May, 1891 (vol. xlvii), in continuation of a paper on the same subject in the same Journal for 1887 (vol. xliii).

11. *Panama Geology.*—A note by M. DOUVILLÉ (Bull. Soc. Géol. de France, April, 1891) states that he has studied specimens received by him from the beds cut by the Panama canal, and has found that to the north, near Colon, the Miocene outcrops and is very fossiliferous; that beyond, occur beds characterized by an abundance of *Orbitoides* and the presence of *Nummulites*, indicating the presence of the Oligocene. Along the southern part of the canal, to the Pacific, there occur lignitic beds of the Eocene. All the beds are horizontal or but little inclined.

12. *Geological Map of Scotland* by Sir ARCHIBALD GEIKIE (John Bartholomew & Co., Edinburgh).— This finely colored geological map, 30×26 inches in size, is an interesting study for the geologist from many points of view. One of the most instructive parts is the multitude of dikes of igneous rocks, which cut through the rocks in various directions, part following the great valleys in nearly parallel interrupted lines, and others crossing the country irrespective of topographical features. All the great formations are represented excepting the Tertiary. The map is accompanied by 23 pages of text giving a brief review of the geology of Scotland.

13. *Quaternary Carnivores found on the island of Malta.*— Until recently the known extinct Quaternary Mammals of Malta have included only Herbivores. "Nature" of November 17 announces (from the "Mediterranean Naturalist" of Malta) that Mr. J. H. Cooke, in excavating last spring the Har Dalam cavern, found, along with hundreds of bones of *Hippopotamus Pentlandi, Elephas mandraensis, Cervus barbaricus* and of many other species, discovered an entire ramus of the lower jaw of a bear, *Ursus arctos*, and teeth also of a species of wolf.

14. *Excavation by Glaciers.*—Prof. Baltzer, of Berne, has made preparations for investigating the "Erosive action of Glaciers" in the valley of the Grindelwald glacier. He states that according to his examinations the work of excavation is partly simple abrasion, and partly splintering or crushing, especially in the region where limestone is the exposed rock. He has bored 15 holes 1 to 2 meters deep in the limestone at the smoother and otherwise most favorable spots. The glacier of the Grindelwald is now commencing its new advance and therefore offers special facilities. Moreover, owing to the variations of the seasons, he hopes to obtain conclusions in the course of two or three years.— *Arch. Sci. Phys. et Nat. Geneva,* Nov. 15, 1892.

15. *Chamberlin on the Glacial period.*—Prof. Chamberlin's reply to the paper by Prof. G. F. Wright on the Unity of the

Glacial epoch is unavoidably deferred to the following number of this Journal.

16. *Mikroskopische Physiographie der petrographisch wichtigen Mineralien* von H. ROSENBUSCH. *Dritte Auflage.* 712 pp. Stuttgart, 1892. (E. Schweizerbart'sche Verlagshandlung — E. Koch.)—Nothing is more significant of the great progress in recent years in petrographical and mineralogical research than the appearance of this important work in its third edition. In thus keeping this book abreast of the times Prof. ROSENBUSCH is continually placing all petrographical students and investigators under deep obligation. The new edition contains much newly added matter, new methods of research and of determination of physical constants, the latest corrections in the optical and chemical constitution of the mineral species, with added observations upon their occurrence, alterations, etc. Besides this, many new mineral species have been added, that the progress of research has shown in the last half dozen years are to be regarded as important rock-forming constituents. A large part of these latter are the minerals described by Brögger from the eleolite-syenite of southern Norway but among them will be found such species as allanite, chondrodite, dumortierite, lasurite, lazulite, pectolite, piedmontite, prismatine, sapphirine, xenotime, etc., as examples. The addition of these species cannot fail to stimulate petrographical research. The index to literature has been removed and the author promises it undivided in a new edition of the second volume which it is to be hoped will soon appear.　　　　L. V. P.

17. *Die Gesteine de Ecuatonanische West Cordillere. Inaug. Diss.* M. BELOWSKY, Berlin, 1892. 70 pp.—This work is a continuation of that of Küch on the rocks collected by Reiss and Stübel.* After a short notice of some gneisses, mica schists and diabases, the main body of the work is devoted to a description of series of andesites and dacites. These are described as to their structure and mineral composition with great minuteness but no analyses are given nor are their chemical relationships discussed. It is to be hoped that these points may be taken up in a later work of the series.　　　　L. V. P.

18. *Chemical Contributions to the Geology of Canada, from the laboratory of the Survey,* by G. CHRISTIAN HOFFMANN, 1892. —This report contains a number of valuable contributions to the Mineralogy of Canada. Among others is to be noted the occurrence of a massive cobaltiferous arsenopyrite, or *danaite*, in the township of Graham, Algoma, Ontario. An analysis by R. A. A. Johnston, after deducting 4·77 p. c. quartz, gave:

	As	S	Fe	Co	Ni	Sb	Au
G. = 5·988	42·22	18·84	33·32	4·09	0·93	0·60	*tr.* = 100

The rare mineral *gersdorffite*, not before noted in Canada, has been found in the township of Denison, Algoma, where it occurs

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* W. Reiss und A. Stübel: Reisen in Süd Amerika; Geolgische Studien in der Republik Columbia, I Petrographie 1 Die vulkanischen Gesteine bearbeitet von R. Küch, Berlin, 1892.

with niccolite, pyrrhotite, chalcopyrite, etc. It occurs massive and lamellar with occasional octahedral crystals. An analysis by Johnston gave, after deducting 13·55 p. c. SiO_2 the following results:

As	S	Ni	Fe	Co	Cu
46·96	16·71	26·32	7·90	2 01	0·10 = 100

The results of an examination of some thirty nickel and cobalt ores is given. Most of these are identified as pyrrhotite and show amounts of nickel varying from a trace up to 4 per cent. Two nickel minerals from the Vermilion mine, Denison, Algoma, gave respectively 9·40 and 40·80 per cent of nickel. An analysis is given of the harmotome from the Beaver mine, O'Connor, Thunder Bay. A hygroscopic opal from Savona Mt., B. C., containing 7 p. c. H_2O, lost 3·25 in a dry atmosphere at ordinary temperature retaining the rest; in a moist atmosphere it regained this and 3·50 p. c. in addition.

19. *On the presence of Magnetite in certain Minerals and Rocks.*—Prof. LIVERSIDGE has undertaken to solve the question as to the cause of the magnetic character of certain minerals, such as hematite, franklinite and others. Upwards of fifty specimens were examined and by the same method in each case, viz : the mass was pulverized finely in a porcelain or agate mortar and then the magnetic portion separated by a rather feeble electro-magnet. The results show that while the magnetic properties of pyrrhotite unquestionably belonged to the mass, as always assumed, those of chromite, franklinite, spinel, garnet and some hematite, limonite, and other minerals and rocks examined, were due to scattered particles of magnetite. For example, a dark compact hematite from Elba yielded 15 per cent of magnetite; a specimen of franklinite from New Jersey yielded 32·23 per cent of magnetic particles; a chromite from New Caledonia yielded 0·7 p. c. ; a number of serpentines gave from a trace up to 14 p. c.

The author also shows that iron sesquioxide obtained by precipitation from the acid carbonate of iron is magnetic; also that magnetic iron sesquioxide can be obtained by heating the magnetic oxide ; further, that ordinary iron rust formed under atmospheric conditions by the oxidation of metallic iron is usually magnetic and polar.— *Trans. Austral. Assoc. Adv. Science,* 1891.

20. *Manual of Qualitative Blowpipe Analysis and Determinative Mineralogy,* by F. M. ENDLICH. 456 pp. 8vo. New York, 1892 (The Scientific Publishing Company).—Dr. Endlich has given us in this volume a very thorough discussion of the subject of Qualitative Blowpipe Analysis, developing the many methods and reactions employed with a fullness which may fairly be said to be exhaustive; a beginner might indeed be pardoned for feeling a little overwhelmed by the amount of matter placed before him. The author's wide experience in the use of the blowpipe has enabled him to discriminate between the many reactions which have been proposed, to develop a number of new ones, and

throughout to describe the necessary manipulation with the minuteness and care needed in practical work. About half the volume is given to the discussion of the different methods of examination and the reactions of different substances and their compounds; the remainder is devoted to determinative mineralogical tables based first upon physical characters and then upon blowpipe and chemical tests. The use of these tables is facilitated by a number of examples fully explained in advance, but the student using them will regret the absence of an index to the names of species.

III. Miscellaneous Scientific Intelligence.

1. *Geminid Meteors of Dec. 11, 1892.*—Dr. Elkin saw on the evening of Dec. 11th, a goodly number of shooting stars. Between $10^h 50^m$ and $11^h 10^m$ and again between $11^h 30^m$ and 12^h (in all 50 minutes) he saw about 25 flights, that had a radiant close to *iota* Geminorum. This radiant was determined by five flights. They were very swift and of all degrees of brilliancy, though most of them were equal to stars of the third and fourth magnitude. Three were as bright as Jupiter. At 2^h A. M. of the 12th in two minutes he saw none.

Dr. Chase counted 39 between $10^h 40^m$ and 12^h. Several exceeded first magnitude stars in brightness. The flights were rapid and often long, 20° or upwards. The radiant was near *iota* Geminorum, perhaps 2° beyond iota from the middle point of line joining Castor and Pollux. Three shooting stars seen by him about eight o'clock probably belonged to the same group, but at that time failed to attract much attention.   H. A. N.

2. *La Planète Mars et ses Conditions d'Habitabilité par* CAMILLE FLAMMARION. 608 pp. Paris, 1892 (Gauthier-Villars et Fils).—Flammarion's volume deserves no less praise than to say that it should stand beside the work of Lockyer on the sun and that of Naysmith and Carpenter on the moon. Greater praise no author should expect.

The author has happily chosen the historical in preference to the topical or technical method of presentation. This was indeed almost inevitable since one topic, the physical geography of Mars, so dwarfs all others; but it adds greatly to the interest and profit of the reading to be shown how we know, as well as what we know. The time of publication is opportune. Ten years ago the material for the most interesting chapters had not been created and ten years hence it is not likely to be greatly enlarged.

The history of the planet is divided into three periods. The first, beginning with a drawing by Fontana in 1636, extends to 1830 and established the main surface markings, the polar caps and their changes with the seasons and also the existence of a cloud bearing atmosphere. The second period, inaugurated by Beer, Maedler and Sir John Herschel, extends to 1877. The third, to the present

summer, is chiefly made up of the astonishing work of Schiaparelli, and those inspired by him. It has given us elaborate topographical maps distinguished by the unique features known as channels (*canaux*) and has satisfactorily proved that many of these sometimes appear doubled and otherwise strangely modified to the point of entirely disappearing. It has also sown the seeds of theories which are now springing up in rich profusion and confusion.

To history the author devotes 490 pages and 268 illustrations.

The remaining 100 pages are devoted to the conclusions which the author regards as proved beyond controversy. The last two chapters, treating of the channels, rivers, continental areas, water circulation and conditions of life on the planet, will naturally excite the most interest and criticism.   W. B.

3. *Investigation of the Coral Reefs of the West Indies.*—A letter from Prof. ALEXANDER AGASSIZ of December 3, states that he will soon start on an exploring trip of three months among some of the islands of the West Indies—the use of a yacht for the purpose having been generously tendered him by the Hon. John M. Forbes of Milton, Mass. He will study the reefs of the Bahamas and vicinity and those also of the north shore of Cuba from Cape Mayzi to Havana, and probably visit also for the same purpose the Bermudas. Mr. Emerton and a son of Prof. Mayer of the Stevens Institute will accompany him as draughtsmen. Mr. Mayer has been studying at Cambridge for the last two years and is especially interested in the Jelly Fishes.

4. *Gelatine slides for lantern projection.*—Prof. W. J. WAGGENER states that he has been very successful in making diagrams and pictures for projection by the magic and the solar lantern by printing the same, with the ordinary printing press and engraved blocks, on sheets of transparent gelatine. By this means excellent lantern slides from diagrams and engravings of nearly if not quite all kinds can be made and multiplied as rapidly and almost as cheaply as paper prints. The extreme of cheapness in the production of the pictures can be reached by assembling many engraved blocks together and printing all at once on large sheets of gelatine or celluloid, which can be afterward cut into pieces of suitable size.

5. *Transactions of the Texas Academy of Science.* Vol. I, No. 1, 44 pp. 8vo, Nov., 1892, Austin, Texas.—This first number of the Transactions of the Texas Academy contains short papers by A. Macfarlane, E. T. Dumble, W. F. Cummins, W. H. von Steernwitz, G. Everhart and G. W. Curtis.

6. *Die Klassiker der exakten Wissenschaften, herausgegeben von* W. OSTWALD (W. Engelmann, Leipzig).—Attention has been called repeatedly in these pages to the issues of this valuable series. Nearly forty numbers have now been published and the service thus done to the student of Physics and Chemistry can hardly be overestimated. All of the volumes are scientific classics which the worker often wishes to consult, and yet as given

in their original places of publication they are practically inaccessible to all those who have not a large library at hand. Even to those so fortunately situated the convenience of having a small, compact, inexpensive volume in hand, which can be used with perfect freedom and without fear of injury, is very great. The series should be on the shelves of every working physicist and in every physical and chemical laboratory.

The six numbers last issued are as follows :

Nos. 31, 32, 33. Lambert's Photometrie (1760), Theil I and II, III–V, VI and VII.

No. 34. Photochemische Untersuchungen von R. Bunsen und H. E. Roscoe (1855–1859): Erste Hälfte.

No. 35. Versuch die bestimmten und einfachen Verhältnisse aufzufinden nach welchen die Bestandtheile der unorganischer Natur mit einander verbunden sind von Jacob Berzelius (1811–1812).

No. 36. Ueber ein allgemeines Princip der Mathematischen Theorie inducirter elektrischer Ströme von Franz Neumann (1847).

No. 37. Betrachtungen über die bewegende Kraft des Feuers und die zur Entwickelung dieser Kraft geeigneter Maschinen von S. Carnot (1824).

7. *Royal Society of London.*—Professor H. A. Newton of Yale University, New Haven, has recently been elected a foreign member of the Royal Society.

OBITUARY.

JOHN STRONG NEWBERRY, Professor of Geology in Columbia University, New York City, died on the 7th of December, having nearly reached the 70th anniversary of his birthday. He was born, on the 22d of December at Windsor, Connecticut, graduated at Western Reserve College in 1846, and at the Cleveland Medical School in 1848, and began the practice of medicine at Cleveland, Ohio, in 1851. In 1855 he commenced his labors in geology, the science to which, in connection with its fellow-science, paleontology, he devoted the chief part of his remaining years. He received that year an appointment of Geologist and Botanist of the expedition sent out by the government under Lieutenant Williamson to explore the region on the Pacific between San Francisco and the Columbia River; and the 6th volume of the Government Reports on a " Practicable Route for a Railroad to the Pacific," published in 1857, contains the results of his work. In 1857 and 1858 he was engaged in exploring the Colorado River on the expedition under Lieutenant Ives. The party ascended the river in a steamer for 500 miles from its mouth and brought back grand views of the wonderful scenery of the cañon, then for the first time explored for the illustration of his excellent Geological Report, as well as for that of the Commander of the Expedition. Again in 1859 he was geologist of the government expedition under Captain Macomb, which explored the country of the San Juan and Upper Colorado, and thus had an opportunity for the geological study of part of Utah, Northern Arizona and New Mexico. His report appeared,

after much delay, in 1876, in connection with the Report of an Expedition from Santa Fé to the Junction of the Grand and Green rivers. The volume contains, besides a general report of the Geology of the regions visited, descriptions by F. B. Meek of his Cretaceous fossils, and by himself of the other fossils, including Carboniferous Brachiopods and fishes, Triassic plants from Abiquiu, New Mexico, and Sonora, Mexico, the figures of the plants occupying five of the eight plates.

During the Civil War, Dr. Newberry was a member of the Sanitary Commission for the five years following September, 1861, and had chief charge of the work of the Commission in the valley of the Mississippi.

In 1866 Dr. Newberry received the appointment of Professor of Geology at the Columbia College School of Mines. In 1869 he was made State Geologist of Ohio ; and the volumes published on Geology and Paleontology contain much on the stratigraphy of the various parts of the State, by him, but more on the wonderful collections of Fossil Devonian and Carboniferous fishes which the rocks afforded him and on the numerous fossil plants.

In 1888 Dr. Newberry published, in connection with the United States Geological Survey, a quarto volume of 95 pages and 26 plates on the Fossil Fishes and Fossil Plants of the Triassic rocks of New Jersey and the Connecticut Valley ; and in 1889, a similar volume of 228 pages and 53 plates on the Paleozoic Fishes of North America. A Report of like completeness on the Amboy Clays (Cretaceous) of New Jersey was nearly ready for publication two years since, when a stroke of paralysis put an end to his long and most fruitful scientific labors. Besides his larger reports above-mentioned, he published many shorter papers connected with all departments of geology.

Dr. Newberry was one of the corporate members of the U. S. National Academy of Sciences. He received from the Geological Society of London the Murchison medal in 1888. From 1867 until recently he was President of the New York Academy of Sciences. He was a man of great excellence of character. While deeply devoted to Science and an earnest worker, he was yet willing to give up several years to the superintendence of Soldiers' hospitals at the time of his country's need.

Dr. Newberry leaves a widow and six children. One of his five sons is a professor in Cornell University.

SIR RICHARD OWEN, the eminent zoologist and comparative anatomist, died in London on December 18th. He was born in 1804 and hence his active life almost spanned the century now closing; more than fifty years have passed since he was made Professor of Anatomy and Physiology at the College of Surgeons. His many contributions to science brought him distinguished honors from the highest sources and are too well known by all interested to need to be rehearsed here.

APPENDIX.

Art. VIII.—*A New Cretaceous Bird allied to Hesperornis;* by O. C. Marsh.

THE genus *Hesperornis* and its near allies have hitherto been found only in a definite horizon, the Pteranodon beds, in the Cretaceous of Kansas, and all now known have been described and figured by the writer.[*] Recent researches in the Cretaceous of Montana have brought to light another form distinct from *Hesperornis*, and of smaller size, but evidently belonging to the same general group of gigantic swimming birds. A single specimen only has been found, associated with marine fossils of Fox Hills types, and certainly from a much higher horizon than that in which *Hesperornis* occurs.

The specimen secured is represented one-half natural size in the figures below, and is a most characteristic part of the skeleton. It is the lower half of the right tibia of a fully adult bird. It shows that the tibia as a whole was very long and slender, with the shaft hollow throughout. In its general features, the specimen resembles most nearly the corresponding part in *Hesperornis*. The general proportions of the two are similar. The cavity in the shaft of each is equally extensive, and is bounded by smooth, well-defined walls. The ridge for the fibula is equally developed, indicating that this bone was proportionately of the same length in both, and probably of the same form.

---

[*] Odontornithes, 4to, Washington, 1880.

The differences between the present fossil and the corresponding part in *Hesperornis* are, however, strongly marked. In the latter, the distal end of the tibia is curved inward, and the smaller inner condyle is especially prominent below. In the present specimen, the outer condyle is the lower, and the inner one is nearly on a line with the inner margin of the shaft, as shown in figures 1 and 3, below. These characters are of generic importance, and hence the present specimen may be regarded as distinct from *Hesperornis*. The new genus it represents may be called *Coniornis*, and the species may be known as *Coniornis altus*.

1.   2.   3.

1 a   *3 a*
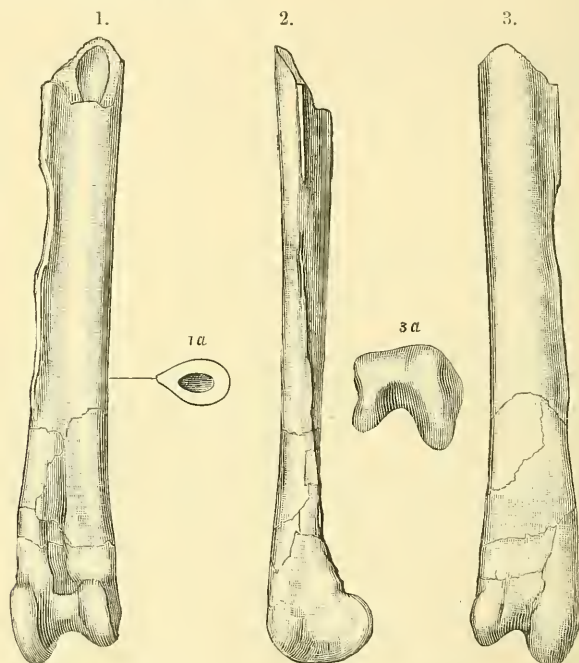
FIGURE 1.—Portion of right tibia of *Coniornis altus*, Marsh; front view.
FIGURE 1*a*.—Section of same; showing cavity.
FIGURE 2.—The same bone; seen from the right.
FIGURE 3.—The same bone; back view.
FIGURE 3*a*.—The same; seen from below.
        All the figures are one-half natural size.

The present type specimen indicates a bird about two-thirds the size of *Hesperornis regalis*, Marsh, or about four feet in length, from the point of the bill to the end of the toes. It was recently found by Mr. J. B. Hatcher, near the mouth of the Judith River, in Montana.

New Haven, Conn., Dec. 12th, 1892.

ART. IX.—*The Skull and Brain of Claosaurus ;* by
O. C. MARSH. (With Plates IV and V.)

IN previous numbers of this Journal, the writer has de-
scribed and figured various remains of Cretaceous Dinosaurs
belonging to the genus *Claosaurus,* and a restoration of one
very perfect specimen was given in the number for October
last.* Another specimen apparently of the same species has
the skull in remarkable preservation, thus affording an oppor-
tunity to make out all its principal characters. This skull is
well represented in the accompanying plates, and the descrip-
tion is given below. The brain in this genus had many points
of interest, and a cast of the brain-cavity is also described
briefly and figured in the present communication.

The Skull.

The skull of *Claosaurus* is long and narrow, with the facial
portion especially produced. The anterior part is only moder-
ately expanded transversely. Seen from the side (Plate IV,
figure 1), the skull 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 median septum between the two narial orifices was only
in part ossified, the large oval opening now present in the
skull probably having been closed in life by cartilage.

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 is bounded above by the
postfrontal and squamosal, and below by the jugal. The
quadrate forms a small portion of the posterior border.

Seen from in front (Plate IV, figure 2), the skull of
Claosaurus is subovate in outline, with the narrow portion
above. The premaxillaries and the predentary bone forming
the rugose muzzle are especially massive and prominent, and
the powerful lower jaws seem out of proportion to the more
delicate bones of the cranium.

* This Journal, vol. xxxix, p. 423, May, 1890; vol. xliii, p. 453, May, 1892;
vol. xliv, p. 171, August, 1892, and p. 344, October, 1892.

Seen from above (Plate IV, figure 3, and Plate V, figure 5), the structure of the skull itself is shown to the best advantage. In front are the large premaxillaries, deeply excavated for the nasal openings. These bones are separate, and each sends back a long, slender process inside the anterior projection of the nasal, and a still longer process forming the lower border of the narial orifice, and extending to the lachrymal. The front of the premaxillaries is especially massive, and its surface rugose, indicating that it had been covered with a horny beak. The lower border is sharp, conforming to the corresponding surface of the predentary bone, which was doubtless also enclosed in a horny covering. The premaxillaries were entirely without teeth.

The nasal bones are long and slender, and especially produced in front, where they embrace the posterior median extensions of the premaxillaries. They also meet the lateral processes of the premaxillaries behind the nasal openings, and likewise touch the lachrymals. Further back, they meet the prefrontals, and closely unite with the frontals, as shown in Plate IV, figure 3.

The frontal bones are quite short, and nearly as wide as long. They are united to each other by a well-marked suture. Their upper surface is smooth, and there is a slight depression on either side, posterior to the suture with the prefrontals. Each frontal bone forms a portion of the upper border of the orbit, and behind this meets the postfrontal. Posteriorly, the frontals form the anterior border of the supra-temporal fossæ, and between these unite by suture with the coössified parietals.

The latter bones are quite small, and appear on the upper surface of the skull mainly as a narrow ridge separating the supra-temporal fossæ, and ending behind in a point, between the median processes of the squamosals. The parietals expand below, where they cover the posterior portion of the brain-cavity.

The squamosal bones are robust, and their position and connections are well shown on Plate IV, figures 1 and 3. On the median line above, they meet the narrow extension of the parietals, and exterior to this, they form the posterior borders of the supra-temporal fossæ. In front, they unite by a strong process with the posterior branch of the postfrontals. Their posterior border is joined mainly to the exoccipitals. On the outer surface of each squamosal, there is a deep pit to receive the head of the quadrate, and in front of this, a short narrow process extends down the quadrate, forming a part of the border of the infra-temporal fossa.

The quadrate bone and its main connections are shown on Plate IV, figures 1–3. It is firmly supported above by the

squamosal, but its distinct, rounded head indicates the possibility of some motion. On the outer surface in front, it joins by open suture the strong jugal bone, and below this, unites with the small, discoid quadrato-jugal. Its inner margin extends forward into a broad, thin wing for union with the pterygoid. The lower extremity is massive, and moderately expanded transversely for articulation with the lower jaw.

The jugal is one of the most characteristic parts of the skull, as may be seen from the figures on Plate IV. Its main portion is robust, much compressed, and convex externally. On its upper margin, it forms the lower border of the orbit and of the infra-temporal fossa, sending up a strong process between them, which extends inside and in front of the postorbital branch of the postfrontal. In front, it is strongly united to the maxillary, and above joins by suture with the lachrymal.

The maxillary bone in *Claosaurus* is of moderate dimensions, and seen from the outside is overshadowed by the premaxillary and jugal, as shown in Plate IV, figure 1. Its lower dentary border is thickly studded with a regular series of teeth, which slightly overlap those of the lower jaw. From above, only a small portion of the maxillary is visible, as seen in Plate V, figure 5, *m.*

The lower jaws are long and massive. The predentary bone is robust, and especially fitted for meeting the strong beak above. The dentary bones are large and powerful, with elevated coronoid processes. The angular and surangular bones are, however, quite short, and not especially strong.

The Teeth.

The teeth of *Claosaurus* are confined entirely to the maxillary and dentary bones. In each, the teeth are very numerous, and are arranged in vertical series, so that they succeed each other as the functional teeth are worn away. This is seen in Plate V, figures 1–3, which show the form of the teeth and their relations to each other in the same series. The number of teeth in each series depends upon the position, those near the middle of the jaw having the greatest number, sometimes six or more. The teeth of the upper jaw have the external face of the crown covered with enamel and ridged. In the lower jaw, this is reversed, the ridged face of the crown being on the inside. This arrangement greatly increased the cutting power of the jaws. The food was probably soft vegetation.[*]

[*] In describing the skull and teeth of *Hadrosaurus*, an allied form, Cope made many serious errors, among them 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. (Proc. Phil. Acad., 1883, p. 97, plates vi–vii.) Another mistake in the same paper is the statement that the name *Atlantosauridæ* was given in 1882. It was given by the writer in 1877. See this Journal, vol. xiv, p. 514.

The Brain.

The brain of *Claosaurus* was very small, its size in proportion to the skull being represented in Plate V. figure 5, which also shows the exact position of the brain in the cranium. A cast of the brain-cavity is shown in the same plate, figure 4, one-fourth natural size. The brain as a whole was considerably elongated, especially the posterior half. The olfactory lobes were well developed, and not separated by an osseous septum. The cerebral hemispheres were comparatively large, forming nearly or quite half of the whole brain. The optic lobes were narrow, but considerably elevated. The cerebellum was rather small, and also much compressed. The medulla was of good size, and nearly circular in transverse outline. The pituitary body was quite large. The interpretation of some of the more minute features of the brain is a matter of difficulty, and will be more fully discussed elsewhere.

The specimens here described were obtained by Mr. J. B. Hatcher and Mr. A. L. Sullins, in the Ceratops beds of the Laramie, in Wyoming. In the same horizon were found other herbivorous Dinosaurs, especially the gigantic *Ceratopsidæ*, and with them various small Cretaceous mammals.

New Haven, Conn., Dec. 14th, 1892.

EXPLANATION OF PLATES.

PLATE IV.

FIGURE 1.—Skull of *Claosaurus annectens*, Marsh; seen from the left.
FIGURE 2.—The same skull; front view.
FIGURE 3.—The same skull; seen from above.
       All the figures are one-tenth natural size.

PLATE V.

FIGURE 1.—Series of five lower teeth of *Claosaurus annectens*; inner view.
FIGURE 2.—The same teeth; side view.
FIGURE 3.—The same teeth; outer view.
       The figures are one-half natural size.
FIGURE 4.—Brain cast of *Claosaurus annectens*; side view; one-fourth natural size.
       c, cerebral hemispheres; *cb*, cerebellum; *m*, medulla; *ol*, olfactory lobe; *on*, optic nerve; *op*, optic lobe; *p*, pituitary body.
FIGURE 5.—Skull of *Claosaurus annectens*, with brain cast; top view; one-tenth natural size.
       a, nasal opening; *b*, orbit; *c*, infra-temporal fossa; *d*, dentary; *e*, exoccipital; *f*, frontal; *fp*, postfrontal; *j*, jugal; *l*, lachrymal; *m*, maxillary; *n*, nasal; *pf*, prefrontal; *pm*, premaxillary; *q*, quadrate; *qj*, quadrato-jugal; *s*, squamosal.

CONTENTS.

SCIENTIFIC INTELLIGENCE.

VOL. XLV.

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ART. X.—*Isothermals, Isopiestics and Isometrics relative to Viscosity;* [*] by C. BARUS.

1. *Historical.*—In the following paragraphs, I endeavor to give a preliminary account of what may be called the isothermals, the isopiestics, and the isometrics with respect to viscosity. Notwithstanding the great geological importance[†] of these relations, nobody has as yet attempted to represent them systematically.

2. *The Material chosen.*—In order to obtain pronounced results for the effect of pressure on viscosity, substances must be selected on which temperature has a similarly obvious effect. For, in addition to the direct access to the molecule which is beyond the reach of pressure, temperature has the same marked influence on the expansion mechanism per unit of volume increment as the other agency. Hence liquids like marine glue, pitch, etc., which change continuously from solid to liquid, and in which this change takes place at an enormously rapid rate and is complete within relatively few degrees, are especially available for the present investigation.

The following data refer to *marine glue.* Viscosity is considered as a physical quality, and apart from such chemical considerations as are introduced in passing from one body to another. I must state, however, that the marine glue can be made to change its viscosity permanently, by cautiously heating it for different lengths of time. Thus I obtained charges

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[*] Enlarged from a note in the Proc. American Acad., January, 1892.

[†] As has been indicated by Mr. Clarence King, in this Journal for January.

in which, at the same temperature and pressure, the larger viscosities were three or even five times as high as the smaller viscosities, and my work is therefore to this extent independent of the material operated on.   Finally marine glue has the advantage of being both adhesive and tenacious, and errors due to slipping (§ 5) are thus reduced as much as possible.

3. *Definitions.*—In my paper[*] on the absolute viscosity of the three states of aggregation, I defined a fluid (liquid or gas) as a body which, under constant conditions of pressure, temperature, and stress, shows constant viscosity as to time.   In a solid *cæteris paribus*, viscosity markedly increases with the time during which stress is brought to bear.   The molecular instabilities of a liquid, therefore, are supplied at the same rate in which they are used in promoting viscous motion.   In a solid they are used more rapidly than the small rate of continuous supply.

The point of essential concern in these definitions is the constancy of stress, and its value below a certain critical datum. For instance, if in a solid stress be *increased* at the (small) rate necessary to insure a constant supply of instabilities, then solid viscosity will also be constant, and I am by no means sure that in such a case[†] yield points would eventually present themselves as breaks in the continuity of the solid flow.

On the other hand stress may be conceived to increase so fast, that even a liquid fails to present sufficient instabilities for truly viscous motion.   The elasticity and brittleness of many viscous liquids, especially at low temperatures, is a case in point.

4. *Hardness.*—Throughout my work on viscosity,[‡] I have adverted to the association of viscosity with zero forces acting for infinite times, and of hardness with infinite forces (relatively) acting for zero times, and have adduced many new examples showing the distinctiveness of these two properties.   The subject of hardness has, however, recently taken more definite shape in the researches of Auerbach,[§] based on a principle due to Hertz.[‖]   According to these observers, hardness is an expression for the elastic limits of a body in case of contact between its plane surface and the curved surface of some other (harder) body.   Hardness so defined admits of absolute measurement in terms of dynes per square centimeter.

5. *Method of Work.*—In all experiments like the present, one cannot be too careful to preconsider the conditions under

* Phil. Mag., V, vol. xxix, p. 337, 1890.   Cf. p. 354.
† Cf. this Journal, III, vol xxxiv, p. 19, 1887.
‡ Phil. Mag., V, vol. xxvi, p. 210, 1888.   Cf. Bull. U. S. Geolog. Survey, No. 73, pp. 42–44, 97, 98. 1891.   See § 6 below.
§ Auerbach, Wied. Ann., vol. xliii, p. 61, 1891.
‖ Hertz, Crelle's Journal, vol. xcvi, p. 156, 1882.

which the results are obtained; for one is only too apt to attribute an absence of flow to the effect of pressure on viscosity, when the real cause is to be found in the geometry of the apparatus employed. I have therefore availed myself of transpiration methods, since the theory of the experiments is in this case very fully given.

The marine glue, § 2, was forced out of a sufficiently large reservoir, through tubes of steel about 10^{cm} long, and 0·5 to 1^{cm} in diameter, cf. figure 1. Pressures as high as 2,000 atm. were applied at the reservoir, by aid of my screw compressor.* Temperatures between 10° and 30° were kept constant by a suitable water bath. Throughout the work the flow was so excessively slow (amounting to an advance of only a few millimeters per hour), that Poiseuille's law was at once applicable. The only considerable source of error in the work is the occurrence of more or less incidental slipping. However, inasmuch as the outflow of marine glue is capped by a rounded surface, it follows that the flow is most marked at the axis of the tube compatibly with the theory of the experiment. Methods of charging, manipulation, etc., must here be omitted.

Figure 1.—Sectional elevation of the high pressure transpiration apparatus. Scale ½, E, steel reservoir; D, steel transpiration tube; C, charge; B, movable solid disc; A, compressed oil forced in through the tube F.

6. *Volume Viscosity.*—At the end of stated intervals of time (usually hours), the small cylinders of marine glue which had exuded were cut off in the plane of the top of the tube with a sharp knife, and weighed. Now it was curious to note that these cylinders, left to themselves for about a day, showed a gradual and marked deformation, such that the originally plane bottom or surface of section eventually expanded into a symmetrical projecting conoid, with an acute apex angle of less than 45°. I take this to be an example of volume viscosity, inasmuch as an expansion gradually increasing at a retarded

* Phil. Mag., V, xxx, p. 338, 1890.

rate in the lapse of time, is the chief feature. The case, how-
ever, is much more complex, for the restitution of volume is
greatest in the axis of cylinder where the flow is a maximum,
and it is accompanied by a series of distortions of the kind
given in figure 2. Here G shows the shape of the cylinder
or button immediately after cutting it off of the column H,
surrounded by the steel transpiration tube. After 24 hours,
when both were left free from pres-
sure, G passed into the form I, and
H into K. The emergence of the
cone begins visibly, soon after cut-
ting. After long waiting, a cavity
sometimes dimples the top of the
button as shown at L. I have also
obtained cup-shaped deformations,
like M. The height of the project-
ing cone bears no obvious relation
to the length of the cylinder. Thus
on flat buttons ·6^{cm} in diameter and less than ·4^{cm} high, the
apices of the conoids will often be at a distance of ·3^{cm} and
·4^{cm} from the geometric base.

Figure 2.—Sectional diagrams,
showing the elastico-viscous defor-
mations of exuded cylinders of the
charge C, Fig. 1, external pressure
being zero.

    In general, therefore, the originally plane right sections of
the transpiring column tend to become plane after stress ceases;
or plane right sections of the axially stressed column, tend to
bulge out conoidally, symmetrically around the axis, and in a
direction opposite to that of the stress, when stress ceases.
Thus the experiment points out in a beautiful way how much
residual viscosity resembles a slowly reacting elasticity.[*] Com-
plete restitution of form cannot occur because of the dissipa-
tion of energy.

    7. *Viscosity and Pressure.*—Inasmuch as marine glue is a
nonconductor and highly viscous, much time must be allowed
before temperature and pressure can be assumed to have pene-
trated the mass uniformly. Again whenever the oil of the
compressor accidentally reaches the transpiration tube, the slip
error is enormously increased and the results are worthless. A
single charge will not therefore outlast many experiments.
These are the chief reasons why much time has to be spent on
the work and why it is difficult to coördinate the results.
Another annoyance is the unavoidable lack of homogeneity of
the charge, and the possibility of a reservoir correction. It
will therefore be expedient to briefly indicate the method by
which trustworthy results were eventually reached.

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[*] A suggestive example of the gradual passage of true elasticity into true
viscosity is given by the phenomena observed on stretching a string of (dry)
vulcanized india rubber deposited from solution. If the string be suddenly re-
leased, elasticity and viscosity appear as the two extreme phases of contraction,
terminating a continuous series of intermediate phases.

Table I gives an example of my earlier results. The transpiration tubes were *smooth* internally as shown in figure 1.

The table is one of double entry, and the data contained show the absolute viscosity (η) of marine glue at the stated temperatures and pressures, in terms of one billion g/cs units. The pressure excess is the difference of pressures at the two ends of the tube.

TABLE I.—Mean Values of $\eta/10^9$ for Marine Glue.

Δp = Pressure Excess	100 atm.	300 atm.	1000 atm.	1500 atm.	2000 atm.
Temperature = 8·5°	----	----	>30 000	12·0	>60 000
" = 18·3°	(2·5)	----	8·30	12·0	15·2
" = 22·5°	----	----	1·12	----	2·2
" = 30·5°	·065	·073	----	----	----

Rates at	18·3°	22·5°
$10^{-9} \times \Delta\eta/\Delta p$ =	·0137	·00220
$b = \Delta\eta/\eta_0 \times \frac{1}{2}\Delta p$ =	·0091	·020

In constructing the rate of change of viscosity with pressure, I assumed that the whole thread *transpired at the mean of the pressures at the two ends of the steel tube ;* or since the pressure at the open end is zero, at half the pressure excess. Furthermore, that

$$\eta_p = \eta_0(1 + bp) = \eta_0(1 + \tfrac{1}{2}b\Delta p)$$

If therefore $\Delta\eta$ be the increment of viscosity corresponding to the pressure $\frac{1}{2}\Delta p$, the final data of Table I (rates) are at once intelligible.

What is chiefly striking in this table is the preponderating influence of temperature. Thus the material, which between 20° and 30° C. transpires readily enough, is at 8° so nearly solid, that a burden of 2000 atmospheres, brought to bear at one end of a transpiration tube 10^{cm} long and as wide as 1^{cm}, is unable to produce perceptible flow even after 5 hours. It also appears that *in proportion as the viscosity of a body increases with fall of temperature, its isothermal rate of increase with pressure also increases.*

Some time after, I repeated this work with great care and obtained—

Temperature =	1·8°	·20°	·22°	·24°
$\eta_0 10^9$ =	2·7 } 5·2 }	4·3	·94 } 1·16 }	·28
$b \times 10^3$ =	8·0 } 3·0 }	1·3	3·9 } 1·8 }	4·8

It would be premature to speculate on the nature of the relation of viscosity to pressure and to temperature, on the basis of these results. As to the pressure coefficient b, one

can only infer that its value is of the order of ·005, and that
it bears no obvious relation to the initial viscosity, or to tem-
perature.

In endeavoring to improve upon this work I cut a screw
thread in the *inside* of the transpiration tube and thus largely
obviated slipping, by compelling the charge to flow on itself.
I also made all observations in triplets, including each measure-
ment at a high pressure or temperature between two fiducial
measurements at a given lower pressure or temperature. Only
such observations were taken for which the fiducial data were
identical. Finally by treating the charges individually, I
found that although the viscosities at the same temperature
were very different, the pressure coefficients followed each
other in the order of the initial viscosities.

Experiments made in this way showed—

Temperature =	16·5°	13·9°	11·9°	18·0°	15°	15°	20°
$\eta_0/10^9$ =	·50	2·15	2·50	·70	3·7	3·7	·40
$b \times 10^3$ =	4·2	4·3	8·9	5·3	4·6	4·8	6·5

These are the best results I have been able to obtain. How
nearly linear the variation of viscosity with pressure is, may
be seen in the following example of consecutive measure-
ments :

Pressure excess Δp =	340	700	1055	1410	1770	340	*atm.*
Viscosity, $\eta/10^9$ =	·87	1·20	1·60	2·07	2·30	·87	*g/cs*

Even in case of high viscosity ($> 10^{10}$), a tendency of vis-
cosity to increase at an accelerated rate with pressure is only
vaguely apparent, e. g.,

Pressure excess, Δp =	505	1020	505	1540	1022	1540	*atm.*
Viscosity, $\eta/10^9$ =	8·4	12·6	7·9	17·9	12·9	17·1	*g/cs*

Taking the above work as a whole, therefore, I am bound
to infer that within the range of observation (2000 atm.), the
pressure coefficient is constant : for though varying between
·004 and ·009, it shows no discernable relation to the initial
viscosity (η_0 for $\Delta p = 0$), or to temperature. In other words,
to assume that the rate at which viscosity increases with pres-
sure at any temperature, is proportional to the initial viscosity
at that temperature, is the nearest approach to the actual state
of the case which my observations enable me to make. Tak-
ing the mean of all values in hand I thus obtain—

$$\eta_{\theta, p} = \eta_{\theta, 0}(1 + \cdot 0057 \, p) \tag{1}$$

where the subscripts show the temperature (θ) and pressure (p)
at which viscosity (η) is taken ; and where p is the mean of the
pressures at the two ends of the transpiration tube.

8. *Viscosity and Temperature.*—It is next in place to find a suitable expression for the relation of viscosity to temperature. Contrary to my expectations this was comparatively easy; and the reason seems to be that so long as pressure is constant, the error due to slipping is less liable to change. An example of the results worked out from triads as above, and obtained with screw tubes is given in the following tables. $\Delta p = 505$ *atm.*

	Observed.	Computed.			Observed.	Computed.	
Temperature	$\eta/10^9$	$\eta/10^9$		Temperature	$\eta/10^9$	$\eta/10^9$	
12°	7·70	7·78	$A=11\cdot895$	15°	8·15	8·13	$A=12\cdot385$
14°	3·75	3·61	$B=\cdot167$	17°	3·82	3·80	$B=\cdot165$
16°	1·61	1·67	$\eta_0=7\cdot8\times10^{11}$	19°	1·72	1·78	$\eta_0=2\cdot4\times10^{12}$
				21°	·81	·83	
				23°	·42	·39	

It is seen at once that within the range of observation (12°–16° C., 15° to 23° C.) temperatures increase in arithmetical progression while viscosities decrease in geometrical progression. Hence (2) $\log \eta_{p, \theta} = \log \eta_{p, 0} - B\theta$, and the factor B has the large value, ·165. Of the two sets of data given, the initial viscosity, $\eta_{p,0}$ is fully three times larger in one case than in the other. Nevertheless the quantity B is practically the same in both. For this reason I shirked the great labor attending experiments at higher pressures and concluded conformably with the suggestions of the preceding paragraph, that as a first approximation the rate at which viscosity increases with temperature at the temperature $\theta°$, is proportional to the viscosity at $\theta°$, and is independent of pressure.

9. *Summary and chart.*—With the principle thus laid down I am able to give a graphic exhibit of the isothermals and the isopiestics. This is done in the chart, figure 3, where the ordinates are absolute viscosities, and the abscissas, pressures and temperatures respectively. The isopiestic for $p = 250$ atm. is directly observed between 15° and 23°. The other curves are computed from this by aid of the coefficients deduced in §§ 7, 8. The range as a whole may be taken as that of the present experiments. The (computed) initial viscosity $\eta_{0, 0}$ (for $p = 0$ and $\theta = 0$) is very nearly 10^{12}. As usual $p = \Delta p/2$.

10. *Isometrics.*—From these data the isometrics may be constructed graphically and in this way the curves marked η were obtained. I am now able to answer some important questions as to how temperature and pressure must vary, in order that viscosity may remain constant. Equations (1) and (2) lead easily to

$$(dp/d\theta) = (ln\ 10)\, B(1 + bp)/b \qquad (3)$$

Hence the isometrics are all identical as to contour and ob-

tained by dropping the initial curve over stated amounts. For any viscosity and at any temperature within the range of observation, therefore, the increment of pressure which will just annul the decrement of viscosity due to a rise of temperature of one degree Centigrade is, for instance,
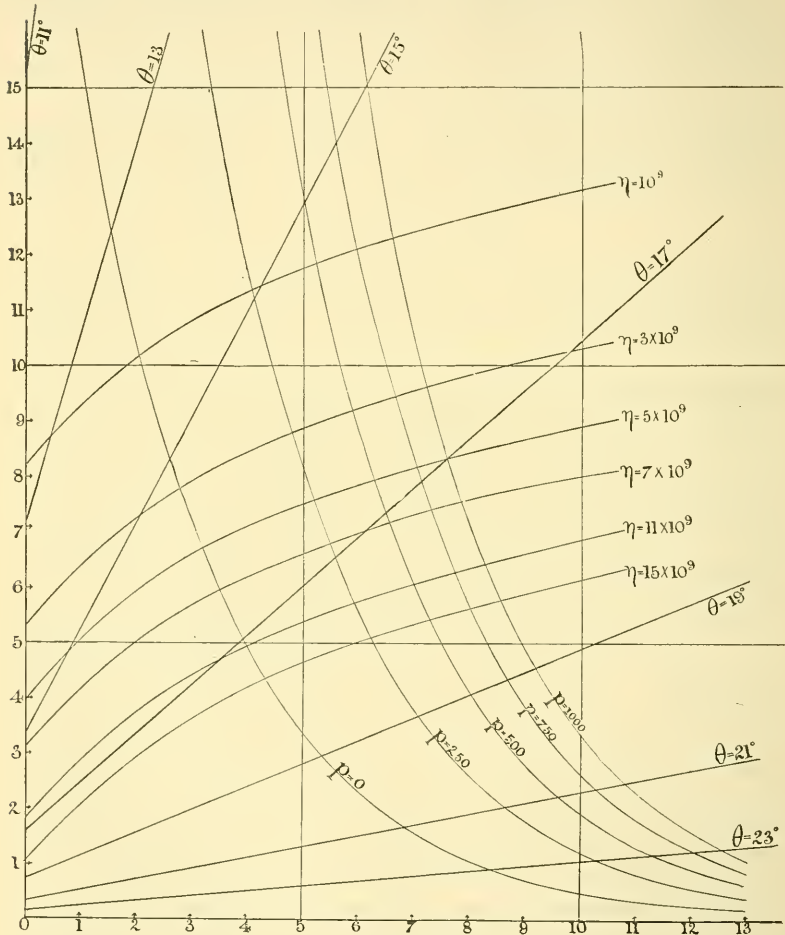
Fig. 3.

Fig. 3.—Chart showing the isothermals (θ), the isopiestics (p), and the isometrics (η), relative to the viscosity of marine glue.

Abscissas : Pressure in *hundreds* of atmospheres, or in *two hundreds* of atmospheres of pressure excess.

Temperatures in degrees Centigrade beginning with 10° C.

Ordinates : Viscosities in *billions* of absolute (*g/cs*) units.

Temperatures in degrees Centigrade beginning with 10° C.

Pressure	=	0 atm.	500 atm.	1000 atm.
Increment of pressure	=	67 atm.	256 atm.	380 atm.

and so on. Thus the relative inefficiency of pressure as compared with temperature is apparent, though to make the comparison just, both agencies should be taken per unit of volume increment. Cf. § 11.

11. *Digression, Logarithmic isothermals.*—Believing that the error due to slipping increases with pressure, i. e. in proportion as the charge becomes more solid, and noting the tendency (§ 7) of isothermals for high viscosity to slope upward, I thought it worth while to compute the isothermals on the supposition that $\log \eta = a' + b'p$, as an extreme case. Necessarily, marked violence is thus done to the observations, and b' obtained from high pressures must be smaller than b' from low pressures. Preferring the latter, I found, for instance

$\eta_0/10^9$	=	·69	5·9	4·7	2·9	·64
$b' \times 10^5$	=	81	73	93	73	74

As before a dependence of b' on η_0 does not appear and $b' =$ ·00078 may be taken as the mean value.

The interest which attaches to this case is its bearing on the isometrics, which now appear as straight lines. For if

$$C = \eta_{\theta p}/\eta_{oo}, \quad \log C + B\theta = b'p, \quad \text{and} \quad (dp/d\theta) = B/b' = 210$$

In other words 210 atm. would annul the decrement of viscosity produced by a rise of temperature of 1° C., at all temperatures and pressures.

Seeing that in an elegant research of Ramsay and Young,[*] and in high pressure work[†] of my own, the volume isometrics of liquids appear as straight lines, the present considerations may possibly claim more than passing comment.

The immediate object of the present paragraph, however, is to give warrant to the statement, that in high pressure phenomena *at least* 200 atm. must be allowed per degree Centigrade, in order that there may be no change of viscosity.

12. *Maxwell's theory.*—If for the sake of definiteness, viscosity (η) be defined as proportional to the ratio $(N-n)/n$, of the number of stable configurations ($N-n$), to the number of unstable configurations (n), in a given volume, then the above expressions may easily be translated into the language of Maxwell's theory of viscosity.[‡] I shall therefore withhold further remarks here. The conditions are simplified since for

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[*] Ramsay and Young: Phil. Mag., xxiii, p. 435, 1887; xxiv, p. 196, 1887.

[†] Barus: Phil. Mag., xxx, p. 338, 1890.

[‡] This was done in my note in this Journal for September, p. 255.—In the series, atom, molecule, viscous configuration, the last can not be as sharply defined as the other two, and only the former as yet admits of generic classification (periodic law). Cf Am. Chem. Journ., xiv, pp. 197-201.

a substance like marine glue, n is probably small as compared with N.

13. *Measurement of excessively high pressure.*—Let there be given a tube of length l and radius ρ.   Let $\eta = \eta_0(1+bp)$ be the viscosity of the viscous liquid forced through it by the pressure excess $\Delta p = 2p$ (so that there is no pressure at one end of the tube), and at the constant temperature θ.   The length (λ) of a cylinder of fluid issuing per unit of time (t) will then be $\rho^2 \Delta p/8l\eta_0(1+b\Delta p/2)$.   Hence if negative pressures be excluded, the function λ/t is of a kind which continually increases with Δp, a state of the case which would not be true if the expression of § 11 were applicable.

In view of the observed property of λ/t, it is worth inquiring in how far the transpiration method is available for high pressure measurement, when most other means fail.

Take for example a tube $\frac{1}{16}$ inch in diameter and 1 inch long.   Then the mass m of the above marine glue which at say 18° would exude per hour is

$$m \times 10^6 = \quad 5970 \qquad 7550 \qquad 7810 \qquad 7900 \qquad 7950 \; grams.$$
$$\Delta p \quad\; = \quad 1000 \qquad 5000 \qquad 10000 \qquad 15000 \qquad 20000 \; atm.$$

where $\eta = 10^9(1 + \cdot 00285\Delta p)$.

Thus it appears that whereas a hole $\frac{1}{16}$ inch in diameter may be efficiently sealed by marine glue at 18° C., pressure measurement by aid of the exuding mass is impossible above 10,000 atm., whereas even between 5000 atm. and 10,000 atm. the method is insensitive.   To use a method like the present for very high pressure measurement, a substance of smaller pressure coefficient must therefore be sought, if such a one with other necessary qualities, exists.   It is with the object of searching for such a body, as well as of finding the maximum of hydrostatic pressure attainable in the laboratory that I had a tinned screw and socket constructed,* and hope to be able to report the results of my work at an early opportunity.   To my knowledge the only other gauge available under the circumstances is the one I based on the resistance of mercury. It is sufficient, however, for making the comparisons in question.

Phys. Lab. U. S. Geolog. Survey, Washington, D. C.

* Proceed. American Acad., xxv, pp. 94, 108, 1890.

ART. XI.—*"Potential" a Bernoullian Term;* by
GEO. F. BECKER.

POTENTIAL as the name of a function was undoubtedly
introduced by Gauss in 1840. He wrote: "Zur bequemern
Handhabung der dazu dienenden Untersuchungen werden wir
uns erlauben dieses V mit einer besondern Benennung zu
belegen, und die Grösse das *Potential* der Massen, worauf sie
sich bezieht, nennen."* But Gauss was certainly not the first
to employ the corresponding adjective in a similar sense.
George Green employed the term *potential function* in 1828
in his famous paper on electricity and magnetism. He intro-
duced the phrase by remarking that certain memoirs of
Poisson's "are in fact founded upon the consideration of what
have, in this essay, been termed potential functions."† In
section 1 of the paper he says: "As this function . . . will
occur very frequently in what follows, we have ventured to
call it the potential function belonging to the system." No-
where in this paper can I find the word potential used as a
noun, while "potential function" is met with on almost every
page.

Most physicists give Gauss full credit for independent in-
vestigation of the potential, but Todhunter refers to the matter
in a manner which would seem to convey an innuendo. "We
may observe," he says, "that the name *Potential* was first
used by the late George Green. . . . Gauss used the word in
his memoir . . . published in 1840. As Gauss does not refer
to any previous authority we are, I presume, to infer that he
had independently selected the name."‡ As was pointed out
above, this is not a correct statement, since Green did not use
the *name* potential but only the adjective; and the effect of
the words "I presume" is to suggest a doubt whether Gauss
might not have been acquainted with Green's nomenclature,
and consequently also with the theory portions of which he is
credited with rediscovering. Gauss however never displayed
any tendency to plagiarism.

It is not very generally known, though it has been men-
tioned in modern literature, that Daniel Bernoulli and Euler
employed the term *vis potentialis*. A single passage from
Euler will illustrate its use: "Quamobrem cum vir celeberri-

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* Allgemeine Lehrsätze in Bez. auf . . . Anziehungs- u. Abstossungs-Kräfte.
Collected works, vol. v, 1867, p. 200.
  † Reprinted in Crelle's Journal, vol. xxxix, p. 77, 1850, and in his collected
papers.
  ‡ Math. hist. theories of attraction and the figure of the earth, vol. ii, 1873,
p. 26.

mus . . . Daniel Bernoulli mihi indicasset se universam vim, quae in lamina elastica incurvata insit, una quadam formula quam *vim potentialem* appellat complecti posse, hancque expressionem in curva elastica minimam esse oportere, etc." In stating his problem he says again "atque, secundum Bernoullium, exprimetur *vis potentialis* in laminae portione AM contenta hac formula $\int \frac{ds}{RR}$," *s* being the arc of the spring and *R* the radius of curvature.* It is evident that in these passages *vis* is used in the same sense as in *vis viva* and that it is to be translated energy, so that Bernoulli's proposition was that the elastic curve must be such as to make something which he regarded as the potential energy of a bent spring a minimum.

Todhunter in his History of Elasticity, 1886, quotes passages from D. Bernoulli's letters in 1742–3, in which the vis potentialis is mentioned; but since the historian makes no allusion to his earlier remarks on the origin of the name Potential, it must be inferred that no relation between the two terms suggested itself to him. Had Todhunter lived to edit his history, perhaps this omission would have been supplied.

It is well known that Green's great memoir was not published in the ordinary manner, but by subscription in Nottingham, and that it attracted no attention for many years either in Great Britain or on the Continent. Gauss was thus very naturally ignorant of it. On the other hand it is substantially impossible to suppose Gauss ignorant of the famous memoir of Euler quoted above. The methods there developed of finding curves have been superseded by those of the calculus of variations; but the appendix, *Additamentum de curvis elasticis*, from which the passage quoted above is taken, contains the classification of elastic curves into nine species which, so far as I am aware, has received no addition or improvement.

There can thus be substantially no doubt that Daniel Bernoulli's vis potentialis suggested to Gauss the name potential for a somewhat similar but more general function. Either he considered the change of form of the expression and the increased generality of its significance as sufficient to make any reference to Bernoulli needless; or, as seems more probable, he assumed that his readers were as well read as himself and that an allusion was superfluous.†

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* De Methodis inveniendi lineas curvas maximi minimive proprietate gaudentes. 1744, pp. 246, 247.

† The potential has received a variety of names in modern times. "Force function," which seems to be used by European mathematicians at least as frequently as potential, was proposed by W. R. Hamilton in his famous memoir on varying action, Phil. Trans., 1834, p. 249. In the same year B. de Saint-Venant called it "latent dynamic capital" (Leçons de Navier, 1861, p. 786) and Ampère suggested "implicit vis viva." Ann. chim. phys., vol. lviii, 1835, p. 438.

It is natural to inquire what Euler and Bernoulli meant in terms of modern nomenclature by vis potentialis.   Now Saint-Venant has pointed out* that if M is Young's modulus and J the moment of inertia of the cross section of the spring, the work done in flexure for a length s is

$$\frac{MJ}{2}\int_o^s \frac{ds}{R^2}$$

so that Bernoulli's function is simply proportional to the potential energy as that expression is now understood and to the *Potential*, a fact to which the great French elastician calls attention.

There seems to be a general impression that the natural philosophers of the last century, when they used the quantities now known as kinetic, potential and total energy at all, regarded them from a purely algebraical or geometrical point of view, failing to perceive their great physical significance. In this respect these physicists seem to have been underrated : as some passages from the first John Bernoulli, Euler's teacher and D. Bernoulli's father, will show.   In a paper on the true conception of living forces† he generalizes the idea of vis viva and defines it as equivalent to capacity for doing work, or *facultas agendi*, which is simply a Latin equivalent of the Greek energy.   In Section I of this paper he says (translated) :

" Vis viva does not consist in the actual exertion, but in the capacity for doing work ; for it subsists even when it does no work nor has any object whereon it could act ; so for example a strained spring, or again a body in motion, has in itself the capacity of doing work, so that if nothing external to itself come in its way upon which it may exert itself, and so long as there is no object present with which it can come in contact, it infallibly retains it all undiminished by time, and does not do the work which it would be capable of doing if it had the opportunity."

This seems a clear and even a vivid statement of the law : " When a system is subjected to no external forces, its energy remains constant."

In Section III he takes a further step.   " Vis viva (which would be more aptly named facultas agendi, gallice le pouvoir)‡

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* Leçons de Navier, edition of 1864, p. cxij.

† De vera notione virium vivarum, Acta Eruditorum, Leipzig, 1735, p. 210.

‡ The term power is now rarely used for energy, but it is scarcely a generation since this meaning was common enough. Saint-Venant (op. cit., p. 785) in 1864 defined the potential of one or more forces as " leur pouvoir moteur total."   B. Peirce in his great work on analytical mechanics 1865 always uses " power " instead of "energy."

is something real and substantial, which has an independent existence and, whatever it consists of, depends upon nothing else. Whence we conclude, that any given vis vivâ is of determinate quantity of which none can disappear except it reappear in the effect produced. Hence it follows at once, that vis viva is always preserved, and so perfectly that what inhered in one or many bodies before action is now, after action, necessarily found in another or in several others excepting what remained in the first system. And this we call the *conservationem* virium vivarum."

Compare this with the modern statement: In any system the variation of energy is equal to the external work done by the system less the work done by external forces upon the system.

John Bernoulli was under no misapprehension as to the importance of the principles he had stated. He says in substance: Whether bodies are regarded as communicating motion to one another or whether one considers the various modifications of the motion of one and the same body depending on its own force (where nothing can vanish without an equivalent effect), " pro fundamento et principio universali poni debet conservatio virium vivarum, hoc est illius *facultatis agendi.*"

That such men as Daniel Bernoulli and Euler should have been deaf to teachings like these is impossible and they must therefore have had an idea of the vis potentialis differing but little from that which the words convey to modern ears.

It would be interesting to know whether they really omitted to show in any portion of their writings why they felt themselves at liberty to base investigations on the statement that the potential energy of a strained solid is a minimum. Indeed it appears to me that the few notes given above are sufficient to indicate an opportunity for a physicist to write a most interesting essay on the evolution of the potential up to the date of Lagrange's memoir on the movement of a number of mutually attracting bodies (1777) in which the potential seems to have been used for the first time in an entirely general form.

Washington, December, 1892.

ART. XII.—*Datolite from Loughboro, Ontario ;* by
L. V. PIRSSON.

THE crystals of datolite which are the subject of this note were sent to this laboratory for examination through the kindness of Messrs. English & Co., of New York. They had been forwarded to them by the owner and the occurrence is the

Lacy Mine, Loughboro, Ontario.   More magnificent crystals of this species have probably never been found in America and they are equalled by few European specimens.   They are pure and transparent with a yellowish green tinge and enclose only a few small crystals of chalcopyrite as impurities.   At first glance they resemble large topaz crystals.   In size they measure for the largest crystals $3 \times 2\frac{1}{2} \times 2^{cm}$.   Nothing is known of the mode of occurrence save what can be gathered from the examination of a small amount of associated material on the hand-specimens.   From this, the mineral seems to have formed in veins in a light colored igneous rock too much acted upon by fumarole agencies for satisfactory determination, but containing a considerable amount of a brownish biotite.   On the specimens the datolite crystals are associated with quartz, calcite and chalcopyrite.

The material consisted of two hand specimens with groups of large crystals and one detached crystal of the size mentioned. In habit these crystals are nearly all alike in the development of their planes, being characterized by a prismatic like development in the zone of clinodomes following the orientation given this species by E. S. Dana.[*]

The loose crystal could be easily measured and was also the most complex in the development of its planes.   The following forms were identified:

a (100) $i\text{-}\bar{\imath}$	u (104) — $\frac{1}{4}\text{-}\bar{\imath}$	n (111) — 1
b (010) $i\text{-}\hat{\imath}$	x (102) — $\frac{1}{2}\text{-}\bar{\imath}$	ε ($\bar{1}$12) $\frac{1}{2}$
c (001) O	ξ ($\bar{1}$02) $\frac{1}{2}\text{-}\bar{\imath}$	β (121) — 2´2
m (110) I	g (012) $\frac{1}{2}\text{-}\hat{\imath}$	Q (122) — 1-`2
o (120) $i\text{-}\grave{2}$	m_x (011) 1-$\hat{\imath}$	U (123) — $\frac{2}{3}$-`2

This crystal is shown in the accompanying figure.   All the faces except the pinacoids and clinodomes have been relatively

exaggerated in size to exhibit them better.   No other forms beyond these were observed on any other of the crystals.   The zone o, β, Q, U was well developed and gave excellent reflections on the goniometer.
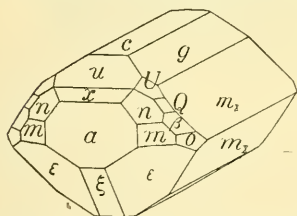
The crystals were not studied optically as no material was available without damage to the specimens, but, as confusion has frequently occurred in the orientation of this species owing to the great similarity of angles in the zones of prisms and of clinodomes, the following table of measured and calculated angles is appended to show the correctness of the orientation and the identification of the forms.

[*] System of Mineralogy, New York, 1892, p. 502 *et seq.*

The calculated angles are those from Dauber's[*] measurements from which we have the elements,

$$\bar{a} : \bar{b} : \dot{c} = 0\cdot63446 : 1 : 1\cdot26574 \text{ aug. } \beta = 89° 51' 20''$$

		Calc.	Meas.		
$c \wedge u$	$001 \wedge 100$	89 51½	89° 36′		
$a \wedge m$	$100 \wedge 110$	32 23½	32 26½	32 26½	
$m_x \wedge m_x$	$011 \wedge 01\bar{1}$	76 37	76 37		
$a \wedge n$	$100 \wedge 111$	38 55	38 52	38 53	
$a \wedge m_x$	$100 \wedge 011$	89 55	89 50		
$c \wedge n$	$001 \wedge 111$	66 57	66 49		
$a \wedge x$	$100 \wedge 102$	45 0⅛	44 52		
$a \wedge u$	$100 \wedge 104$	63 22⅓	63 16		
$a \wedge \xi$	$100 \wedge 10\bar{2}$	45 08⅔	45 12		
$c \wedge g$	$001 \wedge 012$	32 19¾	32 15	32 24	32 08
$c \wedge m_x$	$001 \wedge 011$	51 41½	51 41½	51 35	
$\varepsilon \wedge \varepsilon$	$11\bar{2} \wedge 1\bar{1}\bar{2}$	48 19½	48 21		
$a \wedge \varepsilon$	$100 \wedge 11\bar{2}$	49 57	49 59		
$a \wedge o$	$100 \wedge 120$	51 45½	52 19		
$a \wedge Q$	$100 \wedge 122$	58 12	58 10		
$a \wedge U$	$100 \wedge 123$	62 58	62 54		
$a \wedge \beta$	$100 \wedge 121$	53 43½	53 41	53 42	
$c \wedge \beta$	$001 \wedge 121$	72 41	72 33		
$c \wedge Q$	$001 \wedge 122$	57 58½	57 59		
$c \wedge U$	$001 \wedge 123$	47 0⅓	46 54		

Probably the largest European crystals of datolite are those from Baveno, Italy. One of these described by Sella[†] is mentioned by Brush[‡] as being $4\cdot5 \times 3\cdot75 \times 1\cdot5$ inches.

Laboratory of Mineralogy and Petrography,
   Sheffield Scientific School, Oct., 1892.

Art. XIII.—*A New Machine for Cutting and Grinding thin sections of Rocks and Minerals;* by George H. Williams.

A brief description of a new machine for cutting and grinding rock sections in which electricity furnishes an economical and satisfactory motive power, may prove acceptable to the constantly increasing number of workers in mineralogy and petrography. This machine was devised for the petrographical laboratory of the Johns Hopkins University over a year ago, and since then it has been in more or less constant use. It has thoroughly established its reputation for accurate and rapid work, while experience has suggested some improvements on the original model.

* Pogg. Ann., 103, 116, 1858.
† Wien. Akad. Berichte, **xxix**, 239.
‡ VIII Supp. Dana's Min. This Journ., May, 1860, vol. **xxix**, 2d series.

The accompanying cut of the machine (fig. 1) hardly needs any explanation. It is seen to consist of a substantial table, carrying in its lower part the electric batteries and motor
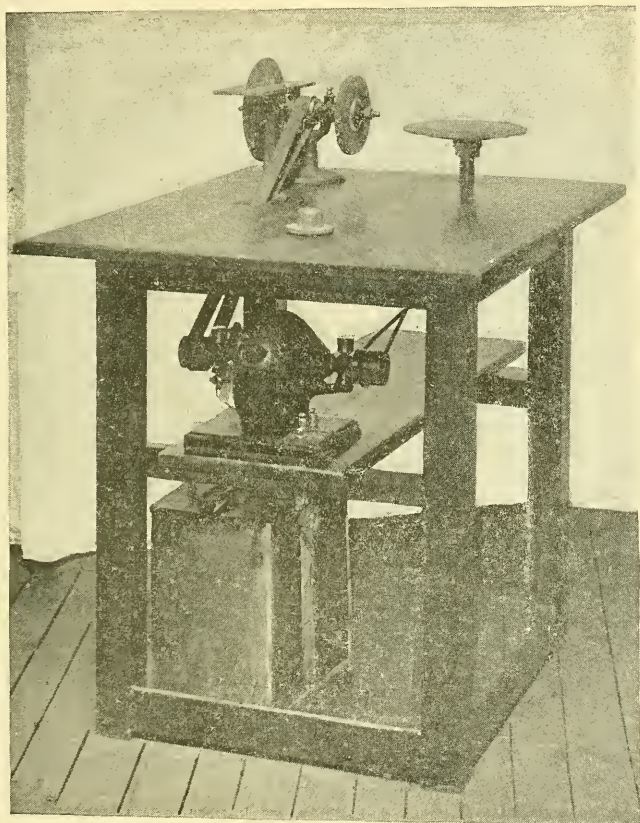
Fig. 1.

while upon its upper surface is placed the apparatus for grinding and sawing.

The table is approximately three and one-half feet square and two feet nine inches high. It is constructed with all of its appurtenances by the Donaldson-Macrae Electric Company of 215 N. Calvert St., Baltimore, whose storage batteries and electric motors are well known. The price of the machine complete is $130.00, consisting of the following parts:

1. Three two hundred ampère-hour storage batteries, 13 inches high, in portable rubber cases. These batteries stand

on a firmly constructed cross-piece from which they may be readily removed for recharging.

2. One one-eighth horse power electric motor of the Donaldson-Macrae pattern (fig. 2). This is fastened to a second cross-piece above the batteries and below the table surface. It is provided with two pulleys f r o m which belts pass to the shafts on the table, which carry the grinding disks and diamond saw.
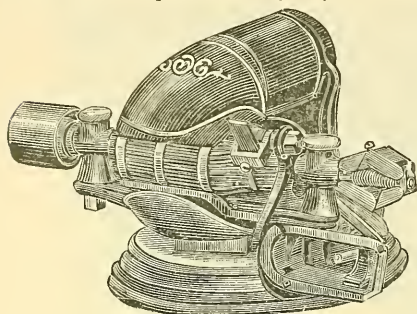
3. The grinding apparatus consists of two circular disks of solid copper, 9 inches in diameter and $\frac{3}{8}$ inch thick, which may be used alternately as different grades of emery are required. They are attached either by a screw or square socket to a vertical iron spindle which revolves smoothly in a conical bearing. The grinding disk is surrounded when in use by a large cylindrical pan of tin (not shown in the cut) which has an opening in its center to allow of the passage of the spindle.

Fig. 2.

4. The sawing apparatus consists of a horizontal countershaft, placed on a different part of the table from the grinding disk, and connected with the motor by a separate belt. It carries at one end a vertical wheel of solid emery, and at the other an attachment, level-table and guide for the diamond-saw.* A small water-can and spout (not shown in the cut) is suspended over the level-table to keep the edge of the saw wet when it is in use.

Under some circumstances it may be found advantageous to obtain electricity for this motor by a direct wire from an electric light or power company. Considerable inquiry has shown, however, that in Baltimore the storage batteries are more convenient, safe and economical. A single charging lasts the needs of a laboratory of ten students for a month. The batteries are removed by the electric company and returned with little or no delay at a cost of $3.75 for recharging.

Petrographical Laboratory,
Johns Hopkins University, Dec. 10, 1892.

* Admirable saws, circular tin disks 8 inches in diameter with one inch center aperture whose edge is provided with diamond dust secured by cement, may be had of Wm. Kerr, No. 292 Westminster St., Providence, R. I., for $12.00 per half dozen.

ART. XIV.—*Stannite and some of its Alteration Products from the Black Hills, S. D. ;* by WM. P. HEADDEN.

SEVERAL years ago Mr. Fred. J. Cross found at the Peerless Mine, which is located about one-half mile northeast of the Etta Mine post office, and was then being worked for mica, a piece of some mineral imbedded in the pellucid quartz of the locality which he did not recognize as having seen before either from this or any other locality in the Hills. This material which he kindly gave me forms the subject of this investigation. One piece was all that Mr. Cross found at the time and, though he has subsequently sought for it diligently, he has been unable to find more of it, and I have been entirely unsuccessful in my search for it; therefore the description of the occurrence of this mineral in the Black Hills must be confined to the description of this one specimen with such exception as will be mentioned hereafter.

The exterior of the mass is earthy in texture and from dirty green to brownish yellow in color. The texture and color change rapidly the former becoming in the interior firm, almost massive, with uneven to subconchoidal fracture, while the color passes through a pure copper-green to greenish black. The appearance of the mass leaves no doubt but that it is what remains of an original mass now in an advanced stage of alteration. This is plain to the naked eye, but is best seen under a good pocket magnifier. The texture of the mass varies, even in those portions which are earthy, and where the alteration is most complete there are portions varying in size from mere points to particles as large as small shot which have a vitreous luster, a green color, and an uneven fracture which is rather difficult to observe. A closer study of these spots shows that they, like the mass itself, are filled with seams and are only remnants of an unrecognized decomposition product. While these particles are readily distinguishable from the enveloping mass, they are so permeated by seams filled with other material, probably identical with the mass itself, that no mechanical separation of the two would be possible. The dull earthy substance becomes less abundant in the interior but is nowhere absent.

The portion having a copper-green color is similar to the lustrous spots of the other portion and the two are probably identical. The former like the latter is traversed by a fine network of seams whose centers are filled with a substance appearing to be almost white when viewed with a rather strong magnifier. This is particularly easily observed in the larger

seams; but this substance which is one of the end products of
the alteration, an impure oxide of tin, can be traced as minute
threads running through the mass in every direction even into
its deeper portions where small portions of the original stan-
nite still remain.

The meshes of this reticulation are sometimes filled with an
apparently homogeneous mass of a varying green color and
strong vitreous luster, but this is rather exceptional. The rule
is that they are filled with material which varies macroscopi-
cally and probably chemically; as some of the patches are
white while others are different shades of blue or green.

The firmer portion of the mass is really not uniform in
color, green and grayish black portions being intimately
mingled, producing a greenish black. The stannite frequently
shows a bronzy tarnish which makes the mixed nature of the
mass apparent. The luster of this mass on a fresh fracture
surface is metallic, its streak and powder are green and it
yields three products when treated with hydric chloride, i. e. a
solution containing a large amount of tin and a residue made
up of fragments of the remaining stannite and a yellowish
white powder consisting of stannic oxide with a trace of iron.

The stannite is grayish black. It tarnishes blue and bronze.
Hardness 4; Sp. gr. 4 534, streak black. The material used
for analysis appeared to be quite pure and free from the
accompanying alteration products, but both the quantity of
the material and the size of the fragments forbade any further
attempt to purify it by gentle rubbing or other means. The
analysis yielded the following results :

		At. eq.
Sulphur	28·26	88·31
Tin	24 08	20·40
Copper	29·81	47·16
Iron	7·45	13·30
Zinc	8·71	13·40
Cadmium	0·33	0·20
Antimony	trace	
Insoluble	1·51	

$$100·15$$

If we assume the copper to be present as cuprous and the
tin as stannic sulphide, and express the atomic equivalents in
terms of sulphur, we obtain :

Sulphur	88·31	or	6·64	6·64	1
Tin	40·80		3·06		
Copper	23·58		1·77	6·83	1·02
Iron	13·30		1·00		
Zinc	13·40		1·02		
Cadmium	0·20				

The ratio of the sulphur required by the tin as stannic sulphide to the total sulphur is as $1 : 2\cdot16$ or $1 : 2$ giving us the formula $2RS + SnS_2$ in which $R = Cu_{1/2}$, $Fe_{1/4}$, $Zn + Cd_{1/4}$, which agrees with the formula heretofore accepted for stannite except that a small portion of the zinc in this specimen has been replaced by cadmium.

I have been very explicit in describing the mass from which I obtained this portion of stannite for the reason that about four years ago I found a similar earthy material occurring in patches in the coarse-grained granite of the Etta Mine. I succeeded in obtaining small quantities of this material at various times and finally enough for an analysis. The quantity actually obtained was rather more than 0·5 grm.

Whether it occurs more abundantly at some point in the workings which I have failed to find, I cannot say, but I found it occurring very sparingly. The chief portion of all that I obtained on my various visits to the locality extending over a period of two years was found scattered in small bunches through a large piece of granite which had been removed from its place and carried some distance from the mine. The point at which I found it most abundant in place was in the face of an open cut on the northeast side of the hill together with cassiterite; they are intimately associated with a somewhat laminated feldspar. I have reason to believe that it was more abundant formerly than now, as I came into possession of a specimen taken from the mine, under its first management, which is much richer in this material than any specimen which I have myself been able to find or to subsequently obtain. The association of this material with the cassiterite is more intimate in this specimen than is usual; in only one instance have I seen it more so, namely in a piece of massive cassiterite which has a small depression partly filled with it inclosing fragments of stannite. This is interesting because the specimen was found at the point where this cut was opened, and establishes the identity of the Etta and Peerless material so far as their origin is concerned. An analysis of the best Etta material that I could obtain was made in 1889 and is given here for comparison with one of Peerless material which was made recently. The air-dried material had a dirty green color and gave, after deducting 9·84 per cent gangue:

				Atomic equivalents.		
H₂O	13·87	H	·0154	15·40	14·66	29·3	30
CuO	12·53	Cu	·1021	1·615	1·44	2·88	3
Fe₂O₃	8·94	Fe	·0626	1·119	1	2	2
SnO₂	64·33	Sn	·5061	4·289	3·83	7·66	8
SO₃	trace	O	·3105	19·400	17·38	34·76	35
Sb₂O₅	trace					
ZnO	trace		0·9967			
	99·67					

It is true that we can give an interpretation to the ratios obtained, but a simple and necessary relation between them is not evident. Still if we assume the iron present as xanthosiderite and the copper as cupric hydrate we obtain the following: $Fe_2O_3 2H_2O$, $3Cu(OH)_2$, $5Sn(OH)_4$, $3SnO_2$. This would demand but two more atoms of oxygen than we have really found and this slight violence to the ratios found may be justifiable on the ground that these ratios are only approximate.

The identification of a new mineral, cuprocassiterite, has recently been announced by Mr. Titus Ulke.* The material which served for this identification was also from the Etta Mine and according to his description from the same (?) point in the mine, as no work has been done at this locality for several years, no new openings have been made. Mr. Ulke does not give the detailed results of his analysis but states " Upon analysis 60 per cent Sn, 12 per cent Cu, and 8 per cent H_2O were found with traces of iron and silica." This when calculated into oxides in which form these constituents evidently existed in the material gives :

				At. equiv.	
SnO_2	76·27	Sn	60·00	5·08	5
CuO	15·04	Cu	12·00	1·94	2
H_2O	8·00	H	·888	8·88	9
	————	O	26·43	16·52	16
	99·31				

Mr. Ulke proposes $4SnO_2 + Cu_2Sn(OH)_6$ as the formula corresponding to this analysis. He notices the presence of iron and silica but as the calculated analysis falls less than seven-tenths of one per cent short of one hundred there could have been no considerable quantity of either of these present. This must be an accident, for as I have stated before, the probabilities are strongly in favor of the material serving for the respective analyses being from the same spot, again there can be no doubt but that this material is an alteration product derived from stannite and it is somewhat remarkable that the iron should be so completely removed while the copper and so much of the tin remains in the form of hydrate. The varying composition of this material is not only indicated by the difference in the quantity of iron present but also by the ratios of the anhydrous to the hydrous oxides. Mr. Ulkes gives $4:2$, i. e. $4SnO_2$: $\begin{cases} Cu_2(OH)_2, \\ Sn(OH)_4, \end{cases}$ while my analysis gives $3:9$, i. e. $3SnO_2$: $Fe_2O_3 2H_2O + 3Cu(OH)_2 + 5Sn(OH)_4$ in which the copper is considered as cupric instead of cuprous hydrate.

* Proceeding American Institute of Mining Engineers, meeting of Feb., 1892.

Having a larger quantity of similar but purer material from the Peerless I subjected a portion of it to analysis. The air-dried material loses 5·06 per cent when dried at 100° and the dried mass is so hygroscopic that it regained 4·35 per cent of its original weight when exposed to the atmosphere for forty-five minutes, and after eighteen hours its loss amounted to only a few tenths of a milligram.

This material can be scratched with the finger nail ; absorbs water with avidity and adheres quite strongly to the tongue and has a clayey odor and taste. I found the sp. gr. for two portions of the material 3·312 and 3·374 respectively. Mr. Ulke reports specific gravity nearly 5. Analysis of material dried at 100° :

$$
\begin{array}{llr}
\text{Loss upon ignition} & 8\cdot20 & \\
Fe_2O_3 & 11\cdot85 & \\
CuO & 18\cdot02 & \\
SnO_2 & 46\cdot07 & \Big\} = 84\cdot65 = \text{Soluble in HCl} \\
ZnO,\ CdO & 0\cdot51 & \\
SO_3 & \text{trace} & \\
Sb_2O_3 & \text{trace} & \\
\end{array}
$$

$$
\begin{array}{lll}
\text{Gangue} & 1\cdot68 & 14\cdot64 \quad \text{Insol. in HCl} \\
SnO_2(\text{Fe trace}) & 12\cdot96 & \overline{} \\
& & 99\cdot29
\end{array}
$$

Computing the portion soluble in hydric chloride to 100, we obtain

			Atomic equivalents.				
H_2O	9·68	H	0108	108·	11		$11H_2O$
Fe_2O_3	13·98	Fe	0978	17·46	2		$2Fe_2O_3$
CuO	21·34	Cu	1704	26·96	3		$6CuO$
SnO_2	54·40	Sn	4279	35·41	3·5	2	
$ZnO,\ CdO$	·60	Zn	0048	·74			$7SnO_2$
	100·00	O	[2883]	180·10	18		

This gives no approximation to any simple and evident formula for the portion soluble in hydric chloride. The solution gave no reaction for ferrous oxide even after gentle boiling indicating the absence of any ferrous, stannous or other lower oxide which would reduce the ferric salt under these conditions, while the color of the mass and the bright blue coatings on the fracture planes in the quartz point to the absence of an anhydrous cupric oxide. That the stannic oxide insoluble in hydric chloride is present as such and ought not to be considered as a part of some other combination is indicated by the macroscopic properties already detailed and even more strongly by the deportment of the material in lumps when

treated with hydric chloride, which removes the green, vitreous portion leaving a smaller or larger portion of yellowish stannic oxide, which usually preserves in some degree the form of the original network and sometimes sufficiently well, to show it plainly. I could observe no evolution of carbon dioxide when the powdered mass, thoroughly wet with water, was treated with hydric chloride.

The San Antonio tin ore as described by Professor F. A. Genth of Philadelphia[*] suggests the same problem presented here, but much more involved. In this article he calls particular attention to the fact that a portion of the stannic oxide amounting to 3·86 per cent of the weight of the ore is soluble in hydric chloride and adds that "it is difficult to perceive in which form this tin existed," but adduces proof that it was not present as stannous oxide.

It may justly be urged that my analyses of the Etta and Peerless material are not comparable because they were made by different methods. This is true only in regard to some of the data given by them, it does not change the fact that the constituents are the same but present in varying proportions and it is also probable that no material change was produced by drying at 100° as the water lost and no more was regained. Until fuller and more satisfactory data can be acquired concerning several points relative to this substance it can scarcely be considered as more than a mixture containing one or more hydrated compounds of copper, iron and tin related to the stannates, respectively the metastannates, which are soluble in hydric chloride but for which we cannot at the present time establish a formula.

The almost complete removal of the sulphur, the green and blue stains which are without doubt largely but not wholly due to the copper, found both in the quartz of the Peerless and to a less extent in the feldspar of the Etta, suggest that some of these alteration products are soluble in water and that such salts may have furnished the solutions from which the stannic oxide forming the imitative forms described by Prof. Genth in the article referred to was deposited. This may also help to the explanation of the pseudomorphs of stannic oxide after feldspar, first observed in Cornwall by Mr. Richard Pearce now of Denver, Colo. It seems very probable that such solutions have been the source of the stannic oxide deposited in small irregular patches on some of the spodumene crystals found in the Etta Mine.

State School of Mines, Rapid City, S. D.

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[*] Contribution to Mineralogy, No. XXXI, 1887. Read before American Philosophical Society, March 18th, 1887.

Art. XV.—*The Occurrence of Hematite and Martite Iron Ores in Mexico ;* by Robert T. Hill.

The iron ores of Mexico have been frequently mentioned, but the writer is aware of no attempt to define their position and origin. The admirable paper of Mr. John Birkinbine, the well-known mining engineer, has made known the chemical composition and extent of the famed iron mountain of Durango,* and Prof. B. Silliman has described the peculiar occurrence of martite at this locality.†

The writer has recently studied several deposits of similar iron ores in Mexico, and in August, 1892, gave special attention to the study of certain beds situated on the line of the Mexican International railway, near the city of Monclova, in the State of Coahuila. The mountain in which the ore occurs, like the iron mountain of Durango, is known as the Sierra de Mercado, and is one of the elongated, isolated masses characteristic of the Great Basin region of the United States, of which the so-called Mexican plateau is a geographic continuation, and is surrounded by the customary basin plains, or valleys, filled in by debris of the mountains.

In structure the mountain is composed of sub-vertical strata of a hard blue and gray limestone, very much resembling the familiar Paleozoic mountain limestones of the Appalachian region, but which, in fact, as will be shown is of Mesozoic age. . Through this limestone, in a direction usually corresponding with the strike of its stratification are vast masses of eruptive diorite. which simulate the limestone in color. Inasmuch as this diorite includes large fragments of the limestone in its substance there can be no doubt of its later origin.

The talus which imbeds the base of the mountain, and is widely distributed over the plain, is composed principally of limestone cobble, with a large admixture of rounded lumps of iron ore, black upon the surface, strongly resembling magnetite, but which reveal a lustrous (specular) surface structure upon fracture, and give the streak of hematite. This iron ore is so abundant in the talus that it suggests the fact that the beds from which it was originally derived have long been exposed to denudation.

In ascending one of the numerous lateral cañons at the south end of the mountain, many alternations of the limestone

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* "The Cerro de Mercado (Iron Mountain) at Durango, Mexico, by John Birkinbine," Trans. of the Am. Inst. of Mining Engineers, 1884, pp. 1–19.

† "Martite of the Cerro Mercado, or Iron Mountain of Durango, and Certain Other Ores of Durango, by B. Silliman, this Journal, November, 1882.

and diorite are crossed, all of which strike in the direction of the axial trend of the mountain, with slight local sinuosities. At an elevation of about 1000 feet above the railway which skirts the base of the mountain, and nearly at the summit, the original source of the iron debris of the plain is found in large masses, or pseudo-veins, of ore, the bodies of which occur in a line corresponding with the strike of the limestone diorite contacts, and are principally exposed at the crests of the ridges dividing the lateral cañons. The ore bodies resemble fragments of a vertical vein, but apparently have no direct continuation. They occur along the line of contact between the upper limestone and the diorite, but some of the masses are entirely embedded in the limestone and others in the diorite, while several present a wall of each. The bodies could not be described as lenses, as are the masses of specular ore in either Algonkian or Archæan schist in Llano county, Texas, nor are they true beds, but apparently formed by the replacement of the limestone at the limestone-diorite contact, or replacement of the masses of limestone included in the diorite. The principal outcrops, seen along a north and south line of six miles, were as follows, beginning at the south end of the mountain :

1. The first lateral ridge projecting from the east side of the north end of the mountain is crossed by the vein or bed which upon one side reveals a cross section of 30 feet and an exposure of 250 feet parallel to the mountain crest north and south. 2. On the opposite side of the ridge apparently the same bed reappears with a vertical exposure of 50 feet. 3. In the same line of outcrop is a third exposure of apparently the same mass as No. 1. 4. Northward are two outcrops with areal exposures of 65×32 feet and 150×30 feet respectively. 5. One-half mile north of the above is another outcrop of the ore with a surface area of 30×240 feet. 6 One quarter of a mile northward is the mine known as La Paloma which has been somewhat developed; it has an areal exposure of 45× 200 feet and a vertical face of 50 feet. 7. Still northward is an outcrop resembling No. 2 in quantity exposed. 8. Two miles north and nearest to Monclova is the last outcrop visited ; it has a vertical exposure of 150 feet and a width of 30 feet at the top which rapidly diminishes downward.

All of these masses, from their uniform width and continuity of strike are apparently genetically connected continuously along a structural parting between the diorite and limestone.

The ore presents peculiar mineralogical conditions. Where the interior of the vein is exposed by blasting its mass consists of a bright lustrous (specular) hematite. This would not

be inferred from surface examination, however, for everywhere the mass has the exterior appearance of black magnetite and has been mistaken for this ore by many observers. Close examination of the surface shows it studded with minute granules and the octahedral crystals of martite—a hematitic pseudomorph after magnetite—resembling similar phenomena with the ores of Durango and other Mexican localities described by Prof. B. Silliman.* Of the Durango ores Prof. Silliman said:

"At first sight the octahedral crystals of various sizes suggested only magnetite, but the magnet failed to attract the ore while the streak immediately indicated hematite."

Mr. Birkinbine also notes the resemblance of the Durango hematite to magnetite ; the writer was obliged to make the magnet tests before he was satisfied that the substance was not magnetite. In view of these facts it is necessary to be cautious about accepting the determinations of magnetite made by casual observers in other localities. In most of the outcrops only the hematite and martite could be seen, but in several outcrops, especially the one nearest Monclova, about a foot of limonite could be seen against the hanging wall of the limestone. Prof. Persifor Frazer has mentioned the occurrence of pyrite in the Paloma opening, and says :† "There is the clearest evidence that the iron ore is an alteration product of pyrite, but so complete has been the alteration that a few inches above the line of demarcation between the sulphide and the oxide hardly a trace of the sulphur remains." The writer must confess that after having examined many of these iron masses, he has never seen a trace of the pyrite beds above alluded to.

In chemical composition the ore shows great resemblance to many other localities in Mexico, especially those given by Mr. Birkinbine and Prof. Silliman, as shown by comparison with the following analyses of Paloma made by Mr. Davenport Fisher of Milwaukee, from eighty pure specimens collected by Mr. H. M. Wakefield of the same city:

Iron	64·83	Oxide	92·61
Silica			2·98
Phosphorus	·018		·04
Alumina			4·35
			99·98

No sulphur, manganese, lime, magnesia or titanium were found.

* Martite of the Cerro de Mercado or Iron Mountain, Durango, Mexico, and certain other Ores of Sinaloa, this Journal, Nov., 1882.

† Certain silver and iron mines in the States of Coahuila and Nuevo Leon, New Mexico," Trans. Am. Inst. Mining Engineers, vol. xii, pp. 538–568.

Dr. Frazer "in order to test the value of this ore severely" took a sample across the face inclosed in the pit inclusive of a horse of limestone there visible, and some scattered masses of sandy material, which gave 53·80 per cent of metallic iron." He gives 0·61 to 4·5 of sulphur in the various analyses of this impure sampling.

It is not the purpose of this paper to advance an opinion of the origin of this ore, for the writer is unable to satisfy himself upon this subject, but the opinion of Prof. Frazer that they are altered pyrites is contrary to his observation. The limestone may be looked upon as the most probable source, however, for occurrences of smaller quantities of iron ore have been frequently reported at the contact of igneous and calcareous rocks, and ores of Jalisco are reported entirely surrounded by limestone. It is interesting to note that these masses always occur in the vicinity of eruptive intrusions into the limestone and in some cases are entirely embedded in it. In some of the adjacent Cretaceous limestones was found a small weathered ammonite encrusted with limonite, showing that the limestone contains iron ore and that it concentrates upon the surface. In the silver-bearing fissures and veins of the same limestone which the writer has examined in many parts of Mexico there is always a residuum of excessively ferruginous clay. In the unaltered limestones of the Comanche series in Texas, notably at Austin, there are many nodules of iron oxide, especially in the Washita beds (the horizon of the Monclova limestones) which are the result of alterations of balls of pyrites. Along the veins and faults of Barton creek are deposits of ferruginous clay derived from the apparently pure white chalky limestone. The fissure at the contact of the Comanche limestone and diorite in which these Mexican ores are deposited can readily be explained by the mountain stresses or chemical solution of the limestone. The diorite is cross or double jointed and the fissures are filling with limonite by hydrous deposition, as can be seen in every crevice. We learn that certain Norwegian geologists have thus explained the origin of iron deposits in that country, but it is not proposed to maintain that the Mexican ore bodies so originated, although Barcena the eminent Mexican geologist asserts that in the mineral district of Agostadero, in the State of Jalisco, one can see specular iron ore in process of formation in the feldspathic rocks, through the agency of percolating waters charged with the hydroxide of iron, and percolating into the fissures of the rock.[*]

* Tratado Geologica, etc., por Mariano Barcena; Edicion de la Secretaria de Fomento. Mexico, 1886, p. 90.

The most interesting fact is the unusual geological age of the ore, and its occurrence different from any of our own country, unless the ore at Van Horn, in Trans-Pecos Texas, a part of the same geological province, is similar.*

The principal specular ores of the United States are from the older Paleozoic and Archæan rocks, and as we proceed upward in the geological column they decrease in compactness and in luster. In fact the Mexican ores have a strong resemblance to those of the Superior district, and practical miners often speak of them as identical, a mistake which is further instigated by the Paleozoic aspect of the Mesozoic and Tertiary phenomena of the region. The diorite is called "granitico" by the natives, and is spoken of as granite by one of our prominent mining engineers.† The coal fields of the Sabinas, which extend to within thirty miles of the iron deposits have been often referred to as Carboniferous and Triassic‡ until their Laramie age was shown by Dr. C. A. White, in 1886. The massive Paleozoic-looking limestone is undoubtedly of Lower Cretaceous age, and contains the characteristic Terebratulas, Pectens, Limas, Aviculas, Monopleuras, Ammonites, Radiolites and Nerineas of the Comanche Series of Texas, and is the result of alteration of the same beds which have a chalky aspect in the non-mountainous portion of the latter state. This limestone was published as Silurian by Rock,§ and Frazer received conditional opinions from Prof. Angelo Heilprin and James Hall to the effect that it was probably of Carboniferous age.‖

The diorites, as shown by their intrusion through the Comanche limestone at the Sierra Mercado of Monclova, and through both the limestone and the Laramie beds in the Sierra Candella, are clearly of post-Cretaceous age. Mr. Whitman Cross, of the U. S. Geological Survey, has kindly studied these for me, and his mineralogical notes are appended. His remark that they strongly resemble certain post-Cretaceous eruptives in Colorado, is an important point. These diorites have a wide distribution over the Mexican plateau. It is very evi-

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* The writer has seen masses of ore from Van Horn which resemble in mineralogical characters the Mexican ore.

† Dr. Frazer in the paper already cited, speaks of the diorite both of the Sierra de Mercado of Monclova and of the Carrissal and Villadama regions as " granite."

‡ Mr. W. H. Adams, in an otherwise excellent paper refers these coal fields to the Trias. See " Coal in Mexico: Santa Rosa District," Trans. Am. Inst. Mining Engineers, vol. iii, pp. 25–28, 1874.

§ Report on Examinations of the San Rafael Mining Company's Mines, by Adolphe Rock, Mobile, 1876.

‖ Both of these geologists stated that the paleontologic evidence furnished them by Prof. Frazer was insufficient to accurately determine the age of these limestones, and that their opinions were largely based upon their lithologic characters. See Dr. Frazer's paper, previously cited.

dent that the iron ores are of later age than the rocks in which they occur, and this period was probably near the Eocene, for many of the basin plains of Mexico similar to that of Monclova in which the debris of the iron ore is found, contain the Loup Fork and Equus vertebrate Tertiary faunas of Cope.

Having now described the geology of the Monclova ores as a typical locality of these peculiar Tertiary Mexican martite hematites, it may be well to examine the distribution of similar occurrences in Mexico. The local geology of Monclova, is typical of the geology of the whole of the Mexican mountainous (plateau) region, which may be briefly described as remnants of numerous folds of Comanche limestone (also the Laramie sands and clays in the northeast), frequently broken by protrusions of eruptive material, and separated by basin valleys, largely covered by the debris of the mountains. Only along the southern border of the plateau and in the extreme northwestern States are the older rocks of the Archæan or Paleozoic exposed.* All the following localities of iron ore are from this region of Cretaceous limestone and Tertiary eruptives, with the possible exception of Prof. Silliman's localities in Sinaloa, where Carboniferous limestones also occur as well as the Cretaceous.

The Sierra Candella Beds.—Seven miles west of the town of Salomon de Botia, and about sixty miles east of Monclova near the Mexican National railway, the writer examined several large deposits of ore similar in composition and occurrence to that of Sierra de Mercado at Monclova. Although an entirely different group of mountains from those of Monclova, the Sierra Candella consists of the same Comanche limestone, and dioritic eruptives. The Laramie beds however occur as foot hills on both sides of the Sierra Candella.

The Sierra de Mercado of Durango.—About three hundred miles southwest of the Sierra de Mercado of Monclova is the Sierra de Mercado of Durango, commonly known as the iron mountain of Durango. It was from this locality that the occurrence of martite was first noted by Prof. Silliman. The mountain has been well described by Mr. John Birkinbine† who says, "The hill is nearly a mile long and a third of a mile wide, and from four to six hundred feet high." . ... . "I am inclined to believe that the Cerro de Mercado is formed of one or more immense lenses of specular ore, standing vertically, the fragments of which have for ages been thrown down to

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* The writer has reserved for a future paper the discussion of the general geology of the region.

† Loc. cit.

form the slopes of the mountain as a talus." . . . . " I am free to say that after having visited the iron mines of the United States, I have found nothing as yet to compare as to quantity in sight with the Cerro de Mercado of Durango." Unfortunately there has been no attempt at a description of the geology of this mass except that given by Wiedner,* whose allegation that it is the cone of an ancient volcano is erroneous, as can be seen by referring to Mr. Birkinbine's excellent picture of the mountain which was reproduced in this Journal.† The only mention throwing light upon the nature of the country rock is that given by Prof. Silliman, who says:‡ "From samples of the country rock which I find in Mr. North's collection the (enclosing) walls are of purple porphyry; which would indicate that the Durango mass is accompanied by eruptive rocks as in the other cases mentioned." Inasmuch as the iron has been smelted for many years in primitive furnaces, requiring fluxes without rail transportation, it is very probable that the Comanche limestone (the chief sedimentary rock of Durango) cannot be very far distant from the mines. Prof. Silliman's description of the martite and hematite ores of Durango makes them appear to coincide so perfectly with those of Monclova, that it is difficult to believe otherwise than that the two deposits are geologically related.

Jalisco.—Iron has been smelted for many years in this State, in the vicinity of Tula, southwest of Guadalajara. The deposits have been briefly described by Mr. J. P. Carson.§ According to this writer, the ore occurs in four distinct districts. The Amole mine in the district of Tula is bounded on one side by " a trap dyke" and on the other by a shaly disjointed sand rock. In the other districts the ore occurs under conditions similar to those of Monclova. In the district of Chiquilistlan, Mr. Carson says "the formation is limestone— probably Tertiary—greatly upheaved by volcanic action and penetrated in various directions by volcanic dykes." In the Tecotes mine the "vein is what is termed segregated, occupying a space between parallel seams of limestone." The Los Animas mine, which he says can be traced for a distance of over one thousand feet is also in a segregated vein of limestone." These limestones, instead of being Tertiary, as conditionally stated by Mr. Carson, are very probably the Comanche limestones of the Cretaceous, for Barcena describes them as Cretaceous and gives a list of fossils which are char-

* Quoted by Mr. Birkinbine.
† See Prof. Silliman's paper previously cited.   ‡ Loc. cit.
§ Iron Manufacture in Mexico, by J. P. Carson; Trans. Am. Inst. Mining Engineers, vol. vi, 1887–88, pp. 399–415.

acteristic Comanche species.   The latter author also publishes
a map of Jalisco, in which the eruptive rocks in the vicinity
of these mines are for the most part called dioritic.*

Sinaloa.—Prof. Silliman, in the valuable paper referred to,
describes several occurrences of martite in Sinaloa.   Almost
nothing is known of the general geology of this State, but
from the descriptions given of the ores at Tepuche, Bescuino
and Cosolu, the conditions seem similar to those of Durango
and Monclova.   He says that the iron of Tepuche " occurs in
a porphyry resembling that of the Sierra de Mercado " (of
Durango), and that those of Cosolu are surrounded by calcare-
ous rocks.   The localities also yield magnetite.

Hidalgo, Mihoacan, Queretaro, Zacatecas and San Luis.—
There are many references to ores in these States in the Mexi-
can geological literature, which lead to the inference that they
are of the same character as those we have described.   In
Queretaro, Barcena mentions the occurrence of a hematite
which he "believes is contemporaneous with the porphyry."
He also describes the occurrence of hematite associated with
tin in a Tertiary porphyry in the Meza de los Caballos of
Zacatecas.   In Hidalgo he says there are large beds of hema-
tite, mixed with magnetite, in the post-Cretaceous formations.
He refers to many other localities in the States of Jalisca,
Durango and Mihoacan, and says that these ores constitute the
chief deposits of iron in the republic.†   Virlet‡ mentions the
occurrence of iron ore at the contact of limestone and diorite
in the eastern Sierra Madres, in the State of San Luis.

Guerrero.—One of the most interesting descriptions of iron
ore in Mexico is that given by Manross in this Journal for
May, 1865.   He mentions eight localities of the occurrence of
iron ore in Guerrero, which, with the exception of his age
determinations, greatly resemble the Monclova and Durango
deposits.   " The first of these is situated at a distance of four
miles from Mescala.   It is a vein twenty five feet wide and
nearly vertical, and consists of solid magnetite ore."   Another
is " three hundred feet high, half a mile long and fully one-
third of its bulk is pure magnetic ore."   It "contains a bed of
limestone at its summit."   Another is four hundred yards
long and one hundred yards wide.   The unfortunate death of
this young student renders it impossible to ascertain further
data from him concerning the ores.   At the time he wrote his

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* Ensayo Estadistico del Estado de Jalisco, etc, por Mariano Barcena.   Mexico,
1891.

† These notes are taken from various observations following the mineral de-
scriptions in Barcena's " Tratado," already quoted.   Other notes on iron are
found in his various statistical essays on the separate States of Mexico.

‡ Coup d'œil général de la topographie et la géologie du Mexique, etc., par M.
Virlet d'Aoust, Bull. Soc. Géologique de France.   1866.

descriptions, however, the massive Cretaceous limestones of Mexico were generally supposed to be of Paleozoic age, and the difficulties of liability to mistake the superficial martite of the hematite deposits for magnetite has already been cited in the experiences of Mr. Birkinbine, Prof. Silliman and the writer. Mr. Manross himself remarks that "what is still lacking is the evidence of the fossils" to prove that a coal vegetation has once existed in these latitudes." Señor Castillo, upon his geological map of Mexico gives no sedimentaries of Paleozoic age in this region, the only ones indicated being Cretaceous. He does give metamorphic and primitive rocks however and eruptives, and the Archæan which has been reported east of this State may extend into it.

In conclusion it may be said that the occurrence of such large masses of hematite in rocks of Cretaceous and Tertiary age is of great interest, and that the Mexican ores of this character, accompanied by martite have a wide occurrence in that republic, which will be an important factor in the future iron supply of the world. Prof. Frazer remarks that it would pay to import these ores for mixture, as Cuban ores are now imported. Ten years ago Prof. Silliman said of the Durango iron : "The enormous mass of valuable iron ore, thanks to the near approach of the railway of Mexico, is now likely to become of commercial importance." Exactly ten years from the month of publication of his article the Mexican International railway celebrated the completion of its line to the foot of the Durango iron mountain, connecting it by rail with the coal fields of the Sabinas, and the prophecies of Profs. Silliman and Birkinbine are on the eve of fulfillment.

The accompanying note by Mr. Whitman Cross upon the eruptive rocks of Coahuila are of interest in connection with the discussion of the iron deposits. The general geology of the region will be given in another paper.

Igneous rocks from the Coal and Iron regions of Coahuila and Nueva Leon, Mexico, collected by R. T. Hill; by WHITMAN CROSS.

1. *Basalt overlying Laramie coal fields.*—Mesa, 6 miles east of Santa Rosa de Musquez. A rock of simple normal constitution. *Olivine* crystals in various stages of decomposition are the only porphyritical constituent. Groundmass of small plagioclase staves and augite grains. There seems to be no

magnetite in usual form, but a black substance occurs in angu
lar spaces between other minerals. This seems to be secondary.
There is no glass base.

Composite quartz grains are surrounded by zones of augite
as described by Iddings, Diller and others.

2. *Diorite from Sierra Mercado of Monclova.*—A quartzose
hornblende-diorite. The rock is a mass of small stout plagio-
clase crystals and irregular hornblende prisms pressed close
together with quartz as the chief cementing substance though
there is probably a little orthoclase, and plagioclase also, as
interstitial matter. This rock is quite different mineralogically
from the diorite of Sierra Candella.

3. *Hornblende-porphyrite.*—The rock has hornblende and
plagioclase phenocrysts in a prominent finely granular crypto-
crystalline groundmass. It might be a porphyritic equivalent
of diorite No. 2.

4. *Vein matter in diorite.* — A fine-grained mixture of
orthoclase and quartz. Has no microcline or micropegmatite,
or plagioclase. Is like vein matter commonly found in granite
or diorite masses.

5. *Hornblende-porphyrite.*—Hornblende and plagioclase are
the main phenocrysts and the groundmass is unevenly granu-
lar, orthoclase being the chief substance. There is very little
if any quartz.

7. *Augite-diorite.*—Sierra Candella. This rock is chiefly
made up of a dark green augite in imperfect prisms, plagio-
clase in tablets with very strongly marked zonal structure, and
orthoclase, the latter surrounding the plagioclase in a regular
growth. There is some biotite, occasionally appearing in
blades nearly an inch long ; hornblende is intergrown with
augite in the outer zone of some crystals. It is never very
intricately intergrown with augite. Quartz occurs in a few
small grains, and magnetite, titanite, apatite and zircon, are
accessory as usual.

This rock differs in composition from the other diorite in
the presence of augite in place of hornblende, and in the
abundance of orthoclase.

These diorites are deep-seated eruptives similar in composi-
tion to several Colorado occurrences which were erupted in
some period not long after the Cretaceous, as they cut upper
Cretaceous strata, but are affected by orographic movements
of early Tertiary time.

The porphyrites are no doubt equivalent to the diorites, but
from smaller masses and perhaps consolidated nearer the sur-
face.

ART. XVI. — *On the Cæsium- and the Potassium-Lead Halides ;* by H. L. WELLS.

As a continuation of the work on double halides, in this laboratory,[*] a study of the cæsium-lead salts has been undertaken by Messrs. G. F. Campbell, P. T. Walden and A. P. Wheeler. These gentlemen have carried out the investigation with much enthusiasm and skill, and I take pleasure in expressing my obligations to them. They have established the following salts :

$$Cs_4PbCl_6 \qquad Cs_4PbBr_6 \qquad \text{------}$$
$$CsPbCl_3 \qquad CsPbBr_3\dagger \qquad CsPbI_3$$
$$CsPb_2Cl_5 \qquad CsPb_2Br_5 \qquad \text{------}$$
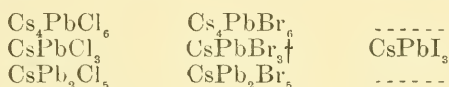
These results showed the existence of three types of lead double halides, the first of which fails to conform with Remsen's law[‡] concerning the composition of this class of bodies.

Since the recent investigations of Remsen and Herty[§] had indicated the existence of only a single type of potassium-lead halides, a new investigation of these seemed desirable, especially since these authors had denied the existence of Boullay's salt,[ǁ] K_4PbI_6, which corresponds to one type of the new cæsium compounds. I have, therefore, undertaken this work and, as a result, have obtained the following salts :

$$\text{--------} \qquad K_2PbBr_4 \cdot H_2O \qquad \text{--------}$$
$$3KPbCl_3 \cdot H_2O \quad \left\{ \begin{array}{l} 3KPbBr_3 \cdot H_2O \\ KPbBr_3 \cdot H_2O \end{array} \right\} \quad KPbI_3 \cdot 2H_2O$$
$$KPb_2Cl_5 \qquad KPb_2Br_5 \qquad \text{--------}$$
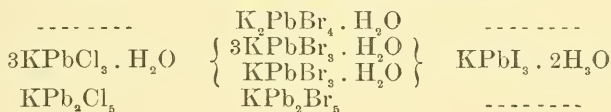
It is to be noticed that neither Boullay's iodide nor any corresponding chloride or bromide was obtained among these salts. On the other hand, the compound $K_2PbBr_4 \cdot H_2O$ belongs to a type which had not been discovered among the cæsium salts, so that, taking the cæsium and potassium series together, the existence of four types of double lead halides is shown.

The compound K_2PbBr_4, the anhydrous form of the salt just mentioned, is ascribed to Löwig,[¶] but although iodides belonging to the same type have been described, $K_2PbI_4 \cdot 4H_2O$ by Ditte[**] and $K_2PbI_4 \cdot 2H_2O$ by Berthelot,[††] neither Remsen

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* This Journal, III, xliv, 155, 157 and 221.
† This compound is dimorphous.   ‡ Am. Chem. Jour., xi, 296.
§ Am. Chem. Jour., xiv, 107.   ǁ Ann. Chim. Phys., II, xxxiv, 336 (1827).
¶ Gmelin's "Handbook," English Ed. of 1850, v, 162.
** Ann. Chim. Phys., V, xxiv, 226, 1881.
†† Ann. Chim. Phys., V, xxix, 289, 1883.

and Herty nor I have been able to prepare them. Although these iodides and Boullay's salt, K_4PbI_6, belong to types which certainly exist, I am inclined to believe, with Remsen and Herty, that the products which gave these formulæ were mixtures of $KPbI_3 . 2H_2O$ and KI. The absence of more than one iodide in the cæsium series strengthens this view.

Remsen and Herty obtained the salt $KPbI_3$ $2H_2O$ under wide variations of conditions and I have confirmed their results. This salt was first obtained by Boullay* and analyzed by him, after drying over lime, in an anhydrous condition. Berthelot† has described a compound, $K_4Pb_3I_{10} . 6H_2O$, which differs but slightly in required composition from the above salt, and his description of it agrees with that compound. There is no doubt, therefore, that he really obtained the compound $KPbI_3 . 2H_2O$ and that his analyzed products were slightly contaminated with potassium iodide. Berthelot attributes $K_4Pb_3I_{10}$ to Boullay. The latter chemist, however, derived the correct formula, equivalent to $KPbI_3$, from his analysis, but since this did not agree closely with theory, Gmelin‡ derived the above-mentioned formula from it, and this has been frequently copied in more recent chemical literature.

Schreinemakers,§ in connection with an investigation on the equilibrium of the double salt of iodide of lead and potassium in aqueous solution, has assumed that Ditte's formula was correct as far as the composition of the anhydrous compound was concerned. By making a number of water determinations, without determining lead, potassium or iodine, he arrived at the formula $K_2PbI_4 . 2\frac{1}{2}H_2O$. It is absolutely certain, from his description of the salt and his method of preparing it, that he had the compound $KPbI_3 . 2H_2O$; moreover, his water determinations, 5·52, 5·72, 5·89, 5·93 and 5·16 per cent, agree satisfactorily with the calculated amount, 5·90, for this salt.

Remsen and Herty made only a single chloride, and likewise only one bromide. The other chloride, and the two bromides belonging to other types crystallize beautifully and are as easily made as the salts which they prepared, and it is a strange coincidence that the latter happened to correspond in type to the iodide which they had obtained. I have confirmed the composition of their bromide, $KPbBr_3 . H_2O$, but their chloride, to which they gave the formula $KPbCl_3$ is evidently identical with the compound which I have found to be undoubtedly hydrous, $3KPbCl_3 . H_2O$.

* Ann. Chim. Phys., II. xxxiv, 336, 1827.
† Ann. Chim. Phys, V, xxix, 289, 1883.
‡ ' Handbook," English ed., 1850, v, 161.
§ Zeitschr. Physikal. Chem., ix, 57, 1892.

Löwig, as already mentioned, has described the compound K_2PbBr_4. I have been unable to find his original article, but from the fact that I have not obtained an anhydrous form of this compound, I believe that he overlooked the water of crystallization or dehydrated the salt before analyzing it.

A bromide, $K_2Pb_3Br_8$ is mentioned by Berthelot.[*] He does not give any analysis or description of it, and I am convinced from my own experiments that he obtained a mixture of $KPbBr_3 \cdot \frac{1}{3}H_2O$ and KPb_2Br_5.

Strohecker[†] states that he produced three different chlorides of potassium and lead by mixing potassium chloride and lead nitrate solutions. It is remarkable, considering the abundance and cheapness of the materials and the ease with which large quantities of the double salts can be made, that he did not obtain them in sufficient quantities for exact analyses. Since I have succeeded in making only two double chlorides, I believe that one of Strohecker's salts, which he describes as feathery, was simply lead chloride.

The results of previous investigators may be summed up by saying that it is probable that no potassium-lead halides have been correctly described, if water of crystallization is taken into consideration, except two of Remsen and Herty's salts, $KPbBr_3 \cdot H_2O$ and $KPbI_3 \cdot 2H_2O$.

Method of Preparation.

Both the cæsium and potassium salts have been investigated, in every case, by making hot, aqueous solutions of the component halides and cooling to crystallization. Some previous investigators had used solutions of lead nitrate and an alkaline halide for the purpose, but their example has not been followed, because it was not believed that the presence of an alkaline nitrate would in any way facilitate the operation, and it was feared that it might incur contamination in some cases. The conditions were gradually varied from a point where the alkaline halide crystallized out, to a point where the lead halide was deposited uncombined, and the experiments were so carefully carried out and so frequently repeated that it seems scarcely possible that any double salt was overlooked.

The salts have been made on a rather large scale. In the case of the cæsium compounds, the rarity of the material made it necessary to perform the separate experiments with only about 50 or 75 grams of a cæsium halide, but in making the potassium salts 400 or 500 grams of a potassium halide were frequently used.

* Ann. Chim. Phys., V. xxix, 289, 1883.
‡ Jahresbericht, 1869, 282.

Solutions which were neutral or slightly acid were generally used. The effect of the presence of a large amount of free acid, hydrochloric, hydrobromic or hydroiodic, as the case required, was also carefully studied, but these had no apparent effect upon the results.

Very large crops of the potassium salts were sometimes formed, so that the homogeneity of the mass was doubtful. In such cases the greater part of the crop was removed and satisfactory crystals were obtained by dissolving the remainder in the mother-liquor by the aid of heat and cooling.

The cæsium material used was wholly from the pollucite of Hebron, Maine.[*] The salts were carefully purified for this investigation. Godeffroy's method[†] was found to be very satisfactory for the purpose of separating cæsium from the sodium and potassium which accompany it in the mineral.

Kahlbaum's potassium chloride, bromide and iodide were usually used for making the potassium salts, but for a few experiments the ordinary medicinal potassium bromide was substituted. Since some of the analyses of the double bromides show an excess over 100 per cent, it is suspected that the salts contained a little chlorine. Calculation shows that one per cent of chlorine replacing bromine would cause an excess of 0·71 per cent if the chlorine was weighed as silver chloride and calculated as bromine.

The lead halides which were used were prepared by ourselves from reliable materials.

General Properties.

The lead double halides are all decomposed by water, and the presence of a large excess of the alkaline halide is necessary for the formation of all the compounds to be described except $CsPb_2Cl_5$ and $CsPb_2Br_5$, which are almost stable with water. The concentration of the alkaline halide solution evidently determines, in the cases of the chlorides and bromides, the type of salt produced. Since the simple cæsium halides are much more soluble than those of potassium, it is possible to use them in much more concentrated solutions, and the salts Cs_4PbCl_6 and Cs_4PbBr_6 are readily obtained. In the case of potassium bromide the solution becomes saturated with the simple salt by concentration just beyond the point where $K_2PbBr_4 . H_2O$ is obtained, and with potassium chloride, which is less soluble than the bromide, the limit is reached at the compound $3KPbCl_3 . H_2O$. The apparent existence of only a single double iodide, both with cæsium and potassium, is remarkable since cæsium iodide is

very soluble and potassium iodide is much more soluble than the bromide and chloride.

On account of their decomposition by water, no determinations of the solubility of the double halides have been made, but it was noticed that the cæsium compounds were much less soluble in the saline solutions than the corresponding potassium salts. This relation corresponds with the observation of Godeffroy,[*] that while the simple salts increase in solubility from potassium to cæsium, the double and complicated salts show a decrease in this direction.

All the chlorides and bromides described in this article are colorless, or in one case nearly so, except two cæsium salts, $CsPbCl_3$ and one modification of $CsPbBr_3$. The first of these is pale yellow and the other bright orange. These colors are very remarkable since the simple halides from which they are made are all colorless. I have previously observed a similar case, where a colored double halide was formed from two colorless halides, in the compound $CsHgBr_3$.[†] Both double iodides are yellow, the hydrous potassium salt being the paler of the two.

Analytical Methods.

Great care was used in selecting homogeneous material for analysis. The crystals were dried as rapidly and thoroughly as possible by pressing them between smooth filter-papers, and where the substance did not lose its luster by the operation, it was then exposed to the air for several hours.

Water was determined by collecting and weighing it in a calcium-chloride tube, the substance being ignited in a combustion-tube, behind a layer of dry sodium carbonate, in a current of dry air. The water lost over sulphuric acid or at certain temperatures was determined by the usual methods.

Lead was determined in two ways. With all the cæsium salts the substance was dissolved in hot water (an easy operation with all these salts, but impracticable in the case of some of the potassium compounds), and all except a trace of lead was precipitated by ammonium carbonate in presence of ammonium hydroxide. The precipitate of lead carbonate was removed by filtration and the remaining trace of lead was precipitated by passing hydrogen sulphide into the alkaline solution. The lead sulphide was collected and ignited by itself in a porcelain crucible. The amount of this was so small that it was evident that no appreciable error would arise from any lead sulphate that the ignited residue might contain, so that the main precipitate of lead carbonate was ignited in the same

[*] Berichte d Chem. Ges., ix, 1365.　　　[†] This Journal, III, xliv, 227.

crucible and the whole was weighed and calculated as lead oxide. A different method was selected for the determination of lead in the potassium compounds, for the reason that some of them could not be readily dissolved in hot water, and it was found to be more convenient and expeditious than the other. About one gram of substance was dissolved in about 10^{cc} nitric acid (sp. gr. 1·20), about 2^{cc} concentrated sulphuric acid, previously diluted with water were then added and the nitric acid was removed by evaporation. After diluting with about 25^{cc} of water and cooling, the lead sulphate was collected in a Gooch crucible, washed with very dilute sulphuric acid, ignited and weighed.

In order to determine cæsium, the alkaline solution from which the lead had been removed was concentrated until the ammonium carbonate, hydroxide and sulphide had been nearly or quite removed, a small excess of sulphuric acid was added, and, after evaporation and ignition, normal cæsium sulphate was obtained by igniting in a current of air containing ammonia and this was weighed.

The filtrates from the lead sulphate did not contain an appreciable amount of lead. Normal potassium sulphate was obtained from these solutions by evaporating, igniting and heating in an ammoniacal atmosphere.

The halogens were determined as silver halides. Where the substance could be completely dissolved in hot water, an excess of silver nitrate was added to the hot solution and it was afterwards acidified with nitric acid. When it happened that the lead halide remained partly undissolved, the nitric acid was not added until this had been completely decomposed by long digestion on the water-bath with an excess of silver nitrate. The precipitates were collected and weighed in Gooch crucibles.

The Cæsium-Lead Chlorides; by G. F. Campbell.

Cs_4PbCl_6.—When lead chloride is dissolved, by the aid of heat, in a solution of cæsium chloride which is so concentrated as to be nearly saturated when cold, this salt is deposited on cooling in the form of brilliant, white rhombohedrons. Crystals having a diameter of 2 or 3^{mm} were sometimes obtained. Two entirely separate crops were analyzed, both of which were undoubtedly free from other compounds.

	Found.		Calculated for Cs_4PbCl_6.
Cæsium	55·60	56·03	55·90
Lead	----	21·63	21·75
Chlorine	21·97	22·23	22·35
		99·89	100·00

$CsPbCl_3$.— On gradually diluting the concentrated solution of cæsium chloride, such as was used in making the previous salt, and dissolving lead chloride in it as before, a point is soon reached where short prismatic crystals of small size and of a pale yellow color are deposited on cooling. Three different crops of apparently pure crystals were analyzed.

		Found.		Calculated for CsPbCl₃.
Cæsium	31·33	30·54	30·13	29·79
Lead	44·99	45·28	46·29	46·36
Chlorine	23·85	23·75	23·71	23·85
	100·17	99·57	100·13	100·00

$CsPb_2Cl_5$.—Experiments with still more dilute solutions, carried out in a similar manner, gave, under wide variations of conditions, this salt in the form of thin white plates which were often several millimeters in diameter. These plates presented marked variations in habit, which were apparently due to changes in the conditions under which they were made. In two crops, of which A and B are the analyses, the plates were uniformly rhomboidal in form. Two other crops, C and D, were made up of lengthened plates, so twinned as to form feathery aggregates. In another crop, E, made from a more dilute solution than the others, the plates were apparently square.

	A.	B.	Found. C.	D.	E.	Calculated for CsPb₂Cl₅.
Cæsium	19·99	18·44	18·27	....	18·45	18·36
Lead	57·14	57·16	57·06	56·98	57·08	57·16
Chlorine	....	24·47	....	24·52	24·35	24·48
		100·07			99·88	100·00

The three different habits in which this salt crystallizes are so distinct in appearance that, before the samples were analyzed, it was supposed that they were separate compounds. It appears probable that the compound is at least dimorphous.

The Cæsium-Lead Bromides ; by P. T. Walden.

Cs_4PbBr_6.—This salt is produced, in concentrated solutions, similarly to the corresponding chloride. Like the latter salt it forms white rhombohedrons. The crystals were usually not over 1 or 2^{mm} in diameter. Two separate crops were prepared and analyzed.

	Found.		Calculated for Cs_4PbBr_6.
Cæsium _ _ _ _ _ _ _ _ _ _ _ _	43·61	43·42	43·64
Lead _ _ _ _ _ _ _ _ _ _ _ _ _	16·83	16·83	16·98
Bromine _ _ _ _ _ _ _ _ _ _ _	39·24	39·33	39·38
	99·68	99·58	100·00

$CsPbBr_3$.—This compound is dimorphous. One modification forms small prisms of a bright orange color, the other is pure white and crystallizes in slender needles. The orange salt is obtained when lead bromide is dissolved in somewhat more dilute solutions of cæsium bromide than those required for the formation of Cs_4PbBr_6, and there is a narrow range of conditions where it crystallizes upon the latter salt. There is, therefore, no evidence of the existence of an intermediate compound, Cs_2PbBr_4, corresponding to one of the potassium-lead bromides. Whenever solid lead bromide is added to a concentrated solution of cæsium bromide, it instantly loses its white color and takes on that of the orange salt. The white needles are formed in solutions which are slightly more dilute than those required for the orange modification. The limits of the conditions, under which this white salt is formed, are very narrow and a great many trials were necessary before satisfactory crops were obtained. Two distinct samples of each salt were analyzed. The white needles were not absolutely free from the orange compound, but there is no doubt that they were sufficiently pure to show their composition accurately.

	Found.				Calculated for $CsPbBr_3$.
	Orange salt		White salt.		
Cæsium _ _ _	23·19	23·13	23·02	22·49	22·93
Lead _ _ _ _ _	35·69	35·39	35·24	35·88	35·69
Bromine _ _	41·37	41·34	41·47	41·45	41·38
	100·25	99·86	99·73	99·82	100·00

On heating the white modification to about 140°, it gradually assumes the exact color of the orange salt, without changing its external form, and this color is permanent on cooling.

$CsPb_2Br_5$.—This salt is produced in solutions which are still more dilute than those from which the preceding compounds are obtained. It was first noticed at a volume of about 160^{cc} of a solution containing about 50^g of cæsium bromide. It continued to form, on further dilution and the addition of lead bromide, until the volume reached 1250^{cc}, when lead bromide began to be deposited. The conditions under which the salt is formed are, therefore, very wide. The

compound crystallizes in thin, white plates, which, like the corresponding chloride, present considerable differences in habit. Plates having a diameter of about 5^{mm} were sometimes obtained. Three separate crops of crystals were analyzed.

		Found.		Calculated for $CsPb_2Br_5$.
Cæsium	14·13	14·35	- - - -	14·05
Lead	43·39	43·72	43·45	43·71
Bromine	42·23	42·21	- - - -	42·24
	99·75	100·28		100·00

The Cæsium-Lead Iodide, and some Mixed Double-Halides ; by A. P. Wheeler.

$CsPbI_3$.—Under a great variety of conditions this was the only double iodide that could be produced. The compound is but slightly soluble in hot cæsium iodide solutions, so that the crops obtained were always small. It forms very slender, rectangular prisms which are yellow in color. The following analyses were made on separate products :

	Found.		Calculated for $CsPbI_3$.
Cæsium	17·90	- - - -	18·45
Lead	28·38	27·40	28·71
Iodine	52·83	52·57	52·84
	99·11		100·00

Three double salts have been made by dissolving lead bromide in solutions of cæsium chloride. The analyses show that the two salts do not combine unchanged, but that there is usually an extensive exchange of halogens. Each of the products must be considered, therefore, as a mixture of a double chloride with the corresponding double bromide.

$Cs_4Pb(Cl, Br)_6$.—This was produced in rhombohedrons, like the chloride and bromide. Two crops were analyzed.

	Found.	
Cæsium	54·65	55·50
Lead	19·30	18·61
Chlorine	15·89	19·90
Bromine	9·52	4·03
	99·36	98·04
Ratio, Br : Cl	1 : 3·8	1 : 11·2

$CsPb(Cl, Br)_3$.—This occurred in small rectangular prisms, like the chloride and bromide and having a yellow color intermediate between them.   Two crops gave the following analyses :

	Found.	
Cæsium _____	30·24	30·50
Lead _____	44·23	43·55
Chlorine _____	21·44	18·94
Bromine _____	4·00	8·79
	99·91	101·96
Ratio Br : Cl_____	1 : 12	1 : 4·8

$CsPb_2(Cl, Br)_5$.—This was obtained in white plates resembling the two double salts.   Two products were analyzed.

	Found.	
Cæsium _____	18·94	. . . .
Lead _____	51·40	51·97
Chlorine _____	16·29	19·31
Bromine _____	13·27	8·62
	99.90	
Ratio Br : Cl_____	1 : 2·8	1 : 5

The Potassium Lead Halides.

In studying these bodies care has been taken to record the conditions under which they were made.   These conditions, in many cases are only approximately given, because uncertain quantities of salts had often been removed from the solutions, either for analysis or in order to obtain smaller and better crops of crystals.   A large number of analyses have been made in some cases.   This was due to the fact that the salts often varied so little in appearance that it was necessary to analyze many products in order to identify them and to be certain that they were not different compounds.

$3KPbCl_3 . H_2O$.—When lead chloride is dissolved in a hot solution of potassium chloride which is so concentrated as to be nearly saturated when cold, this double salt is deposited on cooling.   It forms brilliant prismatic crystals which are largest in the most concentrated potassium chloride solutions.   The largest crystals obtained had a length of more than 10^{mm} and a diameter of 1 or 2^{mm}.   It was noticed that, when sufficiently concentrated solutions were used, pure potassium chloride crystallized upon this compound, and no evidence was obtained of the existence of a double salt containing a larger proportion of potassium chloride than this.

The following table gives the approximate conditions under which the five samples which were analyzed were made.

	KCl.	PbCl₂.	Volume.	Volume for 1gKCl.
A	400^g	30^g	1100^{cc}	$2\frac{3}{4}^{cc}$
B	400	80	1200	3
C	150	40	450	3
D	100	25	350	$3\frac{1}{2}$
E	300	55	1300	$4\frac{1}{3}$

The results of the analyses are as follows :

	A.	B.	C.	D.	E.	Calculated for 3KPbCl₃ . H₂O.
K	11·38	11·10	10·79	----	----	10·90
Pb	57·46	57·68	57·43	57·94	57·14	57·73
Cl	29·91	29·87	29·81	----	----	29·70
H₂O	1·45	1·39	----	1·51	1·88	1·67
	100·20	100·04				100·00

All the samples were thoroughly air-dried before they were analyzed. By this treatment the crystals did not lose any of their luster. A finely pulverized portion of sample A lost only 0·02 per cent in weight after standing over concentrated sulphuric acid for eight days. The same sample suffered an additional loss of 0·23 per cent when heated for twelve hours in a steam drying-oven. The water was not rapidly given off until a temperature of about 200° was reached. The salt decrepitates when heated rapidly to about 200°, corresponding in this respect to the salt which Remsen and Herty described as anhydrous and to which they gave the formula $KPbCl_3$. There can be no doubt, therefore, that Remsen and Herty's formula is incorrect.

KPb_2Cl_5.—This salt is formed in more dilute solutions than those which produce the previously described compound. It occurs, like that compound, in white prismatic crystals, but it differs considerably from it in luster and form, so that the two salts can be distinguished by microscopic examination. The salt under consideration is anhydrous, and this fact makes it easy to distinguish this compound, when pure, from the other.

Four analyzed crops were made under the following conditions :

	KCl.	PbCl₂.	Volume.	Volume for 1gKCl.
A	200^g	50^g	1500^{cc}	$7\frac{1}{2}^{cc}$
B	150	30	1100	$7\frac{1}{3}$
C	150	20	1100	$7\frac{1}{3}$
D	250	55	1200	$4\frac{8}{10}$

The analyses were as follows:

	A.	B.	C.	D.	Calculated for KPb_2Cl_5.
Potassium	6·14	5·97	6·18	6·07	6·20
Lead	64·74	66·43	65·85	65·72	65·65
Chlorine	28·11	----	28·13	28·08	28·15
Water	0·11	----	----	----	0·00
	99·10	100·16	99·87		100·00

There was no indication of the formation of any other double chloride as the dilution was increased beyond that given for the above products, and when a solution containing 1^g of KCl in 11^{cc} was used pure lead chloride was deposited.

$K_2PbBr_4 . H_2O$.—This salt is obtained by dissolving lead bromide in the most concentrated solutions of potassium bromide. It forms brilliant, prismatic crystals which are permanent in the air. The largest of these which were obtained were about 1^{mm} in diameter and 5^{mm} in length. A number of crops were made under the following conditions:

	KBr.	PbBr₂.	Volume.	Volume for $1g$KBr.
A	400^g	70^g	700^{cc}	$1\frac{3}{4}$
B	400	90	700	$1\frac{3}{4}$
C	400	120	800	2
D	400	130	650	$1\frac{6}{10}$
E	500	130	850	$1\frac{7}{10}$
F	500	130	775	$1\frac{6}{10}$

These products gave the following analyses:

	K.	Pb.	Br.	H_2O.	
A	12·51	34·25	51·47	2·50	= 100·73
B	12·21	34·59	51·21	2·51	= 100·52
C	11·89	34·47	51·14	2·44	= 99·94
D	12·37	34·50	51·35	----	
E	----	34·26	51·40	2·61	
F	12·70	33·89	51·46	2·57	= 100·62
Calculated for $K_2PbBr_4 . H_2O$	12·55	33·21	51·35	2·89	= 100·00

This salt is apparently stable in the air, but it loses water very slowly over sulphuric acid. A finely powdered sample of A lost 0·23 per cent after remaining 12 hours in the desiccator, and the same portion suffered an additional loss 0·33 after eight days. A sample which was not pulverized lost only 0·09 per cent in 12 hours and, in addition, 0·17 per cent in eight days. About one-half of the water went off when the substance was heated for 12 hours in a steam drying-oven. At 200° the water is rapidly and completely expelled.

$3KPbBr_3 . H_2O$.—The conditions under which this salt can be made are rather narrow, and these conditions encroach upon those of the preceding compound, so that small differences in the amounts of lead chloride used or in the temperature of the solution are sufficient to cause the formation of the other salt. It forms brilliant, colorless, lozenge-shaped crystals which can be easily distinguished from the other compound. The crystals which were obtained sometimes had a diameter of 2 or 3^{mm}.

The crops analyzed were made under the following conditions:

	KBr.	PbBr₂.	Volume.	Volume for 1gKBr.
A	500^g	130^g	950^{cc}	$1\frac{9}{10}$
B	500	130	1050	$2\frac{1}{10}$
C	500	140	900	$1\frac{8}{10}$
D	500	120	1050	$2\frac{1}{10}$
E	500	120	1125	$2\frac{1}{4}$

The analyses were as follows:

	K.	Pb.	Br.	H₂O.
A	8·44	41·91	....	1·29
B	8·02	42·71	48·95	1·62 = 101·30
C	8·60	41·61	49·16	1·60 = 100·97
D	8·08	42·69	48·91	1·14 = 100·82
E	....	42·61	....	1·17
Calculated for 3KPbBr₃ . H₂O	7·95	42·06	48·77	1·22 = 100·00

The salt is stable in the air. A sample, after standing seven days over sulphuric acid, lost only 0·04 per cent. The water is given off very slowly at 100°.

$KPbBr_3 . H_2O$.—This salt was described by Remsen and Herty. At summer temperature, about 25°, I was unable to obtain it, but by placing the mother-liquors from the preceding salt in an ice-chest, beautifully crystallized crops of it were obtained.

Its formation was also noticed at laboratory temperatures when the weather was somewhat cooler than in mid-summer. It forms prismatic crystals. Some of those obtained were about 10^{mm} long and 2^{mm} in diameter. Two crops were analyzed.

	Found.		Calculated for KPbBr₃ . H₂O.
Potassium	8·24	7·90	7·76
Lead	41·23	41·20	41·06
Bromine	47·81	....	47·61
Water	3·28	3·64	3·57
	100·56		100·00

The salt is usually permanent in the air, but in dry weather the crystals gradually become opaque, and over sulphuric acid about two thirds of the water is rapidly given off.

KPb_2Br_5.—This salt crystallizes in square plates, sometimes 3 or 4^{mm} in diameter. It can be readily distinguished from the other double bromides, not only by its form, but from the fact that it quickly assumes a pale green color when exposed to daylight. On long exposure, or in direct sunlight, this color changes to a pale dirty-brown. I have observed that lead bromide itself becomes nearly black on long exposure to daylight. This fact does not appear to be generally known.

The samples analyzed were made under the following conditions :

	KBr.	PbBr₂.	Volume.	Volume for 1g KBr.
A	400^g	130	1050^{cc}	$2\frac{2}{3}$
B	400	150	1250	$3\frac{1}{8}$
C	200	75	1000	5

The results of the analyses are as follows :

	A.	B.	C.	Calculated for KPb₂Br₅.
Potassium	4·75	4·75	4·71	4·58
Lead	49·22	49·11	48·48	48·53
Bromine	47·03	46·98	46·89	46·89
	101·00	100·84	100·08	100·00

$KPbI_3 . 2H_2O$.—It has already been mentioned that this is the only double iodide that either Remsen and Herty or I have been able to make. It forms slender, pale yellow needles, and is produced under a great variety of conditions. Two samples were analyzed. A was made with about 450^{g}KI, 75^{g}PbI₂, and 600^{cc} volume. For B about 400^{g}KI, 45^{g}PbI₂ and 280^{cc} volume were used.

	A.	B.	Calculated KPbI₃ . 2H₂O.
Potassium	6·03	6·07	5·90
Lead	30 73	30·13	31·21
Iodine	57·57	56·99	57·46
Water	5·26	6·04	5·43
	99·59	99·23	100·00

The salt is apparently stable in the air, but it loses water in the desiccator.

Sheffield Scientific School.
New Haven, Conn., October, 1892.

Art. XVII.—*The Ceratops Beds of Converse County,
Wyoming;* by J. B. Hatcher.

In the December number of this Journal for 1889, Prof.
O. C. Marsh gave the name Ceratops beds to certain strata in
the upper Cretaceous of Wyoming, Montana, and Colorado,
containing the remains of horned Dinosaurs (*Ceratopsidæ*) and
many other reptilian and mammalian forms.

Of these beds, those in the northeastern portion of Con-
verse county, Wyoming, are best known and have been most
thoroughly explored. Fully ninety per cent. of all the verte-
brate fossils described by Prof. Marsh from the Ceratops beds
were found in this region. This fact is sufficient to warrant a
more detailed description of the stratigraphical and geograph-
ical position of the beds, and of their geological and litholog-
ical characters, than has yet appeared. Not only has this
region proved especially rich in vertebrate fossils, but the
Ceratops beds seem to have attained a greater development
here than has been noticed elsewhere. Since the present
border of the beds is nearly that of the eastern shore of the
fresh-waters in which they were deposited, and erosion has
exposed many continuous sections in them down through the
underlying Fox Hills sandstones and into the Ft. Pierre shales,
this region offers exceptional advantages for determining the
position of the Ceratops beds and for establishing their age
upon stratigraphical as well as paleontological evidence.

Geographical Position of the Ceratops Beds.

The Ceratops beds of Wyoming have thus far been explored
only in a very limited region in the northeastern part of Con-
verse county. Going north from Lusk, a small station on
the Freemont, Elkhorn, and Missouri Valley railroad, they
first appear about twenty-five miles from that place, occupy-
ing the summit and northern slope of a yellow sandstone
ridge extending in a westerly direction from Buck creek to
Lance creek and crossing the latter stream near the mouth of
Little Lightning creek, a small tributary from the west. A
short distance west of Lance creek, the Ceratops beds pass
under other beds composed of very similar material, and pre-
sumably of Cretaceous age. From Buck creek, the eastern
border of the Ceratops beds has been traced in an almost con-
tinuous exposure, extending northeasterly to the Cheyenne
river, and crossing this stream a short distance below the
mouth of Lance creek. From this point, it takes a more

northerly direction, and skirting the western slope of the Black Hills, it has been traced to the north line of Converse county and on into Weston county. As stated above, the eastern shore of the fresh-waters in which the Ceratops beds were deposited was nearly that of the present border of these beds. The eastern limit of the fresh-waters was confined to the western slope of the Black Hills and that chain of minor uplifts connecting them with the Laramie range to the south-west. The Black Hills were at one time connected with the Laramie range through the Rawhide range and a less elevated series of uplifts extending in a northeasterly direction from the latter to the southern limit of the Black Hills. Remnants of this connecting range are still to be seen in the bluff just back of Lusk, known as Silver Cliff; on Duck creek two and one-half miles a little west of north of Lusk; near the head of Old Woman creek, about six miles north of the last mentioned place; in the ridge on the east side of Sage creek, two miles below Hat Creek post-office and eight miles northeast of the locality just mentioned; in another bluff ten miles below this and on the same side of the creek, but farther to the east; and doubtless in many other places as yet unobserved. The Ceratops beds were originally confined to the western slope of the Black Hills and of the less elevated series connecting the latter with the Rawhide range. This is conclusively shown by the absence of the Ceratops beds not only on the eastern slope of this range where they could have been removed by erosion, but in the region to the eastward where all the beds are approximately horizontal, and where, if they ever existed, remnants of them, at least, should yet be seen. The surface of the region to the east of the Black Hills and their south-western extension, as just described, is composed for the most part of Miocene deposits, with many sections showing the underlying beds. In all such exposures in this region, hundreds of which have been examined, the Miocene is underlaid by marine Cretaceous or older formations. In no instance have the Ceratops beds been observed east of the Black Hills or their less elevated continuation to the southwest.

The Ceratops beds proper, that is, those beds containing remains of the *Ceratopsidæ*, are known to have a surface exposure in that portion of Converse county embraced within their eastern and southern border, as defined above, and a line extending from that point on the latter where it passes under the overlying beds a short distance west of Lance creek, nearly due north to Weston county; i. e. the country drained by lower Lance, Lightning, Cow, Doegie, and Buck creeks, and that portion of the Cheyenne river and its tributaries between the mouth of Lance creek and the north line of

Converse county. The creeks mentioned in this paper will be found on any good map of Wyoming.

Description of the Deposits.

The Ceratops beds are made up of alternating sandstones, shales, and lignites, with occasional local deposits of limestones and marls. The different strata of the series are not always continuous, a stratum of sandstone giving place to one of shales and *vice versa.* This is especially true of the upper two-thirds of the beds. The lack of continuity in the different strata has rendered it well nigh impossible to establish any definite horizons in the upper members of the series. All the deposits of the Ceratops beds of this region bear evidence of having been laid down in fresh-waters. Among the invertebrate fossils found in them, only fresh-water forms are known. There is no evidence that marine or brackish-waters have ever had access to this region since the recession of the former at the close of the Fox Hills period.

The sandstones largely predominate in the lower members of the beds. They are always fine-grained, massive to well-stratified, and nearly white to yellowish brown in color. They are occasionally compact and hard, but for the most part quite soft and friable. They are composed of sharp, angular grains of quartz with some clay and mica, the whole being loosely cemented together with carbonate of lime. Almost everywhere in the sandstones are numerous concretions of varying size and shape. Some are almost perfect spheres and vary from the size of a marble to 18 or 20 feet in diameter. Others are from a few inches to several feet in transverse diameter and sometimes several hundred feet in length, a cross section forming a nearly perfect circle. Others still are very irregular in form. These concretions usually show no concentric structure, and while they sometimes enclose foreign objects, as a *Triceratops* skull or a single bone as a nucleus, they are for the most part simply centers of solidification and not true concretions. This is frequently shown by the cross-bedding in them, so often seen in the sandstones themselves.

The shales are almost entirely wanting in the lower 400 feet of the Ceratops beds, but they are well represented in the succeeding series. They are quite soft and loosely compacted, composed mostly of clay with more or less sand in places. The prevailing color is dark brown, but they are sometimes red or bluish. They are well stratified and finely laminated, and contain occasional limestone concretions enclosing numerous invertebrates.

The lignites occur in thin seams, never more than a few inches thick, of only limited extent, and with many impurities. At no place in the Ceratops beds of this region have workable coal beds been found. These do occur, however, in the Ceratops beds of Montana. The best exposure of them observed there is in Fergus county, on Dog creek, about 15 miles from its mouth, just above where it enters the Bad Lands of the Missouri. Workable coal seams occur in Wyoming, in the beds west of Lance creek, which overlie the Ceratops beds, and will be referred to later.

Intercalated with the sandstones, shales, and lignites, are quite local deposits of limestones, clays, and marls. The latter are composed almost entirely of fresh-water shells, fragments of bone, teeth, etc.

Along their southern and eastern border, the Ceratops beds dip to the northwest, at an angle of about 16° between Buck creek and Lance creek. One half mile east of Lance creek, the dip is 29° to the northwest. This angle of inclination rapidly diminishes toward the interior, and is scarcely noticeable in the vicinity of Lightning, Cow, and Doegie creeks. The fold is quite abrupt as is further shown by cracks which were made in the strata at the time of disturbance at right angles to their dip and parallel with their strike. These fissures have been filled by infiltration with materials now harder than those forming their walls, and now appear in many places as projecting veins, from a fraction of an inch to a foot or more in width, and from a few yards to several hundred in length.

Stratigraphical Position of the Ceratops Beds.

The Underlying Beds.—Along their southeastern border, especially between Lance and Buck creeks, are many fine exposures of the Ceratops beds and the underlying Fox Hills. Perhaps the best exposure is that made by a small tributary emptying into Buck creek, about four miles east of Lance creek and one-half mile northwest of the Buck creek pens used by the cattle men for round-up purposes. This watercourse has here cut its way in a southeasterly direction, at right angles to the strike, down through the lower half of the Ceratops beds, through the underlying Fox Hills sandstones, and into the Ft. Pierre shales. At this place, the bed of Buck creek and the rounded hills of that region at the head of this stream, embraced between the border of the Ceratops beds and Fox Hills sandstones on the north and the bluffs of Miocene clays and conglomerates on the south, are composed of Ft. Pierre shales. All the strata of this entire section dip to

the northwest at an angle of 16°. The exposure is a continuous one, and commencing from below, the section is as follows :

At the base are the Ft. Pierre shales of unknown thickness, several hundred feet of which are exposed. They consist of argillaceous, finely laminated, dark shales, quite soft and easily eroded. They contain many limestone concretions and numerous invertebrates ; among others are *Baculites ovatus*, *B. compressus*, *Scaphites nodosus*, *Placenticeras placenta*, *Nautilus Dekayi*, etc.

Overlying the Ft. Pierre deposits is an alternating series of sandstones and shales with an estimated thickness of 500 feet. In the lower portion of this series, the shales predominate, but toward the middle the sandstones are in excess, and in the upper 50 feet they entirely replace the shales. The sandstones are of a yellowish brown color, very fine grained, firm, and well stratified below, but softer, and quite massive at the top, where they contain numerous large concretions and a rich marine invertebrate fauna. Representatives of this fauna have been sent to Mr. T. W. Stanton of the U. S. National Museum, and were pronounced by him to be characteristic of the uppermost Fox Hills in direct conformity with their stratigraphical position.

The Ceratops Beds.—Next come the Ceratops beds with an estimated thickness of 3,000 feet, resting directly upon the Fox Hills series. Immediately above the Fox Hills is a very thin, but quite persistent, layer of hard sandstone, well stratified, and quite cleavable along the lines of stratification. This stratum of sandstone is about six inches thick, and is regarded as the dividing line between the marine and fresh-water beds. It is overlaid by about 150 feet of yellowish brown, well-stratified sandstones apparently non-fossiliferous. These are in turn overlaid by about 250 feet of almost white, fine-grained, massive sandstones with numerous concretions, but no fossils were found in them. Next comes the fossiliferous portion of the Ceratops beds, consisting, as before stated, of alternating sandstones, shales, and lignites.

All the beds of the entire section are conformable, and bear evidence of a continuous deposition, from the Ft. Pierre shales up through the Fox Hills sandstones and the overlying fresh-water Ceratops beds. The Ft. Pierre shales are not suddenly replaced by the Fox Hills sandstones, but the transition is a gradual one, and it is impossible to say just where the one ends and the other commences. The same is true of the beds overlying the Fox Hills. The thin seam of hard sandstone, just referred to as separating the fossil-bearing Fox Hills sandstones below from the very similar non-fossiliferous sandstones

above, is here regarded as the dividing line between the Fox
Hills and Ceratops beds. But this decision, it must be admit-
ted, is quite arbitrary, and the evidence in its favor is negative
rather than positive. The only reason for placing the over-
lying 400 feet of non-fossiliferous sandstones in the fresh-
water series is the absence of fossils in them, which may per-
haps be accounted for by the destruction of the marine forms
brought about by the change from salt to fresh-waters. The
overlying non-fossiliferous beds may have been deposited in
the fresh-waters before fresh-water forms had distributed them-
selves over this region. The sandstones of the entire series
are very similar, and since there is entire conformity through-
out, it is absolutely impossible to determine just where the
marine beds end and the fresh-water beds commence. The
Ceratops beds of this region are a natural sequence of the Fox
Hills. The materials composing both were evidently derived
from a common source. The only safe criteria for distinguish-
ing one from the other are their fossils.

The Overlying Beds.—Along their eastern border, the Cera-
tops beds are occasionally unconformably overlaid by Miocene
clays and conglomerate. But these deposits, if they ever
extended over any considerable portion of the region now
occupied by the Ceratops beds, have been almost entirely
removed by erosion. To the west of Lance creek, the Cera-
tops beds pass under a very similar series of sandstones, shales,
and lignites, of about the same thickness, and conformable
with them. In this series, the sandstones are more massive
than the underlying sandstones; the shales contain more sand;
and the lignites are more frequent, of a better quality, and
attain a greater thickness, as shown at the Shawnee coal-mine
on Shawnee creek, where a single bed of coal is 10 feet thick,
and of a quality sufficiently good to enable it to be profitably
mined for commercial purposes. Thus far no vertebrate or
invertebrate fossils have been found in these beds, but they
contain a rich fossil flora, representatives of which have been
sent to Prof. F. H. Knowlton of the National Museum, with
a request for his opinion as to the age of the beds, based upon
the evidence afforded by the fossils. Upon no other evidence
than a general similarity to known Laramie deposits in other
regions, they are here regarded as Upper Laramie.

Age of the Ceratops Beds.

In a series of articles commencing in the April number of
this Journal for 1889, Prof. Marsh has referred the Ceratops
beds to the Laramie, mainly upon evidence afforded by their ver-
tebrate fossils. Owing to the fact that very few vertebrates

had previously been described from the typical Laramie, as first defined by Mr. Clarence King, and the consequent lack of vertebrate forms known to have come from the Laramie for comparison with those found in the Ceratops beds, it must be admitted that the vertebrate fauna of the latter is, in itself, at present not sufficient proof to establish the Laramie age of the Ceratops beds.

Fortunately the Ceratops beds contain an extensive invertebrate fauna, in which Dr. C. E. Beecher has identified the following : *Unio Couesii*, White, *Sphærium formosum*, M. & H., *Linnæa compactilis*, Meek, *Campeloma multilineata*, M. & H., *Tuloioma Thompsonii*, White, and others known from the typical Laramie, some of which are characteristic of it. The invertebrate fossils may, therefore, be considered as additional evidence of the Laramie age of the beds.

But the most conclusive evidence that the Ceratops beds belong to the Laramie period is that afforded by their actual position in regard to the Fox Hills. As stated above, they conformably overlie the Fox Hills, which is the normal position of the Laramie. This conformability must be regarded as an actual and not an apparent one, since it is shown in an almost continuous exposure for many miles along the southeastern border of the beds, where they are upturned at an angle of from 16° to 29°, and where an unconformability, if any existed, would be plainly visible.

The evidences in favor of referring the Ceratops beds to the Laramie are :

(1) They conformably overlie the Fox Hills sandstones and contain both a reptilian and a mammalian fauna, with decided Mesozoic affinities. Among the reptiles, the Dinosaurs are, in degree of development and point of numbers both as to individuals, and genera and species represented, probably unsurpassed in any previous smilar division of the Mesozoic ; while as regards degree of specialization, they are superior to all previous forms. This age was preëminently an age of reptiles.

(2) They contain an invertebrate fauna comprising many forms identical with those already described from the typical Laramie, some of which are unknown except in the Laramie.

(3) They immediately and conformably overlie the Fox Hills, and show evidence of a continuous deposition through both series.

Probable Conditions attending the Deposition of the Ceratops Beds.

The change from marine to fresh-waters which took place at the close of the Fox Hills and the beginning of the Laramie was brought about by the great continental elevation going on

in previous Cretaceous periods, and sufficient to cause a reces-
sion of the salt waters at the close of the Fox Hills.   During
the Laramie, this region was occupied by fresh-waters or in
places by dry land.

This period of elevation which brought about the close of
the marine Cretaceous is thought to have been followed by a
period of subsidence during the Laramie.   For, since the beds
of the Laramie were evidently deposited in shallow waters, as
is abundantly shown by the great number of lignite seams
which they contain, and still further in the Ceratops beds, at
least, by the absence of continuity of strata, frequent cross-
bedding, etc., it is impossible to account for so great a thick-
ness of beds, all bearing evidence of having been deposited in
shallow waters, except on the theory of a subsidence going on
over the region during the period in which they were laid
down.   This subsidence must have been so gradual that the
upbuilding by sedimentation at the bottom of the waters kept
pace with the subsidence; any increase in the rate of the
latter increasing the depth of the waters, and a decrease in the
rate of subsidence causing a decrease in depth.   The latter
would bring about a condition requisite for the deposition and
preservation of vegetable matter which would be transformed
later into lignites.

The Ceratops beds are thought to afford evidence in them-
selves of having been deposited not in a great open lake, but
in a vast swamp, with occasional stretches of open waters,
the whole presenting an appearance similar to that which now
exists in the interior of the Everglades of Florida.   This con-
dition would account for the frequent changes from one mate-
rial to another in the same horizon, before referred to.   In
some places in the beds, these changes are quite frequent,
strata of sandstones and shales replacing one another in great
confusion.   It would also explain the cross-bedding so often
seen in the sandstones of this region, in localities remote from
the present border of the beds, and hence far removed from
the shore of the ancient lake or swamp.   This cross-bedding
could hardly occur in off-shore deposits of a great fresh-water
lake of any considerable depth.

The conditions that prevailed over this region during the
period in which the Ceratops beds were deposited were prob-
ably those of a great swamp with numerous small open bodies
of water connected by a network of water courses constantly
changing their channels.   The intervening spaces were but
slightly elevated above water level or at times submerged.
The entire region where the waters were not too deep was
covered by an abundant vegetation, and inhabited by the huge
Dinosaurs (*Triceratops, Torosaurus, Claosaurus,* etc.), as well

as by the smaller crocodiles and turtles, and the diminutive mammals, all of whose remains are now found imbedded in the deposits. That these animals at one time inhabited the very region where they now lie entombed is conclusively shown by the occasional finding of entire skeletons with every bone in place, at localities far distant from the border of the beds, and in a state of preservation which could not possibly exist had they lived and died on a distant shore, and their carcasses been transported by the waters to their present resting places after death. Moreover, skeletons are sometimes found in an upright position or inclined to one side or the other, showing that the individual met death by miring in the immediate spot where the remains now rest. A noteworthy example of this was that of the skeleton of a Dinosaur discovered in August, 1891, by Mr. A. L. Sullins, and recently described by Prof. Marsh as *Claosaurus annectens.** · This skeleton when found was in a partially erect position, the limbs extended, and every bone in its natural position except where exposed and worn away by recent weathering. The ribs were still distended, retaining the exact form and capacity of the thoracic and abdominal cavities. The whole showed that the animal in its wanderings had mired in the quicksands, and in its struggles for liberation had been engulfed by them.

In the sandstones of the Ceratops beds hardly a fossil bone of any considerable size is to be found that does not bear evidence of having been dropped in shallow waters. In many instances, it is still possible to determine the direction of the currents which succeeded in burying the bones, and thus prevented their decay. For instance, on one side of a bone the matrix will be made up entirely of sand, while on the opposite side the stems and leaves of plants have been dropped, and, now partially lignitized, form a considerable portion of the matrix. This arrangement of the materials of the matrix in which the bone is imbedded shows the direction of the current to have been from that side containing only sand, and toward the side containing the plants. So shallow were the waters, the bone itself became an obstacle sufficient to produce an eddy on its lower side, in which the leaves and other vegetable materials accumulated, and sank to the bottom.

Conclusions.

If the Ceratops beds of Converse county, Wyoming, are the equivalents of the typical Laramie of southwestern Wyoming, the remarkable vertebrate fauna of the former will prove of great importance in determining the age of other beds now

* This Journal, vol. xliii, p. 453, May, 1892; and vol. xliv, p. 171, Aug., 1892.

in doubt, containing like or similar faunas.   Notably among
the latter are the Denver and Arapahoe beds in the vicinity
of Denver, Colorado, and their probable equivalents in other
portions of the same state, recently described by Mr. Whitman
Cross, as " The Post Laramie Deposits of Colorado."[*]   Mr.
Cross refers these beds to a period later than the Laramie on
account of unconformities existing, in some places, at least,
between them and the underlying recognized Laramie and
older Cretaceous formations, and in opposition to the evidence
afforded by the vertebrate fossils thus far obtained in them.
Whether it is better to ignore the evidence afforded by the
vertebrate fossils, or to treat these unconformities as local,
remains to be decided by future investigations.   It is quite
possible that Dinosaurs continued into the early Eocene, but
they were represented there, if at all, only by degenerate
types, and less· specialized forms.   It would certainly be
remarkable, not to say impossible, that a group of Dinosaurs
showing so great a development and marked specialization as
are to be seen in *Triceratops* and *Claosaurus* should continue
uninterruptedly from near the base of the Laramie up into
the Tertiary.   Nevertheless at least two species of *Triceratops*
have been described from the Denver beds referred by Mr.
Cross to the Post-Laramie.   Regions affording such contra-
dictory evidences should be thoroughly examined, and, where
possible, their actual stratigraphical relations should be deter-
mined.   Results thus attained might be sufficient to harmonize
observations now in apparent opposition.

ART. XVIII.—*On the Use of Planes and Knife-edges in
Pendulums for Gravity Measurements ;*[†]   by
T. C. MENDENHALL.

In the theoretical discussion of the pendulum it is usual
to assume that it vibrates about an axis which is a straight line.
In practice it is generally attempted to realize this condition
as nearly as possible and the method almost if not quite uni-
versally adopted has been to attach what is technically known
as a knife-edge to the pendulum and allow it to rest upon a
suitably supported plane horizontal surface.   The axis about
which rotation takes place is at any moment determined by
the contact of the edge with the plane surface.   To satisfy
theoretical conditions it is evident that this edge must be

formed by the intersection of two perfectly plane surfaces, a condition which can never be quite realized in practice. It is important, therefore, to inquire how it may be most nearly approached and especially by what disposition of parts, both as to form and arrangement, a given departure from it will produce the minimum effect upon the period of the pendulum and upon the value of the force of gravity obtained by its use.

What is believed to be an important departure from the universal practice in regard to the arrangement of parts has recently been experimentally investigated and with very satisfactory results. It consists in an exchange in place of the knife-edge and plane, the latter being attached to the pendulum and the former to the fixed support. This arrangement offers many advantages to which it is desirable to invite attention. It will be best, however, to refer in the beginning to what will at once suggest itself to many as a serious objection to this plan. When the knife-edge is attached to the pendulum it may be assumed to have a constant relation to its mass, at least so long as the pendulum does not suffer an injury which alters its configuration. The axis about which vibration takes place may therefore be regarded as constant as far as relates to different sets of swings, and it will be practically indifferent as to what part of the supporting plane it rests upon. When the plane is attached to the pendulum this axis of vibration is entirely determined by the position of the plane upon the knife-edge.

This difficulty, which at first sight appears to be formidable, readily disappears in practice. In fact, a little calculation will show that the line of contact between the knife-edge and the plane must vary in position by a relatively large amount in order to effect sensibly the period of the pendulum. Even if the placing of the pendulum for successive swings were accomplished by no more accurate devices than the eye and hand, it would not be difficult to avoid sensible error from this source. The apparatus by means of which the pendulum is lifted from and lowered upon the knife-edge is readily made adjustable so that any desired line of contact can be secured and retained indefinitely.

As an illustration of the constancy of period of a pendulum arranged in this way, as well as showing the ease and accuracy with which the period of vibration is ascertained, the following results are exhibited.

They show the period of the pendulum derived from individual swings extending through about an hour each. Twelve such swings were distributed nearly uniformly through a period of twenty-four hours, in order to eliminate any effect of irregular hourly rate of the chronometer. The figures as

shown below include this effect, of course, it being eliminated only from their mean.

The two sets shown were made for the purpose of determining a "pressure coefficient," the first being made in air at a pressure of 25^{mm} and the second at a pressure of 600^{mm}. It will be seen that in no case does the variation from the mean amount to as much as one part in a million, a constancy which leaves little to be desired.

Pres. 25^{mm}. Period v.	Pres. 600^{mm}. Period v.
·5006904 — 4	·5007368 + 4
901 — 1	74 — 2
898 + 2	71 + 1
900 0	73 — 1
902 — 2	72 0
899 + 1	75 — 3
901 — 1	73 — 1
898 + 2	71 + 1
896 + 4	70 + 2
902 — 2	68 + 4
899 + 1	69 + 3
900 0	75 — 3
Mean ·5006900	Mean ·5007372

The advantages of the new form of pendulum will be made evident on an examination of its application to the differential method or use of a so-called invariable pendulum as well as to the reversible form for absolute determinations of gravity.

There is an advantage in the matter of construction. It is not easy to insert the knife-edge in the head of the pendulum so that it shall be at right angles to the axis of symmetry of mass. The plane used in its stead may be accurately adjusted by simple optical methods.

The advantage of the plane in the matter of permanency or invariability is so evident as hardly to need remark. The knife-edge is usually the most delicate part of a pendulum, that most liable to be injured and generally incapable of being repaired when once damaged. In an invariable pendulum the knife-edge cannot be reground or replaced by another, without destroying the identity of the whole so that swings at different places or times are no longer comparable with each other. A pendulum carrying a plane instead of a knife-edge is evidently vastly less liable to accidental injury and is entitled in a much greater degree to the name "invariable." The knife-edge being no longer an integral part of the vibrating mass can be reground or replaced at will. In fact in practice it is desirable to have several knife-edges and in an extensive pendulum campaign a "standard edge" will be used

upon which swings will only rarely be made in order to detect any deterioration which may take place in those in daily use. Knife-edges of different material may also be used if such a course is found to be desirable.

In the reversible pendulum for absolute measures, in addition to the advantages already described there is also the very important fact that the measurement of the length of the pendulum is likely to be more accurate. Whether the knife-edge is a part of the pendulum or of the fixed support, a certain amount of elastic compression will always take place when the weight of the pendulum is upon it and this is likely to be relatively greater the more perfect the edge. If the knife-edge is a part of the pendulum the length of the latter must be greater when vibrating than when at rest and supported with the edge free for length measurement.

The measurement of the distance between the two knife-edges of a reversible pendulum as ordinarily made is a matter of much difficulty. It is believed that without resorting to extraordinary methods the distance between the two planes of the newly constructed reversible pendulum will be capable of measurement with higher accuracy and if necessary or desirable, recourse may be had to the method of Michelson and Morley for relating the distance between surfaces to the length of light waves.

Perhaps the most important gain thus far from the new arrangement is that it has made it possible to investigate the knife-edge, as to form and material, with an ease and thoroughness hitherto unattainable. As long as the knife-edge forms a part of the pendulum it is impossible to study the effects of variation in its angle, width or material because every such alteration must necessarily alter the vibration-period by changing the mass and form. With the new form this difficulty no longer exists; the vibrating body remains constant in mass and configuration and any change in its period is due to the influence of the knife-edge.

Some of the results already obtained are of sufficient interest to justify their publication in advance of a full and complete investigation now in progress.

In order to investigate the effect of a wearing or slight flattening of the edge, such as may, and in fact does result from long and not too careful use, a steel knife-edge was used, the plane, forming a part of the pendulum, being of agate. A steel edge was used on account of the greater ease with which it could be manipulated in grinding. The agate knife-edge has been in general use, but experiment showed that both steel and agate being made as perfect as possible, the vibration periods were essentially the same. The angle which the two

planes forming the edge made with each other was 110°. The edge was first ground until it was pronounced as perfect as was practicable by the artist, Mr. E. G. Fischer, chief mechanician of the Coast and Geodetic Survey, who has shown rare ingenuity and skill in the solution of the mechanical problems arising during the investigation. The width of the edge was then measured, using a microscope magnifying from 100 to 500 times. This was a difficult operation, the question of illumination being troublesome. It seemed tolerably certain, however, that the width of such an edge was not greater than 1^μ ($\cdot 001^{mm}$) Several different edges ground in this way were measured with essentially the same result. After the vibration period on one of these had been ascertained it was given one or two light touches upon the stone, producing an edge which was found on measurement to be approximately 2^μ in width. After the pendulum had been swung on it it was still further flattened.

Theory shows that a pendulum will vibrate more rapidly upon a slightly flattened or rounded edge than upon one which is perfect. The table below shows the results of experiment conducted as above described. The pendulum used was one of the short, approximately half-second, pendulums of the form referred to a year ago.[*] The numbers showing the width of the knife-edge must be regarded as approximations only but they are probably relatively not far from correct.

They indicate very clearly and positively the important part played by the knife-edge and the importance of having it perfectly ground. There is good reason to believe that this matter has not hitherto received that attention in pendulum researches which it is here shown to demand. While the effect of a given amount of flattening on the vibration-period would be less with a long seconds pendulum than with one of shorter period, the tendency towards flattening, arising out of greater weight and greater difficulty of handling would be very much increased. There is no doubt that in some important gravity operations knife-edges have been used which, in the light of these results must be considered intolerably poor. It will be observed that going from what may be accepted as a practically perfect edge to one only one two-hundredth of a millimeter wide, changes the period by one part in forty thousand, an amount entirely outside of a reasonable limit of accuracy for work of this kind.

The question of the best angle for the knife-edge is also important and interesting. If the material of which the edge is composed were physically perfect and if the faces were perfect planes all angles, within certain wide limits, would be

equally good. Imperfection of substance, as to strength, continuity, etc., is the principal difficulty and this is met by making the angle of the faces as great as possible. But the errors arising from the impossibility of grinding the faces to true planes are reduced to a minimum by making the angle as small as possible and hence there is indicated an angle neither very large nor very small which is better than others. In other words, if the angle is too small the edge will be entirely crushed and thus broadened and made imperfect. If the faces are not perfect planes it is clear that the larger the angle the wider will be the limits of the horizontal projection of the line of their intersection and this will be equivalent to widening the edge upon which the pendulum swings.

It is interesting that this seems to be verified in practice, as is shown in the results given below. Edges ground to five different angles, varying from 90° to 160° were used. The results show that while there is no *great* difference in the results with the range of angles examined, it is tolerably certain that the angle should not (with this material—steel) be less than 110° nor more than 140°. An angle of 130° will probably be found the most satisfactory, combining the necessary sharpness (when properly ground) with strength to resist accidental injury or excessive elastic compression.

Steel Knife-Edge.

Width. μ	Period.	Gain.
1	·5008880	0
2	8839	41
5	8756	124
6·5	8503	377
10	7626	1254

Angle.		Period.
90°		5008875
110°		8880
130°		8874
150°		8884
160°		8852
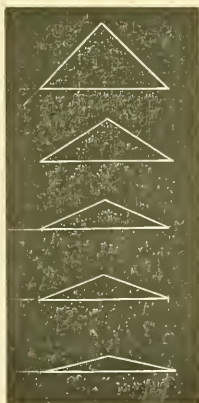
Steel knife-edges have been very generally used in pendulum work but they are inferior to those made of agate.   The brittleness of the latter is rather an advantage than otherwise. When an agate knife-edge receives a blow sufficient to injure it, a piece is chipped out, leaving the remaining portion of the edge clean and perfect as before and the only effect on the vibratory period is that due to the removal of the matter lost. Under the same circumstances an edge of steel will be flattened or distorted and while there may be no loss of matter the edge may be made so imperfect that the period will be decidedly affected.

The grinding of an agate edge demands much more labor and skill than is required in the preparation of one of steel but it is well worth the additional cost.

It has been found that a knife-edge, even if its mass is considerable, is very susceptible to such distortion of figure as will render it imperfect. To avoid this it has been found desirable to insert the edge in a heavy tablet of brass and grind it *in situ.*   The tablet is provided with three feet with hemispherical ends, resting respectively in a conical hole, a V groove and on a plane.   In this way the edge is subjected to no strain after it is ground.

ART. XIX.—*Preliminary note on the colors of cloudy condensation ;* by C. BARUS.

By allowing saturated steam to pass suddenly from a higher to a lower temperature (jet) in uniformly temperatured, uniformly dusty air the following succession of colors is seen by transmitted white light, if the difference of temperature in question continually increases : Faint green, faint blue, pale violet, pale violet-purple, pale purple, muddy brown-orange, straw-yellow, greenish yellow; green, blue-green, gray-blue, intense blue, indigo, intense dark violet, black (opaque); intense brown, intense orange, yellow, white.

Seen by reflected white light, the same mass of steam is always dull neutral white.

If the colors enumerated be taken in the inverse order beginning with white, they are absolutely identical with the interference colors of thin plates (Newton's rings) of the first and second order, seen by transmitted white light under normal incidence.   Thus it is worth inquiring whether small globules of water, when white light is normally transmitted, affect it like thin plates.   For a given homogeneous color if I

be the intensity of the incident light and k (·04 to ·05) the reflection coefficient, then after a single transmission the interference maxima and minima are $(1-k)^2(1+k^2)I$ and $(1-k)^2(1-k^2)I$; they differ only very slightly. But if there be an indefinite number of particles all of the same size available, then this process is indefinitely repeated in such a way that while the colored light is not extinguished, the admixed white light becomes continually more colored. Hence after a sufficiently great number of transmissions the emergent ray will show intense color. Seen by reflected light the case is almost the converse of this. For a single particle the masses which interfere are (kI and $k(1-k)^2I$) weaker but nearly equal, and the interference is therefore very perfect. It is not, however, capable of indefinite repetition for after each interference the direction is reversed. The light which emerges in a direction opposite to the incident ray must therefore have passed through the particles, i. e. it has been brought to interference both by reflection and by transmission, and its color is thus virtually extinguished.

The final point to be considered is the occurrence of black, between brown and dark violet of the first order. Here, however, for relatively very small increase of the thickness of the plate, the colors run rapidly from brown through red, carmine, dark red-brown to violet. Hence these interferences are apt to occur together and an opaque effect is to be anticipated. Particularly is this presumable, because the opaque field is coincident with the breakdown of the steady motion* of the jet.

Thus it seems that the colors of cloudy condensation may without serious error be interpreted as a case of Newton's interferences by transmitted light. In so far as this is true one may pass at once from the color of the field to the size of the particles producing it; and the dimensions so obtained agree well with R. v. Helmholtz's estimate made in accordance with Kelvin's equation for the increase of vapor tension at a convex surface. In the study of the condensation phenomena vapor-liquid, the experimental power of a method, which is adapted for *instantaneous* observation, and which for a certain range of dimensions not only discriminate between vapor and a collection of indefinitely small suspended water globules, but actually defines their size, cannot be overestimated. An account of my work together with other allied observations will be given in the March number of the American Meteorological Journal.

* I refer here to Osborne Reynold's work (Phil. Trans., III, p. 935, 1883) with liquid jets, according to which after a certain critical velocity is surpassed, the uniformly steady motion breaks up into eddying motion. I am also searching for Reynold's lag phenomenon (l. c. p. 957).

ART. XX.—*Lines of structure in the Winnebago Co. Meteorites and in other Meteorites;* by H. A. NEWTON.

THE ground and polished surface of a Winnebago Co. meteorite showed to me some interesting markings. Subsequent examination revealed like markings in other meteorites. Perhaps these markings have been described. If so I have no recollection of the description, and therefore it seems worth while to call attention to them.

The polished surface of a small Winnebago stone, three or four square centimeters in area, shows several hundreds of bright metallic points. The larger iron particles in this surface have great varieties of shapes, — the smaller ones are usually mere points. When seen with a lens, or even at a distance from the eye suited to distinct vision there does not appear to be any regular structure or arrangement of the bright points. But if the surface is so held as to be a little beyond the place of distinct vision, and at the same time, turned around in such way as to reflect always a strong light to the eye, either skylight or lamplight, there appear lines of points across the polished surface of the stone, which suggest very strongly the Widmanstaetten figures on metallic meteorites. At times as the stone is turned no lines can be detected. Again one set of parallel lines or two sets crossing each other become visible. Some of the sets are very sharply manifested, and some are so faint as to leave one in doubt whether the lines are real or only fancied. There are on the surface in question six or eight of these sets of lines.

A second surface was ground nearly parallel to the first, at about one centimeter distant from it, and like lines appeared on this parallel surface. Some of the lines, but not all of them, corresponded in direction in the two surfaces. Four more surfaces approximately at right angles to the first surface, and corresponding to the faces of a right prism were then ground and upon these surfaces the like sets of lines appear with more or less distinctness.

A slab of a Pultusk stone 6×7 centimeters shows over its entire surface like markings. Something like a curvature of the lines appears in one instance but in general the lines run straight from side to side of the slab. The slab is six millimeters in thickness and most of the sets of lines have the same directions upon the two sides.

A Hessle stone, a small slice from the Wold Cottage stone, one from Sierra di Chaco, one from a Sienna stone, a fragment from the Rockwood stone, and a slice from the Rensselaer Co.

stone, all show with more or less clearness the like markings. Of three microscope slides of the Fayette Co. meteorite one shows them clearly, a second shows traces of them, the third not at all.

A considerable number of the ground surfaces of meteoric stones in the Peabody Museum also show these markings. For example a triangular surface of a Weston stone, 8 or 10 centimeters to each side, exhibits them very well.

These markings are such as we might expect if the forces which determine the crystallization of the nickel-iron of the iron meteorites also dominated the structure of the rock-like formations of the stony meteorites and the distribution therein of the iron particles. The relation of quartz crystals to the structure of graphic granite is naturally suggested by these meteorite markings.

ART. XXI.—*Preliminary Note of a new Meteorite from Japan ;* by HENRY A. WARD.

[Read before the Rochester Academy of Sciences, Dec. 12, 1892.]

SEVERAL months ago a friend, Mr. Alan Owston, who had been traveling in the interior of the main island of Japan, told me that he had seen what he thought to be a stone meteorite in a temple in Iwate. As the result of considerable correspondence this specimen has been sent to me, reaching me early in December. It was accompanied by a letter in Japanese language of which the following is a translation :

" This meteorite which I send you herewith fell about forty years ago, viz : in the 3d year of Ka-yei, at dawn on the 4th day of the 5th month, (13th June, 1850). It fell obliquely from the W.N.W. with a great sound like thunder, at the village of Kesen in the district of Kesen, in this Prefecture. It entered the ground five feet, and remained hot for two days. The original size was said to be about equal to 2½ sho of rice. This would be about 1½ cubic feet. There were ten or more pieces of it which have been distributed about in various places.

(Signed)   SATO KENJI, of Nota village, Iwate Prefecture."

The specimen which I have received is $6\frac{1}{16}$ ounces in weight. Its shape is an irregular triangle about 6½ inches in its greatest (vertical) diameter, and about 5 inches thick (see figure). Two long patches an inch wide on either side of the mass are covered with crust ; the rest is broken surface, showing inner

structure.   This crust has the usual characteristic pittings, very clearly indented, yet shallow.   It is of a dull blackish brown color, with a pebbled or grained appearance.   Close examination shows numerous shining metallic points, appar-

Kesen meteorite, two-thirds natural size.

ently of iron, with reddish stains, doubtless due to the oxidation of these.   This surface shows clear signs of fusion, but there is no *flow* of the melted part, which might give clue to the direction of flight of the mass.   The interior shows no signs of arrangement either in planes or concentric.   There are several short fine fissures or fractures from one and a half to two inches in length, some of which reach to the lower side of the surface.   They are not parallel, and they were doubtless caused by the shock of reaching the earth.   One inner face however seems a little smoothed, as if prior to the breaking off of the contiguous piece there had been a sliding of sur-

faces. This stone is eminently chondritic. There is a fine-grained paste, and through it are distributed little rounded grains. Both the matrix and the grains are of the same material,—the minerals olivene and enstatite. This is all that is visible to the naked eye. But an ordinary low power lens shows many bright, metallic points. Also glossy, waxy pimples of red color, perhaps an effusion of chloride of iron. Some larger blotches of iron rust occur here and there. In determining the metallic portion of the meteorite (which has been done by Mr. John M. Davison of the Reynolds Laboratory of the University of Rochester), pieces of the mass were finely crushed and the metal separated by the magnet, washed in alcohol and dried rapidly. Its weight having been taken, it was dissolved in nitric acid, and a little insoluble stony matter was separated, weighed and deducted from it. A mean of two determinations made in this way gave the metallic proportion about 16 per cent of the whole mass. This is an unusual per cent of metal,—much more than in the Waconda, which stone resembles in some respects the Kesen,—which we now name this new meteorite from Japan.

We are expecting to soon receive some other pieces, which may give new facts; and also a fuller examination of the mineral constituents—metallic and non-metallic,—will be made ere long.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Re-conversion of Heat into Chemical Energy in the production of Gas.*—As is well known, the reaction H_2O(liquid) $+C = H_2 + CO$ is endothermic, the production of water gas from steam and ignited coke absorbing 38770 calories. On the other hand, the reaction $C + O = CO$ is exothermic, the production of generator gas by passing air over excess of ignited coke evolving 29690 calories; the nitrogen being left in the gas. This amount of heat would raise the temperature of the carbon monoxide to 2169°; so that if used at once, the 29690 calories would be utilized. But in general the gas is stored in a holder before use and so is cooled to 15°; thus losing the heat of formation, which is 30·4 per cent of the total heat of combustion of the coke. In order to avoid this loss of energy, Naumann has suggested combining an exothermic with an endothermic reaction and thus storing up the heat energy in the gas itself in the form of chemical energy. This may be done (1) by mixing air and water-vapor together in such proportion that by their mutual action upon

ignited coke, neither absorption nor evolution of heat will take place; producing a water generator gas, as in the Dowson process. Or (2) by mixing the air with carbon dioxide before passing it over the ignited coke; the reaction $CO_2 + C = (CO)_2$ being endothermic, 38270 calories being absorbed, and the resulting product being a carbon-dioxide generator gas. The author gives the composition of gases thus prepared, and compares them together, with respect (A) to the heat of combustion of one liter of the gas, calculated from composition, (B) to the calorific intensity, so calculated, and (C) to the specific heat of the combustion-products of the gas; i. e. the heat evolved by one liter of these combustion products when cooled 1°. These results are as follows:

Gas.	A.	B.	C.
1. Generator gas	1044 cal.	1904°	0·5487 cal.
2. Carbon-dioxide gas	1739 "	2449	0·7101 "
3. Water generator gas (liquid water at 15°)	1652 "	2356	0·7016 "
4. " " " (water-vapor at 15°)	1790 "	2431	0·7363 "
5. Water gas	2812 "	2830	0·9934 "

—*Ber. Berl. Chem. Ges.*, xxv, 556 ; *J. Chem. Soc.*, lxii, 673, June, 1892. G. F. B.

2. *On the Temperature of Ignition of Electrolytic Gas.*—More than a year ago Krause and V. Meyer showed that electrolytic gas, slowly passed through a glass tube immersed in boiling stannous chloride, at 606°, does not explode. FREYER and V. MEYER have now repeated this experiment using other liquids of higher boiling points. The bath was of sheet iron, in the form of a crucible, and was 10 cm. high and 6 cm. in diameter. Through the cover passed a sheet-iron tube 2 cm. in diameter closed at its lower end and extending nearly to the bottom of the vessel. Outside this tube was half a kilogram of zinc chloride. Within the tube a cylindrical glass bulb was placed, connected by capillary tubes with the gas-evolution apparatus and with a water trough. The zinc chloride was heated to boiling, the temperature rising to redness. On passing the electrolytic gas through the bulb, explosion took place at once, and this, whether the gas was moist or dry. By means of an air thermometer constructed of platinum, the temperature of the boiling zinc chloride was fixed at 730°. The experiment was then repeated with zinc bromide and it was found that the explosion did not take place in actively boiling zinc bromide, the boiling point of which was found to be 650°. Hence the ignition point of electrolytic gas lies between 650° and 730°. The authors observed that the explosion in the zinc chloride takes place with certainty only when the gas is introduced into the chloride in active ebullition. If it be passed through below the boiling point and then the temperature be raised to 730°, a slow union takes place, forming water.—*Ber. Berl. Chem. Ges.*, xxv, 622 ; *J. Chem. Soc.*, lxii, 680, June, 1892. G. F. B.

3. *On the Electromotive Activity of the Ions.*—In 1890, Nernst and Planck deduced the electromotive forces between liquids

from the osmotic pressure and dissociation hypothesis. NERNST and PAULI have now determined experimentally the electromotive forces produced in liquid cells made by the combination of decinormal and centinormal solutions of potassium chloride and hydrogen chloride and have compared their results with those obtained from theory in 1890. The agreement between theory and observation is quite satisfactory. Consequently it follows that, since solutions of zinc sulphate and of copper sulphate having equal molecular concentrations, are both very nearly dissociated into ions, there should be no considerable electromotive force at their surface of contact. Now on investigating the combination

Hg | HgSO$_4$ | 1/10n CuSO$_4$ | 1/10n ZnSO$_4$ | HgSO$_4$ | Hg
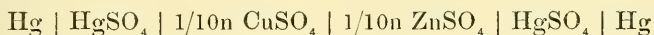
the authors have found that in fact the electromotive force developed is only ·00024 volt. Hence the contact of the two liquids in a Daniell cell is not the seat of an appreciable electromotive force. —*Ann. Phys. Chem.*, II, xlv, 353; *J. Chem. Soc.*, xlii, 671, June, 1892. G. F. B.

4. *On the Separation of Precipitates at the Surface bounding Electrolytes.*—It was long ago observed by Faraday that if a saturated solution of magnesium sulphate be placed in the bend of a U-tube and a layer of water be placed in each limb of the tube resting upon the sulphate, so that the two liquids do not mix, then on passing a current through the whole, a precipitation of magnesium hydroxide takes place at the surface which separates the sulphate from the water containing the negative electrode. In 1887, Herrmann repeated these experiments with zinc sulphate. KÜMMELL has now investigated the matter more thoroughly, using in place of aqueous solutions of the metallic sulphates, solutions prepared with sufficient gelatin so that they solidify on cooling. The presence of the gelatin does not interfere with the phenomenon in question while at the same time it prevents the admixture of the solution and the water, which it is not easy to prevent otherwise. Experimenting in this way, he found that of the many sulphates examined, the precipitation occurred only with those of magnesium, zinc, cadmium and aluminum. The separation of the hydroxide always takes place first, at the negative electrode itself; the appearance of the precipitate at the boundary of the two liquids taking place later. By modifying suitably the method of experimenting it was ascertained that the phenomenon is due to a transfer of the solid particles from the negative electrode through the feebly conducting water by the electric current.—*Ann. Phys. Chem.*, II, xlvi, 105; *J. Chem. Soc.*, xlii, 1038, Sept., 1892. G. F. B.

5. *On Chemical Phenomena at low Temperatures.*—PICTET has experimented on the chemical and physical phenomena observable at very low temperatures. He finds that by means of powerful compressors and aspirators, a mixture of sulphur dioxide and carbon dioxide will give a temperature of −110°, nitrogen

monoxide and ethylene about —150°, and air a minimum temperature of —210° to —213°. These low temperatures were measured with a dry hydrogen thermometer, or by alcohol or ether thermometers, verified by the hydrogen thermometer. The author observes that the very long radiant waves emitted at these very low temperatures pass readily through almost all bodies. Thus a vessel at —110° for example will cool with practically the same rapidity whether the layer of cotton enveloping it be 50^{cm} or 10^{cm} or only 2^{cm} in thickness. Moreover, he finds that when chloroform is immersed in nitrogen monoxide at —120°, a thermometer placed in it sinks to —68·5° and crystallization begins. If transferred to a mixture of carbon dioxide and sulphur dioxide at —80°, the thermometer falls to —80° and the crystals of chloroform melt again. Replaced in the nitrogen monoxide at —120°, the thermometer rises to —68·5° and crystallization begins again. At —83·5° the crystals remain stationary increasing when the temperature falls and melting when it rises. Since crystallization takes place on the inner wall when the vessel is cooled at —120° it seems probable that the thermometer in the middle is affected by the heat of crystallization and at —68·5° is in dynamic equilibrium with the medium in which it is immersed. At —80° no crystals are formed and the thermometer is affected by radiation only.— *C. R.*, cxiv, 1245 ; *J. Chem. Soc.*, lxii, 1138, October, 1892.　　　　　　　　G. F. B.

6. *The new Telephotographic lens.*—This invention of T. R. Dallmeyer makes it possible to obtain large pictures of objects situated at long distances by short exposures. The anterior element of his combination of lenses is a positive lens of large aperture and short focus, while the posterior is a negative and of fractional part of the focal length of the former lens. One is reminded of the principle of the Galilean telescope, with this difference, that the emergent rays are convergent and not divergent. The size of an image thrown on a screen can be varied at will by altering the distance between the elements. The farther the lens is from the focussing screen the longer will be the time of exposure. Some pictures taken by this lens were exhibited at a meeting of the Camera Club in London. One picture represented a building at a distance of 500 yards. The telephotographic lens, with 30 inches extension, represented the house as 6¼ inches long, while a rapid rectilinear lens, with extension of 14 inches, gave the house as ¾ inch long.—*Nature*, p. 161, Dec. 15, 1892.

　　　　　　　　J. T.

7. *Oxygen for lime light.*—The oxygen gas obtained from atmospheric air by what is known as the Brin process, gives on an average a purity of 95 per cent oxygen. T. C. Hepworth in a letter to *Nature*, has compared the performance of this gas in a lime light with an impure gas containing only 60·6 per cent oxygen. The light afforded by the impure oxygen was about one-half as intense as the light given by the purer oxygen. With the good oxygen the lime cylinder was quickly fitted, while with

the other it showed no signs of destruction.—*Nature*, p. 177, Dec. 22, 1892. J. T.

8. *Interference of Electric Waves.*—A Ruhmkorf coil was made to vibrate 130 times per second by means of a thermopile. To one of its terminals was attached a copper wire ending in a hook, to which a linen thread soaked in calcium chloride was attached by one end, the other hanging free. One of the terminals of a telephone was placed in contact with the thread, the other being isolated. The sound in a telephone was completely extinguished at a certain distance from the copper. When both ends of the thread (which was 3^m long), were connected by fine copper wires, two points of extinction were reached, one from each end. On shortening the thread these points approached each other and formed a zone of extinction between them. This zone of extinction spread over the entire copper wire as the thread was shortened to zero. The neutral zone is due to interference of two waves of the same period and of equal potential meeting in opposite directions.— *Comptes Rendus*, Nov. 14, 1892, *Nature*, Nov. 24, 1892. J. T.

9. *Explanation of Hall's phenomenon.*—E. LOMMEL in a preliminary notice, states that by means of a suitably strong current, magnetic filings sprinkled upon a conducting plate will arrange themselves so as to form a beautiful representation of the equipotential lines of the current. When this conducting plate is brought into a magnetic field these magnetic force lines alter in length and the stream lines of the current, perpendicular to the magnetic force lines, also change, and in these changes can be found an explanation of the Hall phenomenon.—*Ann. der Physik*, No. 12, 1892, p. 766. J. T.

10. *A Mercury Voltaic arc.*—H. AVON has succeeded in producing a mercury vapor light, of great intensity, by suitably inclining a column of mercury held in a Ω shaped tube which is connected at its point of greatest curvature with a straight tube which is provided with a T-shaped connection, which allows connections to a manometer and to an air pump. When the column of mercury in the inverted U-tube is caused to separate at its bending by a slight shock a Voltaic arc results at this point which fills the whole section of the tube with an extraordinarily intense light. Avon gives a list of the spectrum lines which he has measured by means of this light. In addition to the thirteen lines measured by Kayser and Runge, he finds twenty more.— *Proceedings of the Physical Society of Berlin*, Oct. 21, 1892, *Ann. der Physik und Chem.*, No. 12, 1892, p. 767. J. T.

II. Geology and Natural History.

1. *North American Fossil Mammals.*—Volume IV, of the Bulletin of the American Museum of Natural History, just completed, contains the following important papers on Fossil Mammals :—

Fossil Mammals of the Wasatch and Wind River beds, (collection of 1891), by H. F. OSBORN and J. L. WORTMAN, covering 68

pages.—The paper contains valuable notes on several of the species of these beds. The facts with regard to the Creodont, *Palæonictis occidentalis* are illustrated by a large plate showing the jaws and teeth; and figures of the dentition of Pachyæna and other genera are contained in the text. Coryphodon is described as being plantigrade behind while digitigrade in the forefeet, and figures are given. The skull of *Systemodon tapirinus* is represented. These are a few of the many points brought out.

Revision of the Species of Coryphodon, by CHARLES EARLE. For the preparation of this paper Mr. Earle had access to the collections of the American Museum of Natural History, and the collection of Coryphodon remains of Prof. Cope which was liberally placed at the author's disposal. The number of species which had previously been described is twenty-one, seven of these under the genus Coryphodon, ten under Bathmodon, two pertaining to Metalophodon, and one to each Manteodon and Ectacodon. All were described by Cope except one species of Coryphodon, *C. hamatus* of Marsh. The study of the specimens by Mr. Earle has led him to reduce the number of species to ten ; *Coryphodon radians, C. testis, C. elephantopus, C. cuspidatus, C. hamatus, C. obliquus, C. curvicristis, C. anax, Manteodon subquadratus* and *Ectacodon cinctus.* He expresses doubt with regard to *C. hamatus*, as he had not seen the specimen.

Characters of Protoceras (Marsh), *the new Artiodactyl from the Lower Miocene,* by H. F. OSBORN and J. L. WORTMAN.—The specimens of this horned Artiodactyl belong to the species *P. celer* of Marsh. The collections of Prof. Marsh include a female skull, and those of the American Museum a male. Both are here described and figured, and also the bones of the fore and hind feet. The *Protoceras celer* was made the type of a new family by Marsh; and this view is sustained by the authors. They place the family between the Tragulina and the Pecora. From the latter they are widely different, having no marked affinities in the direction of either of the families, the Giraffidæ, Cervidæ or Bovidæ. From the former the divergence is less great, but instead of having no horns, they have multiple horns, there being paired bony protuberances on the parietals, frontals and maxillaries, besides having several other important points of difference. The number of these bony protuberances on the cranium is ten. These protuberances however are not horn-cores, but had a dermal covering. "The grotesque appearance is heightened by the large canines, which give the lateral aspect of the skull a decided suggestion of resemblance to that of the Uintatherium."

The Proceedings of the Academy of Natural Sciences of Philadelphia for August, 1892, contains (pp. 291–323) a "*Revision of the North American Creodonta*" by W. B. SCOTT, with notes on some genera which have been referred to that group, based chiefly on the large collection of Professor Cope. The following provisional families are described : Oxyclænidæ, Arctocyonidæ,

Triisodontidæ, Mesonychidæ, Proviverridæ, Hyænodontidæ, Palæonictidæ, Miacidæ; and then notes follow on the genera referred to these groups.

The same volume of the Proceedings of the Academy (p. 326) contains a note by Prof. COPE on the discovery of remains of *Hyæna* and other Carnivores in the Pliocene Blanco beds on the Llano Estacado in western Texas. The Hyæna—the first found in America—is named the *Borophagus diversidens*. One of the other Carnivores, is a Weasel, and is named by Prof. Cope *Canimartes Cumminsii*, after its discoverer; and a third, *Felis Hillianus*, after Prof. R. T. Hill.

Memoir on the Genus Palæosyops of Leidy and its allies, by CHARLES EARLE. pp. 267–388, 4to, of the Journal of the Academy of Natural Sciences of Philadelphia, vol. ix (Oct., 1892).— This able monograph on the genus *Palæosyops*, 120 pages in length and illustrated by five plates, is based on the study of the collections of the Philadelphia Academy, those of Prof. Cope, others of the Princeton Museum, and specimens in the Yale College Museum. The Princeton collections, obtained in four expeditions to the region under the leadership of Professors Scott and Osborn, are especially large, and have enabled the author to add to his many excellent illustrations a restoration of Leidy's *Palæosyops paludosus*. With regard to the relations of the genus, he says: " I think that *Palæosyops* and the allied genera, *Diplacodon*, and *Titanotherium*, should be placed in "the family Titanotheriidæ." As the prefatory remarks state, "the association of the renowned name of Dr. Joseph Leidy with this genus gives to these investigations especial interest at the present time."

2. *Geology of the Eureka District*, by ARNOLD HAGUE. 396 pp. 4to, with 8 plates and a folio Atlas of 13 plates. Volume XX, of the Memoirs of the U. S. Geological Survey.—This volume, besides treating of the general geology and ores of the Eureka region, discusses at length the nature and origin of its igneous rocks. The system of flexures and faults in the rocks is referred to time after the Carboniferous and before the close of the Jurassic period. No Mesozoic rocks occur in the region. The igneous rocks are termed volcanic; but no volcanoes are reported ; instead, the eruptions were along the old faults of the region, and through fissures made at the time of the eruptions. The ejection of the andesites and rhyolites was followed by the deposition of the ores, and the latter are stated to have come up from below as the result of solfataric action which accompanied the igneous action, but as having become more or less changed into different kinds, and distributed by the prolonged continuance of this action.

The final conclusions of the author as to the relations and origin of the igneous rocks, are presented in a closing summary as follows (p. 289).

The Eureka District presents a most instructive volcanic region standing quite apart from all other centers of similar eruption, yet, in the nature of its extravasated material, typical of many localities in the Great Basin.

The region offers no direct proof of the age of volcanic energy; yet all evidence points to the conclusion that the eruptions belong to the Tertiary era and for the most part to the Pliocene period. They may have extended well on into Quaternary time, although there is no reason to suppose that eruptions took place within historic time.

As regards their mode of occurrence the principal eruptions may be classed under four heads : First, they broke out through profound fissures along the three great meridional lines of displacement, the Hoosac, Pinto, and Rescue faults, and to some extent along the lesser parallel faults; second, following the lines of orographic fracture, they border and almost completely encircle the large uplifted masses of sedimentary strata like the Silverado and County Peak block and the depressed Carboniferous block between the Hoosac and Pinto faults ; third, they occur in numerous dikes penetrating the limestone ; fourth, they occur in one or two relatively large bodies, notably Richmond Mountain and Pinto Peak, along lines of displacement already mentioned.

All the lavas may be classed under the heads : hornblende-andesite, hornblende-mica-andesite, dacite, rhyolite, pyroxene-andesite, and basalt. They pass by insensible gradations from one to the other. All division lines are more or less arbitrary ; they are necessary for the purposes of classification, although they may not exist in nature.

Field observations clearly show that the order of succession of these natural groups into which the lavas have been divided was as follows : First, that the hornblende-andesite was the earliest of all the erupted material; second, that the hornblende-mica-andesite followed the hornblende-andesite ; third, that the dacite followed the hornblende-mica-andesite ; fourth, that the rhyolite closely followed the dacite ; fifth, that the pyroxene-andesite succeeded the rhyolite ; sixth, that the basalt was the most recent of all these volcanic products.

In chemical composition this entire series of lavas shows a range in silica amounting to about 25 per cent, a range which is quite as wide as is usually found in most centers of eruption even where the volume of lavas thrown out is vastly greater and the duration of volcanic energy far longer. Analyses show endless transition products between the extreme basic and acidic lavas, with a tendency of the alkalies and silica to accumulate at the acidic end and the material forming the ferro-magnesian minerals at the basic end.

It is maintained in this work that all the varied products of eruption are derived from a common source, a homogeneous molten mass. Under a process of differentiation this earlier mass split up into two magmas, designated as a feldspathic and a pyroxenic magma. The lavas at Eureka are the result of the same process of differentiation derived from one or the other of these magmas. Beginning with hornblende-andesite, the earliest lava, the feldspathic magma became more siliceous until the close

of rhyolitic eruptions. The rhyolite was followed by pyroxene-andesite and the eruptions became more and more basic until the close of the volcanic period. The feldspathic and pyroxenic lavas do not approach each other in their tenure of silica within 2·25 per cent. In chemical composition the earliest eruptions of both magmas resemble each other, but from this common ground they differentiate steadily until the feldspathic reaches the extreme acidic, and the pyroxenic the extreme basic end of their respective series. The extreme products of differentiation in any volcanic center in the Great Basin are rhyolite and basalt.

3. *Geological Survey of Alabama*, Prof. E. A. SMITH, the State Geologist, has recently issued a brief sketch of the Geology of Alabama, occupying 36 octavo pages. There has been published also Bulletin No. 4, of the Alabama Survey, consisting of a Report on the Geology of Northeastern Alabama and adjacent portions of Georgia and Tennessee, by C. WILLARD HAYES, Assist. Geol. U. S. G. S., which describes the rocks and the orographic structure of the region, gives figures of the flexures and faults, and closes with an excellent colored map showing the distribution of the Paleozoic formations from the Cambrian upward.

4. *Geological Atlas of the United States, Chattanooga sheet, Tennessee.*—A large folio brochure, consisting of 6 pages of text and 4 maps, has just been published by the United States Geological Survey. The maps include a topographical map of the region, two detailed geological maps in colors, and one sheet of sections. The area represented covers about 100 square miles. The size of the maps is $14\frac{1}{2}$ by $17\frac{1}{2}$ inches. The work is in the best style as regards the exhibition of the geological formations, and is also faultless esthetically. The charts are the commencement of a series, already far advanced as regards geological investigation, which has in view the representation of the geological structure of the Appalachian region. The names of the geologists mentioned on the charts are G. K. Gilbert, Chief Geologist, Bailey Willis, Geologist-in-charge, and Geology by C. Willard Hayes.

5. *The North American Continent during Cambrian Time*, by C. D. WALCOTT. From the 12th Report of the Director of the U. S. Geological Survey, for 1890–91, pp. 529–568.—Mr. Walcott here exhibits in an instructive way by maps and descriptions his results as to the geographical condition of Cambrian North America.

6. *The Lafayette Formation*, by W. J. McGEE, Ibid., pp., 351–521.—This paper is a very full exhibition of the characters and distribution of the Lafayette formation. The latter subject is presented on a colored geological map, which exhibits also the author's views as to the distribution of the Columbian formation.

7. *The Origin and Nature of Soils*, by N. S. SHALER, Ibid. pp. 217–346.—Professor Shaler considers the subject of soils from a geological point of view. The sources of soils are explained, their various characteristics, the processes by which they have been formed over regions of diverse conditions, and the geological

agencies, living and physical, concerned in modifying them, and many fine plates illustrate the topics discussed. The paper closes with observations on the action and reaction of man and the soil.

8. *Cambrian Fossils of New Brunswick.* — Bulletin of the Natural History Society of New Brunswick, No. X, St. John, N. B., contains a paper on *Protolenus*, a new genus of Cambrian Trilobites from the St. John group, by G. F. MATTHEW. The same genus is described by Mr. Matthew and two species figured in the Canadian Record of Science for October, 1892.

9. *Experiments in Physical Geology.*—Professor ED. REYER of Vienna has lately issued three interesting brochures upon subjects in physical geology. They are entitled : Ursachen der Deformationen und der Gebirgsbildung (pp. 40) ; Geologische und Geographische Experimente, Heft I, Deformation und Gebirgsbildung (pp. 52) ; Heft II, Vulkanische und Massen-Emptionen (pp. 55, Wm. Engelmann, Leipzig.) The first named is a general statement of conclusions based on the experiments which are very thoroughly illustrated in the last two. The subject is treated in the form of a discussion of several hypotheses to explain mountain-making. These are: I, Changes of substance as by oxidation, hydration, solution, etc.; II, Contraction of the earth; III, Differences of density; IV, Loading or as it is termed the " Onerar-hypothesis ; " V, Hypotheses based on heat; VI, Deformations due to eruptions. The author's wide experience in many regions of geological disturbance and of igneous activity enables him to throw much light upon the subject treated. The numerous experiments were made on small models, which were compressed in the usual way with a screw. Materials of varying firmness were employed, so as to represent both stiff and yielding strata. The results of the successive steps in each experiment are liberally illustrated, so that the application to the similar cases in nature are obvious, almost without the verbal explanation.   J. F. K.

10. *Brief notices of some recently described minerals.*—GEIKIE-LITE and BADDELEYITE are two species described by Fletcher as occurring in the form of pebbles in the gem washings near Rak-wana, Ceylon.

Geikielite shows two cleavages at right angles to each other, one of them perfect. It has a splendent metallic luster and bluish black color, though thin cleavage flakes have a purplish red tint. The hardness is 6·5 and specific gravity 3·98. An analysis shows it to be a magnesium titanate, $MgTiO_3$ corresponding to perovskite, $CaTiO_3$.

Baddeleyite resembles columbite in general aspect and has a specific gravity of 6·02 and hardness of 6·5 ; the crystallization is probably monoclinic. In composition it is also highly interesting, it consisting of zirconia, ZrO_2, an oxide not before found among minerals but whose existence in nature was to have been anticipated.—*Nature*, Oct. 27, 1892.

BRAZILITE is described by Hussak from the granular pyroxenic rock called jacupirangite at the iron mine of Jacupiranga, Brazil.

It occurs in monoclinic crystals tabular parallel to *a* (100) ; they are usually twins and often complex. The color is yellow to dark brown, the luster greasy to vitreous, the hardness 6·5, and the specific gravity 5·006. It is announced as a tantalo-niobate probably near to yttrotantalite, but the author (priv. contrib.) has stated later that Prof. Blomstrand finds it to consist of zirconia ; it hence is to be united with baddeleyite. (Jahrb. Min., ii, 141, 1892,). Fletcher (letter of Jan. 7) suggests that the original qualitative tests may have been made upon a different mineral, from that described crystallographically and analyzed by Blomstrand.

Folgerite, Blueite, Whartonite.—Dr. Stephen H. Emmens has recently given (Jour. Amer. Chem. Soc., xiv, No. 7) the results of an examination of some nickel minerals from the Sudbury district, Algoma, Ontario, to which the above names have been given.

Folgerite occurs massive with a light bronze-yellow color and grayish black streak ; specific gravity 4·73 ; hardness 3·5 ; non-magnetic. One of three analysis is given below (I), the composition corresponds to $NiFeS_2$ or intermediate between millerite and pentlandite. It is named after Commodore W. M. Folger of the U. S. Navy.

Blueite occurs massive with olive-gray to bronze color, black streak, specific gravity 4·2 and hardness 3 to 3·5 ; it is non-magnetic. An analysis (deducting gangue) is given under II below ; in composition it is a nickeliferous pyrite with Fe : Ni = 12 : 1, though it differs in being easily soluble in nitric acid without separation of sulphur. It is named after Mr. Archibald Blue, now Director of the Bureau of Mines of Ontario.

Whartonite occurs in cellular form with granular structure, the cavities being lined with minute cubic crystals ; color bronze-yellow, streak black ; hardness 4 and specific gravity 3·73 : About 10 p. c. of the fine powder was found to be magnetic and the analysis leads to the conclusion that it is a mixture of a nickeliron disulphide with some magnetite ; deducting the latter the results in III are obtained, corresponding to $(Fe, Ni)S_2$ with Fe : Ni = 7 : 1. It is named after Mr. Joseph Wharton, of Camden, N. J.

The analyses are as follows :

		S	Fe	Ni	
I.	*Folgerite*	31·10	33·70	35·20	= 100
II.	*Blueite*	55·29	41·01	3·70	= 100
III.	*Whartonite*	52·29	41·44	6·27	= 100

To these analyses of the Sudbury nickel ores may be added those quoted in Dana's Mineralogy (1892, pp. 65, 74, 75), also those by Hoffmann mentioned in the January number (p. 76) ; it can hardly be supposed that all of these ores are distinct homogeneous minerals.

Nickel-Skutterudite. A gray metallic mineral of granular structure occurring in silver ore (native silver) near Silver City,

New Mexico, is described by E. Waller and A. J. Moses. It has a hardness of about 5, gray color and black streak. An analysis, after deducting 4·56 of SiO_2 and 8·38 silver gave the results below; these correspond to RAs_3 with $R = Ni : Co : Fe = 4 : 2 : 1$, or skutterudite in which the cobalt is largely replaced by nickel.

As	Ni	Co	Fe
78·67	12·25	6·16	2·92 $=$ 100

—*School of Mines Quarterly*, vol. xiv, No. 1.

HAUCHECORNITE is a nickel-bismuth mineral described by Scheibe from the Friedrich mine in the Hamm mining district, Germany. It occurs in tetragonal crystals and massive of a light bronze-yellow color; hardness 5, specific gravity 6·4. Analyses by R. Fischer and others gave discordant results because of the want of homogeneity of the material, but the conclusion is reached that the composition is essentially $Ni(Bi,Sb,S)$. —*Jahrb. Preus. Geol. Landesaustalt*, 1891, p. 91.

CUPROCASSITERITE.—A note upon this supposed new tin mineral from the Black Hills is given by Titus Ulke in the Transactions of the American Institute of Mining Engineers; a further critical investigation is given by Headden on p. 108 of this number.

11. *Large Variations in the Metamorphosis of the same species.*—An elaborate memoir entitled, *The Embryology and Metamorphosis of the Macroura*, by W. K. BROOKS and F. H. HERRICK, makes 140 pages quarto of the fifth volume of the Memoirs of the U. S. National Academy of Sciences, and is illustrated by 57 plates. The species microscopically investigated and here reported upon are of the genera *Gonodactylus Alpheus* and *Stenopus*. The authors mention, in the introductory pages, as one remarkable result of their study of the genus Alpheus, the discovery that while the larval stages of different species are similar, the individuals of a single species sometimes differ more from each other as regards their metamorphoses than the individuals of two very distinct species, and make on this point the following remarks :

This phenomenon has been observed by us and carefully studied in two species—*Alpheus heterochelis* and *Alpheus Saulcyi* —and it is described in detail, with ample illustrations, in the chapter on the metamorphosis of Alpheus. In the case of the first species the difference seems to be geographical, for while all the individuals which live in the same locality pass through the same series of larval stages, the life history of those which are found at Key West is very different from that of those which live on the coast of North Carolina, while those which we studied in the Bahama Islands present still another life history. In the case of the second species—*Alpheus Saulcyi*—the difference stands in direct relation to the conditions of life. The individuals of this species inhabit the tubes and chambers of two species of sponges which are often found growing on the same reef, and the metamorphosis of those which live in one of these sponges is

sometimes different from that of those which inhabit the other. In this species the adults also are different from each other, but as we found a perfect series of transitional forms there is no good reason for regarding them as specifically distinct; and in the case of the other species—*Alpheus heterochelis*—we were unable, after the most thorough and minute comparison, to find any difference whatever between adults from North Carolina and those from the Bahama Islands, although their life histories exhibit a most surprising lack of agreement. In fact, the early stages in the life of *Alpheus heterochelis* in the Bahama Islands differ much less from those of *Alpheus minor* or *Alpheus Normani* than they do from those of the North Carolina *Alpheus heterochelis ;* and, according to Packard, the Key West *heterochelis* presents still another life history.

In the summer of 1881 I received the American Naturalist with Packard's very brief abstract of his observations at Key West upon the development of *Alpheus heterochelis,* and read with great surprise his statement that this species has no metamorphosis, since, while still inside the egg, it has all the essential characteristics of the adult. As I had under my microscope at Beaufort on the very day when I read his account a newly hatched larva of the same species and was engaged in making drawings to illustrate the metamorphosis of which he denies the existence, and as my experience in the study of other Crustacea had taught me that all the larvæ of a species at the same age are apparently facsimiles of each other down to the smallest hair, Packard's account seemed absolutely incredible, and I hastily decided that, inasmuch as it was without illustrations and was written from notes made many years before, it involved some serious error and was unworthy of acceptance. This hasty verdict I now believe to have been unjust, since my wider acquaintance with the genus has brought to my notice other instances of equally great diversity between the larvæ of different specimens of a single species.

The phenomenon is, however, a highly remarkable one and worthy the most thorough examination, for it is a most surprising departure from one of the established laws of embryology—the law that the embryonic and larval stages of animals best exhibit their fundamental affinities and general resemblances, while their specific characteristics and individual peculiarities make their appearance later.

This is one of the important subjects illustrated in the following descriptions.

12. *Morphologische Studien* von K. Schumann. 1te Abtheilung. —206 pp., 6 Taleln. 8vo. Leipzig, 1892 (Wm. Engelmann.)—Prof. Karl Schumann has just published the first part of his " Morphologische Studien," in continuance of his investigations into the anatomy of the flower. These studies will concern themselves not only with flower-structure but also with the anatomy of flowering plants in general, along the lines laid down by Hofmeister in his " Allgemeine Morphologie." The first half of this part, therefore, is

devoted to a discussion of phyllotaxy. The arrangement of leaves in spiral lines is first considered and then the various published views upon this topic are discussed with some fullness. Schumann passes in review Braun's work in establishing the study of phyllotaxy upon a scientific basis, Hofmeister's effort to explain the spiral arrangement by the fact that new organs are formed in the largest gaps left between organs already formed, Schwendener's success in demonstrating the mechanical basis for phyllotaxy, and Sachs's theory that the spiral lines, e. g. in the Screw-Pine, are produced by torsion during the growth of the axis. He, himself, points out that the arrangement of leaves in straight or spiral ranks is intimately connected with the symmetrical or asymmetrical development of the sheathing bases of the leaf, which make their appearance upon the growing point of the plant before the leaves do. This relation holds true in all Monocotyledons and most Dicotyledons. In the second half, the special morphology of the genus *Adoxa* and of the Cohort *Fluviales* is discussed in support of this view.   w. a. s.

III. Miscellaneous Scientific Intelligence.

1. *Bulletin from the Laboratories of the State University of Iowa.* Vol. ii, No. 2.—This number of the Iowa Bulletin opens with a long paper on the Myxomycetes of Eastern Iowa by T. H. McBride, with ten beautiful plates from drawings by Miss Mary P. McBride. It also contains four important paleontological papers by S. S. Calvin; a paper by B. Shimek on the identity of *Pyrgula scalariformis* with *P. Mississippiensis*, and its occurrence, with other species, in the loess of the Mississippi, but known only in the fossil state; and Notes on Karyokinesis, by L. B. Elliott. Prof. Calvin reports on fossils from the Lower Magnesian limestone of Northeastern Iowa, showing their relations to those of the Calciferous of New York.

2. *Astronomical Journal Prizes.*—Two prizes of two hundred dollars each, in a gold medal or in money, are offered in the *Astronomical Journal*, No. 284, to be awarded to resident citizens of the United States. Details of the conditions are given in the *Astr. Journal.*

The first will be given for the best series of determinations of the positions of comets during the year ending March 31st, 1894: —the second for the best discussion of the path of a periodic comet, the investigation to be made within the two years next preceding Sept. 1, 1894.

3. *Ostwald's Klassiker der Exakten Wissenschaften.*—A notice of this valuable series was given in the January number of this Journal; the three following volumes have just been issued :

No. 38. Photochemische Untersuchungen von R. Bunsen and H. E. Roscoe, (1855–59). Zweite Hälfte.

No. 39. Die in der Atmosphäre vorhandenen organisirten Körperchen: Prüfung der Lehre von der Urzeugung von L. Pasteur (1862).

No. 40. Zwei Abhandlungen über die Wärme von A. L. Lavoisier und P. S. DeLaplace (1780 u. 1784).

APPENDIX

Art. XXII.—*Restoration of Anchisaurus;* by
O. C. Marsh. (With Plate VI.)

The Triassic Dinosaurs now known from the Connecticut
river sandstone have been investigated by the writer, and some
of the results have already been placed on record in this
Journal.* Remains of five individuals have been discovered,
sufficiently well preserved to indicate the main characters of
the animals to which they pertained. These were all carnivo-
rous forms of moderate size, and the known remains are from
essentially the same geological horizon. Many larger forms,
probably herbivorous, are indicated by footprints, but no
characteristic portions of the skeleton have yet been found.

The genus *Anchisaurus*, one of the oldest known members
of the *Theropoda*, is so well represented by parts of four
skeletons, two nearly complete, from these deposits, that a
restoration of one species can now be made with considerable
certainty. This has been attempted, and the result is given,
one-twelfth natural size, in the accompanying plate. The
animal when alive was about six feet in length.

The skeleton chosen for this restoration is the type speci-
men of *Anchisaurus colurus*, already described by the writer.
This skeleton when discovered was entire, and apparently in
the position in which the animal died. Portions of the neck
and the tail vertebræ were unfortunately lost before the
importance of the specimen was realized, but the skull and
nearly all the rest of the skeleton were saved. From these
the matrix in great part has been removed, so that the more
important characters can be made out with certainty. The
parts missing are fortunately preserved in a smaller specimen
of an allied species (*Anchisaurus solus*) found at the same
locality, and these have been used to complete the outline of
the restoration. Portions of two other specimens, nearly
allied, and from the same horizon, were also available, and
furnished some suggestions of value.

The restoration as shown on Plate VI. indicates that
Anchisaurus colurus was one of the most slender and delicate
dinosaurs yet discovered, being only surpassed in this respect
by some of the smaller bird-like forms of the Jurassic. The

* This Journal, vol. xxxvii, p. 331, April, 1889; vol. xlii, p. 267, September,
1891; and vol. xliii, p. 543, June, 1892.

position chosen is one that must have been habitually assumed by the animal during life, but the comparatively large fore limbs suggest the possibility of motion on all four feet. The compressed terminal digits of the fore feet, however, must have been covered by very sharp claws, which were used mainly for prehension, and not for locomotion.

The small head and bird-like neck are especially noticeable. The ribs of the neck and trunk are very slender. The tail apparently differed from that of any other dinosaur hitherto described, as it was evidently quite slender and flexible. The short neural spines and the diminutive chevrons directed backward indicate a tail not compressed, but nearly round, and one usually carried free from the ground.

The present restoration will tend to clear up one point long in doubt. The so-called "bird-tracks" of the Connecticut river sandstone have been a fruitful subject of discussion for half a century or more. That some of these were not made by birds has already been clearly demonstrated by finding with them the impressions of fore feet, similar to those made by reptiles. Although no osseous remains were found with them, others have been regarded as footprints of birds, because it was supposed that birds alone could make such series of bipedal, three-toed tracks and leave no impression of a tail.

It is now evident, however, that a dinosaurian reptile like *Anchisaurus* and its near allies must have made footprints very similar to, if not identical with, the "bird tracks" of this horizon. On a firm but moist beach, only three-toed impressions would have been left by the hind feet, and the tail could have been kept free from the ground. On a soft, muddy shore, the claw of the first digit of the hind foot would have left its mark, and perhaps the tail also would have touched the ground. Such additional impressions the writer has observed in various series of typical "bird tracks" in the Connecticut sandstone, and all of them were probably made by dinosaurian reptiles. No tracks of true birds are known in this horizon.

The genus *Ammosaurus*, represented by remains of larger size from the same strata, was a typical carnivorous dinosaur, and apparently a near ally of *Anchisaurus*. So far as at present known, the footprints of the two reptiles would be very similar, differing mainly in size.

The only other reptile known from the Connecticut sandstone by any part of the skeleton is a large *Belodon* from a lower horizon. This crocodilian may be called *Belodon validus*, and will be described by the writer later.

New Haven, Conn., Jan. 21, 1893.

CONTENTS.

SCIENTIFIC INTELLIGENCE.

Chemistry and Physics—Re-conversion of Heat into Chemical Energy in the production of Gas, Naumann, 155.—Temperature of Ignition of Electrolytic Gas, Freyer and V. Meyer: Electromotive Activity of the Ions, Nernst and Pauli, 156.—Separation of Precipitates at the Surface bounding Electrolytes, Kümmell: Chemical Phenomena at low Temperatures, Pictet, 157.—New Telephotographic lens, T. R. Dallmeyer: Oxygen for lime light, T. C. Hepworth, 158.—Interference of Electric Waves: Explanation of Hall's phenomenon, E. Lommel: Mercury Voltaic arc, H. Avon, 159.

Geology and Natural History—North American Fossil Mammals, 159.—Geology of the Eureka District, A. Hague, 161.—Geological Survey of Alabama, E. A. Smith: Geological Atlas of the United States, Chattanooga sheet, Tennessee: North American Continent during Cambrian Time, C. D. Walcott: Lafayette Formation, W. J. McGee: Origin and Nature of Soils, N. S. Shaler, 163.—Cambrian Fossils of New Brunswick, G. F. Matthew: Experiments in Physical Geology, E. Reyer: Brief notices of some recently described minerals, 164.—Large Variations in the Metamorphosis of the same species, W. K. Brooks and F. H. Herrick, 166.—Morphologische Studien, K. Schumann, 167.

Miscellaneous Scientific Intelligence—Bulletin from the Laboratories of the State University of Iowa: Astronomical Journal Prizes: Ostwald's Klassiker der Exakten Wissenschaften. 168.

A. E. FOOTE,

4116 Elm Avenue,   **Philadelphia, Pa., U. S. A.**

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ART. XXIII.—*The Diversity of the Glacial Period;* by
T. C. CHAMBERLIN.

IN the November number of this Journal, there appeared
an article entitled "The Unity of the Glacial Epoch," by
Prof. G. Frederick Wright, that seems to call for a rejoinder,
partly to set right the personal views of some whose positions
are opposed, and partly to state with a greater approximation
to correctness the leading facts bearing on the question and
the necessary inferences from them. There are many ques-
tions relating to the problem that are legitimate subjects of
difference of opinion. Were the article confined to these, it
would be foreign to my habit to reply to it. Even as it is, if
this were the first or the second or the third discussion by the
author that has failed to correctly represent personal views and
scientific determinations, I should doubt whether I were justi-
fied in writing an article that must necessarily embrace a large
controversial factor.

The article is not of the nature of a constructive advocacy
of the unity of the Glacial epoch, as its title seems to imply,
but an attempt at destructive criticism of the evidences ad-
vanced in support of the duality or diversity of the Glacial
period, and an attack upon the individual positions of some of
the advocates of these views. The insufficiency of all argu-
ments advanced for duality or diversity, even if demonstrated,
would, without positive arguments in proof of unity, only put
the question back where it was two decades ago. It would
make it simply a matter of doubt, with only conservatism on
the side of simplicity. That is an effort of doubtful utility at

the present time. The advocates of unity should present direct evidences of indivisibility and of the persistence of like conditions throughout the period if they are to merit attention. Destructive arguments have their place in such discussions, but they have an inferior value, unless they are attendants of affirmative arguments.

Prof. Wright's introductory statement of the question seems to me to need radical reconstruction to be even approximately representative of the present attitude of glacialists. If we set aside the views of those who hold glacio-natant theories of the origin of the drift, in whole or in part, there will remain at least four classes of views, with an ulterior fifth class. These may be designated, (1) the primitive views of unity, (2) the later views of unity, (3) the several views of duality, (4) the several views of plurality or diversity, and (5) ulterior synthetic views based on exhaustive analysis.

1. *Primitive views of unity.* — The old views of unity recognize but a single comparatively short ice invasion (modified by oscillations of the margin), involving but one stage of land elevation followed by one stage of depression, the Champlain. Local glaciation was held to be an incident of the retreat, and an elevation was thought to accompany the succeeding Terrace epoch. The stages of elevation and depression were quite generally held to have a genetic relationship to glaciation, but that was not universal, nor is it essential to the classification. It was the view of some that local glaciation accompanied the elevation of the Terrace epoch, thus constituting a species of second glaciation, but this is immaterial so far as the interpretation of the great body of drift in the United States is concerned

2. *Later views of unity.*—The later views of unity depart somewhat radically from the old ones in postulating a long depression, or series of depressions, in the earlier stages of glaciation (perhaps preceded by a stage of elevation), followed by a prolonged stage or series of stages of elevation followed again by a stage of depression, this last being the Champlain depression in the strict sense of the term. This view differs from the old doctrine of unity in the important and very necessary feature of recognizing at least one early stage of depression, of which several separate episodes of glaciation have already been determined. It also parts company with the old view in entertaining a radically different conception of the extent and complexity of the period and of the importance of its constituent episodes. The working methods of those who hold this view are radically different from those of the old school, as well as their habits of interpretation, in that they are analytical and discriminative in respect to structural,

genetic and historical factors. In these respects, this view does not very essentially differ from the following views. It only diverges from them in recognizing the whole complex series of glacial movements as connected and bound together across the episodes of retreat and advance by conditions that are to be interpreted as signifying continuity rather than discontinuity.

3. *Duality.*—The several views of duality differ in detail, but they agree in recognizing one, and only one, epoch of deglaciation of such nature and importance as to justify a division of the period into epochs by means of it. Each of the two epochs is held to have been marked by episodes of ice advance and retreat and other changes, but these are thought to be subordinate to a bipartite division. The separation of the epochs of lake-formation in the Great Basin region by an interval of aridity, the separation of the epochs of glaciation of the interior by an interval of extensive and high-gradient erosion and weathering, and the intervention of a temperate fauna and flora between glaciated deposits in Europe, are typical illustrations of the class of data to which these views appeal. It is not essential to prove or to hold that the ice completely left the continent, any more than it is necessary to prove or to hold that the sea retreated from the land between the recognized epochs of the Niagara period. The question is not a question of two glacial *periods* but of two glacial *epochs*, as these terms have come to be commonly used in America and England. This does not make the distinction merely a choice of terms. It is a distinction of ideas, and of not unimportant ideas. The dualist holds that he has grounds for an important subdivision of glacial history comparable in significance to that which divides the periods preceding. There is, it is true, an element of judgment here, as in all similar cases, but back of that there is an essential distinctness of ideas.

4. *Plurality or diversity.*—Some of the most experienced glacialists of Europe and of this country who have held to the last class of views, have come to feel their inadequacy in the interpretation of the vast growing mass of evidence, and have enlarged their views in the direction of still greater diversity. These have come either to recognize three or more glacial epochs, or to feel that the diversity is so great as to make a simple bi-partite division unsatisfactory. One of the latest and most notable expressions of this class of views is to be found in a recent paper by Dr. James Geikie, "On the Glacial Succession in Europe" (Trans. Roy. Soc. Edinburgh, May 16th, 1892) in which five glacial epochs are recognized, and a map of the distribution of the ice in the second and fourth of these epochs is given.

1. Doubtless nearly or quite all the older students of drift, of the glacial school, once entertained views that should be placed under the first class. Such views linger with some whose later attention has been turned in other directions chiefly, and with some whose studies have been confined to areas presenting only one time-phase of the drift conspicuously, and some hold these views for reasons less felicitously explained. I should class Professor Wright's views in the primitive group. He is doubtless in advance of many phases of the older views and his papers show some progress, but he has failed to definitely recognize and accept two stages of depression separated by an important stage of elevation. This is best illustrated by his position respecting the formations of the Delaware region, which will be noted further on. His impression of the extent and complexity of the ice age is of the earlier rather than of the later order. He does indeed use terms that by themselves would signify great extension and complexity, but he employs arguments and interpretations which show that they carry a significance very different from that which is given them by those who take the newer and enlarged views of unity. For instance, he objects to the reference of the erosion of the lower gorge of the Allegheny and Upper Ohio Rivers to an interglacial epoch on the ground of the length of time required by the erosion, and speaks of such views as "making unnecessary demands on the forces of nature." (Man and the Glacial Epoch, p. 218.) His descriptions of the Ice age in his two books and elsewhere seem to me to convey an archaic and bedwarfed impression both of the extent and complexity of the period. I cannot, therefore, think that his views of the glacial period have any such extension as would entitle them to be classified under the newer views of unity. The most serious phase of the matter is that neither analytical methods nor their results seem to find even an approximately accurate reading, much less exposition and discussion, at his hands.

2. The later views of unity seem to have few, if any, declared advocates, due, doubtless, to the fact that as soon as a glacialist comes to realize the nature of the phenomena involved to an extent sufficient to cause him to dismiss the primary views, he quickly passes on into the third or fourth class, or else takes an attitude of conservatism and reserve, and awaits further evidence before engaging in a definite advocacy. These views are, however, entitled to a distinct place and to full recognition, because they not only represent the attitude, whether transient or otherwise, of a considerable body of glacial students, but they are still kept among the working hypotheses of many who employ the method of multiple working

hypotheses. That method requires that all hypotheses not absolutely excluded by evidence should be retained in the working group. If any doctrine that can properly be designated a doctrine of unity shall ultimately prevail, it will be one that will be developed along the lines of effort which characterize this class and distinguish it from the first class.

So far as the attitude of those who entertain this class of views concerns analytical methods of working, it stands, so far as it is typical, in sharp antagonism to that of the advocates of the first class, because the ultimate establishment of their views depends upon the clear discrimination of the glacial deposits that were formed in the apparent intervals appealed to by the advocates of the third and fourth classes and upon the demonstration that such episodes of glaciation occupied these intervals. This involves not only the clear discrimination of the intervals but the determination of the special deposits that bridge them. This demands the utmost resources and highest refinements of analytical and discriminative methods. Success will not lie in ignoring or belittling the extension of glacial time or the greatness of the intervals now discovered; but, if attained at all, it will be through ability to fill in the gaps with undiscovered deposits and to bridge over the unquestionable changes of surface attitude with gradational stages and concurrent glaciation, and to demonstrate that the variations in the character of glacial action took place by such gradual steps as to bind the whole into inseparable unity. This requires an attitude toward discriminative work precisely opposite that assumed in Professor Wright's discussion of the subject.

3. It is difficult to name, and moreover unprofitable to attempt to name, the glacialists who at the present hour advocate the doctrine of duality as distinguished from plurality or diversity, since so many of those who some time ago felt compelled by evidence to believe in at least one interglacial epoch, but who were not convinced that it was necessary to recognize more than one of the major type, have in recent years passed on to, or at least toward, the recognition of two or more such intervals under the impress of the accumulation of evidence. No one can have followed conscientiously the onward movement of opinion during the last few years and have failed to note the strong drift from simple duality toward either a strongly diversified duality or toward plurality. In the midst of this movement, it is idle, as well as harmful, to attempt to define the positions of individual glacialists in so far as they have not recently defined them for themselves.

4. What has just been said applies to the lower limit of the fourth class, but there are some whose declared opinions make

this a distinct and important group. The very able paper by Dr. James Geikie, already referred to, is a notable expression of advanced opinion of this kind. Incidentally it indicates a similar attitude on the part of some other European glacialists of large and varied experience and of unquestioned ability, and some American glacialists have indicated at least a hospitable attitude to similar views. A comparison of the actual position of Dr. Geikie with that assigned him by Professor Wright, and a comparison of the array of evidence which Dr. Geikie advances with the treatment it received in the article in the November number of this Journal is one of several illustrations of the ground of my protest.

5. There is an ulterior synthetic view to be based on a previous exhaustive analysis to which every cautious student of the subject looks forward as the ultimate interpretation. This is an ulterior view because it is impossible to take such a view at the present time, except in a crude prophetic sense. The method may now be clearly seen but the data for its realization are not at hand. The first step toward it is a thoroughgoing analysis of the glacial complex into its constituent deposits and the definite delineation of these both in plot and in section involving the tracing out of the connections and the correlations of the constituent sheets, the determination of the intervals that occur at different horizons and in different sections of the country (for they are not the same everywhere), and the evaluation of the nature and length of the intervals and their climatic, orographic and other characteristics. Then will come the final test of the unity views, in the demonstration, or the failure to demonstrate, that episodes of glaciation fill in the intervals and bind the whole into indivisible unity. Then will come, also, the final test of the doctrines of duality or diversity in the establishment, or nonestablishment, of intervals which prolonged research has failed to bridge, and which temperate faunas and floras show to be necessarily interglacial intervals, unless there be brought into the series the distant polar connections which are presumed to exist in any case. It is in the interest of each of the classes, unless it be the archaic one, to press on analytical and discriminative studies and to give to them and to their results full recognition.

Immediately following his general statement of the question, Professor Wright remarks, "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 of "The Terminal Moraine of the Second Glacial Epoch" [correct title "Preliminary Paper on the Terminal Moraine of the Second

Glacial Epoch], thus assuming the truth of his theory in the title." I am puzzled to see how the title " The Terminal Moraine of the Second Glacial Epoch " any more assumes the truth of a theory than the title " The Unity of the Glacial Epoch." If the purpose of the sentence was to convey the impression that I commenced my consideration of the subject by assuming the truth of the duality theory, it is precisely antipodal to the fact. This paper was my seventh discussion of the moraine or some part or phase of it. The first of these was prepared while I entertained primitive and inherited views closely similar to those which Professor Wright now advocates. These views I gradually abandoned as my information increased and my series of papers show a progressive change of opinion. It was only at the close of my official work on the Wisconsin Survey, when called upon to sum up and interpret finally the results reached, that I definitely announced an abandonment of the old view and an acceptance of the dual view, assigning reasons therefor.* If anything relative to the history of my personal views is of any importance in the matter (which is not my assumption), it is this statement of change of view at the close of several years of consecutive study, a statement which had more of a final than of an inaugural character.

The effort of Professor Wright to lay the groundwork of presumption that my whole interpretation of the facts bearing on the duality of the epoch is possibly a mistake by reason of a change in my mapping in Illinois would have been without force had he made a fair statement of the case. He states, " 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 one 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," etc. (p. 353.) There is here a complete omission of all reference to the provisional lines which were marked with dots on the map in my earlier paper, and concerning which the following was said in the text :†

" There may be no more fitting place to make a qualifying remark in regard to the whole region between the moraine above traced and that adjacent to Lake Michigan. The drift of this area bears undoubted evidence of being recent, and, though this is in considerable part due, superficially, to aqueous

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* Wis. Geol. Sur., vol. i, pp. 271, 272.
† Third Ann. Rep. U. S. Geol. Sur., 1883, p. 331.

agencies, it seems to me probable that the region will prove to have been largely, possibly completely, covered by ice in the earliest stage of the second glacial epoch. It is not, however, traversed by conspicuous moraines, at least not by any as well developed as those above outlined. Low ridged belts of sub-dued morainic aspect have been observed at numerous points, but their relations have not yet been traced out.

" A similar qualifying remark may be here made concern-ing a considerable area in Northern Illinois, outside the mo-raine described in this paper. The freshness of its drift, and the unsculptured contour of its surface, bear evidence of recent origin. Some portions of this area seem clearly to be of lacustrine and fluviatile origin, at least superficially, and I have at times supposed that all might be due to waters mar-ginal to the adjacent glacier, since there is no conspicuous bordering morainic ridge; but the tendency of recent evi-dence, gathered in a special study of this class of deposits, seems to favor the hypothesis of more extensive glacial occu-pancy, even where the evidence of it in obvious moraines is feeble or wanting. This questionable region is now under investigation. The dotted lines on the map indicate some of my working hypotheses."

Prof. Wright neglects to say that my later mapping relates to this area, thus announced to be under investigation, and that its morainic lines were such as the preliminary map had foreshadowed. He further failed to say that this later map was one constructed merely to exhibit the location and direc-tion of striæ in connection with my paper on " Rock Scorings of the Great Ice Invasions."[*]   I have not yet re-discussed the region nor the moraines in question. The more recent investi-gations bring out into clearer definition and justification the ground of doubt which lay in my mind at the time of the first mapping, for they show that there are two groups of moraines representing two important episodes of glacial his-tory, and that both mappings will be retained, when corrected and perfected, as factors in an ultimate differential map of the drift of the region. To demonstrate their exact correlations east and west still remains difficult, because the later lines override the earlier at large angles and conceal their connec-tions, and because the moraines of both epochs bunch them-selves in the reëntrant angles between the ice lobes in such a way as to make their demonstrative disentanglement a work of extreme difficulty. On this account I have left the pro-visional correlations set forth in the earlier paper standing without re-discussion, that the work of later correlation might be the freer.

* 7th Ann. Rep. U. S. Geological Survey, pp. 147–248.

Having made it appear by such omissions that I had changed my mapping to the amount of a hundred miles, Professor Wright states that Mr. Leverett draws "his later moraine line" one hundred miles still farther south. If by this expression it is meant that Mr. Leverett referred this moraine line to my second glacial epoch, I think a reading of Mr. Leverett's language will fail to show warrant for it. Mr. Leverett distinctly recognized two groups of moraines coincident with two orographic attitudes. He did not discuss the relations of either of them to my correlations. If it is meant simply that this moraine was announced "later" than the others, it has no pertinence, unless it is assumed that any moraine of any sort is to be referred to my later epoch, which is not Mr. Leverett's view nor mine. As to still more southerly moraines, Mr. Leverett and myself are quite aware of the hilly belt at Greenville (whose course it may be remarked in passing makes a high angle with the drift border) and also of other more or less definable but obscure tracts of thickened drift of a terminal or quasi-terminal kind. It is a part of our hope and expectation to be able at length to trace out obscure sub-marginal thickenings of the drift sheets, and other quasi-marginal markings of one kind or another, over the whole drift field, old as well as new, where the more pronounced terminal moraines are absent. This has formed a feature of my plans for many years and considerable preliminary data have been gathered and some detailed tracing has been done in pursuit of it, in connection with work on the more important and significant moraines which mark advances of the ice and define glacial episodes if not epochs. Some of these moraines of minor significance have been mapped, and others are yet to be added. Some of them will lie not far from the border of the drift at some points, and it is to be hoped that the more obscure older drift will yield marginal indices in all districts sufficient to show its history with approximate accuracy. With this in view, I have developed new criteria of discrimination and have proposed additional distinctions between marginal moraines and have sought other marginal and submarginal markings suited to the requirements of this more critical work. Of course a map showing all these moraines and marginal lines without indicating their differences, gives a more or less anti-divisional impression, much as does the diagrammatic geological column of the text-books and dictionaries, and of course it is possible to lump these all together as "moraines of recession," or "receding moraines," just as all the sedimentary strata south of the Archæan terrane may be disposed of as deposits of sea-recession. These moraines are moraines of ice-retreat in much the same sense as the Paleozoic sediments are

beds of sea-retreat. There was a general retreat in both cases, but there were advances in both cases, and the recognition of these constitutes the essence of the science in both cases.

Besides the implications involved in the attempt to make the older moraines—even undiscovered ones—do duty as correlatives of what others regard as obviously much younger ones of different character, there is a specific erroneous impression conveyed by the statement that closer observation is not unlikely to carry the exterior moraine farther south still which would be " all that 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 carries the implication that there is a constant relation between the extreme boundary and the outer terminal moraine in the eastern part of the Mississippi Valley. This is not the case. The fresh stout moraine that lies near the border in the upper Ohio region departs from it in going westward and disposes itself in a strongly looped fashion that is not coincident with that of the border. It is precisely because of this lack of coincidence and because of the marked differences in the character of the drifts that a distinction between them is urged. In Illinois there is nothing within a hundred miles of the border that presents any rational grounds for correlation with the outer terminal moraine in Western Pennsylvania. Professor Wright claims to have spent five seasons on the border between Pennsylvania and the Mississippi River,[*] and yet he has not found in Western Ohio, Indiana and Illinois any such moraine-and-" fringe " in any such relationship as he has so often described in Western Pennsylvania. One would think that five seasons, work would give a better suggestion of what is likely to be found true respecting a moraine-and-" fringe " border, than the one offered to the effect that Mr. Leverett or some one else is not unlikely yet to find a moraine of some sort somewhere near the border. In Bulletin 58 U. S. Geol. Survey (p. 75) Professor Wright says, " In Illinois nothing like a moraine was encountered in any portion of the State which I traversed, which included Randolph, Perry, Franklin, Jackson, Williamson, Saline, Gallatin and White counties "

Mr. Leverett recognizes the following stages applicable to the region between its limit of drift in southern Illinois and the the head of Lake Michigan.

1st stage. Sheet of drift averaging perhaps 20 feet in thickness. Intervals of slight or partial deglaciation shown by occasional presence of soil between sheets of till.

2nd stage. Interval of deglaciation of great length. Surface of old drift sheet deeply oxidized, leached and much eroded. Thick and widespread soil.

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[*] The Dial, Dec. 16, 1892, p. 380 ; Jan. 1, 1893, p. 7.

3d stage. Deposition of main body of loess and associated silts. Apparently very low altitude and slack drainage.

4th stage. Long interval of deglaciation. Large valleys cut in loess.

5th stage. Formation of thick drift sheet with morainic border 75 to 100 feet deep. Ice reached Shelbyville (not Litchfield) at maximum advance. Later sub-stages of glaciation marked by moraines or thickenings of drift at the margin of the sheets (40 to 50 feet). Intervals between successive moraines probably short since evidences of oxidization, leaching, erosion and soil accumulations are scant. Elevation about as at present when Shelbyville moraine was formed. Drainage less vigorous when later moraines of this stage were formed.

6th stage. Interval during which ice lobes and ice currents were shifted. Length probably considerable, though decisive evidence is wanting.

7th stage. Latest series of ice lobes south of Lake Michigan formed. Elevations greater, drainage freer. Minor moraines marking later sub-stages. Followed by the lake deposits of the region.

Mr. Leverett is inclined to correlate the outer moraine in Eastern Ohio and Northwestern Pennsylvania (there called the terminal moraine in a double sense by some writers), with the outer member of this last group, which is about 240 miles from the extreme limit of drift in Illinois, but owing to the fact that the moraines in the intervening region became bunched together in the angles between the ice lobes, an entirely demonstrative correlation by tracing is difficult, and he withholds a final judgment. But leaving the doubt as wide open as the phenomena will admit, he regards a correlation of the outer moraine of Western Pennsylvania with anything within 120 miles of the southern limit in Illinois as opposed to all evidence.

In his elaborate monograph on " The Pleistocene History of of Northeastern Iowa,"[*] Mr. McGee defines and illustrates, with great fullness, the following series:

1. A lower till ranging in thickness from a mere veneering to 200 feet, averaging perhaps 50 feet, characterized by greenstone erratics (in contrast with the granitic erratics which characterize the upper till); nowhere displaying a morainelike peripheral thickening, but everywhere attenuated toward its margin. General facies ancient, ferrugination and oxidation greater than that of upper till.

2. A forest bed found in 40 per cent of the well-sections, 20 to 25 per cent of them showing a definite bed. Old soil

[*] 11th Annual Report U. S. Geological Survey.

thicker than that of to-day. Pine, oak, elm, sumac, walnut, willow, ash, hickory, and tamarac recognized.

3. An upper till, ranging in thickness from a veneering to probably 100 feet, averaging perhaps 20 feet. Erratics gener- ally granitic. Grades horizontally at the south into loam, and vertically either grades upward into lœss, or is overlain with a certain unconformity by lœss. Only rarely and locally do terminal moraines mark the margin.

4. A lœss mantle, which in part grades into the upper till, and in part overlies it with a definite dividing plane between. Regarded as a deposit contemporaneous and continuous with the upper till.

These formations are older than the moraine-bordered tongue of till which occupies the north central part of the State and they pass under it. They are separated from it by great general erosion, oxidation, leaching, etc.

Back of this lie the complicated moraine-bordered deposits of Minnesota. We have here, therefore, a series comparable to that on the east side of the Mississippi. The upper till of Mr. McGee was deposited at a time of slack drainage. The moraine-bordered tongue of Central Iowa was deposited at a higher gradient, as shown by the freer drainage from its edge.

It thus appears that the latest studies of these two experi- enced investigators, the fullness and detail of whose work in this region is unsurpassed, bring into clearer and sharper defi- nition than ever before, the distinction between these drift sheets, and magnify the importance of the intervals.

While the question of one or more epochs is not necessarily dependent upon that of the origin of glaciation, there is so intimate a connection between them, that whatever bears upon the one, is not without application to the other. If the great intervals of deglaciation and the great advances of the ice were due to astronomical causes of the type advocated by Croll, every great change, being due to a reversal of the action of the controlling agency, is entitled to distinct recognition. If the chief cause of glaciation is northern elevation, any evi- dence which shows a depression far to the northward carries with it as a logical conclusion the assumption of general deglaci- ation. Prolonged glacial action at low altitudes puts the theory to a severe strain. Halts and advances at low altitudes impose still greater difficulties, the more severe the greater the interval. Even if it is granted that just after the ice reached its max- imum extension, a depression took place because of the load- ing of the ice and that low gradient deposits attended the retreat of the ice, it is evident that there could be no consider- able readvance without a restoration of high altitude. For instance, the ice could not rationally be presumed to retreat to

the northward and remain long enough to permit the accumu-
lation of a soil equal to that of the present and then advance
again while the country still lay at a low altitude. It certainly
could not be supposed that the ice would retreat so that low-
gradient deposits should take place six or seven degrees of
latitude back from the edge of the ice without general degla-
ciation also taking place. Now, in the Mississippi Valley we
have silt deposits spreading over many thousands of square
miles and connecting themselves with the second main drift
sheet of the series given above. They overlie the oldest drift
throughout large areas but are separated from it by a soil hori-
zon. (The older drift seems to have its own silt-appendices
in some regions also.) These silts occur on the highlands ad-
joining the main rivers throughout the older glaciated regions
from Ohio to Nebraska, and they reach northward to the west-
ern part of Wisconsin, the southeastern part of Minnesota,
the southwestern part of Minnesota, the southeastern part of
Dakota and the northern part of Nebraska, and from these
tracts they extend without detectable interruption to the gulf
region. In other words, they reach seven degrees north of
the extreme drift limit in the Mississippi region and six de-
grees in the Missouri region. To account for the phenomena
in harmony with the hypothesis of glaciation by elevation, it
appears to be necessary to suppose that the northern region
was elevated to a height sufficient to cause an ice sheet to
creep down to a point south of the latitude of 38 degrees on
a plain of great extent; that this was followed by a depression
sufficient to cause the withdrawal of the ice for an unknown
distance and to remain withdrawn long enough for a soil and
for peat and forest beds to accumulate to thicknesses fully
comparable to those of the present; that there was then an
advance sufficient to form the second till which overlies this
forest bed, followed by a retreat under such conditions as to
permit silts to gather over the wide areas indicated for six or
seven degrees northward and at considerable heights above the
present streams, spreading well back on the uplands. Now a
depression that would permit a deposit of these silts through-
out this great extent and at these heights, carries with it the
presumption of the removal of the ice from the whole north-
ern region, because the depression is assumed by the hypothesis
to have been caused by the ice itself, and to have been pro-
gressively greater to the north, and so, unless an entirely in-
consistent supposition be interpolated, the northern region
must be presumed to have been lower than it is to-day. The
great extent of silts, therefore, in the Mississippi region car-
ries with it the presumption of complete deglaciation of the
northern region, if elevation be assumed to be the chief cause

of the Ice age. This, it seems to me, holds good under any form of the aqueous hypothesis of these silt formations that is consistent with the phenomena. If they are attributed to wind action, the aridity and the combination of conditions necessary for the accumulation of the silts make the presumption of disappearance of the ice equally great.

Subsequent to this period, on the theory of elevation, there must have been another uplift at the north sufficient to cause the ice to readvance to points as far south as the first advance in certain regions, and within 300 to 500 miles of the first advance in others.

Now an elevation sufficient to produce glaciation as far south as 38°, followed by a depression sufficient to permit silts to accumulate 7° north of this, followed by another elevation sufficiently great to cause ice to advance to like degrees of latitude, in the main, seems to me a sufficient change in the great agency of the time and a sufficient orographic movement to justify the distinction of separate epochs. So far as I can see, nothing less than these extraordinary oscillations are sufficient to explain the phenomena, and to these must be added minor oscillations of very considerable moment. For myself the phenomena of low altitude deposition seem so great and so completely demonstrable as to be fatal to the hypothesis. But if not, the very multiplication of overlapping sheets and marginal moraines signifying halts and advances, that is appealed to in the endeavor to weaken the evidence of two or more epochs. bears in precisely the opposite direction when the demonstrable conditions of such halts and advances are duly taken into consideration.

In the matter of the " fringe," Professor Wright's statement, " 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," is unwarranted and tends to confusion historically and scientifically. The chief questions regarding these phenomena were squarely and broadly before scientific readers before Professors Lewis and Wright urged their single view of one variety of the phenomena. But that is a trivial matter. On the contrary, the confounding of the phenomena designated and interpreted as a " fringe " with the phenomena of the attenuated border is a serious source of error. The phenomena are not only not equivalents, but they stand in some measure as antitheses. There are four classes of facts to be distinguished.

1. A drift sheet bordered by a terminal moraine attended by scattered drift on its outside formed at the same time as the moraine by minor incidental action. This scattered drift may not inaptly be called a "fringe." It is a trivial phenomenon, a mere incident of the main action.

2. A drift sheet that, in contrast with the above, thins out gradually to an attenuated edge. A specific example of this, described in detail, may be found in the Sixth Annual Rep. U. S. Geol. Surv., p. 265. There may be scattered incidental drift on the border of this as well as of the moraine.

3. A bordering tract of scattered bowlders, sometimes reaching out many miles beyond any continuous drift. The origin of this is not certainly known, but it is probably due to temporary bordering lakes or glacial floods. It is well developed at some points in Dakota and Montana.

4. A bordering tract of scattered pebbles attended by silt. This is probably due to glacial waters acting at low gradients in conjunction with detached ice, perhaps local, perhaps glacier derived. An example of this is described in detail and discussed in the paper above cited (p. 271.)

To confound all these and to merge them under a single term is to push science backward. It is especially unfortunate to create confusion respecting the vital distinction between a moraine-bordered sheet with incidental drift scattered outside, and a thin-edged sheet that may be attended by similar scattered drift. The scattered bordering drift is trivial in significance in either case. This is especially so when the terminal action is strong and vigorous, expressing itself in a definite moraine and when the outer drainage is free. The attenuated edge, as distinguished from the moraine-thickened edge, has a radical significance, because it expresses a vital distinction in mode of action. If the term "fringe" had been confined to the first class of phenomena, and the phenomena discriminated with reasonable accuracy, its introduction might prove a convenience. But the attempt to make it a synonym with the "attenuated border" which happens to be the form the old drift sheets assume, and the failure to distinguish the two phenomena has made its introduction most unfortunate and renders the propriety of its further use very questionable. The more important phenomena outside the Pennsylvania terminal moraine to which the term "fringe" has been applied I think has been demonstrated to be the border of an older drift sheet, and not at all a "fringe" of the terminal moraine with which it has no genetic connection.

Turning to the phenomena of the Delaware Valley, it will assist to a clear understanding of the question if it be recalled that in the original mapping of the drift of the region by the

geologists of New Jersey and Pennsylvania, the terminal moraine which crosses the river at Belvidere, and which may be spoken of conveniently as the Belvidere moraine, was represented as the boundary of the glacial drift. This was not rigidly affirmed by the geologists of New Jersey, and from personal statements made to me by Professor Cook at the Paris International Geological Congress in 1878, soon after the appearance of his report on that region, and from recent statements of Professor Smock, it appears that a knowledge of some drift outside of the Belvidere moraine was possessed by them, and that the moraine was regarded as representing only the approximate border. Professors Lewis and Wright insisted much more rigidly upon the limital character of the moraine ;* and Professor Lewis published a paper subsequent to his final report on the terminal moraine, in which he attempted to show that all the supposed drift outside of the moraine in Pennsylvania except obvious valley wash was illusive.† In recent years several geologists, notably Professor Salisbury, have observed drift on the uplands, extending to a distance of at least 25 miles south of the moraine. Rare occurrences of glaciated bowlders have been found fully 60 miles south of the moraine. Professor Salisbury refers a portion of this extramorainic drift extending in places at least 12 miles beyond the moraine, to direct glacial action at a time much antecedent to the formation of the Belvidere moraine. Respecting other and generally more distant deposits he has reserved opinion.

It is fair to those geologists who in an early day overlooked this outer drift, or failed to see its full meaning, to note that in its character and expression it is markedly different from the drift of the moraine and from that within it, and that this is ample excuse for the oversight at that stage of work. But even then it did not escape Professor Smock, although we are not aware that he has anywhere published statements concerning it. The oversight is less pardonable if the truth be, as insisted by Professor Wright, that this outer drift is of the same age and kind as that of the terminal moraine.

Notwithstanding his own oversight, Professor Wright insists that those who saw at once the essential facts upon their first visits failed to see what ordinary competency required. In particular, he asserts that Professor Salisbury is in error in referring to a glacial origin the deposits at High Bridge and Pattenburg, which lie about 12 miles distant from the nearest point of the moraine. He claims to be able to demonstrate this. One essential part of his demonstration is the assertion

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* Second Geol. Sur. Penn., Rep. Z, p. 45.
† On supposed Glaciation in Pennsylvania South of the Terminal Moraine. This Journal, Oct. 1884, pp. 276–285.

that " There is no foreign material in the cuts, at least, Professor A. A. Wright and I could not find any "; (p. 307) and a second is that drift from the Medina sandstone is absent from these localities, and that its absence is decisive.

1. The absence of any single lithological element is not demonstrative of the absence of drift of glacial origin. Only a short distance to the north, the whole group of crystalline erratics is reported by Professor White to be absent from a large part of Susquehanna and Wayne counties.* No one questions the glaciation of that region because of their absence. Most experienced glacialists I think must have encountered similar instances of the local absence of a particular rock constituent. Such apparent absences over considerable areas have been encountered by Mr. Buell in a specially careful tracing of bowlder trains from the isolated crystalline knobs of Wisconsin, and for a time such absence seemed to indicate a limitation of that particular kind of drift; but further search has shown that beyond this barren area the particular erratics reappear and extend onward for considerable distances.

2. It so happens that Mr. Kummel of the New Jersey geological survey, without a knowledge that the localities were the subjects, or were likely to be the subjects of special question, made collections of rock specimens at both High Bridge and Pattenburg, simply with a view to rendering them as complete and representative as possible. Upon request, these collections have been sent to Chicago and examined, and Professor Smock has also kindly given his opinion of them. Referring to a group of specimens belonging to the collection, Professor Smock expresses the opinion that " they belong to or have come from the ledges of Cambrian, Green Pond Mountain and Potsdam, in New Jersey and New York. Of course it would be possible to duplicate the lot in the Green Pond Mountain range in the Kittatinny Mountain series, and in the Potsdam." These all lie at distant points. Among the specimens are pebbles of sandstone so closely resembling the Medina sandstone that only an expert familiar with the special character of the formation in New Jersey could give an opinion of any value at all. Professor Smock, after a careful examination, does not feel justified in giving a positive opinion. In the presence of these specimens, the alleged absence stands upon a very slender basis.

The collections contain specimens of gneiss, sandstone of at least two distinct types, quartzite, shale of two kinds, and chert. These appear to represent certainly five different

* Sec. Geol. Sur. Penn., G 5, 1880, p. 26.

formations.   This petrographic variety, taken in connection
with Prof. Smock's opinion, seems to be a sufficient answer to
the claim that there is no foreign material in the cuts.

As a collateral point, Professor Wright asserts that " South
of Musconetcong Mountain stretch the Triassic red shales which
cover so much of the central part of New Jersey.   But in
this portion of the State, there has been absolutely no trans-
portation of northern material out upon the Triassic shales,
showing that no movement here ever passed the Musconetcong
Mountain " (pp. 365–6).   Drift lying upon the Triassic shales
is reported to occur at the following points by the following
observers :

1.	West and N.W. of Pittstown.	A. R. Whitson.
2.	Hensfoot.	H. B. Kummel.
3.	Pattenburg.	R. D. Salisbury, C. E. Peet and H. B. Kummel.
4.	South of White House Station.	A. R. Whitson.
5.	North (1½ or 2 miles) of Somerville.	F. C. Schrader and R. D. Salisbury.
6.	New Brunswick.	C. E. Peet, R. D. Salisbury.
7.	Liberty Corners.	F. C. Schrader, R. D. Salisbury.
8.	Berkley Heights.	A. R. Whitson, R. D. Salisbury.
9.	New Vernon.	R. D. Salisbury.
10.	Bernardsville.	F. C. Schrader, R. D. Salisbury.
11.	Basking Ridge.	R. D. Salisbury, F. C. Schrader.

It is not affirmed that all these are direct glacier deposits,
but they are identified as drift and other than obvious valley
drift.   Of these, the Pattenburg and Hensfoot deposits and
the area near Pittstown lie south of Musconetcong Mountain
and fall directly within the territory alleged to be barren.
The remaining localities lie to the east of this, and while they
do not come within the strict limits of Professor Wright's
statement they bear on the general question involved.   Of
these localities, all, or nearly all, lie in such topographical
situations as to absolutely exclude the interpretation placed
upon the High Bridge and Pattenburg deposits by Professor
Wright.

It appears, therefore, that he has based his assumed demon-
stration, first, upon a general proposition that experience has
shown to be entirely inadmissible ; secondly, upon the absence
of foreign material at High Bridge and Pattenburg when the
specimens gathered by a young geologist sent there merely to
make a representative collection embrace a large variety of
rock specimens unrepresented by formations in the vicinity
and referred by Professor Smock to distant terranes ; and
thirdly, upon an assertion, in the most positive terms, of the
absence of drift on the Triassic areas south of Musconetcong
Mountain, when such drift is found there by other observers.

Turning now to the interpretation which Professor Wright puts upon the High Bridge and Pattenburg deposits, it is to be noted first, that the one occurs upon a spur as shown by the New Jersey topographical maps and that to reach higher ground a line running along the back of the spur must be followed, rather than one down the maximum slope in the most natural line of slide and creep. No height exceeding 460 feet above the deposit in question occurs in the neighborhood, except such as are separated from it by depression; and to reach even this moderate height, it is necessary to go one mile back from the locality. In the other case, heights 500 feet above the area in question occur within two miles to the north, but they are separated by gentle slopes and a shallow valley. The slope on which the deposit lies is composed of Triassic rock. These facts bear upon the suggestion of Professor Wright that these deposits are due to degradation, slide and creep. Bearing more specifically upon that interpretation is the fact that in these deposits there are bowlders and pebbles of rock not now in the adjacent ridges, and these are polished and scratched in a manner precisely similar in every respect to the well-known polishings and scratchings of glaciated pebbles. One or two in the collection of Mr. Kummel take rank among the best examples of typical glaciation; and if they were passed through the hands of a hundred glacialists of the greatest experience, not one could be expected to hesitate for a moment to refer them to glacial action. Nothing at all closely simulating them has ever been reported as the demonstrable work of either land slide or creep. Furthermore, the deposits in question are in part distinctly stratified, a feature foreign to the products of landslide and creep. The deposit at High Bridge is about 30 feet in maximum thickness, and that at Pattenburg scarcely less.

To refer to creep or landslide deposits having these considerable thicknesses, containing derivatives from five formations, embracing nine recognizably different varieties of rock, a part of the deposits being stratified, and containing in both localities scratched stones, the glacial origin of which no glacialist would ever independently question, is most extraordinary in what claims to be a demonstration of an illusion on the part of one of our best trained and most critical observers.

As another proof of alleged error on the part of Professor Salisbury, Professor Wright says, p. 364: "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." That extensive oxidation affected the old surface material that became a part of the old drift, here as elsewhere, goes without saying. In a profes-

sional discussion of the character of the drift, it is as much presumed that this factor has been eliminated as, in the discussion of an astronomical question, it is presumed that the error of refraction has been eliminated.   To discourse upon the existence of such previously oxidized material, in a serious paper written for professional glacialists, at this date, has an archaic flavor.   To presume that Professor Salisbury, who has done some of the most critical work that has ever been done upon residuary products and their contributions to the older drift, overlooked this factor in the study of the Delaware region, is a reflection upon the critic, rather than upon the work he criticised.   I have discussed with Professor Salisbury upon the ground the pre-glacial factor in the sum total of oxidation presented.   To presume that a geologist cannot distinguish whether the aging of a pebble took place before or after it became a pebble, is to suppose that this department of geology is yet in a primitive condition.   To assume that there are no criteria for distinguishing pre-glacial oxidation from post-depositional oxidation and to fail to see the applicability of those criteria to the region under discussion, and make use of them, is to condemn the whole work of whomsoever makes the assumption ; for the evidence of post-depositional oxidation, weathering, degradation and aging in its several forms, is so perfectly clear and so completely demonstrative, that it should not fail to impress itself upon any observer who has even a moderate command of the discriminations which such a study necessarily involves.   If any critical student will examine the terminal moraine and the drift north of it, and the gravel train that leads from the moraine's outer edge down through the gorge of the Delaware, on the one side, and will examine the higher terraces and their fluvial deposits and the drift scattered over the highlands, on the other, he will find clear and abundant evidence that the one is relatively young and fresh, and that the other is markedly old and that the two deposits cannot, by any rational interpretation, be made contemporaneous.

That Professor Wright is in radical error, respecting the deposits of the Delaware Valley, is evident from the self-contradictory nature of his own interpretations.   He refers the slack drainage deposits along the Delaware (Philadelphia Brick-clays, McGee's Columbia) to the Champlain depression.*
But he admits, what is incontestable, that after this epoch of slack drainage deposition there was an elevation during which were deposited the Trenton gravels, which he refers to a "time when the ice had melted far back towards the head

* See this Journal, Nov. No., pp. 358, 366, 370, 371 and 372.   See also, " Man and the Glacial Epoch," pp. 254–261; also, "Ice Age of N. A.," pp. 522–527.

waters of the Delaware, and after the land had nearly resumed its present relations of level, if indeed, it had not risen northward to a still greater height."* Now it is incontestable that it was after the ice had retired from the head waters of the Delaware, that the depression occurred during which the marine deposits of Montreal and the Champlain region were laid down. Professor Wright also states that between the deposit of the Philadelphia brick-clay and that of the Trenton gravel, there was a "long interval."† We, therefore, have Professor Wright referring to the Champlain depression deposits that were laid down long anterior to the Trenton gravels, which, in turn, were deposited at a time of elevation which, in its turn, was demonstrably early than the Champlain deposits. To refer the slackwater deposits of the Delaware and the marine deposits of the Champlain Valley to the same depression, and yet put between them a "long interval" and a period of elevation, is a characteristic instance of the self-destructive interpretations to which the old doctrine of unity naturally invites.

Besides the evident error of confounding two depressions, separated from each other by the acknowledged interval occupied in the erosion of the gorge of the Delaware and by the intervention of an elevation comparable to the present, there is a specific error in Professor Wright's correlations. He makes the well-known gravel terrace at Trenton the correlative of a terrace of less than half its height at Yardville, a few miles above, overlooking the fact that terraces of the same nature and gradually rising altitudes occur at short intervals all the way from Trenton to the Belvidere moraine. There they join the moraine in the characteristic fashion of moraine-headed terraces with which students of the high-gradient terminal moraines have become familiar. That this connection is clear and demonstrative is the judgment of at least five geologists who have studied the formations.

It is altogether probable that a complete analysis of the drift formations of the Delaware will develop some additional factors, and possibly extend its history, but the following features I think may be accepted as demonstrative:

1. That there was an earlier invasion of the ice which reached at least a dozen miles south of the Belvidere moraine. For present purposes it does not matter at all whether it included the High Bridge and Pattenburg deposits or not, nor whether the more distant drift is glacial or glacio-natant.

2. That there is an older fluvial deposit (the Philadelphia brick-clay) which is likewise much older than the Belvidere

* "Man and the Glacial Period," p. 261.
† "Man and the Glacial Period," p. 257.

moraine and which for the present is to be associated in age with the old glacial drift, though the two may not prove, upon further examination, to be strictly contemporaneous.

3. That after the formation of this older river deposit, which took place at a low altitude and low gradient, there was an epoch of elevation and of erosion, during which the Delaware cut its channel down to the depth of 200 to 300 feet below the upper old terrace.

4. That there followed a second incursion of ice which formed the Belvidere moraine, the over-wash of which ran down into this previously formed gorge and filled it up to a height of about 100 feet in the immediate vicinity of the moraine, and to progressively less and less heights farther down stream until at Trenton the height had declined to about 40 feet.

If Professor Wright were correct in his correlation of the terrace at Trenton, it would not affect, in any essential degree, the history here given, because the other terraces within the gorge above, some of them in the immediate vicinity of the moraine and in immediate connection with it, constitute the essential part of the evidence. I do not think that any geologist, at all expert in these lines, can entertain any doubt as to contemporaneity of these terraces with the moraine, or that the gorge was formed antecedent to the moraine, or that the higher terraces, capped with the old gravels and clays, were formed earlier than the gorge; and I am surprised that anyone professing familiarity with drift phenomena, should question the markedly superior age of the old drift.

The phenomena on the Delaware, therefore, taken in connection with those of the St. Lawrence and Champlain Valleys, seem to admit of no rational interpretation, that does not involve two depressions and an intermediate stage of elevation. The duration of the elevation has as its minimum measure the cutting of the river gorge and the high-gradient glaciation beginning with the Belvidere moraine and embracing several subsequent episodes of undetermined length. I conceive that there may be differences of judgment as to how much divisional value such orographic stages and such alternations of action and such evidences of aging may be entitled to; but that here are tangible divisions of the glacial history of the region that are of fundamental importance in the interpreta- of the deposits and in the determination of the glacial relations of supposed art relics, does not seem to me to admit of question.

The phenomena on the Susquehanna are, so far as known, very closely similar to those upon the Delaware, but they have been much less fully worked out and may be passed over.

The phenomena upon the Allegheny, Upper Ohio and adjacent rivers, seem to me to be in precise harmony with those of the Delaware. Before discussing them, however, I need perhaps to say a word respecting Professor Wright's hypothesis regarding the effects of a supposed glacial dam at Cincinnati which, in his view, destroys the force of the data upon which I postulate an interval of deep river erosion between the earlier and later glacial invasions.

In the first place it should be noted that, although nearly a decade has passed since the hypothesis was advanced, no outlet for the great hypothetical lake has been found, though it has been called for as the necessary credential of such an hypothesis. Such an outlet must, in the nature of the case, be a marked phenomenon.

It is to be noted, in the second place, that the decisive facts brought out by Mr. Leverett with reference to the white silts which spread over the drift north of the Ohio throughout the whole reach of the supposed dam, destroy one of the chief arguments for the hypothetical lake above the supposed ice dam, and this holds true when the dam is given the greatest extension assigned it by Professor Wright. It will be borne in mind that Professor Wright appeals to the silts of Beech Flats as evidence of a lake caused by the dam. Mr. Leverett has shown that these are but a part of an extensive sheet stretching westward over the very area occupied by the ice supposed to have formed the dam, reaching even to and beyond its western border, covering wide areas in southwestern Ohio, northern Kentucky and southeastern Indiana. Mr. Leverett's language is clear and covers the whole ground; it is as follows:

"Not only are the clays of these two localities [Beech Flats, Pike county and the till area, Highland county, Ohio] "similar in macroscopic and microscopic aspect, but they form a practically continuous sheet extending from the Beech Flats and adjoining lowlands outside Wright's glacial boundary westward onto the glaciated districts of southwestern Ohio, northern Kentucky and southeastern Indiana, occupying the site of the hypothetical Cincinnati ice-dam and showing as strong development below (west of) the site of the supposed dam as they do above it. The fact that these clays cover a part of the glaciated district proves that their deposition occurred subsequent to the time of maximum glaciation, and their distribution shows that the ice-sheet nowhere reached the Ohio river while they were being deposited. It is evident, therefore, that their deposition cannot be attributed to an ice-dam on the Ohio at Cincinnati or any point below."*

* Am. Geol., vol. x, July, 1892, p. 21.

Prof. Wright strives to elude the force of this by the following statement :

" 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."[*]

In Prof. Wright's own language, " A theory driven to such extremities cannot be said to be altogether free from difficulty."[†]

Prof. Wright thus explains the discovery of these Beech Flat silts : "So confident have I become in the reality of this dam that I have not hesitated to use it as a means of putting myself in the line of discovering other facts which are the natural consequence of this. Many of the facts enumerated in this paper (as, for example, those connected with the headwaters of Brush Creek) were thus discovered. It was reasoned that they must exist from the nature of the supposition ; and upon examination in proper localities it was found that they did exist according to previous calculation. I need not say that such experience is the most convincing proof of a theory."[‡]

The succession of deposits even in this region on which such large conclusions have been staked, and which I therefore touch incidentally, is very significant. There is here (1) a till sheet with an attenuated edge reaching across the Ohio into Kentucky for a few miles, (2) an interval of deglaciation indicated by a soil horizon at the surface of this sheet, (3) a silt deposit overlying this and indicating a period of slack or still-water deposition, and (4) a till sheet edged by a terminal moraine, from the outer side of which there was free vigorous drainage, as shown by moraine-headed terraces of gravel. At two localities these silts have been seen beneath this later drift, and there is much indirect confirmatory evidence of this relation. These facts indicate an interval between the two during which occurred the change from conditions of silt

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[*] This Journal, Nov., 1892, pp. 369–370.

[†] Ibid., p. 371. Where this sentence is used by Prof. Wright it has no pertinency whatever, as Mr. Leverett's suggested hypothesis to account for the unusual depths of the rock channels near the border of the drift stands wholly by itself.

[‡] Bulletin 58, U. S. Geol. Surv., p 101.

deposition over the country generally to conditions of free drainage pouring down through valleys cut to considerable depths below the silt horizon (Leverett).

In this region, therefore, between the border of the drift and the outermost moraine there is decisive evidence of a till-depositing period, an interval of soil formation, a silt-depositing period, an interval of radical drainage-change and a moraine-producing advance of the ice. This is a very different collocation of formations from that which seems to be implied by Prof. Wright's language (pp. 353–356 and 357). It is very far from being a simple moraine-and-" fringe " combination.

In Eastern Ohio and Western Pennsylvania the outer moraine runs much nearer the attenuated border of the old drift and the intervening silts are obscure or absent, or confined to the remnants of the old base levels, so that it is not so surprising that the vanishing edge of the old drift should here be mistaken for a dependency of the outer terminal moraine, but that the relationship is really the same as it is demonstrably to the westward, I hold to now be beyond serious question.

These points bear upon the explanation of the glacial gravels that lie upon the high terraces in the Allegheny and adjacent valleys. These terraces I have maintained (Bulletin 58, U. S. Geol. Surv., pp. 20–38) were produced at a time of base level degradation, which in its later stages was contemporaneous with the earlier ice incursion whose waters bore gravels down the Allegheny, Upper Ohio and some adjacent streams, and formed the 40 or 50 feet of capping which lies upon the rock benches that constitute the body of the terraces. I have argued that subsequent to this the land was elevated and the lower newer steep sided gorges of the Allegheny and neighboring streams were cut to a depth that may be roundly stated as 250 feet, and that subsequent to this the later ice incursion formed the outer moraine of the region. From the outer side of this moraine glacial streams bore their sands and gravels down the Allegheny gorge cut during the interglacial interval. The evidence of this, gathered in a joint study by Mr. Gilbert and myself, may be found in Bulletin 58, U. S. Geol. Surv., pp. 32–36. I therefore argue that between the time when the glacial gravels were deposited on the high terraces and the incursion of the later ice there was a cutting of the gorge to the depth of 250 feet roundly speaking. I regard this gorge-cutting as a *minimum* measure of the interval between the two ice incursions. Prof. Wright does not admit the force of this evidence because he interprets the occurrence of the glacial gravels on the high terraces as the work of ice floating from the edge of the glacier on the surface of the hypothetical lake formed by the supposed Cincinnati ice dam.

He now admits, what I have not understood him to do before, that the terraces, so far as they are rock, are due to base-leveling, but that the glacial gravels deposited upon them are due to floating ice. To the latter part of this view, there seem to me to be two fatal objections. In the first place, I think it is entirely foreign to observation, as well as to *a priori* considerations, to suppose that floating ice would produce, in the abandoned bends of old rivers surrounded by hills, and upon remnant shelves along the sides of the valley, fine stratified gravels bearing every aspect of river deposits. Under the conditions postulated a very different class of deposits should be formed. Besides, the deposit should have been practically uniform over the whole bottom of the supposed lake, and not simply confined to the old terraces. In the second place, these terraces rise in altitude toward the headwaters of the river until some of them are considerably higher than the supposed ice dam, notably those at Warren, Tidioute and Oil City, which are respectively 1395, 1390 and 1270 feet above tide, while the height assigned for the dam is 1000 or 1100 feet. (See Bulletin 58, U. S. Geol. Surv., p. 27.) Aside from these definite and tangible factors, the whole aspect, association and relationship of these formations make them river deposits and exclude them from the distinctive lacustrine class.

In admitting to his hypothesis the factor of base-leveling, Prof. Wright has relinquished the last remnant of occasion for postulating his ice dam, for all of the phenomena appealed to are the natural incidents of base-leveling. Stretches of slack water, which are inevitable when a river reaches the base-level stage and begins to build up its bed, furnish deposits indistinguishable from those of lakes; indeed lakes form in the abandoned channels of the stream. So also base-leveling and the resilience from it involve the transfer of the position of low divides which lie near the upper limit of the base plain, the transfer being from the side of the shorter or easier course toward the longer or more obstructed course. The transferred divide is carried into the bottoms of the stream whose territory is invaded, so that its former flood plain deposits become the new divide ; and hence the phenomena of slack water deposits on some of the present divides become, under the hypothesis of base-leveling, precisely what is to be expected. These may occur at altitudes greater than the base plain of the main river. These and coördinate methods of action cover all the phenomena for the explanation of which the supposed ice dam was brought into requisition.

Being left thus without a *raison d'etre*, being robbed of all support from the Beech Flat silts, and being entirely without

the necessary support of a recognizable outlet, the hypothetical
lake may well be dismissed from the literature of the subject.
The whole phenomena fall into perfect consonance with the
phenomena of the Delaware and Susquehanna.

As one of the strong, and as it seems to me, unanswerable
arguments in favor of a considerable interval between an
earlier and a later drift formation, I appeal to the cutting of
the Delaware gorge 200 feet or more, which was demonstrably
later than the high terraces bearing glacial silts and gravels
and demonstrably earlier than the Belvidere moraine from
which a gravel stream was poured down into the gorge cut
during the interglacial interval. I make a like appeal to a sim-
ilar class of phenomena on the Susquehanna, and I repeat the
appeal in respect to the precisely analogous phenomena of the
Allegheny and other tributaries of the Upper Ohio, and the
upper part of the river itself. I make a similar appeal to the
erosion of the lower Mississippi valley and several of its
branches, the erosion here however sustaining a different rela-
tion to the old erosion plane. Doubtless the appeal could be
made to all branches if the import of the phenomena were
equally clear in all cases, or had been equally studied. The
form which the valley erosion took and the material eroded
varied with the antecedent and concurrent conditions which
were not the same in all valleys, nor the same in all parts of
the same valley, but a correspondent erosion occurs on all
branches that have been carefully studied so far as I am in-
formed. All this class of phenomena repeating itself over and
over from the Atlantic to the western plains, carries a force
from which I think there will be found no escape when the
phenomena are critically and judicially investigated.

But the case does not rest upon the interglacial cutting of
these river channels alone. It is supported by concurrent
erosion over the whole surface of the old drift. If there were
any error in the interpretation of the river channels it would
be shown in the facies of the old drift. But its topography
shows an amount and kind of erosion that indicates similar
antiquity. The phenomena are so wide spread that special
enumeration is wholly impracticable. In a paper on the Drift-
less Area, Prof. Salisbury and myself attempted a careful
description of a part of these erosion features and drew a com-
parison between them and those of the new drift. There, it is
to be noted, the two borders were subject to the same condi-
tions save that of age.

One of the best fields for a comparison between the fresh
little-eroded topography of the later drift and the much-eroded
topography of the earlier drift, is found on the borders of the
tongue of the later drift which terminates at the capital of

Iowa.   The surface within the moraine loop has suffered very slight erosion, except in the vicinity of the streams.   Even the channelings of these are sharp-sided and ditch-like.   Over the surface shallow sags, without outlet, occur in extraordinary abundance.   They are to be numbered rather by tens of thousands than by thousands.   On the old drift outside of the loop an erosion surface of pronounced type is presented.   A complete erosion topography has been developed and has sunk itself deeply below the original surface.   To appreciate this contrast let any one make a circuit of one hundred miles north from Des Moines upon the later drift, and he will find, throughout, indisputable evidence of freshness and recency. Let him then make a similar circuit of one hundred miles west, south and east on the area of the old drift and he will find a rolling surface with undulations reaching up to 80 feet and more of perfectly characteristic dendritic erosion topography, and upon examination of the stratified portions of the drift he will readily be convinced, if a topographic geologist, that this erosion supervened upon the formation of the drift.   On the summits of this rolling land he will find the lœss-like silts that cover so much of the earlier drift.   Modern topographic science goes for naught, if evidences of this kind do not signify a prolonged interval between the deposit out of which such an erosion surface has been carved, and the immediately adjacent deposit upon which so little carving has been done.

To this combination of general erosion and of channel cutting, there are to be added evidences of like import from oxidation, ferrugination, decomposition and other characteristic forms of weathering.   These, in the hands of an expert competent to eliminate preglacial and englacial factors, bear testimony of great value.   The value is certainly almost wholly dependent upon the circumspection, skill and conscientiousness with which the criteria are applied, but the value is none the less real.   When these evidences are found, as in this case, concurrent with general surface erosion and with the special erosion of river gorges, the combination has a value much beyond either factor alone.   When to this is added the fact that the drift sheets most eroded and most oxidized, are those which were deposited at low-gradients and without erosion advantages at the start, and that in general, they lie in regions that are now lower than the less eroded drift of later date, the case is still further strengthened.   When, to the combination, there is also added the fact that the deposition of this low-gradient, now much-eroded, much-weathered deposit, was separated from that of the fresher, little-eroded sheet by an elevation of the surface and an increase of slope which gave a markedly more vigorous drainage, and the still further fact

that the interval is emphasized by notable vegetable accumulations, and supported by the strong analogy of the Great Basin phenomena, the whole combination takes on a strength which seems to me altogether irresistible.

While the evidence from plant and animal remains found in the interglacial beds in America has not yet reached a fullness and definiteness which render it altogether decisive regarding the climate of the interglacial intervals, though it indicates something less than a glacial climate, the evidence of this class in Europe, a summary of which is given by Dr. Geikie in the paper already referred to, appears to me entirely decisive, unless the integrity of the observations can be overthrown. The demonstration of a climate in Northern Europe, comparable to the present, seems to carry with it the necessary conclusion that glacial conditions were essentially as remote then as now. It seems to me idle to cite the fact that temperate faunas and floras now exist in the vicinity of glaciers within the temperate zone, for these are mere local phenomena and do not stand related to the general climate of the region, as the great ice sheets of glacial times must have done. The fossil evidence of the acknowledged glacial epoch shows Arctic conditions. On the same basis of reasoning, a temperate fauna and flora show the absence of glacial conditions.

When, therefore, to the strong cumulative physical evidence in America and the similar physical evidence in Europe, there is added the array of organic evidence that has now grown large, it seems to me the case approaches demonstration, so far as the general fact of a great interval or intervals is concerned. To fail to accept this, at least as a working classificatory basis, is to do violence to the highest interests of science.

The history of this question I apprehend, will be very analogous to that of paleontological research. In the earlier stage, investigators were satisfied with very general delineation and rude groupings of forms. But, with the progress of the science, more and more critical scrutiny of likenesses and differences was found requisite, and closer and closer specific and varietal distinctions were drawn. This tendency at length became excessive and the multiplicity of divisions was pushed beyond the actual phenomena. The enlargement of collections then began to bring together many species by inter-gradations, and the elimination of false species resulted. But yet certain species stand clearly differentiated from all other species and unquestionably will continue to stand. The gaps between them can only be filled by tracing them far back in geological time. So I think it may be with the divisional effort in the glacial field. We are very likely to push differentiation to excess in the stage we are now approaching, and to recognize

for a time, episodes of glaciation that are not widely separated from their neighboring episodes. But this will be wholesome for the time, just as species-making was. It is, indeed, almost necessary to the ultimate end sought to make the sharpest possible discriminations, even if they result in excessive divisions which shall last only until such time as they may be brought together by interstitial formations.

Although not fully placed before the public, at least four divisions of the drift south of the Great Lakes are now being employed as working hypotheses and are gaining strength under the tests of the field. The interval I have chiefly discussed in this paper is the middle one. I have regarded it as the most important one, possibly the only one that will ultimately stand as possessing an epochal value, but I am in sympathy with the movement led by Dr. Geikie, because it will develop a more precise delineation of the history of glaciation. If the terminal moraines of Ontario have much divisional importance, they will make the present working classification of of this country closely analogous to that advanced by the distinguished Scotch glacialist.

It is the present judgment of the majority of critical workers in both the American and European field, that amid all future tests two or more of these divisions at least will stand as well sanctioned epochs, to whatever grade others may be relegated by the fuller knowledge of the future.

Art. XXIV.—*The Specific Heat of Liquid Ammonia;* by C. Ludeking and J. E. Starr.

The specific heat of liquid ammonia, though it has often been the subject of calculation in development of theory and practice, has not yet been satisfactorily determined experimentally, if we except the work of Regnault. His results, however, were unfortunately lost during the Paris Commune. He assumed the specific heat to be 0·799. Since then the interest in this constant has very considerably increased through the rapid development of the artificial ice industry. Generally the specific heat has been taken at unity. Thus DeVolson Wood in his "Thermodynamics," page 337, recommends this value "until the experimental value is determined."

It was our good fortune to have ready access to all the means necessary for executing the somewhat laborious experiments involved and we take this opportunity to present briefly

the results. of our work. The liquid ammonia used in the experiments was found on examination to contain 0·3 per cent of moisture and on spontaneous evaporation to leave only a trace of residue. The impurities were therefore of no consequence in influencing the result to the limit of accuracy intended.

Of this liquid ammonia 10·01 grams were introduced into a small steel cylinder of 16·122^{cc} capacity, stoppered by a steel screw. The mode of filling was quite simple. After cooling the cylinder in a bath of the liquid ammonia itself and while still immersed it was possible to pour it brimful by means of a beaker. The steel screw stopper, also previously cooled, was then inserted and drawn almost tight. On then removing the cylinder from the cooling bath the liquid contents gradually expanded and escaped in quantity proportional thereto and besides a very small vapor space was allowed to form as is indicated in the experimental data. Then the stopper was driven tight. Thus the error in the result, due to the latent heat of condensation of vapor of ammonia in the course of the experiments was reduced to a minimum and rendered, as will be seen, almost inappreciable in its influence.

The cylinder was perfectly free from leakage and remained constant in weight during each series of determinations. It was suspended in the drum of a Regnault apparatus heated by the vapor of carbon disulphide. The entire mode of procedure was in all details that commonly used in the Regnault method. After the cylinder had been heated for about six hours it was dropped into a brass calorimeter whose water value was 1·36 cal. and which contained 150 grams of water. In each experiment it required very nearly two minutes to raise the calorimeter to its maximum temperature. The influence of loss by radiation was reduced to a minimum by the Rumford manipulation. The thermometers used were standardized, carefully compared and read to hundredths of a degree by means of a magnifying lens. The experiments were conducted sufficiently far from the critical temperature, which, according to Vincent and Chappuis is 131° C.

The following are the data of Experiment I:

Weight of steel cylinder and ammonia_____ 81·008 grams.
Weight of steel cylinder _____ 70·998 "

Weight of ammonia _____ 10·01

The specific gravity of liquid ammonia being 0·656, the volume of 10·01 grams is 15·26^{cc}.

Total water value of calorimeter, thermometer
    and water .... 151·76 cal.
Water value of steel cylinder .... 8·34 cal.
Temperature of air .... 25°·4 C.
Temperature of steel cylinder............... 46°·51 C.

Temperature of calorimeter after immersion, 26°·69 C.
Calorimeter before immersion .... 24°·44 C.

Rise in temperature........................ 2°·25 C.

Thus 341·46 cal. were given off by the cylinder in cooling 19°·82 or 17·23 cal. for one degree. Of this 8·34 cal. are due to the steel cylinder itself, leaving 8·89 cal. for 10·01 grams of liquid ammonia or 0·888 per gram = specific heat. In a second and third experiment the values 0·897 and 0·896 were obtained. The determination of the specific heat of liquid ammonia would be influenced, as stated, by the latent heat of condensation of part of the small quantity of vapor present, when the cylinder cools in the calorimeter. This would to a degree be neutralized by the contraction of the liquid ammonia itself in the cooling and the consequent formation of more vapor space.

It seemed desirable to ascertain the influence of these factors collectively by experiment. For this purpose specific heat determinations were made in a way somewhat different from the ordinary. The steel cylinder was cooled in an iron shell in melting ice, instead of being heated, and then introduced into the warm calorimeter water. The mode of procedure was in detail similar to that described above and we will therefore only give our results. In three experiments the values 0·878, 0·863, and 0·892 were obtained. They are a trifle lower in their average than the results obtained by the ordinary method. It is reasonable to assume that they are somewhat low, while as stated the other results are presumably somewhat high and in order to arrive at the specific heat of this substance nearest the true value from our experimental evidence, we will take the average of our six values, viz:

$$\begin{matrix} 0·888 \\ 0·897 \\ 0·896 \end{matrix} \Big\} \ \text{1st series.} \qquad \begin{matrix} 0·878 \\ 0·863 \\ 0·892 \end{matrix} \Big\} \ \text{2d series.}$$

and state it as being = 0·8857.

We beg herewith to acknowledge our obligations to Chancellor W. S. Chaplin and Prof. Wm. B. Potter for kindly placing the laboratories under their charges at our disposal.

Cove Mills, Stamford, Conn.

Art. XXV.—*The stratigraphic relations of the Oneonta and Chemung formations in eastern Central New York;* by N. H. Darton, U. S. Geological Survey.

Introductory.—This paper is a condensed account of a recent investigation in upper Devonian stratigraphy, made for the State of New York for the new geological map. Dr. James Hall made some statements regarding the general bearing of the results at the Rochester meeting of the Geological Survey of America, and a detailed report with map will finally be published in the report of the State Geologist of New York.

The principal purpose of the investigation was to determine the relations and distribution of the Oneonta and Chemung formations in their extension from Delaware county through the Catskill Mountains, but some study was also given to their relations in Chemung and Broome counties.

In its typical development in Otsego county, the Oneonta formation comprises a thick mass of red shales and red and gray sandstones similar in character to the rocks of the Catskill Mountains and overlying the Chemung formation in southern New York and northern Pennsylvania. The formation was given its name by Vanuxem who supposed that it was equivalent to the Catskill formation and above the Chemung formation. The organic remains in the Oneonta beds were few and consist of plant remains common to the Catskill rocks and a fresh or brackish water form now known as *Amphigenia.* Later studies by James Hall and others led to the discovery of an overlying series of shales and sandstones containing Chemung fossils at several localities southwest of Oneonta, and it was found that the fauna of the underlying beds was Hamilton in age. These discoveries indicated that the Oneonta formation represented approximately the eastern extension of the Portage formation, considerably modified in character but well defined in stratigraphic position. Nothing however was determined as to the eastward extension of the Oneonta beds and overlying Chemung along the northern and eastern side of the Catskill Mountains and Mather's statements in his report were too vague to throw light on the problem. The great mass of gray sandstone with red shales constituting the Catskill Mountains were designated Catskill by Mather and the mass was supposed to be underlain in eastern New York by an obscure, attenuated representative of the Chemung and under which in turn were recognized the "Portage" and the Hamilton formations.
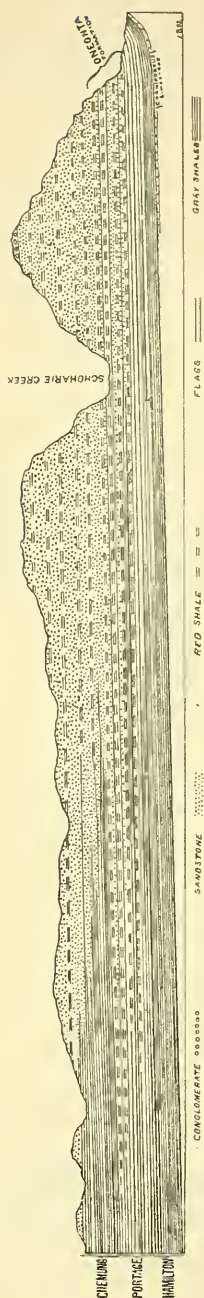
Fig. 1.—Horizontal scale, 1 inch = 16 miles; vertical scale, 1 inch = 6000 feet.

I began my studies at Oneonta and measured an instrumental section southward past Franklin. From this I worked eastward to the eastern front of the Catskill, and westward to the latitude of Binghamton.

General results. — The accompanying sections are intended to illustrate the general relations:

Fig. 1.—Section from central Broome County, eastward through the Catskill Mountains nearly to Catskill.

It may be seen in these sections that the Oneonta formation continues eastward with gradually increasing thickness and comprises the lower thousand feet of beds in the Catskill Mountains. Its characteristics are unchanged and its stratigraphic limits are distinct throughout. Westward its red beds gradually merge into the thin-bedded sandstone and hard dark shales of the Portage and disappear entirely between Norwich and Cortland; the red material extending farthest west in the highest beds.

The thin series of gray shales and fine-grained sandstones, with Chemung fossils, overlying the Oneonta formation about Franklin, southwest of Oneonta, are the basal beds of the great mass of fine grained sediments which constitute the Chemung formation in southwestern New York. They are overlain by several thousand feet of hard, coarse, cross-bedded gray sandstones with intercalated red shales and gray flags into which they merge eastward and at the expense of which they expand westward. This merging was studied with great care and it was found that stratigraphic continuity throughout is beyond question. There is no overlap or wedging out of the beds either as a whole or singly but a gradual transition of coarse materials into fine materials. Lower and lower shaly beds are successively involved eastward until at a point about due south of Oneonta

the lowest beds of shale finally merge into hard, coarse-grained, cross-bedded gray sandstones which then extend eastward through the Catskill Mountain immediately above the Oneonta formation. Westward the shales with Chemung fossils attain a thickness of about six hundred feet near Susquehanna, bed after bed of sandstone becoming finer grained and finally merging into shale of soft fine grained sandstone. This change of character continues to ascend in horizon westward through southern central New York and northern Pennsylvania, until according to Sherwood,[*] Chemung fossils are found within one hundred and fifty feet of the base of the Lower Carboniferous, nearly a thousand feet above the beginning of red beds in that region.
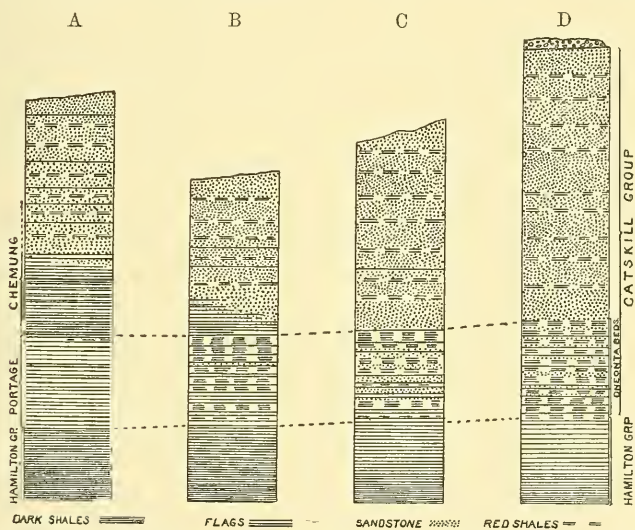
Fig. 2.—A, section through Susquehanna; B, through Oneonta and Franklin; C, Schoharie Creek; D, West of Palenville (C, D, Catskill Mts.). Scale, 2,000 feet to the inch.

Fig. 2.—Columnar sections at intervals along the same line as the section in figure 1, to illustrate the prominent variations in stratigraphy.

From these statements it is evident that the great mass of coarse sandstones with red shale intercalations in the Catskill Mountains gradually changes westward into fine grained sediments with Chemung fossils, the change beginning in the basal beds just above the Oneonta formation in northern central Delaware County. The Oneonta formation is character-

[*] 2d Geological Survey of Penn.; Report on Bradford and Tioga Counties, G. Harrisburg, 1878.

ized by a greater proportion of red shales than are contained in the great overlying series eastward, but both are closely related in their general history. The Oneonta beds preserve their character for a few miles farther west than do the basal members of the overlying series, but finally merge into typical Portage.

The Hamilton group (Marcellus to Hamilton) also change in character eastward similarly becoming coarse-grained and finally flaggy nearly to its base.

The outcrop area of the typical Oneonta formation is a wide belt extending through eastern Chenango, southern Otsego, northern Delaware, southern Schoharie and eastern Greene counties. Its greatest width is on the latitude of Otsego where the belt is about fifteen miles wide. In Delaware county it averages from six to ten miles wide and its beds are everywhere finely exposed. On Schoharie Creek it begins at the Manorkill Falls and extends about twelve miles southward. It extends far north about the headwaters of the Catskill and then southeastward in a narrowed belt along the steep slope of the high northern and eastern front of the Catskills by Cairo and through Palenville.

Stratigraphy.—The stratigraphic components of the Oneonta formation are somewhat variable in its smaller subdivisions but certain members preserve general characteristics throughout. The basal beds are gray flags which merge into the Hamilton. Their thickness averages about fifty feet and they may be regarded in greater part as beds of passage. They are streaked with red shale above and give place to a thick mass of red shales with more or less intercalated gray or greenish flags. Next above is a series of gray sandstones and flags with occasional red shale streaks in some localities, and usually some red sandstone layers. This series averages between two hundred and two hundred and fifty feet in thickness. The upper member of the formation consists of six or seven hundred feet of red shales and sandstones with intercalated gray and greenish flaggy beds and some cross-bedded sandstones eastward. The red shales are bright red in color and moderately hard in texture. They are not in regular continuous beds throughout but constitute greatly elongated lenses in the gray flags and red sandstones.

Toward the western termination of the Oneonta formation these members lose their distinctness and finally give place to the gray beds of the Portage. The formation also gradually decreases in thickness and width and on the Chenango there are not over 500 feet of red beds. West of Norwich the red materials disappear rapidly and their place is taken by gray shales and thin bedded sandstone. This change in character is

from below upward, going west, and there can be no doubt as to the continuity of sedimentation throughout. South of Cortland the red materials are entirely absent and the entire section is typical Portage.

The fossiliferous Chemung shales overlying the Oneonta formation south of Franklin have a thickness of about 300 feet and present the usual Chemung character. They grade upward through a series of flags, into hard, coarse, cross-bedded gray sandstones with intercalated red shale layers. In tracing these fossiliferous shales eastward they were found to gradually merge into flags and then into harder, coarse sandstones until at Croton, ten miles east, their horizon is represented by a heavy mass of coarse, gray, cross-bedded sandstones with flaggy layers. This mass becomes harder and coarser eastward and was traced to and along the eastern front of the Catskill Mountains, its base defining the upper limit of the Oneonta formation. Its thickness averages about 250 feet. It is overlain by a red shale bed twenty-five to thirty feet in thickness and this in turn is overlain by the thick mass of hard gray sandstone on which the old Mountain House is built. At a point about four miles due west of Durham some molluscan remains were found in a softer gray bed about 175 feet above the summit of the Oneonta formation. One fairly distinct individual was recognized by Dr. Hall as *Spirifer disjuncta*, a Chemung form.

From Franklin, westward, the Oneonta-Chemung boundary is clearly marked by the abrupt change from red beds to gray shales and soft sandstones. It extends along the slopes south of Unadilla and Sidney down the Susquehanna to a couple of miles below Afton. Thence south to Guilford and Summit on the New York, Ontario and Western Railroad and down the Chenango to Greene. The exposures along the railroad opposite Oxford from Lyons Creek bridge, where the Hamilton is exposed, to the Chemung at Summit, were described by C. E. Beecher, J. W. Hall and C. E. Hall as a typical section exhibiting the stratigraphic position of the Oneonta formation.[*]

I have not traced the formations farther southward than Palenville along the eastern front of the Catskills but there can be no doubt as to their extension across the Delaware and far into Pennsylvania. The "Chemung" rocks to which Mather and others refer, lies below the Oneonta beds or about 1,000 feet below the actual base of the Chemung horizon, and are Hamilton in position. Their fauna is meager and consists of species supposed by Vanuxem to be "Chemung" in central New York,

[*] Note on the Oneonta Sandstone in the vicinity of Oxford, Chenango County, 5th Report of State Geologist of New York, for 1885, p. 11.

but now known to be Hamilton. Mr. C. S. Prosser[*] in a recent paper on the Devonian system of eastern Pennsylvania, describes the relations along the Delaware, Lackawanna and Western Railroad in Monroe County west of Stroudsburg and shows that Hamilton fossils occur up to the base of the red beds which have heretofore been considered " Catskill" in age. It is probable that these basal red beds to which he refers will be found to be Oneonta for the first 1,000 feet or more, with the overlying Chemung indistinguishable, as in the Catskill Mountain region.

The status of the name " Catskill."—Catskill has been used as a geologic designation with such variable stratigraphic significance that its status as a formation name is worthy of serious reconsideration. No one can fail to be impressed with this who reads Prof. Stevenson's[†] admirably clear and exhaustive review of upper Devonian stratigraphy, or has followed the various controversies on the geology of southern New York and northern Pennsylvania. The typical " Catskill" region is of course the Catskill Mountains and in this region the name was intended to comprise all of the great mass of gray sandstones and red shales up to the base of the doubtful conglomerate capping the higher summits. Rocks of this character overlie the fossiliferous Chemung shales westward, and it has heretofore been supposed in the Catskill Mountains that they were similarly underlain by representatives of the Chemung. This as I have found proves to have been a mistake and the red and gray rocks of the Catskill Mountains—the type locality— comprise not only the Chemung but also the Portage horizons. The term Catskill has been applied in the past to beds of a certain lithologic character—the hard sandstones and red shales—and it has had no definite stratigraphic significance. This fact has been realized in the case of the upper members westward, but the determination of the true stratigraphic range in the Catskill Mountains throws additional light on the matter.

The rocks of the Catskill Mountains, and beds of similar character westward, have no distinctive fauna of stratigraphic significance and they cannot be correlated on paleontologic grounds. The lowest red beds have often been used as a criterion of discrimination between Chemung and Catskill, but they vary in stratigraphic position from the upper beds of the Hamilton in eastern New York to near the base of the Lower Carboniferous in northwestern Pennsylvania, a difference in horizon of several thousand feet. The Chemung

[*] This Journ., III, vol. xliv, pp. 210–221.
[†] Address of Vice-President, "The Chemung and Catskill (Upper Devonian) on the eastern side of the Appalachian Basin, Am. Assoc. Adv. Science, Proc., vol. xl, pp. 219–247.

fauna is distinctive as a whole and it pervades the greater mass of the western extension of the rocks of the Catskill Mountains from the upper part of the Portage in western New York nearly to the Lower Carboniferous in northwestern Pennsylvania.

As the "Catskill" in its type region comprises Portage and Chemung, my proposition now is to discontinue the use of Catskill as a coördinate formation term and use the term Catskill group to include the Portage and Chemung formations, the latter extending to the base of the Lower Carboniferous. I believe the Chemung and Portage are formations distinctly separable over a wide area, but Chemung and "Catskill" as formations are only separable by a lithologic distinction which progressively varies several thousand feet in stratigraphic position in the extension of the beds across southern New York.

Stevenson, in the review alluded to above, points out the general unity of the upper Devonian throughout the Appalachian region, and as its marine fauna is predominately Chemung, proposes the "Chemung" as a period name to comprise three epochs; the Portage, the Chemung, and the Catskill. The new light on the stratigraphic range of the formation comprised under the name "Catskill" in its *typical region* is the ground for my preference for the older term in its original significance, even though its true stratigraphic limits were not originally defined.

Art. XXVI.—*Estimates of Geologic Time;* by Warren Upham.

According to Sir Archibald Geikie, in his presidential address before the British Association last August,[*] the known rates of deposition of sediments imply that for the formation of all the stratified rocks of the earth's crust a duration somewhere between 73 millions and 680 millions of years must be required. Most geologists, before specially looking into this subject, would doubtless regard the lowest of these estimates as a minimum of the time needed for the processes of deposition and of erosion revealed by their study of the rocks, and for the concurrent changes of the earth's floras and faunas from their beginning to the present time. But to some geologists, these figures seem far too small, among whom Mr. W. J. McGee, in a paper read before the American Association the

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[*] Nature, Aug. 4, 1892, vol. xlvi, pp. 317-323.

same month,* reasoning from similar premises of geologic observations, would claim about seven thousand millions of years as the more probable measure of the part of the earth's duration since its earliest fossiliferous rocks were formed, and probably twice as long time since the earth began its planetary existence.

On the other hand, the most eminent writers who have considered this subject from the standpoint of physical experiment and theory and their relationship with astronomy, including Thomson, Tait, Newcomb, Young, and Ball, tell us that geologists can be allowed probably no more than 100 millions of years, and perhaps only about 10 millions, since our earth was so cooled as to permit the beginning of life upon it.

It is comparatively easy to determine the ratios or relative lengths of the successive geologic eras, but is confessedly very difficult to decide beyond doubt even the approximate length in years of any part of the records of the rock strata. The portions for which we have the best means of determining their length are the Glacial and Recent periods, the latter extending from the Champlain epoch, or closing stage of the Ice age, to the present time, while these two divisions, the Glacial or Pleistocene period and the Recent, make up the Quaternary era. If we can only ascertain somewhat nearly what has been the duration of this era, from the oncoming of the Ice age until now, it will serve as a known quantity to be used as the multiplier in the several ratios for giving us the approximate or probable measures in years for the recedingly earlier and far longer Tertiary, Mesozoic, Paleozoic, and Archæan eras, which last takes us back almost or quite to the time when the cooling molten earth became first enveloped with a solid crust.

Sir William Thomson (now Lord Kelvin) long ago estimated, from his study of the earth's internal heat, its increase from the surface downward, and the rate of its loss by radiation into space, that the time since the consolidation of the surface of the globe has been somewhere between 20 millions and 400 millions of years, and that most probably this time and all the geologic record must be limited within 100,000,000 years.†

Prof. George H. Darwin computes, from the influence of tidal friction in retarding the earth's rotation, that probably only 57,000,000 years have elapsed since the moon's mass was

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* Am. Anthropologist, Oct., 1892, vol. v. pp. 327–344. with a plate showing relative durations of natural time units, historical eras, and geologic periods.

† In an article published two months ago in this Journal, since the present paper was written, Mr. Clarence King, from recent physical investigations of diabase when subjected to great heat and pressure. concludes that the age of the earth, deduced by Lord Kelvin's method, is approximately 24,000,000 years.

shed from the revolving molten earth, long before the forma-
tion of its crust. From the same arguments and the rate at
which the sun is losing its store of heat, Prof. Guthrie Tait
affirms that apparently 10,000,000 years are as much as phys-
ical science can allow to the geologist. Professor Newcomb,
summing up the results of these physical and astronomical
researches, writes : " If the sun had, in the beginning, filled
all space, the amount of heat generated by his contraction to
his present volume would have been sufficient to last 18,000,000
years at his present rate of radiation . . . . . 10,000,000 years
. . . is, therefore, near the extreme limit of time that we can
suppose water to have existed on the earth in the fluid state."
Not only the earth, but even the whole solar system, according
to Newcomb, " must have had a beginning within a certain
number of years which we cannot yet calculate with certainty,
but which cannot much exceed 20,000,000, and it must end."*

The geologist demurs against these latter far too meager
allotments of time for the wonderful, diversified, and surely
vastly long history which he has patiently made out in his
perusal of the volume of science disclosed by the rocks. He
can apparently do very well with Lord Kelvin's original esti-
mate, but must respectfully dissent from the less liberal
opinions noted. Somewhere in the assumed premises which
yield to mathematicians these narrow limits of time there
must be conditions which do not accord with the actual consti-
tution of the sun and earth. It must be gratefully acknowl-
edged, however, in the camp of the geologists, that we owe to
these researches a beneficial check against the notion once
prevalent that geologic time extends back practically without
limit; and it is most becoming for us carefully to inquire how
closely the apparently conflicting testimonies of geology and
of physics may be brought into harmony by revision of each.

Among all the means afforded by geology for direct esti-
mates of the earth's duration, doubtless the most reliable is
through comparing the present measured rate of denudation of
continental areas with the aggregate of the greatest determined
thicknesses of the strata referable to the successive time
divisions. Now the rates at which rivers are lowering the
altitudes of their basins by the transportation of sediments to
the sea vary from an average of one foot taken from the land
surface of its hydrographic basin by the River Po in 730
years to one foot by the Danube in 6,800 years. As a mean
for all the rivers of the world, Alfred Russel Wallace assumes
that the erosion from all the land surface is one foot in 3,000
years. The sediments are laid down in the sea on an average

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* Popular Astronomy, pp. 505-519; Astronomy for Schools and Colleges,
p. 501.

within 30 miles from the coast, and all the coast lines of the
earth have a total measured length, according to Dr. James
Croll and Mr. Wallace, of about 100,000 miles; so that the
deposition is almost wholly confined to an area of about
3,000,000 square miles. This area is one nineteenth as large
as the earth's total land area; hence it will receive sediment
nineteen times as fast as the land is denuded, or at the rate of
about nineteen feet of stratified beds in 3,000 years, which
would give one foot in 158 years. With this Wallace com-
pares the total maxima of all the sedimentary rocks of the
series of geologic epochs, measured in whatever part of the
earth they are found to have their greatest development.
Prof. Samuel Haughton estimates their aggregate to be 177,200
feet, which multiplied by 158 gives approximately 28,000,000
years as the time required for the deposition of the rock strata
in the various districts where they are thickest and have most
fully escaped erosion and redeposition.

Most readers, following this argument, would infer that it
must give too large rather than too scanty an estimate of
geologic duration; but to many students of the earth's strati-
graphy it seems more probably deficient than excessive. All
must confess that the argument rests upon many indeterminate
premises, since the total extent of the land areas and the
depths of the oceans have probably been increasing through
the geologic areas, and the effects of tides have probably
diminished. The imperfection of the geologic record, so
impressively shown by Charles Darwin in respect to the
sequence of plants and animals found fossil in the rocks, will
also be appealed to as opposing the assumption that the
177,200 feet, or $33\frac{1}{2}$ miles, of strata represent the whole, or
indeed any more than a small fraction of the earth's history.
To myself, however, this last objection seems unfounded,
since in many extensive and clearly conformable sections ob-
served on a grand scale in crossing broad areas, there is seen to
have been evidently continuous deposition during several or
many successive geologic epochs, and by combining such sec-
tions from different regions a record of sedimentation is made
wellnigh complete from the earliest Paleozoic morning of life
to its present high noon. But perhaps we may do better to
change somewhat the premises of our computation, in view of
the extensive regions where the rock strata remain yet to be
thoroughly explored, and because of certain large land tracts
having little rain and therefore no drainage into the sea. Let
us assume that the total maxima of strata amount to 50 miles,
and that the mean rate of the land denudation is only one
foot in 6,000 years; and we then obtain a result three times
greater than before, or about 84,000,000 years for the deposi-
tion of the stratified rocks.

As a confirmation of the validity of his estimate of 28,000,-
000 years, Wallace cites the estimates differently obtained
through the geologic time ratios of Lyell and Dana, in combi-
nation with Dr. Croll's astronomic theory of the causes of the
Ice age, which attributes the accumulation of ice-sheets to
stages of high eccentricity of the earth's orbit. The Quater-
nary Glacial period is assigned by this theory an extent of
about 160,000 years, from 240,000 to 80,000 years ago. The
next preceding epoch of great eccentricity was about 850,000
years ago, and to that time are referred large ice-borne blocks
in Miocene strata of northern Italy. The union of this assump-
tion with the time ratios for the Tertiary and earlier eras is
explained as follows by Wallace in "Island Life," chapter x.

Sir Charles Lyell, taking the amount of change in the species of mollusca as a
guide, estimated the time elapsed since the commencement of the Miocene as
one-third that of the whole Tertiary epoch, and the latter at one-fourth that of
geological time since the Cambrian period. Professor Dana, on the other hand,
estimates the Tertiary as only one fifteenth of the Mesozoic and Paleozoic com-
bined. On the estimate above given [that the time since a Miocene glacial epoch
has been 850,000 years], founded on the dates of phases of high eccentricity, we
shall arrive at about four million years for the Tertiary epoch, and sixteen mil-
lion years for the time elapsed since the Cambrian, according to Lyell, or sixty
millions according to Dana. The estimate arrived at from the rate of denudation
and deposition (twenty-eight million years) is nearly midway between these, and
it is, at all events, satisfactory that the various measures result in figures of the
same order of magnitude, which is all one can expect on so difficult and exceed-
ingly speculative a subject. . . . The time thus arrived at is immensely less than
the usual estimates of geologists, and is so far within the limits of the duration
of the earth as calculated by Sir William Thomson as to allow for the develop-
ment of the lower organisms an amount of time anterior to the Cambrian period
several times greater than has elapsed between that period and the present day.

Professor Haughton has estimated time ratios from two
series of data. His results deduced from the maximum thick-
ness of the strata for the three grand divisions of Archæan,
Paleozoic, and subsequent time, expressed in percentages, are
34·3 : 42·5 : 23·2 ; and from his computations as to the secular
cooling of the earth, 33·0 : 41·0 : 26·0. From his consideration
of the present rates of denudation and the maximum thick-
ness of the strata, he obtains "for the whole duration of
geological time a minimum of two hundred millions of years."
In my opinion, this is a large rather than a small total esti-
mate ; but the length of Archæan or pre-Cambrian time seems
to me proportionately much greater than is here allowed.
The ratios reached by Profs. J. D. Dana and Alexander
Winchell, from the thicknesses of the rock strata, are closely
harmonious, the durations of Paleozoic, Mesozoic, and Ceno-
zoic time being to each other as 12 : 3 : 1. The Tertiary and
Quaternary ages, the latter extending to the present day, are
here united as the Cenozoic era. Professor Dana has further
ventured a supposition that these three vast eras, from the
Cambrian dawn until now, may comprise some 48,000,000

years, which would give for the Paleozoic era, 36,000,000 years; the Mesozoic, 9,000,000; and the Cenozoic, 3,000,000. He disclaims, however, any assumption that those figures are "even an approximate estimate of the real length of the interval, but only of relative lengths and especially to make apparent the fact that these intervals were *very long*."*

Prof. W. M. Davis, without speaking definitely of the lapse of time by years, endeavors to give some conception of what these and like estimates of geologic ratios really mean, through a translation of them into terms of a linear scale.† Starting with the representation of the Postglacial or Recent period, since the North American ice-sheet was melted away, as two inches, he estimates that the beginning of the Tertiary erosion of the Hudson River gorge through the Highlands would be expressed by a distance of ten feet; that the Triassic reptilian tracks in the sandstone of the Connecticut valley would be probably 50 feet distant; that the formation of the coal beds of Pennsylvania would be 80 or 100 feet back from the present time; and that the Middle Cambrian trilobites of Braintree, Mass., would be 200, 300, or 400 feet from us.

Having such somewhat definite and agreeing ratios, derived from various data by different investigators, can we secure the factor by which they should be multiplied to yield the approximate duration of geologic epochs, periods, and eras in years? If on the scale used by Professor Davis we could substitute a certain time for the period since the departure of the ice sheet, we should thereby at once determine, albeit with some vagueness and acknowledged latitude for probable error, how much time has passed since the Triassic tracks were made, the coal deposited, and the trilobites entombed in the Cambrian slates. Now just this latest and present division of the geologic record, following the Ice age, is the only one for which geologists find sufficient data to permit direct measurements or estimates of its duration. "The glacial invasion from which New England and other northern countries have lately escaped," remarks Davis, "was prehistoric, and yet it should not be regarded as ancient."

In various localities we are able to measure the present rate of erosion of gorges below waterfalls, and the length of the postglacial gorge divided by the rate of recession of the falls gives approximately the time since the Ice age. Such measurements of the gorge and falls of St. Anthony by Prof. N. H. Winchell show the length of the Postglacial or Recent period to have been about 8,000 years; and from the surveys of Niagara falls, Mr. G. K. Gilbert believes it to have been 7,000 years, more or less. From the rates of wave-cutting along the

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* Manual of Geology, p. 795.   † Atlantic Monthly, July, 1891, p. 77.

sides of Lake Michigan and the consequent accumulation of sand around the south end of the lake, Dr. E. Andrews estimates that the land there became uncovered from its ice-sheet not more than 7,500 years ago. Prof. G. Frederick Wright obtains a similar result from the rate of filling of kettle-holes among the gravel knolls and ridges called kames and eskers, and likewise from the erosion of valleys by streams tributary to Lake Erie ; and Prof. B. K. Emerson, from the rate of deposition of modified drift in the Connecticut valley at Northampton, Mass., thinks that the time since the Glacial period cannot exceed 10,000 years. An equally small estimate is also indicated by the studies of Gilbert and Russell for the time since the last great rise of the Quaternary lakes Bonneville and Lahontan, lying within the arid Great Basin of interior drainage, which are believed to have been contemporaneous with the great extension of ice-sheets upon the northern part of our continent.

Prof. James Geikie maintains that the use of palæolithic implements had ceased, and that early man in Europe made neolithic (polished) implements, before the recession of the ice-sheet from Scotland, Denmark, and the Scandinavian peninsula ; and Prestwich suggests that the dawn of civilization in Egypt, China, and India, may have been coeval with the glaciation of northwestern Europe. In Wales and Yorkshire the amount of denudation of limestone rocks on which bowlders lie has been regarded by Mr. D. Mackintosh as proof that a period of not more than 6,000 years has elapsed since the bowlders were left in their positions. The vertical extent of this denudation, averaging about six inches, is nearly the same with that observed in the southwest part of the Province of Quebec by Sir William Logan and Dr. Robert Bell, where veins of quartz marked with glacial striæ stand out to various heights not exceeding one foot above the weathered surface of the enclosing limestone.

Another indication that the final melting of the ice-sheet upon British America was separated by only a very short interval, geologically speaking, from the present time, is seen in the wonderfully perfect preservation of the glacial striation and polishing on the surfaces of the more enduring rocks. Of their character in one noteworthy district, Dr. Bell writes as follows : "On Portland promontory on the east coast of Hudson's bay, in latitude 58°, and southward the high rocky hills are completely glaciated and bare. The striæ are as fresh-looking as if the ice had left them only yesterday. When the sun bursts upon these hills after they have been wet by the rain, they glitter and shine like the tinned roofs of the city of Montreal."[*]

* Bulletin, Geol. Society of America, vol. i, p. 308.

From this wide range of concurrent but independent testimonies, we may accept it as practically demonstrated that the ice-sheets disappeared from North America and Europe some 6,000 to 10,000 years ago. But having thus found the value of one term in our ratios of geologic time divisions, we may know them all approximately by its substitution. The two inches assumed to represent the postglacial portion of the Quaternary era may be called 8,000 years; then, according to the proportional estimates by Davis, the Triassic period was probably 2,400,000 years ago; the time since the Carboniferous period has been about four or five millions of years; and since the middle of the Cambrian period, twice or perhaps four times as long. Continuing this series still farther back, the earliest Cambrian fossils may be 20 or 25 millions of years old, and the beginning of life on our earth was not improbably twice as long ago.

Seeking to substitute our measure of postglacial time in Professor Dana's ratios, we are met by the difficulty of ascertaining first its proportion to the preceding Glacial period, and then the ratio which these two together bear to the Tertiary era. It would fill a very large volume to rehearse all the diverse opinions current among glacialists concerning the history of the Ice age, its wonderful climatic vicissitudes, and the upward and downward movements of the lands which are covered with the glacial drift. Many eminent glacialists, as James Geikie, Wahnschaffe, Penck, De Geer, Chamberlin, Salisbury, Shaler, McGee, and others, believe that the Ice age was complex, having two, three, or more, epochs of glaciation, divided by long interglacial epochs of mild and temperate climate when the ice-sheets were entirely or mainly melted away. Professor Geikie, in a recent very able paper,[†] claims five distinct glacial epochs, as indicated by fossiliferous beds lying between deposits of till, and by other evidences of great climatic changes. In this country Mr. McGee recognizes at least three glacial epochs. The astronomic theory of Croll attributes the accumulation of ice-sheets to recurrent cycles which bring the earth alternately into aphelion and perihelion each 21,000 years during the periods of maximum eccentricity of the earth's orbit. Its last period of this kind, as before stated, was from about 240,000 to 80,000 years ago, allowing room for seven or eight such cycles and alternations of glacial and interglacial conditions. The supposed evidence of interglacial epochs therefore gave to this theory a wide credence; but the recent determinations of the geologic brevity of the time since the ice-sheets disappeared from North America

* "On the Glacial Succession in Europe," Trans. Royal Society of Edinburgh, 1892, vol. xxxvii, pp. 127–149, with map.

and Europe make it clear in the opinions of some of the geologists who believe in the duality or plurality of Quaternary glacial epochs, that not astronomic but geographic causes produced the Ice age.

Glacialists who reject Croll's ingenious and brilliant theory mostly appeal to great preglacial altitude of the land as the chief cause of the ice accumulation, citing as proof of such altitude the fiords and submarine valleys which on the shores of Scandinavia and the Atlantic, Arctic, and Pacific coasts of North America, descend from 1,000 to 3,000 and even 4,000 feet below the sea level, testifying of former uplifts of these continental areas so much above their present heights. But beneath the enormous weight of their ice-sheets these lands sank, so that when the ice attained its maximum area and thickness and during its departure the areas on which it lay were depressed somewhat lower than now, and have since been re-elevated. This view to account for the observed records of the Ice age is held by Dana, LeConte, Wright, Jamieson, and others, including the present writer. It is believed to be consistent either with the doctrine of two or more glacial epochs during the Quaternary era, or with the reference of all the glacial drift to a single glacial epoch, which is thought by Wright, Prestwich, Lamplugh, Falsan, Holst, and others, to be more probable. To myself, though formerly accepting two glacial epochs, with a long warm interval between them, the essential continuity of the Ice age seems now the better provisional hypothesis, to be held with candor for weighing evidence on either side. The arguments supporting this opinion are well stated by Professor Wright.* If there was only one epoch of glaciation, with moderate temporary retreats and re-advances of the ice-border, sufficient to allow stratified beds with the remains of animals and plants to be intercalated between accumulations of till, the duration of the Ice age may only have comprised a few tens of thousands of years. On this point Professor Prestwich has well written as follows:

> For the reasons before given I think it possible that the Glacial epoch—that is to say, the epoch of extreme cold—may not have lasted longer than from 15,000 to 25,000 years, and I would for the same reasons limit the time of . . . . . . the melting away of the ice-sheet to from 8,000 to 10,000 years or less.†.

From these and foregoing estimates which seem to me acceptable, we have the probable length of Glacial and Post-glacial time together 30,000 or 40,000 years, more or less; but an equal or considerably longer preceding time, while the

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* The Ice Age in North America, 1889, chapters xix and xx. Man and the Glacial Period, 1892, pp. 117–120 and chapters ix and x. "Unity of the Glacial Epoch," in this Journal, Nov., 1892.　　　† Geology, vol. ii, p. 534.

areas that became covered by ice were being uplifted to high altitudes, may perhaps with good reason be also included in the Quaternary era, which then would comprise some 100,000 years. The best means for learning the relative lengths of Tertiary and Quaternary time I think to be found in the changes of faunas and floras since the beginning of the Tertiary era, using especially the marine molluscan faunas as most valuable for this comparison. Scarcely any species of marine mollusks have become extinct or undergone important changes during the Glacial and Recent periods, but since the Eocene dawn of the Tertiary nearly all of these species have come into existence. Judged upon this basis, the Tertiary era seems probably fifty or a hundred times longer than the Ice age and subsequent time ; in other words, it may well have lasted two millions or even four millions of years. Taking the mean of these numbers, or three million years, for Cenozoic time, or the Tertiary and Quaternary ages together, we have precisely the value of Professor Dana's ratios which he himself assumes for conjectural illustration, namely, 48,000,000 years since the Cambrian period began. But the diversified types of animal life in the earliest Cambrian faunas surely imply a long antecedent time for their development, on the assumption that the Creator worked before then as during the subsequent ages in the evolution of all living creatures. According to these ratios, therefore, the time needed for the deposition of the earth's stratified rocks and the unfolding of its plant and animal life must be about a hundred millions of years.

Reviewing the several results of our different geologic estimates and ratios supplied by Lyell, Dana, Wallace and Davis, we are much impressed and convinced of their approximate truth by their somewhat good agreement among themselves, which seems as close as the nature of the problem would lead us to expect, and by their all coming within the limit of 100,000,000 years which Sir William Thomson estimated on physical grounds. This limit of probable geologic duration seems therefore fully worthy to take the place of the once almost unlimited assumptions of geologists and writers on the evolution of life, that the time at their disposal has been practically infinite. No other more important conclusion in the natural sciences, directly and indirectly modifying our conceptions in a thousand ways, has been reached during this century.

The error by which Mr. McGee, in the estimate stated in the early part of this article, wanders so far astray, consists in his relying largely on Dr. Croll's theory for the cause of the Glacial period, whereby he concludes that this period was of great length and that the ice-sheets were due to astronomic conditions while the land through the Ice age had somewhat

approximately its present height, with only moderate uplifts and depressions. Drawing his ratios of Postglacial and Glacial time, and of the preceding early Quaternary or late Tertiary epoch to which the Lafayette formation belongs, from the amounts of stream erosion, he has supposed the conditions then similar to those of the present time, so that the relative durations of these epochs may be estimated from their excavations of valleys by water courses. But it seems preferable, as before noted, to refer the Ice age to great elevation of the land, whereby the erosion of streams would be caused to proceed very much more rapidly than if the country were as low as now. With an altitude of our Atlantic coastal plain and whole continental area westward 3,000 feet higher than now, the valley-cutting may have gone forward twenty or a hundred times faster than to-day, or even near the coast a thousand times faster than now. The factor with which Mr. McGee starts on the multiplication of the earlier ratios to change them to years is evidently far too large, and it gives therefore for all the geologic eras and for the earth's total age too vast figures probably by twentyfold to a hundredfold.

Anthropologists, not less than geologists, have a lively interest in the estimates and measurements of the length of the Glacial and Recent periods, for the earliest reliable testimony of man's existence comes to us from the Ice age, both in North America and Europe. Confining our attention to the observations which prove that men were living on our continent as contemporaries of its northern ice-sheet, we have many independent and widely separated localities where traces of man's presence during the Glacial period have been found. Under the beach ridge of gravel and sand on the south side of Lake Iroquois, the glacial representative of Lake Ontario, charred sticks, with ashes and stones laid to form a rude hearth, were discovered about 18 feet below the surface in digging a well in Gaines township, Orleans county, N. Y. Lake Iroquois was dammed on the northeast by the receding continental ice-sheet and outflowed by way of the Mohawk and Hudson. The hearth and fire were made, according to Mr. G. K. Gilbert, "not long after the establishment of the Mohawk outlet and during its continuance." To a much earlier stage of the glacial recession we must refer the extensive gravel deposits of the Delaware River in the vicinity of Trenton, N. J., in which Dr. C. C. Abbott, Prof. F. W. Putnam, and others have found many palæolithic implements and chipped fragments of argillite.* Somewhat farther south,

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* Since this paper was written, two articles by Mr. W. H. Holmes in Science (Nov. 25, 1892, and Jan. 20, 1893) lead me to uncertainty whether the traces of man's existence in this country during the Glacial period are referable, as has been hitherto supposed, to a technically palæolithic stage of culture. They seem

in Delaware, Mr. Hilborne T. Cresson has found similar palæoliths in glacial gravel belonging to a still earlier part of the Ice age, probably deposited during the maximum extension of the ice-sheet. Other localities where palæoliths have been discovered in glacial gravel and sand beds, formed during the departure of the ice, are Newcomerstown, on the Tuscarawas river, in eastern Ohio; on the Little Miami river at Loveland and Madisonville, in southwestern Ohio; on the East fork of the White river at Medora, in southern Indiana; and on the upper Mississippi at Little Falls, in central Minnesota. Again, in one of the beach ridges of the glacial Lake Agassiz, held in the basin of the Red river of the North and of Lake Winnipeg by the barrier of the waning ice-sheet, Mr. J. B. Tyrrell has found chipped fragments of quartzite, evidently of human workmanship, contemporaneous with the rounded gravel and wave-worn sand of the beach. West of the Rocky Mountains, also, an obsidian spear-head was discovered by McGee in the sediment of the Quaternary Lake Lahontan; and stone mortars, pestles, and even human bones, including the famous Calaveras skull, have been obtained by Whitney, King, Becker, Wright, and others, from the gold-bearing gravels under the lava of Table mountain, California. Though these last are south of the continental drift sheet, they seem referable on sufficient geologic evidences, to the Pleistocene or Glacial period.

At one time the Californian discoveries were believed by some to prove man's presence there during the Pliocene period, far longer ago than the Ice age; but no indisputable proof, nor even apparently reliable evidence, for so great antiquity of man has been brought to light in any part of the world. *Homo sapiens*, as Professor LeConte stated in discussions of this subject at the meeting of the American Association last August in Rochester, N. Y., must be regarded, in the present stage of our knowledge, as restricted to the Quaternary era, although his anthropoid ancestors may have begun as far back as in Pliocene or Miocene time their ascent toward man's present intellectual and spiritual eminence.

to me to prove indubitably that men were living here contemporaneous with the ice-sheet, but these men may have possessed the skill to make both rough and polished implements of stone, corresponding with the Neolithic age in Europe. The wide geographic range of the native American race, its differentiation into many divergent branches, and the very remarkable advances of some of them toward civilization before the discovery by Columbus, as in Mexico, Central America, and Peru, indicate that the original peopling of the continent, which was apparently by migration from northeastern Asia, took place before the culmination of the Glacial period, probably during an immediately preceding time of general elevation of northern countries so that land extended across the present areas of Bering Strait and Sea. It may well be true, but probably cannot be proved, that even at that early time the people taking possession of North and South America had attained the stage of culture characterized by the partial use of polished stone implements.

Art. XXVII.—*Notes on the Cambrian in Missouri and the Classification of the Ozark Series;* by Arthur Winslow.

Introductory Remarks.—The Magnesian or Ozark series of rocks in Missouri covers nearly the entire southeastern quarter of the State. The members consist chiefly of dolomitic limestones and sandstones. They were assigned by the first Geological Survey of the State to the Lower Silurian and Calciferous age and were classified as follows, from the top downwards:*

> First Magnesian Limestone.
> Saccharoidal Sandstone.
> Second Magnesian Limestone.
> Second Sandstone.
> Third Magnesian Limestone.
> Third Sandstone.
> Fourth Magnesian Limestone.
> Fourth Sandstone.

This assignment and classification were followed, with slight modifications, by Shumard, Meek, Broadhead and others in later works, though, in the first report cited,† the discovery of a trilobite is noted in the Third Magnesian limestone which was considered identical with one in the *Potsdam* sandstone of New York, and in later reports and papers Broadhead refers to the lower members of the series as of probable Potsdam age.‡

Walcott, in recent writings, reasoning largely from the published results above referred to, has included the lower members of the Ozark series in the Cambrian§ and expresses this conclusion in the following words:|| "The Cambrian rocks in Missouri occur in the southwestern¶ portion of the State, about the Ozark Uplift. As far as known they are of Upper Cambrian age and consist of a sandstone that occurs beneath the third magnesian limestone, or Calciferous, and the fourth magnesian limestone of the Missouri survey, beneath which, according to Prof. G. C. Broadhead, there are other arenaceous and calcareous beds." According to this the last three numbers of the table given above would belong to the Cambrian.

Recent work of the present Geological Survey of Missouri has shown that a re-classification of the members of the Mag-

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* Swallow. 2nd Annual Report 1854, Part I, pp. 115 to 130.
† Ibid., p. 124.
‡ Report Missouri Geological Survey 1873–74, pp. 352, 257, 358.
§ The North American Continent in Cambrian Time, and Bulletin No. 81, U. S. Geological Survey, Correlation Papers—Cambrian.
|| Bulletin 81, p. 339.
¶ Southeastern probably meant.

nesian series is necessary,* and it is further tending to the con-
clusion that rocks placed higher in the series than the Third
sandstone are of Cambrian age. As bearing upon these ques-
tions the results of studies recently made by the writer in
Madison, St. Francois and Ste. Genevieve counties are here
presented.

Fig. 1.—Outline map of St. Genevieve, St. Francois and Madison Counties.

Previous Results in St. Genevieve County.—St. Genevieve
county is in the eastern portion of the State, about 40 miles
south of St. Louis. As is shown in the adjoining sketch it is
bordered by the Mississippi river on the east, by St. Francois

* Vol. ii, Report Missouri Geological Survey, 1892; Iron Ores, chap. v.

county on the west and corners with Madison county on the southwest. A description of the geology of this county by B. F. Shumard was published in 1871,[*] from results of work done during earlier years. According to this report the country lies on the eastern flank of the Ozark uplift and, proceeding from the river westwards, the upturned edges of the eastward dipping strata of Carboniferous, Devonian, Upper and Lower Silurian ages are successively encountered. It is with the last of these alone that we are concerned here. The report describes among the rocks of this period,[†] the First magnesian limestone, the Saccharoidal sandstone, the Second magnesian limestone, the Second magnesian sandstone and the Third magnesian limestone, as they are found in this county, one under the other, dipping gently to the east.

The Second magnesian limestone, in which we are specially interested, is stated to occupy a large area chiefly in the central and northwestern portions of the county, and to extend across the eastern half of the county in a belt from one to three miles wide. The Second sandstones, in which we are also interested, is described as constituting the surface rock over a larger portion of the country than any other formation and is present in greater vertical development. It is particularly well shown over the high central portion of the county. It is described as varying in lithological character, but usually appears in thin beds of white, yellow, or reddish colors and made up of moderately fine siliceous grains; sometimes, however, it is coarse-grained to the extent of being a grit-stone or conglomerate, containing large pebbles of milky translucent quartz. The thickness is stated to be 150 ft.

The Third magnesian limestone is described as occurring in the western and southern portions of the county, with the " usual lithological characteristics."

Previous Results in Madison County.—The geology of Madison county was described by Broadhead in 1873.[‡] According to this report the sedimentary strata fill the valleys between mountains and hills of Archæan rocks. The general section of these strata given is as follows, from the top downwards.

> 6. Sandstone.
> 5. Chert beds and magnesian limestone.
> 4. Magnesian limestone.
> 3. Grit-stone with some magnesian limestone.
> 2. Marble beds.
> 1. Sandstone.

[*] Report Missouri Geological Survey, 1871, pp. 289 to 303.
[†] Opus cit., pp. 298 and 299.
[‡] Report Mo. Geological Survey, 1873 to '74, pp. 342 to 379.

The members of this section numbered 1, 2, and 3 and part of 4 are placed in the Potsdam ; the upper one hundred feet or more of 4 are described as belonging to the Third magnesian limestone ; numbers 5 and 6 are placed in the Calciferous and 6 is thought to be probably the "Third sandstone."

The lowest sandstone (1) is described as occurring in the northern part of the county, in between the granite hills ; it is generally fine grained and of white or buff color, or may be a coarse, brown or red conglomerate. Thicknesses of from 40 to 90 feet are exposed in places. The sandstone found about Mine La Motte is included in this description.

The marble beds (2) are found only at a few localities in the central and southwestern portions of the county. The gritstones are similarly exposed only at a few points. The magnesian limestones (4) are stated to be of wide distribution ; the lower beds are placed in the Potsdam and are separated from the upper beds, of 100 feet or more, which are grouped under the head of the Third magnesian limestone, though the reasons for this separation are not very clear. The chert and sandstones (5 and 6) occupy the hill tops in scattered patches.

No explanation is given of the stratigraphic structure of county and the reasons for differentiating the marble and gritstone beds (2 and 3) and for placing them at the places designated in the section are not plain.

Previous Results in St. Francois County.—No report especially describing St. Francois county has been published ; but the sedimentary rocks there are in direct continuation of those of Madison county and the prevalent limestone has generally been considered to belong, in great part at least, to the Third magnesian. According to our understanding, then, the interpretation of the stratigraphy and structure of this region to be drawn from these reports would be as is expressed in the following section, along the line A, B, drawn in the sketch map on p. 222.
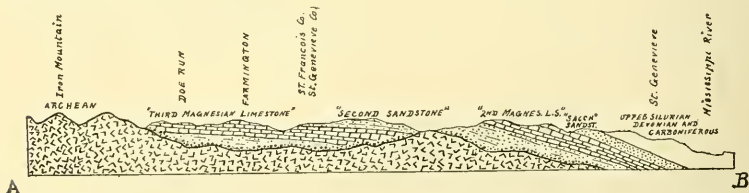
Fig. 2.—A generalized section across St. Francois and St. Genevieve counties, expressing the results of early work.

Results of the present Geological Survey.—During the past few years the present Geological Survey has prosecuted field work during part of each field season in this section of the

State. In this period the writer has carefully examined numerous outcrops and exposures and has, further, had the benefit of the results of a large amount of diamond drilling and shafting which have been done here, notably in the vicinity of Bonne Terre, Flat River, Farmington, Doe Run, Iron Mountain, Mine La Motte and Fredericktown. The results of this work all go to show that in St. Francois and in the northern part of Madison counties the sedimentary rocks between and beyond the granite and porphyry hills may be divided into the following three parts from the top downwards.

Observed thicknesses.
Feet.

1. Limestone, magnesian, crystalline; immediately underlies most of the valleys and constitutes the bulk of the non-Archæan hills. In thin and massive beds; includes some shale, especially in the lower parts; arenaceous layers encountered at places, but are of subordinate importance and not persistent. This is the lead-bearing horizon of southeastern Missouri .... 1 to 500

2. Sandstone, of white, gray and reddish colors; generally composed of pure quartz grains with secondary enlargements liberally developed; sometimes thinly bedded, even shaly, elsewhere massive, but generally friable and difficult to drill through .... 1 to 100

3. Conglomerate, composed of granite or porphyry bowlders with a limestone, grit or clayey matrix, 1 to 50
Granite or porphyry floor.

This section is, of course, not represented in full everywhere. The best succession is perhaps found in the center or the broader valleys, between the Archæan hills. As one approaches the sides of the valleys any or all of the beds may taper out. The detrital conglomerate would, naturally, not be found resting against a steep granite wall, but the bowlders would have slid or rolled to lower levels; the limestone, being often at higher level than the sandstone, may extend beyond the latter up a concealed hill slope of granite or porphyry and, thus, be often directly in contact with either of these latter rocks, or with the conglomerate derived from them. On the other hand, a thickening of the sandstone towards its source, an inclination of the floor or a slight dip, aided by erosion, may bring the sandstone to view at a higher elevation than the geologically higher limestone. This is the case in the vicinity of Doe Run; about three miles southeast of that place the sandstone, which underlies the limestone con-

taining the lead ore at the Doe Run mine, rises to the surface and is exposed in the bluffs of the hills to a thickness of 70 ft. or more.

This bottom sandstone is encountered in the vicinity of Flat River at depths of about 400 ft. Eastward from that place, however, numerous drill holes put down in late years show that the sandstone rises higher and higher and, about two miles east of Farmington, it is exposed at the surface, on Wolf creek. Thence, in the same direction, towards St. Genevieve, this rock continues to occupy the surface to about the middle of the county. Limestone then comes in again with an eastward dip and is, in turn, succeeded by the overlying Saccharoidal sandstone described by Shumard. According to our views, then, the section along the line A–B, is as follows :
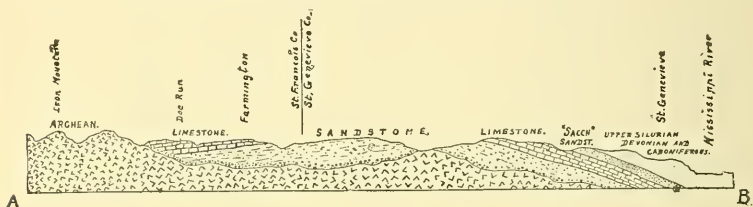
Fig. 3.—A generalized section across St. Francois and St. Genevieve counties, expressing the results of recent work.

On comparing this section with fig. 2, on p. 224, it will be seen that the principal difference is that the sandstone, termed "Second," overlies the limestone to the west in fig. 2, while, in fig. 3, it underlies it. The consequence is that this great body of limestone to the west, in St. Francois and Madison counties, instead of occupying the position of what have been called the Third or Fourth magnesian limestones is more properly in the position of the so-called Second magnesian limestone, and the underlying sandstone becomes correspondingly raised in the stratigraphic scale. Further, if the reasons cited for placing the limestones of Madison county in the Cambrian are good, we are of the opinion that all of the great body of limestone described above as occurring in Madison and St. Francois counties belongs to this age and the underlying sandstone and conglomerates also, as no stratigraphic break can be recognized throughout the section. This would bring the upper limits of the Cambrian to the base of what has been called the Saccharoidal sandstone in Missouri, at least as identified in St. Genevieve county.

Art. XXVIII. — *A Short Cycle in Weather;* by
James P. Hall.

If a diagram is drawn exhibiting the changes of daily mean
temperature in New York City for a few months it will be
discovered that these fluctuations occur every three or four
days, on an average, but that some have much greater ampli-
tude than others. In the course of four weeks, perhaps, there
will be only two or three conspicuous rises and falls. Upon
further scrutiny, there will be observed a tendency in these
more prominent features of the curve to repeat themselves at
intervals of about 27 days. Diagrams marked "Series I,"
"Series II" and "Series III" are submitted herewith to illus-
trate that tendency. The left hand vertical marks the true
beginning of each cycle; and the right hand one, which is
placed at a distance of exactly 27 days, the end; although for
greater distinctness the curves are extended three days in each
direction beyond the strict limits. In each of the three series,
which cover different years, the point at which the second
curve is intersected by the left hand vertical is exactly 27 days
later than the corresponding point in the curve preceding, and
so on through that entire set.

Considering only the general features, and not the minor
details of these traces, one finds a sort of repetition of both
warm and cold waves in nearly the whole succession. Thus,
in Series I (beginning with Aug. 18, 1889, and covering eight
cycles in immediate succession) there is a marked rise, **A**,
which in the first trace culminates on Aug. 21, and in the
second on Sept. 17. Recurrences, more or less distinct, appear
on October 12, November 9, December 9, January 3, January
30, February 26 and March 26. In the third, fourth, fifth,
sixth, seventh and eighth periods another warm wave, **C**,
closely follows **A** at an interval of from four to eight days,
the dates of climax being October 20, November 14, Decem-
ber 13, January 6, February 5, and March 5. After **C** has
become well developed, the cold wave **E** that followed **A** in
the first three cycles becomes inconspicuous for a time. **A** and
C may be regarded either separately or combined; but one or
the other, or both, recur with tolerable regularity. In the
first curve of this first series, we find also a rather sustained
warm spell, designated "**B**," having maxima on Aug. 31 and
Sept. 6 (central point, Sept. 3). The rises of Sept. 26 and of
Sept. 30–Oct. 1 (central point Sept. 28) imitate it, although
the warmth is not well sustained. Recurrences appear on
Oct. 27, Nov. 19–23, Dec. 19, Jan. 13–16, Feb. 12–14 and

SERIES I.   SERIES II.
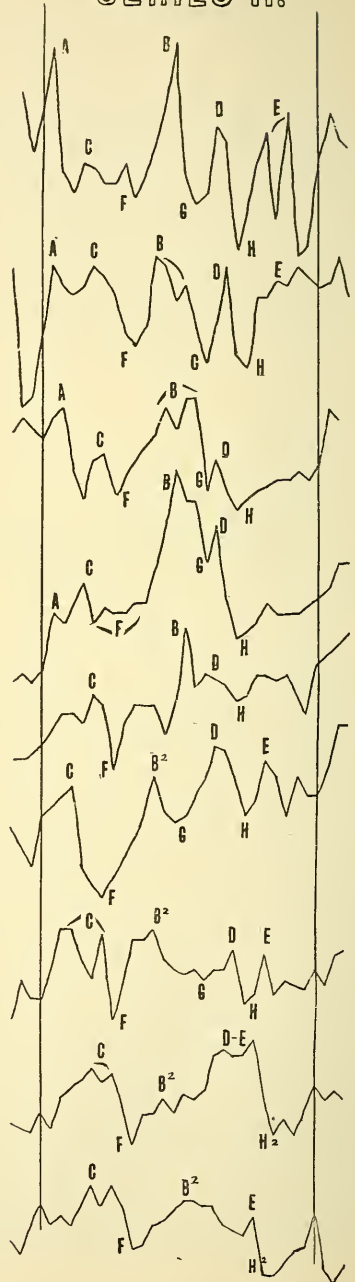
March 12, 13. Following **B**, much as **C** did **A**, another warm wave, **D**, developed in the third curve on Nov. 2 and 3, and was reproduced Nov. 27 and 28, Dec. 25 and 26, Jan. 20, Feb. 18 and weakly March 18. The second considerable decline of temperature in the first period, **F**, culminated Sept. 11. This was distinctly paralleled on Oct. 8, Nov. 5–6, Dec. 4, Dec. 31, Jan. 28, Feb. 22, and ineffectively March 19, when it had almost merged with **H**, a weak fall which separated **B** and **D** in the last six curves.

In Series II, all within 1892, we ·have the warm wave **A** culminating Jan. 2 and 29 and Feb. 26. In the fourth, fifth and sixth curves it practically disappears; in the seventh, eighth and ninth, there is a hint of recurrence. Another warm wave, **C**, weak in the first curve, is strong enough in the second to check the reaction after **A**. It recurs weakly in the third curve, but has good parallels in the rest of the series. The first thermal depression after **A** in the first curve of this second set is really made up of two marked cold waves, reaching their greatest severity on Jan. 4 and 10. The former is not well reproduced; but the second, **F**, is apparent right through the whole nine traces. In this series, as in the preceding one, there is a second conspicuous rise in the curve, **B**, manifest at least five times in succession. Whether or not the less distinct elevations B^2, in the other four traces, should be regarded as repetitions of it, these latter are at least recognizable. Another warm wave, **D**, is in nearly every instance inferior in rank to the two or three preceding it in the same cycle (**A**, **C** and **B**); yet it has a certain weak individuality that entitles it to notice. A fifth tendency to warmth, shown in the two peaks grouped as **E** in the first curve, finds a parallel in the next, but none in the third and fourth; and the subsequent imitations are too feeble to count. The warm waves **B** and **D** are at first fairly well separated by a fall in temperature, **G**, but this gradually fails as **D** grows in importance. The reaction, **H**, after both **B** and **D** is in most cases greater than **G** in the first four curves; but in the latter half of this series it fades out of existence gradually, and cannot fairly be identified with H^2 in the eighth and ninth traces.

In Series III the same tendency of prominent features to recur is at least equally obvious.

In all three sets of curves, and in those for other years, this apparent disposition to repeat an incident is more conspicuous at some times than at others. At best, it is never very striking; often a stretch of the imagination is required to perceive it. Seldom are all parts of a curve reproduced equally well in the next; some one member, perhaps, failing altogether to return, or even being represented by a reversal. Occasionally a

large rise or fall occurs a little too early or a little too late to be regarded confidently as a repetition in the sense here meant. And if one were to employ this phenomenon as a basis for practical forecasting, he would experience frequent failure. Yet in spite of non-recurrences and regardless of the doubts which may arise as to the reality of the parallel in certain instances, there is still so strong a suggestion of periodicity as to command respect when attention is once directed to it; and, as will appear later, some of the failures and discrepancies are susceptible of reasonable explanation; so that investigation eventually strengthens one's confidence in the genuineness of the phenomenon.

The first half of some of the traces presented herewith resembles the last half, and the resemblance may prove to be more than accidental; so that, judging from this alone, one might believe that the true cycle, if there be one, is 13 or 14 days in length, rather than 27; but in Series III, as in others which might be offered, the latter interval seems to be requisite to make out the full outline; one portion having oscillations either of wider range or greater frequency than the other. Reducing, then, the data embodied in all three series to tabular form, we find that while there is often a variation of a day or two from the exact period, only rarely does the departure amount to three days, one way or the other; and the mean length of the 109 cycles exhibited is 27·046 days, which must, however, be regarded as only an approximate result. A slight change would be effected in this value by omitting from the computation some of the instances which have been employed but which may not properly belong therein. The temperature-curve in our latitudes is a very complicated affair, apparently including not only features that for convenience may be called accidents but also several fairly regular undulations of different lengths, which partially mask each other. But even after free elimination from the evidence here exhibited and from other traces which might be presented, there still remains a residuum hinting strongly at a period of not far from 27 days.

Intervals at which Warm and Cold Waves Recurred.

Series I: 1889–90.			Series II, continued.	
Date.	**Interval.**		**Date.**	**Interval.**
A : Aug. 21,	****	**C :**	March 1,	28
Sept. 17,	27		March 26,	25
Oct. 12,	25		April 23,	28
Nov. 9,	28		May 18,	25
Dec. 9,	30		June 13–17,	28
Jan. 2,	24		July 13–15,	29
Jan. 30,	28		Aug. 9–11,	27
Feb. 26,	27	**F :**	Jan. 10,	****
March 26,	28		Feb. 6,	27
C : Oct. 20,	****		March 2,	25
Nov. 14,	25		March 27, ⎫	27
Dec. 13	29		April 1, ⎭	
Jan. 6,	24		April 25,	27
Feb. 5,	30		May 21,	26
March 5,	28		June 18,	28
B : Centr'l Pt., Sep. 3,	****		July 17,	29
C. Pt , Sept. 28,	25		Aug. 13,	27
One peak, Oct. 27,	29	**B :**	Jan. 14,	****
C. Pt., Nov. 21,	25		Feb. 8,	25
One peak, Dec. 19,	28		Mar. 7–10,	29
C. Pt., Jan. 14,	26		April 4,	27
C. Pt., Feb. 13,	30		May 2,	28
March 12, 13,	28	**B²:**	May 26,	****
D : Nov. 2, 3,	****		June 22,	27
Nov. 27–8,	25		July 20,	28
Dec. 25–6,	28		Aug. 18,	29
Jan. 20,	26	**D :**	Jan. 18,	****
Feb. 18,	29		Feb. 15,	28
March 18,	28		Mar. 12,	26
E : Aug. 28,	****		April 8,	27
Sept. 22,	25		May 4,	26
G : Oct. 23,	****		June 1,	28
Nov. 16,	24		June 30,	29
Dec. 15,	29		July 26,	26
C. Pt., Jan. 10,	26	**E :**	C. Pt. Jan. 24,	****
C. Pt., Feb. 8,	29		Feb. 22,	29
March 7,	27		Mar. __	– –
F : Sept. 11,	****		April __	– –
Oct. 8,	27		May 9–12,	18
Nov. 5, 6,	28		June 6,	27
Dec. 4,	29		July 2,	26
Dec. 31,	27		July 29,	27
Jan. 28,	28		Aug 25,	27
Feb. 22,	25	**G :**	Jan. 16,	****
March 19,	25		Feb. 13,	28
H : Oct. 30,	****		Mar. 11,	27
Nov. 26,	27		April 7,	27
Dec. 24,	28		May 3,	26
Jan. 17,	24		May 28,	25
Feb 16,	30		June 27,	29
March 16,	28	**H :**	Jan. 20,	****
			Feb. 17,	28
Series II: 1892.			March 14,	26
A : Jan. 2,	****		April 11,	28
Jan. 29,	27		May 7,	26
Feb. 26,	28		June 4,	28
March 23,	26		July 1,	27
C : Jan. 5, 6,	****	**H²:**	July 31–Aug. 2,	****
Feb. 2,	27		Aug. 27,	26

Series III : 1886.

A :	Date.	Interval.		D :	Date.	Interval.
	Jan. 4,	****			Jan, 12,	****
	Jan. 28,	24			Feb. 5,	24
	Feb. 25,	28			March 1,	24
	March 25-6,	28			Mar. 27-9,	27
B :	Jan. 17–21,	****		E :	Jan. 24,	****
	Feb. 13–19,	28			Feb. 20,	27
	March _ _	_ _			March 20,	28
	April 10–13,	55			April 16,	27

That these and kindred oscillations in New York City are, in the main, representative of temperature-changes over the greater part of the United States becomes evident when one compares the curves for that place with those for St. Paul and St. Louis. Indeed, one may go beyond the Rocky Mountains for this purpose, although at first sight the result is a little un-satisfactory. The four traces presented in Series IV (covering August, 1891), are offered rather to illustrate than to demon-strate the close general parallel between temperature-curves for stations in almost the same latitude, in a chain reaching nearly or quite across the continent. Were the testimony of five years instead of a single month offered the resemblance would still hold good. In-deed, probably no meteorolo-gist would question it. It should be observed, however, that in point of time, there is a sensible difference between places widely separated in longitude, in which respect these curves are unlike traces of magnetic storms, which ex-hibit deflections all around the globe at practically the same instant of time. But a con-spicuous rise in temperature at New York is apt to be a day or two behind that at St. Louis, fully two days behind St. Paul, and sometimes nearly a week behind Utah. The eastward progress of warm and cold waves across the continent is one of the most familiar phenom-ena in meteorology. There is, in Series IV, for instance, a rise (**A**) at Salt Lake City, culminating there on Aug. 4, at St. Paul on the 8th, St. Louis the 10th, and New York the 10th
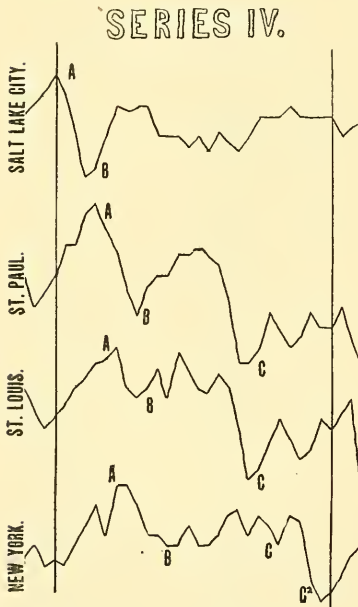
and 11th. That these are intimately related appears from this fact: Such phases of the weather are associated with winds from lower latitudes, bringing warm air upon the scene; these southeasterly, southerly or southwesterly winds constituting part of a system always to be found about a region of low barometric pressure and prevailing on the eastern or southern sides of such depressions. When, therefore, one of these areas approaches a place from the west, and is passing, with its center north of the station, these warm winds dominate; and when the depression has gone far enough to the eastward to permit the northwesterly and northerly winds of its western half to sweep over the spot, air from higher and colder latitudes is transported thither, and the temperature falls. These latter winds are also characteristic of the front of a high pressure system, such as usually follows the low area; and a study of these alternate "lows" and "highs" is the foundation of modern meteorology. A map showing the distribution of air pres-

U. S. WEATHER MAP. 8 a. m., August 7, 1891.
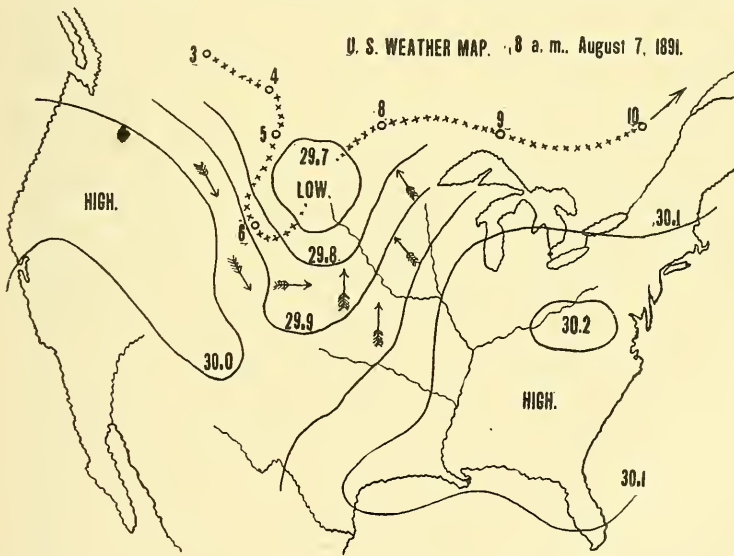
sure on the morning of Aug. 7, 1891, is submitted, and the positions successively occupied by its center from the 3d to the 10th indicated thereon. It will thus be seen that Utah came under the fullest influence of the warm winds of this system on Aug. 4, St. Paul on the 8th, and New York on the 10th. Its effect at the last named place and at St. Louis seems to have been heightened by the passage of a similar area from Manitoba to the St. Lawrence Valley on Aug. 9–11. The high

pressure area overlying Utah, Idaho and Oregon on the 7th is
associated with the cold wave (**B**) felt at Salt Lake City on that
day, at St. Paul and St. Louis on Aug. 12, and New York
Aug. 13–15; its effect being increased somewhat east of the
Mississippi by another high pressure area from British Amer-
ica, which merged with the first one on Aug. 10–11. By the
time that the warm wave **A** had reached St. Paul the cold wave
B was affecting Salt Lake City; so that here, as in many other
instances, the curve for the former station reverses that for the
latter. But the reversal is only apparent. Upon making the
proper time allowance, the parallel is found to be very close;
and, with easily explicable exceptions, it holds good the year
round. When, however, any low or high area changes its size
or shape materially, or follows such a route as not to present in
an equally advantageous way its warm or cold winds, to a series
of stations, the parallel fails; or if it exists, is accidental, not
logical. Exceptions occur, for instance, when low areas or
"storms" come into the United States from the north east of
the Rocky Mountains, or from the Gulf of Mexico, by way of
Tennessee to the lower Lakes, or skirt the Atlantic seaboard
without coming inland at all, having originated in the West
Indies.

The influence of one of these tropical storms is revealed in
Series IV. The cold wave **C** was well defined at St. Paul and
St. Louis, but almost imperceptible in New York. This was
because its progress was obstructed and its intensity reduced
by the abnormal delay for five days (Aug. 21–25) of a depres-
sion directly ahead of it. This delay in turn seems to have
been due to a slight high pressure barrier along the seaboard,
raised, like snow in front of a plow, by the famous Martinique
cyclone. That storm, crossing the Windward Isles on Aug.
18, 1891, advanced slowly to the Bahamas, recurved there on
the 23d and 24th, and then crept off to the northeastward.
Had this interfering depression approached the Carolina coast
more nearly, no doubt a very different effect would have been
produced. The inland storm would have merged with it, escap-
ing quickly to the ocean; the northerly winds in the front of
the anticyclone over the Mississippi Valley would have quickly
reached the coast, and would have been intensified. Indeed,
while this particular high pressure area was retarded until it
almost died out, the next one after it, though insignificant in
the west, was rendered more boisterous and chilly by the suc-
tion of the West India storms, which, by the 29th, was off
Nova Scotia. That is the day on which New York experi-
enced the cold wave marked **C**^{2}.

The deflection of a low area, whose center has kept north of
St. Paul and St. Louis, but which goes out onto the ocean south

of New York City, is another occasional cause of discrepancy in the parallel.

But the general uniformity of storm tracks is conspicuous enough in spite of these freaks to produce a strong resemblance between the temperature curves for the four stations specified, and for intermediate ones; and they will therefore be found to exhibit much the same periodicity as is observed in New York City. And since the same laws of storm movement and wind direction prevail in Europe and Asia as in America, and in the Southern as in the Northern Hemisphere, subject to certain local modifications, it is probable that the tendency of certain weather changes to recur at intervals of 27 days, observed in this country, may be found to exist in corresponding latitudes elsewhere.*

If, as seems to be the case, the immediate cause of warm and cold waves is wind-direction, then the intensity of the former must be proportional to the size and depth of the barometric depressions, and to the breadth and height of such anticyclones as happen to be adjacent thereto on the south. The greater the heaping up of air in the latter and the greater the rarefaction in the former, the steeper will be the gradient between the two systems, and the wider and stronger the sweep of the atmospheric currents. Examination of the daily weather maps for the three periods covered by the temperature curves in Series I, II and III, ought to show whether or not this is a sound conclusion. Such scrutiny does, on the whole, warrant confidence in the existence of such a relation. But the inquiry is more complicated than might be supposed. Were all storms symmetrical or even similar in shape and size, and were their routes always the same, and were high pressure areas also alike in dimensions and movement, the investigation would be very simple; but such differences exist among lows and among highs, and such are the distortions of figure in instances, that the comparison does not yield entirely harmonious results. One encounters occasional anomalies.

Thus the warm wave **A** in the first curve of Series I was associated with a barometric depression whose center was moving eastward over Ontario on Aug. 21, 1889. This was the most conspicuous low area that had crossed the country for ten days, and it had no equal for nearly a fortnight afterwards. The warm wave was correspondingly preëminent. This is a

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* Something of this sort, noted at Innsbruck and Paris by Nervander, and by Buys Ballot at Harlem, Danzig and Zwanenburg, is mentioned at page 80, in " Die wichtigsten periodischen Erscheinungen," by Herman Fritz, of Zurich, who himself contributes further data of the same kind on pages 396–8, exhibiting a single or double oscillation in temperature at several other European stations, four points in the Arctic regions and one in Africa.

clear case, and most of the principal rises of temperature exhibited in all these traces were similarly associated with more than usually intense storms, whose centers kept north of New York while passing eastward to the Atlantic. The warm wave **A**, in the sixth curve, Series I, culminating on Jan. 2, 1890, however, was not related to a deep depression but to a shallow one. But as the pressure over Georgia at that time was exceptionally high, the necessary gradient existed for an extensive movement of air from the warm southwest. This instance is typical; and several other apparent exceptions may be explained by similar situations. After all, it is not the actual barometric readings, but the contrasts, which explain wind force. These cases of high pressure over the South Atlantic or East Gulf States, moreover, suggest the possibility that not only are rapidly moving high and low areas intensified at times, but that the sub-permanent high pressure area which in an almost continuous belt extends around the globe along the 30th parallel of latitude, is also subjected to an occasional intensification. The warm wave **B**, in the first curve, Series II, culminating in New York on January 14, 1892, was as conspicuous as any exhibited in the whole set of traces; yet it had no precedent at St. Paul or St. Louis. This was because the storm to which it was related, instead of coming across the continent near the northern frontier, entered from the Gulf of Mexico and pushed up to the St. Lawrence Valley by a route which brought New York under the influence of its southerly winds; while places west of the Alleghanies were not so affected. On May 18 and 19, 1892, a storm of exceptional intensity prevailed over Lake Michigan, and came eastward on the two following days. New York, however, had a cold wave, not a warm one, in consequence. This was because a high pressure area over New England and the British Provinces obstructed the advance of the storm along its proper route—the St. Lawrence Valley—and forced it to reach the ocean by dipping down toward the Virginia coast. The metropolis, therefore, experienced strong northeasterly winds instead of southerly ones. Thus, the failure of the temperature-curve to rise at the expected time is explained; and the recurrence of storm activity when the 27-day period required it, really happened.

Most severe cold waves, in like manner, may be shown to be associated with the strong northwesterly winds prevailing between a very deep depression which has just passed and a moderately high pressure area behind, as on Sept. 22, 1889. (**E**, second curve, (Series I) or between a moderate low and a big high, as on Oct. 23, 1889 (**C**, third curve, Series I), or between a low and a high that are both very intense, as on Feb. 21, 1890 (**F**, eighth curve, Series I). But sometimes, as on **Dec.**

15, 1889 (**G**, fifth curve, Series I), the cause seems to be inadequate to the effect; and again, as on Jan. 10, 1892 (**E**, first curve, Series II), the results are not quite as great as possibly one might expect. In the former case, however, with only a moderate high and a shallow low, there was a great intensification of the storm after it passed out on the Atlantic, beyond the range of the weather maps, but while it was still near enough to affect the coast by increasing the gradient and wind force; and in the latter, with an exceptionally large anti-cyclone over New Brunswick, the fall would undoubtedly have been greater had not the temperature already been greatly lowered by a previous high pressure area, and by a storm going out to sea south of New York City.

So many of the apparent exceptions to the rule may be reasonably explained away, that one is justified in believing that the few remaining ones would disappear with more careful analysis, or in the light of conditions on land and sea contiguous to the United States but not represented on the ordinary charts. There is strong reason, therefore, to believe that, in the main, if not entirely, the temperature phenomena here exhibited are directly related to the distribution of air pressure, and that the atmosphere, owing either to the increased operation of the cause or causes (whatever they may be) which originate storms, or to the supplementary influence of some other cause, is persuaded periodically to arrange itself in high and low pressure areas of more than usual intensity.

The fact that the periodicity observed in the United States has also been noticed in Europe and in the Arctic regions leads one to suspect that the exciting cause is cosmical and not terrestrial. The 27-day period imperfectly revealed in the weather corresponds nearly to that of the sun's rotation. There are tremendous disturbances on that orb which appear to us as spots and prominences. And a relation between these solar storms and auroras and other phenomena in terrestrial magnetism has long been believed to exist. So that it is natural to seek for a connection between important meteorological episodes and the reappearance, by the sun's revolution upon its axis, of spots, faculæ, prominences, or something else even more permanently located upon that immense globe. It is not surprising to find, therefore, that nearly 20 years ago Broun suspected the existence of certain meridians* on the sun which might be particularly potent in exciting auroras and magnetic storms. Buys Ballot, it will be remembered, referred the fluctuations which he observed to "heat holes" or areas of higher or lower temperature on the solar surface. In line with these ideas was the belief of Prof. Spoerer that cer-

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* Encyclopædia Britannica: article on Terrestrial Magnetism, Section 86.

tain regions on the sun were predisposed to spottedness, although this theory still lacks confirmation. As early as 1883 we find Henry C. Maine, a journalist and amateur astronomer, trying to connect atmospheric storms with solar disturbances. For nearly ten years, in "The Rochester Democrat and Chronicle," he has been printing paragraphs every few days in illustration of this supposed relation. By or before 1889, however, he had concluded that the influence exerted was electrical, and proceeded from the sun's "streamers," but without indicating exactly what he meant by this term.* Mr. Maine, like some other observers, has noticed frequent coincidences between disturbances of the magnetic needle and the outbreak of severe terrestrial storms somewhere on the globe. Dr. M. A. Veeder, of Lyons, N. Y., long a student of auroral phenomena, has also been led by his own researches to think that there are certain solar meridians, or permanent sites, that disturb the earth's magnetism, and affect our weather. He and Mr. Maine further believe that the excitement, magnetic and meteorological, is produced, chiefly if not exclusively, when the solar storm or more permanently located region of influence is coming into view on the sun's eastern limb by rotation ; the former gentleman confining the effect rather to the first two or three days after such reappearance, while the latter extends the interval at least to a meridian passage.

These intuitions of American and foreign students contain unquestionably much of value, even if the precise truth has not yet been ascertained. But either in quantity or manner of presentation, or both, the testimony thus far offered to the public has not been adequate to secure general acceptance for these interesting theories by men trained to strict scientific methods ; nor have official bureaus, with all their enterprise and sense of responsibility, felt warranted in utilizing these suspicions for practical forecasting. The International Meteorological Conference in Munich in 1891, however, advised that all such Government institutions give special attention to the relations between meteorology and terrestrial magnetism. Upon his return to Washington, Prof. M. W. Harrington, Chief of the United States Weather Bureau, secured for this purpose the services of Prof. Frank H. Bigelow, whose original and valuable contributions to the study of solar physics and whose exhaustive and ingenious methods of investigation inspired much confidence in his ability to unravel this mystery, if there be one to unravel. Prof. Bigelow's inquiry is not yet completed ; and the result of his work thus far has not been made public to any great extent. Yet in a pamphlet from his pen, issued by the Weather Bureau last

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* Frank Leslie's Illustrated Weekly, Aug. 31, 1889.

August, he declared that he felt able to show that a real rela·tion does exist between magnetic and meteorological phe-nomena.

This assurance and the facts adduced in the present article suggest the following questions:

(1) What is the sun's exact synodical rotation-period? This needs to be determined accurately before we can make it the basis of comparison with terrestrial phenomena. The testi-mony of spots, magnetic storms, auroras, and spectroscopic observation of the sun's motion at the limbs is conflicting and diverse, yielding results all the way from 26 to 29 days. The mean time required for spots to reappear on the solar disc has been estimated at the Greenwich Observatory to be $27\frac{1}{4}$ days; but as yet we are not justified in regarding even this as final or representative of the whole orb.

(2) If the periodicity in terrestrial weather be due to the return, by the sun's rotation, of some important solar feature, is that feature a spot, facula or prominence, liable to develop in any longitude, and seldom existing for much more than three or four rotation-periods, or is it a permanent center or site? In the former case, the recurrence of any particular weather incident could only be counted upon a few times; in the latter it might be predicted not only months, but even years in advance. In the traces here reproduced, for instance, a warm wave, like **C** in Series I, will appear, without any immediate precedent, and subside after a few appearances. In some such cases purely terrestrial and local interferences can be discerned; in others, the reason for subsidence is not apparent. This would seem to favor the notion that a short-lived solar disturbance was the agent. On the other hand, the traces in Series I represent a minimum of the 11-year sunspot cycle, while Series II represents a period, which, according to Dr. Rudolph Wolf (whose "sunspot numbers" are widely accepted as a standard), exceeded in evidence of solar activity the last maximum stage.[*] Yet the periodicity of the temperature-changes is about as distinct and the ampli-tude nearly or quite as great, in one series as in the other.

(3) If the exciting influence is associated with one or more permanent sites, is the occasional subsidence and revival ob-served in its effects due to variations in the energy itself, to unequally advantageous positions resulting from the inclina-tion of the sun's axis, or to some unequal terrestrial masking or interference? Perhaps an answer to this can be found more easily when the following question is disposed of:

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[*] The mean of Wolf's monthly numbers from Sept. 1, 1889, to March 31. 1890, is 3·5; for the year 1883, 62·8; for 1884, 63·3; for the first nine months of 1892, 74·0.

(4) Is this exciting influence thermal or magnetic? Dr.
Kœppen, a division officer of the North German Weather
Service, believes that as between the maximum and minimum
stages of the 11-year sunspot cycle, there is enough difference
in the heat received from the sun to be sensible at the earth's
equator, and to have an effect on the general circulation of the
air.* This is in conflict with the view that the variations
in solar radiation are too slight to be appreciable; but if it
were true of the 11-year cycle, it might also hold good for
shorter periods. Fritz's evidence of a 27-day temperature
oscillation at Vivi on the Congo for a single year, is inade-
quate to prove this. But were a similar phenomenon noticed
at a dozen or more widely separated equatorial stations, the
fact would possess great significance; since along the Equator
there are no cyclonic systems passing, with winds coming first
from a warmer and then from a cooler quarter. Moreover,
Lockyer has presented some spectroscopic evidence of the
occurrence of great changes from year to year in the temper-
ature of spots,† which has not yet been followed up to a satis-
factory conclusion. The discovery of a "heat pole" on the
sun, such as Buys Ballot believed in, would harmonize well
with a periodical temperature oscillation outside the range of
moving high and low pressure systems, and also with the
thermo-dynamic theory of storm formation and intensification,
of which Espy, Abbe and Ferrel have been such able expound-
ers, but against which a fresh revolution has recently broken
out in meteorological circles. On the other hand, great mag-
netic storms have long been regarded, but without much proof,
as precursors of weather changes; and in many isolated in-
stances, like the great typhoon which smote Mauritius on
April 29, 1892, notable atmospheric disturbances have been
immediately preceded by exceptional agitation of the needle.
Dr. Meldrum, for forty years Secretary of the Meteorological
Society of Mauritius, has long believed such coincidences to
be significant, and he is not alone in that belief.

* Hann's " Klimatologie," p. 707.
† "Chemistry of the Sun," pp. 310–24.

Art. XXIX.—*Kilauea in August,* 1892; by Frank S. Dodge, Assistant Hawaiian Gov't Survey.

By direction of Prof. W. D. Alexander, Surgeon General, the writer was sent to Kilauea in August, 1892, to make such surveys as were necessary to determine the change that had taken place since the last survey in 1888.

While it is unfortunate for the history of Kilauea in recent years that no instrumental survey was made immediately after the great break-down of March, 1891, we have estimates by careful observers of the pit at that time, which range from 450 to 500 feet below the edge, or 750 to 800 below the Volcano House datum, as compared with 900 feet after the collapse of March, 1886. In this article, and the accompanying plans and sections, all elevations are referred to the same datum, as in my survey of 1886, viz., the veranda floor of the old Volcano House, which is approximately 4040 feet above sea-level.

Arriving at the volcano on the 18th of August, we began the survey on the morning of the 19th, several points on the main floor of Kilauea being located by triangulation, and their heights obtained. The summit of the present floor is no longer at "Central Rock" as in 1886, and 1888, but is now about one-fourth of a mile to the westward, and sixty feet higher, the great cone having built up by extensive overflows from Haulema'nma'u, between July 1888, and March, 1891. Careful observations from well-determined points show that Central Rock has not changed its position, and it thus forms a good point of reference for the survey of 1888, and that recently made.

From triangulation, with "Uckahuna" and V. H. Δ as a base, four points on the edge of Halema'uma'u were accurately located and their elevations determined, and from these points the whole periphery was surveyed by stadia measurements. From these same points, a large number of sights were taken on small flags on the very rim of the burning lake, to closely fix its exact size, shape and elevation, and the results are all given on the maps.

This survey gives the total area of Halema'uma'u as 100·4 acres, and that of the active lake as 12·1 acres, or equal to that of a circle with a diameter of 820 feet, which is much larger than any lake in Kilauea in recent years. Dana Lake in 1888 was not more than 300 feet in diameter or 1·6 acres in area. The present lake is nearly circular in form, its longest diameter being 860 feet, and the shortest 800 feet. The

entire rim stands at about the same level—519, or about 240
feet below the edge of Halema'uma'u, at the eastern station.
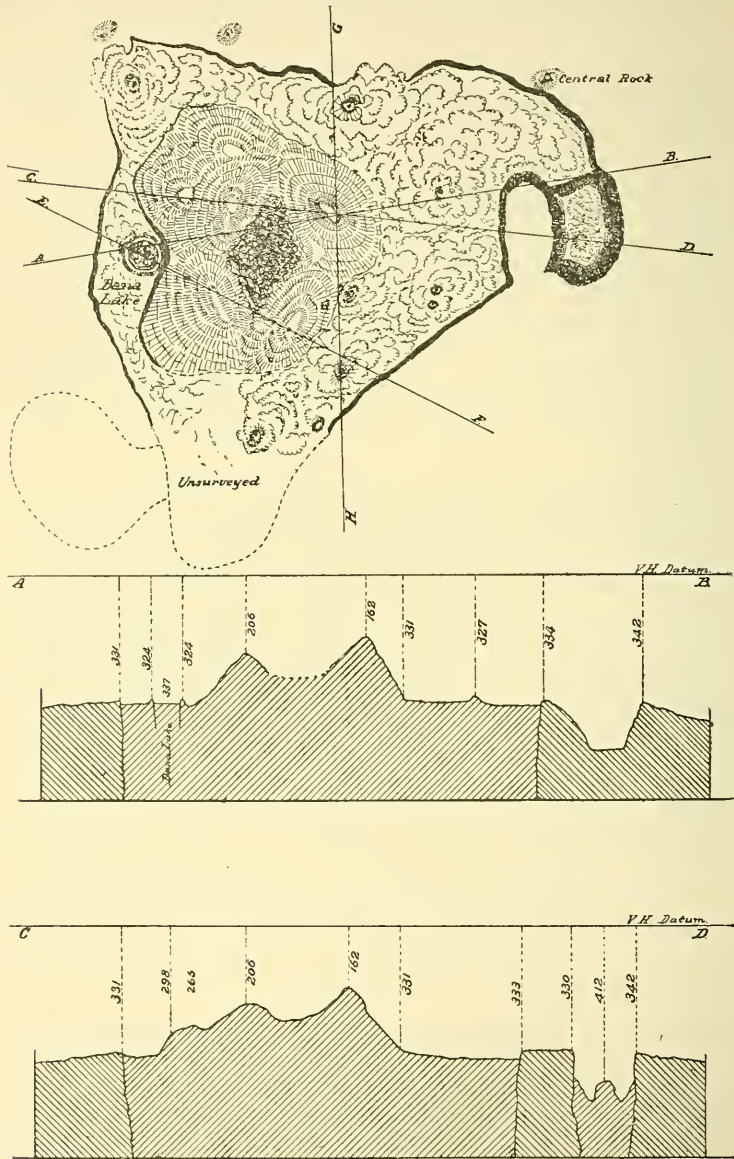
Plan of Halema'uma'u, with cross-sections, in July, 1888.
Horizontal scale, 1 inch = 1250 feet; Vertical scale, 1 inch = 500 feet.

During my various visits, covering a period of seven days, the lava was about three feet below the rim, on an average,— but was subject to a variation in level of four or five feet. Frequent breaks occurred in the rim, from which large flows took place, in some cases covering several acres of the floor. One large flow on the night of August 25th, extended to the foot of the talus slope, on the north and east sides, and covered about one-third of the floor, and raised its level from one to four feet. The lake itself and the surrounding area are rising slowly but surely, and it seems to be a matter of only a few months when Halema'uma'u will again be filled to the brim, and run over the sides, building up the main floor of the crater, as it did in 1888-91.

The deepest portions of the pit are at the foot of the talus slopes on all sides, with a gradual rise of ten or fifteen feet towards the rim of the lake, and then a more abrupt rise to the lake itself, as shown in the sections.

The lake was at times very active, with fountains playing over its surface in every direction, as many as fifteen being counted at one time by a careful observer. The greatest activity was at or near the center, where the largest fountain played almost continuously, and along the edge near the southwest side of the lake, where the overflows were most frequent. But at no time was the entire surface at rest, as was the case in Dana Lake during the short periods of my visits in July, 1888. Small fountains were always to be seen in some locality, and the whole surface was marked by long irregular seams or cracks always in motion. It was an interesting and fascinating sight, as we watch the ever-changing features of the lake, from our point of view on the north bank, some 250 feet above it.

The surrounding walls of Halema'uma'u are absolutely vertical on all sides, with one exception for 100 feet or more, from the upper edge to the talus slope, and at that one place only is it well to attempt a descent into the pit. On the northeast side for a short distance, the walls are broken down, and here it is possible for visitors to descend to a point 40 feet or more below the level of the lake, and then to climb up to the very rim of the lake. It is not difficult for a good climber, and several parties of ladies have recently accomplished it without great risk. The descent and the nearer views of the lake, are well worth the extra trouble and fatigue, but care must be taken to avoid the strong currents of sulphurous vapors to be found on the lee side of the lake. Their presence was much more noticeable than around the lake in 1888.

Mr. S. E. Bishop, in his article of April, 1892, has well described the condition of the lake, and in its most import-

ant features, his description applies to its condition in August. Considering the means at his disposal, his results are very close

Plan of Halema'uma'u, with cross-sections, in August, 1892.　S. C. Summit of Cone; O. S. Old Summit (Central Rock), 1886–88.
Horizontal scale, 1 inch = 1250 feet; Vertical scale, 1 inch = 500 feet.

approximations, and show careful work, but the later instrumental survey shows that he overestimated the diameter of the lake by about 100 feet.   His diameter of Halema'uma'u, 2,400 feet, agrees very nearly with mine, as given in the table at the end of this article.

As shown on Bishop's map of April, and my later one, the location of Halema'uma'u is almost identical with that of 1886, and the new lake is exactly over the mouth of the great funnel-shaped depression shown by Mr. J. S. Emerson in April, '86, but eastward of the Dana Lake of 1888.   The area of Halema'uma'u is not much less than in '86, being about 100 acres as compared with 153 acres by Mr. Emerson's survey.

Of the general condition of Kilauea little may be said, as the changes are hardly noticeable.   With the building up of the Halma'uma'u cone, in the period from 1888 to March, 1891, the summit was changed from Central Rock, with an elevation of −321 to a point directly north of the great pit, with an elevation of −262, a rise of 59 feet.   The whole region to the east and south, by the same agency was raised until it exceeds Central Rock in height by about 40 feet, and on the west side about 30 feet, making the conical form of Halema'uma'u more noticeable.

The trail over the old floor of Kilauea has been improved somewhat and marked by stone monuments at frequent intervals, throughout its length, and there is a trail entirely around Halema'uma'u, and another leading to some interesting caves southwest of the pit.

The new Volcano House is a vast improvement over the old one, and should be well patronized by tourists and others, as it is exceedingly well conducted, and all necessary comforts are provided by the present management.

With the completion of the new Government road from Hilo, the Volcano of Kilauea should have a much larger number of visitors than ever before.

In making my recent survey, valuable assistance was rendered by Mr. W. E. Wall, of the Government Survey, and also by the managers and guides at the Volcano House.

Dimensions and Elevations in Aug., 1892.

Diameter of Halema'uma'u,			N.—S.,	2,500 feet.
"	"	"	E.—W.,	2,250 "
"	"	"	N. E.—S. W.,	2,400 "
"	"	"	N. W.—S. E.,	2,400 "
"	"	"	Greatest,	2,600 "
"	"	"	Least,	2,150 "

Diameter of Lake,	N. – S.,	850 feet.
" " "	E. – W.,	830 "
" " "	Greatest,	860 "
" " "	Least,	800 "

Area of Lake, Aug., 1892,	$12\frac{12}{100}$ acres.	
" " Halema'uma'u,	$100\frac{4}{100}$ "	
" " "	153 "	in 1886.

Elevations, Aug., 1892.

Halema'uma'u, North,	−262 feet,	=highest point of cone.
" East,	−278 "	
" S. W.,	−283 "	
" N. W.,	−300 "	
Lowest point in pit,	−565 "	at foot of slope.
Depth of pit,	265 "	from Hal., N. W.

| Rim of Lake | −519 feet. |
| Surface of lava in Lake, | −522 " |

Art. XXX.—*Address delivered before the American Metro-logical Society, Dec. 30, 1892, by the President,* Dr. B. A. Gould.

The year just elapsed has, like its immediate predecessors, borne witness to the steady growth, in public opinion, of the reforms for which the American Metrological Society was established and to which it has earnestly devoted itself, so far as the resources at its disposal and the earnest efforts of some of its members have permitted. The hoped-for action of Congress in making the employment of the metric system imperative in the United States Custom-houses, as recommended by the late Secretary of State and urged by a very large number of petitions from various parts of the country, has not been successful, although the interest of many members of Congress appears to have been enlisted, and earnest correspondence with some has been carried on. The confident expectation that a committee at Washington might be influential in keeping the subject constantly before the minds of our legislators has likewise not been fulfilled; owing possibly in part to the many exciting matters of political discussion, which have been exceptionally prominent.

But the careful observer cannot fail to notice the increase in knowledge of the metric system among our people, and the

constant accession to the number of its advocates. The technical societies, especially the *Technischer Verein* of Americans of German origin, and the American Pharmaceutical Society, have been actively useful in this respect; and I cannot withhold the expression of my full conviction that a comparatively little more organized and well-directed effort will suffice for making the first steps in an advance which must end in the practically general adoption of the system in the United States.

Elsewhere the movement has been analogous. In those few nations where the use of these weights and measures has not been fully established by law, the tendency to their employment has been constantly increasing to a notable extent; and in those where their use, although prescribed by law, has not yet become generally adopted by the people, the same tendency is constantly asserting itself.

In short, it may be unhesitatingly declared that the employment of the Metric System is constantly increasing throughout the civilized world, and that its advantages, commercial, social and scientific are everywhere becoming better appreciated.

The most important researches, experiments and comparisons for the perfectionment and application of the system are of course those which are carried on at the International Bureau, established for the purpose near Paris by the joint action of most of the civilized nations of the world. Here the elaborate comparison of national prototypes with the two international ones which now serve as the definitions of the meter and the kilogram, has been essentially completed, so that the Bureau is becoming better able to devote a share of its attention to the investigation of other of the important subjects which demand its care.

One of these to which attention has been directed during the past year has been the relation of the yard to the meter, which may now be regarded as definitely settled within one or two units of the fourth decimal. The researches of Dr. Benoit, Director of the Bureau, of which I had the pleasure of giving you some account a year ago, established the true length of the *Toise du Pérou*, Bessel's toise, and the toise No. 9, and thus brought harmony into the previously conflicting results of some of the geodetic surveys. Our colleague and Secretary, Mr. Tittmann, has studied the various determinations by the English and American authorities, and after deducing their appropriate corrections, inferred a value of 39·3698 inches as representing the true relation of the inch to the meter. This differs by little less than a full thousandth of an inch from the value which had been generally accepted and incorporated into the British Act of Parliament of 1878.

During the past year Dr. Guillaume, assistant in the Bureau, has investigated the same question, availing himself of independent data. Using the results obtained last year by Dr. Benoit, according to which, at the temperature 16°·25 C.,

$$\text{Bessel's toise} = 1949 \overset{mm}{\cdot}061$$
$$\text{Toise No. 10} = 1949 \cdot 060$$

and accepting the determination of Clarke

$$\text{Toise No. 10} = 2 \cdot 1315091 \text{ yards}$$

we have the result

$$1^m = 39 \cdot 3699 \text{ in.}$$

which differs from our Mr. Tittmann's previous result by only one ten-thousandth part of an inch.

The relation of the British measure of length to the meter seems thus very closely determined; but the same is now to be still further examined by a direct comparison at the International Bureau of the two principal standard yards, which will be taken to Breteuil for the purpose by the Warden of the Standards.

At our annual meeting a year ago, I had the pleasure of announcing that arrangements had been essentially completed for the determination of the meter in lengths of light-waves corresponding to known and easily reproducible rays of the spectrum. In spite of some serious difficulties this plan was successfully carried out. Its execution was confided to Prof. Michelson, who was granted a six months' leave of absence for the purpose by Clark University. Through his exertions the apparatus was completed in time for him to take it to Paris in the first week of July last, and he has been assiduously occupied with the measurements. Although these are not yet absolutely completed, only a few more weeks of labor will probably be necessary to conclude the investigation, which has been attended with the most gratifying success. Prof. Michelson discovered during the last spring, that the metal cadmium afforded three rays, sufficiently monochromatic for the purposes, and situated respectively in the red, the green and the blue. The number of wave-lengths to the meter for each of these will soon be fixed with extreme accuracy, and the meter thus brought into relation with natural units; so that, were every metric prototype in existence to be lost or destroyed, it would still be possible for the meter to be restored by future generations, with accuracy to less than half a micron.

The feasibility of this investigation, which has sometimes been made the subject of doubts, expressed or implied, has thus been fully demonstrated, and in the most effectual and gratifying way.

It may be added that this method of measurement, which has been so successfully employed by Prof. Michelson in defining the length of the meter, seems applicable to many other physical researches, and will doubtless take its place among the most accurate and important modes of measuring linear dimensions, especially small ones. The processes by which it has been possible to extend its application to the full length of a meter-bar are very ingenious, and must reflect great honor upon the gifted physicist who devised and executed them.

Other important metrological investigations have been carried forward with energy during the year, among which I may mention the extension of the hydrogen-scale for thermometers to very low temperatures, where the alcohol-scale becomes untrustworthy. For practical use in determining temperatures below $-60°$ C., reason has been found to believe that the employment of toluene, or of ethylic alcohol, will be found serviceable. This question, as also that of the definite fixation of the hundredth degree below $0°$ C., has received much attention and the investigations are approaching definite results.

It may be known to some of the society that a physicist in the Netherlands, Mr. Bosscha, published some sharp criticisms of the comparison of the recently established fundamental prototype of the meter with the Mètre des Archives the length of which it had been intended to reproduce. The boldness of the assertions was such as to cause some uneasiness among those who were not especially conversant with the methods employed; although in one sense such an error as was alleged would only possess a historic importance, since the new International Prototype has been definitely adopted for the definition of the meter. Yet inasmuch as it had been desired to reproduce the length of the old Mètre des Archives with all attainable precision, any appreciable deviation from this length would have been a source of much regret. The elaborate comparisons from which the assumed equality was deduced have been subjected, during the last summer, to a new and very detailed recomputation by the Director of the International Bureau, and yield the same result as before. Mr. Cornu has investigated the whole matter anew, and has discovered the source of the discrepancies in erroneous methods employed by Mr. Bosscha, so

that the question is now definitely disposed of. The inference is justified that there is no appreciable difference of length between the two standards. Although the Mètre des Archives is an end-meter, or mètre-a-bouts, made of a relatively soft and flexible metal and its extremities adjusted by filing, while the International Prototype gives the meter by the distance between delicate lines traced upon platiniridium, yet the probable error of the comparison, which gives zero as the difference of length, cannot exceed one micron, a limit of error twenty-five times smaller than the tolerance fixed upon by the constructors of the original standard.

It has seemed to me that this sketch of some of the work of the International Bureau would have interest for you, as showing the advances made in metrology during the present year. Other important physical researches for metrological purposes are in prosecution and promise valuable results, at least from a scientific point of view. Meanwhile the comparison of the chief standards of most countries, whether metric or otherwise, including geodetic bars and those possessing historic value or interest, has been steadily going on, and most of those standards of length which are now, or have in comparatively recent time, been employed in important measurements, have now been compared with the International Prototype.

During the current year our efficient Secretary has distributed nearly 4,500 metric charts, and as many pamphlets, circulars and blank petitions,—as you will learn from his report. It is impossible that these should not bring in due time a fitting return, in the shape of renewed interest throughout the land in the reforms for which we are striving.

In these remarks I have referred chiefly to the metric system of weights and measures, upon which by common accord the efforts of our society are at present concentrated; leaving aside most of its many other ends. Let us trust that by common effort the first victory may soon be achieved and leave us freer to prosecute some of the other purposes of the society. This requires individual effort, exerted according to organized method.

SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *Energy as a Dimensional unit.*—In a communication to the Munich Academy, OSTWALD has suggested the substitution of the unit of energy for the unit of mass as one of the three fundamental units of an absolute system; so that in this case all physical magnitudes would be expressed in units of energy, length and time. The assumption that all such magnitudes can be expressed in units of mass, length and time, appears to him a false one. It is not possible in his opinion, for example, to express in centimeters, grams and seconds the value of the temperature of melting ice, of the chemical affinity between hydrogen and chlorine, or of the electric pressure of a voltaic element. There can be no doubt to-day that energy is the most important quantity in physical science. While mass may be the fundamental quantity in dynamics, energy is the only magnitude which is common to all branches of physics. The mutual convertibility of the various forms of energy is the single bond which unites the theories of heat and of electricity, of chemistry and of dynamics. Starting from the principle of virtual velocities, which is capable, the author thinks, of a more rational expression than that of virtual work, the extension of the energy idea over the entire province of physics and chemistry may be formulated as follows: In order that any system whatever containing forms of energy shall be in equilibrium, the necessary and sufficient condition is that for every displacement of the system consistent with the conditions of its existence, the sum of the quantities of energy which appear and disappear shall be equal to zero. Mass is defined by Ostwald as "the capacity of an object for the energy of motion." The following table shows the changes in the dimensional magnitudes of various units required by the new system:

	Old Units.	New Units.
Energy	$[ml^2t^{-2}]$	$[e]$
Mass	$[m]$	$[el^{-2}t^2]$
Momentum	$[mlt^{-1}]$	$[el^{-1}t]$
Force	$[mlt^{-2}]$	$[el^{-1}]$
Surface-tension	$[mt^{-2}]$	$[el^{-2}]$
Pressure	$[ml^{-1}t^{-2}]$	$[el^{-3}]$
Activity	$[ml^2t^{-3}]$	$[et^{-1}]$

With regard to the electrical magnitudes $[\mu]$ the unit of quantity and $[\varepsilon]$ the unit of electromotive force, we have $[e]=[\varepsilon\mu]$; and hence the dimensions of $[\mu]=[e\varepsilon^{-1}.]$ In the same way the dimensions of the unit of current becomes $[e\varepsilon^{-1}t^{-1}]$ and of the unit of resistance $[e^{-1}\varepsilon^2t.]$ So that the dimensions of electric units may be represented in one of two ways according as ε or μ is made the fundamental unit:—

Quantity	$[\mu]$	$[e\varepsilon^{-1}]$
Electromotive force	$[e\mu^{-1}]$	$[\varepsilon]$
Current	$[\mu t^{-1}]$	$[e\varepsilon^{-1}t^{-1}]$
Resistance	$[e\mu^{-2}t]$	$[e^{-1}\varepsilon^2 t]$
Conductivity	$[e^{-1}\mu^2 t^{-1}]$	$[e\varepsilon^{-2}t^{-1}]$
Capacity	$[e^{-1}\mu^2]$	$[e\varepsilon^{-2}]$

Zeitschr. physikal. Chem., ix, 563, June 1892; *J. Chem. Soc.*, lxii, 1149, Oct., 1892.   G. F. B.

2. *On the Permeability of Precipitated Membranes.*—As long ago as 1867, Traube expressed the opinion that precipitated membranes are porous, the pores allowing the smaller water molecules to pass but not the larger molecules of the dissolved substance; the membrane acting like a sieve. In 1890, Ostwald modified this view by suggesting that the permeability of the membrane referred, not to the salt molecules as a whole but rather to their ions. So that a salt, both ions of which can traverse the membrane, can pass through it as a whole; while if one of the ions is stopped by the membrane, the salt itself is also stopped. TAMMANN has tested these views experimentally, by preparing three membranes, tannate of gelatin, zinc ferrocyanide and copper ferrocyanide, and then determining their permeability to seventeen acids and salts in solution in water. In accordance with the molecular sieve theory, the order of permeability of the three membranes was found to be the same for all the substances dissolved. Moreover, it was found that acids diffuse through a copper ferrocyanide membrane in the order of their strength; i. e. of the degree of their dissociation into ions, thus indicating that it is rather the ions that pass the membrane and not the acid itself. The diffusibility of hydrochloric acid being 9·0, that of trichloracetic acid was found to be 6·6, of monochloracetic acid 3·3 and of acetic acid 2·6. Experiments with a large number of salt solutions, to determine their power to pass through different membranes, gave anomalous results. Thus while the chlorides, bromides and nitrates of potassium, ammonium, sodium and lithium pass readily through membranes of copper ferrocyanide, the corresponding sulphates diffuse with much greater difficulty, and the membrane is impermeable to salts of calcium and magnesium, although it allows the diffusion of the chlorides and bromides of barium and strontium. Moreover, while succinic, tartaric, citric and isobutyric acids diffuse through the membrane, their potassium salts do not. Evidently the views of both Traube and Ostwald require modification. The author thinks the phenomena of diffusion may be due to solution, since all these semi-permeable membranes are strongly hydrated.—*Zeitschr. physikal. Chem.*, x, 255, Aug. 1892; *J. Chem. Soc.*, lxii, 1383, Dec. 1892.   G. F. B.

3. *On Fluosulphonic acid.*—It has been shown by Gore that when liquid hydrogen fluoride is brought in contact with sulphur trioxide, it acts upon it with great violence. THORPE and KIRMAN have studied this reaction and have shown that when the

two substances are mixed in proper proportions at a low temperature, the product is a mobile colorless liquid corresponding to the chlorsulphonic acid of Williamson, and which the authors call fluosulphonic acid. To prepare it a known quantity of sulphur trioxide was distilled into a platinum receiver, this was immersed in a freezing mixture, and connected with a platinum retort containing hydrogen-potassium fluoride in excess. On heating this, hydrogen fluoride passed into the receiver and combined with the trioxide. To free the fluosulphonic acid thus formed from the excess of hydrogen fluoride, it was heated to about 30° and a current of dry carbon dioxide was passed through it. The final ratio obtained was 1 of SO_3 to 1·13 of HF. The analysis of the acid was difficult on account of the extreme violence of its action upon water. Its boiling point was determined to be 162·6°; though like chlorsulphonic acid it slightly decomposes at this temperature, forming probably sulphuryl difluoride. Fluosulphonic acid is a thin colorless liquid, fuming in the air and having a faint pungent smell. It feels greasy to the touch and has but little action on the dry skin; being entirely without the intense blistering action of hydrogen fluoride. It slowly attacks glass, more rapidly in presence of moisture. It readily acts on lead forming sulphate and fluoride.—*J. Chem. Soc.*, xli, 921, December, 1892. G. F. B.

4. *On Carbon di-iodide.*—It has been observed by MOISSAN that when carbon tetra-iodide is exposed to the sun's rays in a vacuum, or even to diffused daylight or a temperature of 120° it splits up into carbon di-iodine and iodine. The di-iodide is best prepared, however, by dissolving the tetra-iodide in carbon tetrachloride and adding the quantity of powdered silver required to abstract half the iodide. It crystallizes in pale yellow nodules, fuses at 185°, volatilizes a little above this and begins to decompose at 200°. Its density is 4·38. It is soluble in carbon tetrachloride, carbon disulphide, ether and hot alcohol. It is not reduced by hydrogen at 200° and is not attacked by chlorine or bromine in the cold. Heated in oxygen it melts and then decomposes, the carbon burning to CO_2. Sulphuric acid decomposes it at 200°.—*C. R.*, cxv, 152 ; *J. Chem. Soc.*, xlii, 1291, Nov. 1892. G. F. B.

5. *Photographic study of the movement of projectiles.*—At a meeting of the Physical Society of Berlin, Nov. 18, 1892, F. NEESEN described a new method of studying the movements of projectiles which had been carried out under the auspices of the Prussian Artillery Commission. Inside the projectile near the head which could be unscrewed was placed a sensitive plate. This plate was opposite an opening 0·5^{mm} in diameter. In a second arrangement a sensitive plate was also placed at the middle of the shot inside it and opposite a small opening which permitted the entrance of the sun's rays. The shot was so directed that the sun's rays formed a small image of the sun on the photographic plate. At each turning of the shot in its path, an

elliptical path was photographed on the sensitive plate. The length of this path changed with the turning of the axis of the shot. The distance of the trace from the middle of the plate and the distance of the plate from the opening which admitted the light, enabled one to compute the angle between the axis of the shot and the sun's rays. In order to determine the turning of the axis of the shot around a vertical and around a horizontal axis, the curves obtained from two firings were combined. These shots were directed under the same conditions of velocity in different directions in regard to the sun's rays. Diffuse daylight did not affect the distinctness of the trace of the sun's image, for plates allowed to remain in the shot for one-half hour showed only a faint pin-hole photograph of the surrounding landscape. Certain curves showed breaks in continuity which were due to the passage of the shot by branches of trees which shielded the sun's rays for an instant from the sensitive plate. The paper contains a short mathematical discussion of Euler's equation with the object of determining from the obtained data the air-resistance moment.—*Ann. der Physik und Chemie*, No. 1, 1893.

J. T.

6. *A New Species of the Magnetic and Electrical Instruments.* —G. Quincke describes with figures, galvanometer and magnetometers which are of novel form, and which constitute a departure from the types which are known to the scientific world. The essential feature of the new form is a glass disc, supported vertically. Around the rim of the disc, a wire or wires are clamped and in a hole at the center of the glass disc is suspended a mirror with magnet. This arrangement can serve either as a tangent galvanometer or as a magnetometer. It is evident that movable coils can be placed on each side of the glass disc which carries the suspended mirror. The extreme simplicity of these forms will commend them to instructors in laboratories, who desire accuracy combined with economical arrangements. The author points out the many simple modifications of his idea, and maintains that greater accuracy can be obtained by instruments of his form than by those of the conventional type. Illustrations accompany his article.—*Ann. der Physik und Chemie*, No. 1, 1893, pp. 25–34.

J. T.

7. *Refraction of electrical waves by alcohol.*—H. O. G. Ellinger has succeeded in showing the refraction of electrical waves by alcohol. The liquid was enclosed in a wooden vessel made in the form of a hollow prism. This prism was one meter high, one meter and fifteen centimeters long. Its angle was 8° 16′ and it held 90 liters of alcohol. The measurement was carried out by Hertz's arrangement of mirror and spark and an index of refraction of 4·9 was obtained which agrees with the theoretical result. —*Ann. der Physik und Chemie*, No. 1, 1893, pp. 108–109.

J. T.

8. *Absorption spectra.*—Julius has by means of the bolometer determined the wave-lengths of absorption bands of a great

number of organic substances in the infra red. His results show that all compounds in which the radical CH_3 enters have a maximum of absorption at wave-length $\lambda = 3.45\mu$ and a second between 8 and 9μ. The fluids which contain oxygen absorbed waves from 10 to 20μ. The chlorine compounds show a certain correspondence at definite points of the spectrum.—*Beiblatter Ann. der Physik und Chemie*, No. 1, 1893, p. 34. J. T.

9. *The Optical Indicatrix and the Transmission of Light in Crystals*, by L. FLETCHER. 112 pp. 8vo. London, 1892 (Henry Frowde, Oxford University Press Warehouse).—To the student who is bewildered by the conflict of optical theories, this treatise will supply a real want in furnishing those relations which can be verified by experiment, unincumbered by any dynamical theory. The deductions are generally based on simple geometrical considerations relating to the ellipsoid which the author calls the *Indicatrix*, analytical formulæ being added for those whose taste requires them, and for the purposes of numerical calculation. The historical notes, though brief, are valuable, and may give a better idea of the actual discovery of the wave-surface, than might be obtained by the reading of some classical memoirs, while the references to optical theories are entirely free from *parti pris*. The standpoint of the author is in fact that of the crystallographer, interested in the optical behavior of crystals, rather than that of the physicist to whom the vital question relates to the essential nature of light.

10. *A Text-book of Physics, largely experimental*, by EDWIN H. HALL and JOSEPH Y. BERGEN, Jr. 388 pp. 12mo. New York, 1892 (Henry Holt and Company).—This text-book is to a considerable extent based upon the Harvard College descriptive list of elementary physical experiments (first issued in 1887) called out by the requirement, made in 1886, of laboratory work in Physics. The experiments are well selected and with the guidance of a competent teacher should produce good results. As the authors remark, however, the book is designed " to guide the student in his thinking not to relieve him from the necessity of thinking;" the danger of early laboratory work seems to be that it may bring the mere experiment before the student's mind more prominently than the physical law which it illustrates. This difficulty the author seems to have attempted to avoid so far as this can be done by written words.

11. *Theoretical Mechanics*, a Class book for the Elementary Stage of the Science and Art Department, by J. SPENCER. 242 pp. 12mo. London, 1892 (Percival and Co.).—The author has added another to his series of successful elementary text-books, several of which have been before noticed in this Journal. The principles are clearly stated throughout and their application well illustrated by numerical examples.

II. Terrestrial Physics.

1. *Gravity Determinations at the Sandwich Islands,* by E. D. Preston (in a letter to J. D. Dana, dated Washington, Jan. 27). —We have just completed the reductions of the gravity work executed recently in the Hawaiian Islands. I have shown them to Dr. Mendenhall and with his permission send the following statement in regard to the results. The stations included in the series are as follows:

Station.	Locality.	Latitude. $\phi\,(+)$.	Longitude. $\lambda\,(+)$.	Elevation. $h.$	Gravity. g (dynes.)
Washington	Smithsonian Inst.	38° 53′ 20″	77° 1′ 35″	34 ft.	980·100
Mt. Hamilton	Lick Observatory	37 20 25	121 38 35	4205	979·651
Honolulu	Kapuaiwa Building	21 18 3	157 51 46	20	978·936
Waikiki	J. F. Brown's	21 16 25	157 50 1	10	978·922
Kawaihae	S. Parker's	20 2 25	155 49 36	8	978·803
Kalaieha	Humuula	19 42 32	155 27 53	6660	978·490
Mauna Kea	Waiau	19 49 11	155 28 48	13060	978·060

From the above figures for gravity at the three stations on Hawaii, it appears that the lower half of Mauna Kea is of a very much greater density than the upper. The former gives a value of 3·7 and the latter 2·1, the mean density of the whole mountain being 2·9. This is somewhat greater than that found for Haleakala and is notably larger than the density of the surface rocks. Indeed this appears to be the highest value yet deduced from pendulum work, as we see by the following comparison:

Mauna Kea	2·9
Fujinoyama	2·1
Haleakala	2·7
St. Helena	1·9
Ascension	1·6

In view of this large value it is probably worth while to remark that it depends on observations of Dr. Mendenhall's new half-second pendulums—which attain a degree of accuracy hitherto unapproached in work of this kind.

In regard to the above Dr. Mendenhall writes (Feb. 2, 1893): I have been very much interested in Mr. Preston's determination of the density of the volcano Mauna Kea, relative to which, as you will see, he has reached what seems to me to be a most remarkable conclusion. When a few weeks ago he brought me the results of his observations which showed a density for the lower half of this mountain, of three and seven-tenths, being greater than that of diamond and, in fact, much greater than that of any ordinary rock, it seemed to me that there must be an error at some point of the reduction of the observations. I therefore requested him to check the entire computation and it has been gone over by two different computers, resulting in the discovery

of no error of sufficient magnitude to sensibly affect the result. It seems also impossible to attribute this result to erroneous observation.

In order to reduce the density of this mountain to ordinary rock density, which is considerably above that generally obtained for volcanic mountains, it would be necessary to assume an error in the period of the vibrating pendulum of 1 : 20,000th part of the whole. Now with our new pendulums and new methods of determining the period of vibration we expect, even with the swinging of but a single hour, to get a result which shall not be out of the way—that is, as far as the mere period independent of the clock error is concerned—more than one part in two millions or two and a half millions. That the difficulty can hardly be with the pendulums themselves is evident from the facts.

First. That the results do not depend upon the gravitation determinations made here in Washington but are relative merely, swings having been made at the level of the sea in the neighborhood of the mountain.

Second. These pendulums, which had been very carefully vibrated before leaving for this expedition, were again swung at our base station here on their return, and although more than a year had elapsed, there was no sensible difference in the period of the pendulums.

I am bound to admit that I have great confidence in the observations themselves. Work which Mr. Preston did on this expedition with these pendulums check very closely with my own work at the same stations, and his previous determination in which the long Peirce pendulums were used are also in very close agreement with the later ones by the short pendulums.

I do not, therefore, see how we can avoid the conclusion that these results are real and that the mountain has an extraordinary density. I should be very glad to hear anything you have to say upon this problem and particularly any suggestion that you have to make as to methods of testing the veracity of the conclusions which we seem to have reached in this work.

Obituary.

Frederick Augustus Genth, the veteran mineralogist, died at Philadelphia on the 2d of February in his seventy-third year. Dr. Genth was born in Waechtersbach, Hesse-Cassel, on May 17, 1820. He early studied at Heidelberg, later under Leibig at Giessen and under Bunsen at Marburg, where he received the degree of Ph.D. in 1846. For three years he acted as assistant to Professor Bunsen, and not long after he came to the United States, where he has since resided. In 1872 he became Professor of Chemistry and Mineralogy in the University of Pennsylvania. He also held the office of Chemist to the Geological Survey of Pennsylvania and to the Board of Agriculture. Dr. Genth was an excellent chemist, a man of great industry and enthusiasm and

thoroughly imbued with the spirit of the scientific investigator. The list of his published papers includes over one hundred titles. He commenced his contributions to science in 1842 and for the ten years following, when in Germany, he published a number of papers chiefly upon chemical subjects. With 1852 commenced his contributions to the Proceedings of the Philadelphia Academy and here, as also in the Proceedings of the American Philosophical Society and in this Journal, his papers appeared at frequent intervals up to a short time before his death though in the later years he had much to contend against in the way of ill health. His last paper appeared in this Journal in January, 1893. These papers are chiefly mineralogical and a considerable number of them are upon new species; they all show the hand of the skillful analyst and the patient industry of the scientific worker. Some of his larger contributions were those on the Mineralogy of Pennsylvania (1875–76), also to the Mineralogy of North Carolina (1871–1881). Bulletin No. 74 of the U. S. Geological Survey (1891) gives an annotated list of mineral localities in the latter State. His monograph upon the North Carolina corundum and the many phases of its alteration is a work of great importance.

Perhaps his most important contribution to chemistry proper was that upon the ammonia-cobalt bases, which he discovered in 1846; in 1856 with Dr. Wolcott Gibbs, he contributed to the "Smithsonian Contributions to Knowledge," a monograph on "Researches on the Ammonia-Cobalt Bases."

Dr. Genth was a member of many scientific societies, and in 1872 he was elected a member of the National Academy of Sciences.

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CONTENTS.

SCIENTIFIC INTELLIGENCE.

VOL. XLV.

Chas APRIL, 1893

THE

AMERICAN

JOURNAL OF SCIENCE.

MINERALS, NEW ARRIVALS.

It was a source of much regret that the finest of the Sicilian and Sardinian minerals that I collected last spring were sold during my short stay in London and Paris. I am happy to announce that my agent in Sicily has just sent me 20 boxes containing over 1000 specimens, many of them the finest ever seen, of **Sulphur, Selenite, Aragonite, Calcite pseudomorph after Aragonite, Celestite**, etc. These are charged to me at several thousands of dollars and my agent has so thoroughly scoured the island that it is not likely that more such specimens will be soon obtained again. It is impossible to describe such specimens, but they range in price from $100 for an immense **Museum Group** of clear crystals of **Sulphur**, covering every side of the mass, 20 inches by 17, to fine, small groups at from 25c. to $1.00, or larger up to $25.00. The red crystals and groups from $1.50 upward are especially fine. Some iridescent crystals and groups are especially beautiful, from $1.00 upward. Crystals of **Sulphur**, about 1 inch in diameter, from 25c. upward.

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[THIRD SERIES.]

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ART. XXXI.—*Distance of the Stars by Doppler's Principle;*
by G. W. COLLES, JR.

AMONG the many interesting and important applications of
Doppler's principle for finding the velocity of a body in the
line of sight or sound, is one which has been apparently little
noticed, namely, that to the determination of distance. It is
true, however, that this is easily accounted for by the fact that
the principle itself is not yet far enough advanced for the
application of such a problem. I believe the first mention of
it is that made by Fox Talbot, in a paper read before the
British Association in 1871, in which he showed how Dop-
pler's principle might be applied to finding the distance of a
binary system. Supposing the orbit of each star to be ac-
curately known, in shape and position, let their relative veloci-
ties be taken by the spectroscope when the two stars are moving
as nearly as possible in the line of sight. Now, since we know
the shape of the orbit, we know the *proportionate* velocities of
the stars at any point of it; hence, knowing also the *absolute*
velocities at one point of the orbit, we can deduce them for the
point where each star is moving only across the line of sight.
Then, finding the angular velocity at this point, and dividing
the computed linear velocity by it, we have the distance of the
system. Or otherwise, knowing the actual period of the sys-
tem, the absolute velocity at any point gives us the true size,
or diameter, of the orbit; and dividing this by the angular
diameter, we have, as before, the distance of the system.
Talbot's idea was taken up in 1886 by Prof. A. A. Rambaut,
now Astronomer Royal of Ireland, and he has quite elaborately

discussed it in two papers published in the *Proceedings of the Royal Irish Academy* and in the *Monthly Notices*, respectively.[*] It could, of course, be extended to multiple systems, the principal drawback being that it necessitates the knowledge of the inclination of the plane of revolution to the line of sight. Obviously it can not be applied to any single body, unless its exact direction,—that is, the ratio of the components of its motion in and across the line of sight,—be known. In such a case as that of the so-called "runaway star" (1830 Groombridge) this might sometime be ascertained, if the star should ever get far enough so that increase or decrease in its annual angular motion could be measured. In general, however, the limitations of our present knowledge of astronomy seem to preclude this method of finding the distance of particular stars.

The application of Doppler's principle which I had in mind, however, is a very much wider one than any of these.[†] It is to the problem of finding the mean distance of all the stars, involving the theory of probability, and giving us a more or less reliable idea of the extent of our cosmus.

For the demonstration, suppose a very large number of stars —so large as to be practically infinite—distributed equably over the celestial sphere; that their motions are perfectly at random, and represented by straight lines according to the usual convention; and that the velocity in the line of sight and the proper angular motion of each star are correctly known. Let r be the radius vector drawn from the earth to any star, ϑ and φ the angles of reference of r to a fixed line and a fixed plane passing through that line, respectively; v the line representing the motion of any star and ϑ' and φ' angles of reference similar to ϑ and φ, and of which r is the initial line. The mean value of the projection of v upon r, which we will call $M(\alpha)$, is, then, *abstracting signs,*

$$ M(\alpha) = \frac{2v \int_0^{\frac{\pi}{2}} \int_0^{2\pi} \cos \vartheta' \sin \vartheta' d\vartheta'\ d\varphi'}{\int_0^{\pi} \int_0^{2\pi} \sin \vartheta'\ d\vartheta'\ d\varphi'} = \frac{2\pi v}{4\pi} = \frac{v}{2}. $$

For it will be seen that, since all directions for r are equally probable, and also all directions for v are equally probable,

* See Proc. Roy. I. Acad., 2nd ser.. vol iv. No. 6, and Month. Not. Roy. Ast. Soc, vol. 1, p 302, "On the Parallax of Double Stars."
† Suggested to me by Prof. H. A. Newton. I believe the problem has been previously discussed, but with inaccurate results. The idea must have long been more or less vaguely in the minds of astronomers.

therefore all values for the solid angle $\vartheta'\varphi'$ are equally probable, and the mean projection on r is the same as if r were fixed. Also, it will be seen that v may vary in any way we please, so long as it is not a function of ϑ' or φ'; its value in the result being some function of its particular values. The mean value of the projection of v on a plane perpendicular to r is, in like manner,

$$\mathrm{M}(\beta)=\frac{v\int_0^\pi\int_0^{2\pi}\sin^2\vartheta'\;d\vartheta'\;d\varphi'}{\int_0^\pi\int_0^{2\pi}\sin\,\vartheta'd\vartheta'\;d\varphi'}=\frac{\pi^2v}{4\pi}=\frac{\pi v}{4},$$

where v has the same value as before. The ratio of the latter mean value to the former is, therefore,

$$\frac{\mathrm{M}(\beta)}{\mathrm{M}(\alpha)}=\frac{v\int_0^\pi\int_0^{2\pi}\sin^2\vartheta'\;d\vartheta'\;d\varphi'}{2v\int_0^{\frac{\pi}{2}}\int_0^{2\pi}\cos\,\vartheta'\,\sin\vartheta'd\vartheta'd\varphi'}=\frac{\pi}{2}.$$

Thus we obtain the ratio of the mean velocity of a star across the line of sight to its mean velocity in the line of sight, supposing the direction and magnitude of its total velocity to be at random, that is, independent of the angles ϑ and φ, or ϑ' and φ'. And if the stars are distributed equally over only one hemisphere (that of which the initial line is the pole, suppose), the above ratio remains the same as before; because one hemisphere is in all respects similar to the other, negative signs having been abstracted. Further, if the stars are distributed equally over *any part* of the celestial sphere, comprised (suppose) between the angles ϑ_1 and ϑ_2, φ_1 and φ_2 (which may be functions of ϑ), the above ratio becomes, remembering that negative values are to be reckoned as positive,

$$\frac{\mathrm{M}(\beta)}{\mathrm{M}(\alpha)}=\frac{\int_{\vartheta_1}^{\vartheta_2}\int_{\phi_1}^{\phi_2}\sin^2\,\vartheta'd\vartheta'd\varphi'}{\int_{\vartheta_1}^{\vartheta_2}\int_{\phi_1}^{\phi_2}\cos\,\vartheta'\,\sin\,\vartheta'd\vartheta'd\varphi'};$$

for it will be seen, on consideration, that we may interchange the limits of ϑ and φ with those of ϑ' and φ', the result being the same if we let ϑ' and φ' vary between the limits ϑ_1 and ϑ_2, φ_1 and φ_2, and ϑ and φ over the whole sphere.

Next, let α and β be the components of the motion of a star (v) in and across the line of sight, respectively; a its proper angular velocity and d its distance; $\mathrm{M}(a)$, $\mathrm{M}(d)$ and $\mathrm{M}(ad)$ the

mean values of a, d and ad; then in the case of distribution over a whole sphere or hemisphere,

$$\beta = ad, \qquad \mathrm{M}(\beta) = \mathrm{M}(ad) = \frac{\pi}{2}\mathrm{M}(a).$$

Now let $a_1, a_2, \ldots, d_1, d_2, \ldots$ refer to the particular stars, and let n be their number; we have then

$$\mathrm{M}(ad) = \frac{\Sigma(ad)}{n} = \frac{a_1 d_1}{n} + \frac{a_2 d_2}{n} + \frac{a_3 d_3}{n} + \ldots + \frac{a_n d_n}{n},$$

$$\mathrm{M}(a)\mathrm{M}(d) = \frac{\mathrm{M}(d)\Sigma(a)}{n} = \frac{a_1\mathrm{M}(d)}{n} + \frac{a_2\mathrm{M}(d)}{n} + \frac{a_3\mathrm{M}(d)}{n} + \ldots \ldots$$

$$+ \frac{a_n\mathrm{M}(d)}{n}.$$

Subtracting the second of these equations from the first, we have

$$\mathrm{M}(ad) - \mathrm{M}(a)\mathrm{M}(d) = \tfrac{1}{n}\{a_1[d_1 - \mathrm{M}(d)] + a_2[d_2 - \mathrm{M}(d)] + \ldots \ldots$$
$$+ a_n[d_n - \mathrm{M}(d)]\}.$$

Now the sum of the coefficients of a_1, a_2, etc. is $\Sigma(d) - n\mathrm{M}(d)$ $= 0$; so that some of the terms within the braces will be positive and some negative. And since positive and negative values for $a_1[d_1 - \mathrm{M}(d)]$, $a_2[d_2 - \mathrm{M}(d)]$, etc., are equally probable, the sum of these terms will be some small finite quantity ε, and the last equation becomes

$$\mathrm{M}(ad) - \mathrm{M}(a)\mathrm{M}(d) = \frac{\varepsilon}{n}.$$

If n is practically infinite, as we have supposed it, the right-hand member of this equation vanishes; giving us, by the previous results,

$$\mathrm{M}(d) = \frac{\mathrm{M}(ad)}{\mathrm{M}(a)} = \frac{\pi}{2} \cdot \frac{\mathrm{M}(a)}{\mathrm{M}(a)} = \frac{\pi}{2} \cdot \frac{\Sigma(a)}{\Sigma(a)};$$

thus reducing the required mean distance d to a simple function of the mean angular velocity and the mean velocity in the line of sight.

Although we cannot employ an infinite number of stars in calculation, yet the error will be quite small if a very large number of stars be used, provided their motions really are at random, i. e. show no "drift" in any particular direction. But, as previously hinted, because of the comparatively small number of stars whose velocities in the line of sight and angu-

lar motions are accurately known, this result can be of little
practical value at the present stage of astronomy. As an
interesting example of the principle, however, it may be worth
while to apply it, making the best use of the material at hand.
As nearly all the stars, whose velocities in the line of sight
have been measured, are in the northern hemisphere, I will
find the mean distance of stars in this hemisphere only. The
annexed table includes the available data, gathered from the
following sources: the right ascensions, north polar distances
and magnitudes are taken from the " Catalogue of Almanac
Stars " in Professor Pickering's *Annals of Harvard College
Observatory*, 1890, the positions being reduced to 1900·0.
The proper motions are computed from the Greenwich *Ten
Year Catalogue* of 1887, and where possible, also, from
Newcomb's list in *Astronomical Papers for the American
Ephemeris and Nautical Almanac* (1882), the latter measure-
ments being given the greater weight. The data of the last
two columns are taken partly from Scheiner's new *Spectral-
analyse* and partly from the record of observations at Green-
wich and Potsdam given in the *Monthly Notices of the Royal
Astronomical Society*. From this table we find, neglecting
signs,

$$\Sigma(a) = 18{\cdot}670, \text{ in seconds of arc per year.}$$
$$\Sigma(\alpha) = 1620{\cdot}7, \text{ in miles per second.}$$

Before dividing the latter value by the former, we must reduce
them to the same units by constant factors. With this altera-
tion, our equation may be expressed as

$$\mathrm{M}(d) = \frac{\pi}{2}\cdot\frac{c_1 \Sigma(\alpha)}{c_2 \Sigma(a)} = \mathrm{C}\frac{\Sigma(\alpha)}{\Sigma(a)},$$

in which, taking our unit of length as the mile,

$$c_1 = 86400 \times 365{\cdot}256, \qquad c_2 = \frac{\pi}{180 \times 3600}$$

$$\mathrm{C} = \frac{\pi c_1}{2c_2} = 10{,}224{,}841{,}560{,}000 ;$$

giving us as a mean distance

$$\mathrm{M}(d) = 887{,}595{,}111{,}000{,}000 \text{ miles,}$$

equivalent to 9,596,000 astronomical units, or about 150·9
light-years.

Before going further, however, it is necessary to return to a
consideration of our values for line-of-sight motions, on
whose accuracy the result chiefly depends. A glance over the
table will show that they fall at once into two classes: Vogel's

(including his assistant, Dr. Scheiner's) and those which are not Vogel's; the former class containing 48 and the latter 47 of the 95 stars used. The latter observations, besides being widely variant among the different observers, have been shown by Professor Vogel's measurements* to be nearly all *too large;* which influences the result correspondingly. Vogel's measurements have accordingly been invariably used, where possible, to the exclusion of others; being estimated with approximate accuracy to the tenth of a mile. Although compelled to halve our already small number of stars, yet it may be worth while to collect Dr. Vogel's observations (and the appropriate proper motions) in the same manner as above, not only for purpose of comparison, but with a probably much more accurate result. This gives us

$$\Sigma(a) = 10\cdot994, \quad \Sigma(\alpha) = 508\cdot7;$$

from which we obtain

$$\mathrm{M}(d) = 473,110,506,000,000 \text{ miles}$$

equivalent to 5,115,000 astronomical units, or about 80·5 light-years, a little more than half the previous value.

But it is to be noticed that these results, even if entirely free from errors of observation, are only for the brightest stars (since these alone give sufficient light for present spectroscopic measurements), and hence for the nearest. But in any case they can be only provisional, for several reasons,—first, as previously stated, on account of the comparatively small number of stars. Again, these stars, though distributed with approximate uniformity, will be seen to be very scarce in places occupied by the Milky Way, *e. g.* between the hours of 5 and 9, and 22 and 24, in right ascension. Again, as regards their motions being at random, an examination of their directions (omitted for lack of space) will show that on one side of the hemisphere the motion is almost entirely to the south, while on the other side it tends toward the north ; and a similar aggregation of signs will be noticed among the motions in right ascension.†‡

* Following are Professor Vogel's observations in connection with his " List of 51 Stars," *Monthly Notices R. A. Soc.*, June, 1892: "Greatest observed velocities, +30·2 mi. (a Tauri); −24·0 mi. (γ Leonis). Average velocity, 10·4 mi. No. of stars with velocity greater than 10·4 mi., positive 7, negative 11. Average probable error of the measurements for a single plate and one observer, ±1·6 mi."

† Similarly Professor Vogel notes of his observations, nearly all of which are in the northern hemisphere (*Monthly Notices*, vol. lii, p. 96), that " fifteen of the stars have a positive and thirty-two a negative motion."

‡ This is due, I suppose, in part, at least, to the motion of the sun in its " way," as the signs correspond pretty closely to what this motion would tend to make them. It will be seen that when the stars are taken over a whole sphere, or a hemisphere (as above), any *general rectilinear drift*, common in magnitude and

All these difficulties, however, may in time be eliminated. A sufficient number of stars to calculate from is, in fact, a matter only of time. These stars may then be selected with regard to uniform distribution, and any drifts seen in certain parts of the sky (if such are large enough to be worth consideration) be allowed for in the equations. Professor Vogel's new spectrographic method* promises accuracy amply sufficient, if, as he claims, the probable error of the measurements is less than one mile per second. We might even go so far, in our speculative fancy, as to classify the stars according to their spectra, and find the average distance of each class from our system; thus throwing some light on its real distribution in the universe, and on our position with respect to the various classes.†

Table of 95 Stars used in the Calculation.

The stars are arranged in order of right ascension. The total proper motion of a star across the line of sight is given by the formula $a = \sqrt{\nu^2 + (15\rho)^2 \sin^2 D}$, in which ν and ρ are the motions in N. P. D. and R. A. respectively, and D is the N. P. D. That is, a is considered the hypotenuse of a rectilinear right triangle of which ν and $15\rho \sin D$ (in seconds of arc) are the sides.

In the sixth column, the + and − signs denote recession and approach of the star, respectively. The letters G, H, S and V represent Greenwich Observatory, Huggins, Seabroke and Vogel respectively (two or more for the same star representing a mean of different observers); but V-S denotes Vogel's mean of his own and Scheiner's measurements given in his "List of 51 Stars" (*Monthly Notices*, June, 1892).

A few stars whose N. P. D. is slightly greater than 90° have been inserted, by which discrepancy however the accuracy of the result is not sensibly affected. The quantities in parenthesis were not given in the sources referred to.

direction to all the stars considered, does not affect the ratio $\dfrac{M(\beta)}{M(a)} = \dfrac{\pi}{2}$; for if the stars had no other motion, this ratio would remain the same. The motion of the sun in its way may, indeed, be thus found by Doppler's principle.

* See *Monthly Notices R. A. Soc.*, December, 1891.

† It is curious to note that Mr. Monck has already discovered that "solar stars of any magnitude will, on the average, have a greater proper motion than the Sirian". (*Messenger*, Nov., 1891)—a statement strongly confirmed by Mr. J. E. Gore's list (*Astronomy and Astrophysics*, Jan. 1892), in which 26 of the 29 greatest proper motion stars whose spectra have been observed are shown to be of the solar class. This may, of course, be suggestive of their relative distance.

	Name of Star.	R. A. Hours.	N, P. D. °	Mag.	Proper Annual Motion. a ''	Motion in Line of Sight a Miles per sec.	Observer.
a	Androm._____	0·05	61·5	2·1	·211	− 2·8	V-S
β	Cassiop._____	0·06	31·4	2·4	·550	− 3 2	V-S
γ	Pegasi _____	0·13	75·4	2·8	·172	−19·	G & S
δ	Androm. _____	0·57	59·7	3·5	·152	−40·	G
a	Cassiop._____	0·58	34·0	2·3	·064	+ 9·5	V-S
γ	Cassiop. _____	0·84	29 8	2·3	·018	+ 2·2	V-S
β	Androm. _____	1·07	54·9	2·2	·214	− 7·0	V-S
a	Urs. Min._____	1·37	1·2	2·2	·042	−16·1	V-S
δ	Cassiop. _____	1·32	30·3	2·8	·294	−14·	G
a	Triang. _____	1·79	60·9	3·5	·231	+56·	G
β	Arietis _____	1·82	69·7	2·8	·138	−27·	G
a	Piscium _____	1·95	87·7	(3·5)	·026	−29·	G
γ	Androm._____	1·96	48·1	2·2	·056	− 8·0	V-S
a	Arietis _____	2·02	67·0	2·1	·235	− 9·2	V-S
a	Ceti__ _____	2·95	86·3	2·6	·088	−16·	G
β	Persei_____	3·03	49·4	2·3	·022	− 1·0	V-S
a	Persei_____	3·29	40·5	1·9	·042	− 6·4	V-S
δ	Persei_____	3·60	42·5	3·1	·051	+30·	G
η	Tauri _____	3·69	66·2	3·1	·183	−23·	G
ζ	Persci_____	3·80	58·4	3·0	·027	−24·	G
ε	Tauri _____	4·38	71·0	3·6	·111	+20·	G
a	Tauri _____	4·50	73·7	1·0	·198	+30·2	V-S
a	Aurigæ _____	5·15	44·1	0·1	·438	+15·2	V-S
γ	Orionis_____	5·33	83·7	1·7	(·090)	+ 5·7	V-S
β	Tauri _____	5·33	61·5	1·8	·182	+ 5·0	V-S
δ	Orionis _____	5·45	90·4	2·3	·012	+ 0·6	V-S
ε	Orionis _____	5·52	91·3	1·8	·016	+16·5	V-S
ζ	Orionis _____	5·59	92·0	1·9	(·090)	+ 9·3	V-S
a	Orionis _____	5·83	82·6	0·9	·024	+10·7	V-S
β	Aurigæ ___ _____	5·87	45·1	2·0	·070	−17·5	V-S
γ	Gemin _____	6·53	73·5	2·0	·049	−10·3	V-S
β	Can. Min. _____	7·36	81·5	3·1	·069	−14·	G
a	Gemin._____	7·47	57·9	1·9	·193	−18·4	V-S
a	Can. Min._____	7·57	84·5	0·5	1·254	− 5·7	V-S
β	Gemin._ _____	7·65	61·7	1·2	·632	+ 0·7	V-S
ε	Leonis _____	9·67	65·8	3·2	·062	− 4·	G
a	Leonis ____ ____	10·05	77·5	1·3	·259	− 5·7	V-S
γ	Leonis _____	10·24	68·6	2·5	·320	−24·0	V-S
β	Urs. Maj. _____	10·93	33·1	2·4	·082	−18·2	V-S
a	Urs. Maj._____	10·95	27·7	2·0	·145	− 7·2	V-S
δ	Leonis _____	11·15	68·9	2·7	·194	− 8 9	V-S
ϑ	Leonis _____	11·15	74·0	3·5	·106	+16·	G & S
β	Leonis _____	11·73	74·9	2 2	·519	− 7·6	V-S
β	Virginis ___ ____	11·76	87·7	3·7	·778	−43·	G
γ	Urs. Maj. _____	11·81	35·7	2·4	·099	−16·5	V-S
δ	Urs. Maj. _____	12·17	32·4	2·7	·107	+11·	G & H
γ	Virginis _____	12·61	90·9	2·9	·566	+ 6·	G
ε	Urs Maj._____	12·83	33·5	1·9	·097	−18·8	V-S
δ	Virginis _____	12·84	86·1	3·5	·505	+63·	G
a	Can. Ven._____	12·86	51·1	3·2	·233	− 29·	G
ε	Virginis _____	12·95	78·5	3·1	·284	−11·	G
ζ	Urs. Maj._____	13·33	34·5	2·5	·123	−19·4	V-S
ζ	Virginis _____	13·49	90·1	3·6	·303	−43·	S
η	Urs. Maj. _____	13·73	40·2	1·9	·111	−16·3	V-S
η	Boötis _____	13·83	71·1	2·8	·362	−24·	G & S
a	Dracon._____	14·03	25·1	3·7	·048	+35·	G
a	Boötis _____	14·18	70·3	0·2	2·285	− 4·8	V-S

Name of Star.	R. A. Hours.	N. P. D. °	Mag.	Proper Annual Motion. a. "	Motion in Line of Sight a Miles per sec.	Observer.
γ Boötis	14·47	51·2	3·2	·197	−38·	G
ε Boötis	14·68	62·5	2 6	·044	−10·1	V–S
β Urs. Min.	14·85	15·4	2·2	·028	+ 8·9	V–S
β Boötis	14·97	49·2	3·7	·062	−42·	G
a Cor. Bor.	15·51	62·9	2·3	·154	+19·9	V–S
a Serpent.	15·65	83·3	2·7	·133	+14·	V
β Serpent.	15 69	74·3	3·7	·060	−14·	G
ε Serpent.	15·76	85·2	3·7	·133	+35·	G
γ Hercul.	16·29	70·6	3·8	·084	−27·	G
η Dracon.	16 38	28·3	2·8	·059	+10·	G
β Hercul.	16·43	68·3	2·8	·107	−22·0	V–S
ζ Hercul.	16·62	58·2	2·9	·612	−25·	G
ζ Dracon.	17·14	24·2	3·4	·028	−30·	G
a Hercul.	17·17	75·5	3·1	·034	−26·	G
β Dracon.	17·47	37·6	3·0	·014	+17·	G
a Ophiu.	17·50	77·4	2·2	·253	+11·9	V–S
ξ Dracon.	17·86	33·1	(3·5)	·144	+ 8·	G
γ Dracon.	17·90	38·5	2.5	·032	+12·	V
a Lyræ	18·56	51·3	0·2	·325	− 9·5	V–S
γ Lyræ	18·92	57·4	3·3	·029	−34	G & S
ζ Aquilæ	19·01	76·3	3·1	·102	−30·	G & S
δ Aquilæ	19 36	87·1	3·5	·251	+ 2·	G
β Cygni	19·44	62·2	3·1	·026	−13·	G
γ Aquilæ	19·69	79·6	2·8	·010	−13·	G & S
δ Cygni	19·70	45·1	2·9	·060	−20·	G & S
a Aquilæ	19·76	81 4	0·9	·648	−22·9	V–S
γ Cygni	20·31	50·1	2·3	·021	− 4·0	V–S
a Delph.	20·58	74·4	3·9	·045	− 8·	G
a Cygni	20·63	45·1	1·4	·008	− 5·0	V–S
ε Cygni	20·70	56·4	2·6	·485	− 8·	G & S
ζ Cygni	21·14	60·2	3·3	·070	+ 6·	G
a Cephei	21.27	27·8	2·6	·157	−41·	G
β Cephci	21·46	19·9	3·4	·012	+53·	G
ε Pegasi	21·65	80·6	2·4	·023	+ 5·0	V–S
ζ Pegasi	22·61	79·7	3 5	·073	− 6·	G
η Pegasi	22 64	60·3	3·0	·033	− 9·	G & S
β Pegasi	22·98	62·5	2·5	·219	+ 4·1	V
a Pegasi	22·99	75·5	2·5	·063	+ 0·8	V–S

ART. XXXII.—*On the Double Halides of Tellurium with Potassium, Rubidium and Cæsium ;* by H. L. WHEELER.

THE existence of double halides of tellurium with potassium, sodium and ammonium was first indicated by Berzelius.* He described the methods by which he obtained them, but gave no analyses of the compounds. Later, Rammelsberg† investigated the double chlorides of tellurium with potassium and ammonium, with the object of determining their composition. He arrived at the formulæ $8KCl . 3TeCl_4$ and $8NH_4Cl$.

* Pogg. Ann., xxxii, 577. † Berlin Monats. Ber., 1875, 379.

$3TeCl_4$. It will be shown beyond that the formula of the potassium compound at least must have been obtained from analyses of impure products. Von Hauer[*] analyzed the double bromide of tellurium and potassium, and concluded that the salt had the composition represented by the formula $2KBr.TeBr_4.3H_2O$. I have reinvestigated this salt and found it to contain two molecules of water and not three. Probably Von Hauer analyzed the salt without previously having dried it sufficiently or without having taken precautions to remove included water which the crystals always contain. He dehydrated this salt and used it in his work on the atomic weight of tellurium.

More recently Wills[†] determined the atomic weight of tellurium by means of the same salt. He does not give any analyses of the hydrous compound, but states that the salt contains water and gives directions for dehydrating it. Rammelsberg in his "Handbuch der krystallographisch-physikalischen Chemie" (p. 289) quotes the formula of the dehydrated compound from Wills' work and assigns to this Baker's[‡] measurements, which do not belong to it, but to the hydrated compound with the three supposed molecules of water of crystallization. The present investigation has shown that the anhydrous salt is isometric, the hydrous one being orthorhombic.

Ramsay[§] says that "By mixing aqueous solutions of the constituent halides, tellurium halides combine thus: $TeCl_4 2KCl$, $TeBr_4 2KBr$, $TeI_4 2KI$. These compounds form reddish crystals. Few attempts have been made to prepare double halides." Although a thorough search of the literature on this subject has been made, in connection with the present work, no analyses of the double chloride or iodide could be found. Berzelius's work as regards their preparation and Rammelsberg's attempt to determine the formula of the chloride comprise all the work that has been done on these two salts. It must be concluded that the formulæ given by Ramsay were deduced by analogy with the double bromide, especially since his statements in regard to color, method of preparation and composition only apply, in all respects, to the double bromide.

It will be seen from the above summary that very little satisfactory work has been done on this class of compounds, and, therefore, the present investigation has been undertaken with the view of making a thorough study of the double
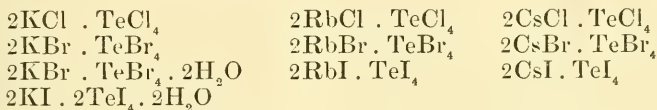
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[*] Journ. prakt Chem., lxxiii, 98.
[†] Jour. Chem. Soc., xxxv, 711.
[‡] Jour. Chem. Soc, xxxv, 711.
[§] System of Inorganic Chemistry, edition of 1891, p. 168.

halides of tellurium with potassium, rubidium and cæsium. As a result the following compounds have been prepared:

$$2KCl . TeCl_4 \qquad 2RbCl . TeCl_4 \qquad 2CsCl . TeCl_4$$
$$2KBr . TeBr_4 \qquad 2RbBr . TeBr_4 \qquad 2CsBr . TeBr_4$$
$$2KBr . TeBr_4 . 2H_2O \qquad 2RbI . TeI_4 \qquad 2CsI . TeI_4$$
$$2KI . 2TeI_4 . 2H_2O$$

It is to be noticed that all of these compounds conform to the usual type of double halides of tetravalent metals in containing the alkali metal and tellurium in the ratio of two atoms of the former to one of the latter, and no indications of the formation of salts of a different type were observed. The anhydrous double halides of tellurium crystallize in the isometric system, with an octahedral habit, and it is an interesting fact that this form seems to be characteristic for anhydrous double halides of this type. The cæsium and rubidium salts are new compounds, as well as the crystallized, anhydrous, double potassium bromide. New formulae have been assigned to the hydrous potassium double bromide and to the double iodide of potassium. A considerable difference is shown in the affinity of the double halides of tellurium and potassium for water of crystallization. The double chloride is anhydrous and no hydrous form of it was observed, the double bromide was prepared in both the hydrous and the anhydrous forms, while the iodide was obtained only with water of crystallization. This water was more firmly held than in the case of the hydrous bromide, as was shown by the fact that it formed from hot solutions and did not as readily effloresce.

The methods used in the preparation of pure material for this work, and which deserve to be mentioned on account of giving satisfactory results, are given below. The tellurium was obtained by purifying the commercial product by precipitation with sulphurous acid, according to the method of Divers and Shimosé.* The halides of tellurium were prepared from this material in the usual way.

Cæsium chloride was obtained in a pure state by the method of Godeffroy.† The bromides and iodides were obtained in the usual manner from the carbonate, the latter having been prepared from the pure chloride by converting into nitrate, then into oxalate and igniting the latter, as suggested by J. L. Smith,‡ for the conversion of potassium chloride into carbonate. The rubidium was purified by Allen's§ acid tartrate method. In the case of the potassium salts, Kahlbaum's pure material was used.

* Jour. Chem. Soc., xlvii, 439.
‡ This Journal, II, xvi, 373.
† Ber. d. chem. Ges., vii, 375.
§ Ibid., II, xxxiv, 367.

The methods by which the double halides were obtained will be given with the description of the salts.

Method of Analysis.

The anhydrous salts were removed from the mother liquor, and, after pressing on filter paper, were dried in the air. The hydrous compounds were rapidly crushed on smooth filter paper, and, as soon as it was certain that no included water was retained by the fragments, they were placed in weighing tubes. Portions of about one-half a gram were taken for analysis. In order to determine the halogens, silver sulphate was added to the solution of the weighed sample in water containing a little sulphuric acid. The silver halide was washed, ignited and weighed in the usual manner. After the removal of the excess of silver by means of hydrochloric acid, tellurium was removed with hydrogen sulphide. This separation of tellurium, best in warm solution, has been found to be complete in a few minutes and in a condition that admits of filtration without inconvenience. The sulphide of tellurium, filtered on asbestos in a Gooch crucible, was washed with water containing a little hydrogen sulphide, then treated with a solution of bromine in dilute hydrochloric acid, which readily dissolves the moist sulphide. An excess of nitric acid was then added to this solution and the whole evaporated on the water bath, the resulting tellurous acid, being transferred to platinum, was ignited and weighed as TeO_2. The alkali metals were determined by evaporating the filtrate from the tellurium sulphide to dryness, with an excess of sulphuric acid. The residues were then converted into normal sulphate by ignition in a stream of ammonia, as suggested by Krüss for potassium sulphate. In the case of the hydrous salts, water was determined by heating them in an air bath to constant weight; the residues were analyzed and found to correspond in composition to the anhydrous salts. The atomic weights used in the calculation of the results were the following:

Te, 125 ; K, 39·1 ; Rb, 85·5 ; Cs, 133 ; Cl, 35·5 ; Br, 80 ; I, 127.

Solubility.

The salts are all decomposed by water. The double bromides, however, show an interesting difference in their deportment with this reagent. Potassium tellurium bromide dissolves in a small amount of water, but, if an excess of water is added, tellurous acid separates, as has been observed by Wills.* Rubidium tellurium bromide also dissolves in a

* loc. cit.

little hot water completely, the difference being shown on cooling, when a considerable portion of the tellurium separates as tellurous acid. While in the case of the cæsium salt both hot and cold water, in large and small amounts, fail to dissolve the salt, the result being immediate decomposition. Only a small part of the tellurium in this case goes into solution. Most of these double salts can be conveniently recrystallized from dilute solutions of the corresponding acid. The exceptions are potassium-tellurium chloride, which is decomposed by this treatment, and cæsium-tellurium iodide, which is practically insoluble in hydriodic acid. The fact, first noticed by Godeffroy,[*] that double halides, containing the metals potassium, rubidium and cæsium, generally decrease in solubility from potassium to cæsium, which has frequently been noticed in this laboratory, is again well illustrated by these compounds. For the determination of the solubility of these salts in acids, they were finely powdered, and saturated solutions were then prepared by digesting a mixture of the acid and an excess of the salt for about a week, at ordinary temperature. This was done in a closed flask. Weighed portions of these solutions were evaporated to dryness and the residues dried at 100° and weighed. These solubilities were all taken at 22°, and the results are the average of two or more closely agreeing determinations.

	100 parts HCl Sp. gr. 1·2 dissolve	100 parts HCl Sp. gr. 1·05 dissolve
$2RbCl . TeCl_4$	0·34 parts.	13·09 parts.
$2CsCl . TeCl_4$	0·05 "	0·78 "

	100 parts HBr Sp. gr. 1·49 dissolve	100 parts HBr Sp. gr. 1·08 dissolve
$2KBr . TeBr_4$	6·57 parts.	62·90 parts.
$2RbBr . TeBr_4$	0·25 "	3·88 "
$2CsBr . TeBr_4$	0·02 "	0·13 "

The double tellurium chlorides, described in this article, are more soluble than the bromides, and the bromides more soluble than the iodides. The solubility of these compounds in strong alcohol shows the same gradation as their solubility in acids, the cæsium salts being practically insoluble in this menstruum, while the rubidium salts dissolve to a trifling but clearly perceptible extent, and the potassium salts dissolve considerably or are decomposed with separation of the potassium halide, or both solution and decomposition take place, according to the salt experimented with.

[*] Ber. d. Chem. Ges., viii, 9.

The Chlorides.

The crystals of the three chlorides have a pale yellow color, resembling that of the well known ammonium phospho-molybdate precipitate, the shade becoming somewhat lighter from the cæsium to the potassium salts.

Cæsium tellurichloride, $2CsCl.\ TeCl_4$.—In the preparation of this compound, and also in the preparation of the rubidium and potassium double chlorides, the tellurium tetrachloride is most conveniently made by converting tellurium into tellurous oxide by means of aqua regia, evaporating to dryness to expel nitric acid and then dissolving the residue in hot hydrochloric acid. An aqueous solution of cæsium chloride, added to this, produces a precipitate, even in quite dilute solutions. There must be an excess of hydrochloric acid present to prevent the separation of tellurous acid. On boiling and adding more water, if necessary, this precipitate dissolves. The solution, left to cool, deposits small brilliantly lustrous octahedrons. It is a general fact with these double halides, that an excess of one or the other of the constituents does not affect their composition. This is shown in this particular case by the fact that it can be recrystallized from strong solutions of tellurium or of cæsium chlorides.

		Analysis gave :			Calculated.
Cs		43·44	43·90	44·63	44·04
Te		20·65	....	21·41	20·69
Cl		35·93	35·14	....	35·27

This compound is perfectly stable in the air. It does not melt below the boiling point of sulphuric acid. It can be precipitated from its solution in dilute hydrochloric acid by the addition of concentrated hydrochloric acid. A portion of the salt, finely pulverized, was treated with water at ordinary temperature. This produced a voluminous white precipitate, which was washed with cold water and dried in the air.

		Analysis gave :	Calculated for H_2TeO_3.
Te		71·43	71·43
H_2O		7·52	10·29
O		17·76	18·28
Cl		2·49	
Cs		0·80	

The oxygen which was not given off in the form of water on heating the substance was calculated by difference. From the above analysis the conclusion may be drawn, that the precipitate produced by the action of water on this salt is essentially tellurous acid, a small amount of oxychloride of tellurium

being present.   Hot water dissolves some of this tellurous acid, and, on cooling slowly, the anhydride separates in the characteristic form of colorless octahedrons.

Rubidium tellurichloride, $2RbCl.TeCl_4$.—The preparation of this salt was in every way analogous to that of the cæsium tellurium chloride.   However, since this salt is far more soluble than the corresponding cæsium compound, no precipitate was obtained in dilute solutions.   The mixture of the hydrochloric acid solution of the constituents was concentrated by evaporation, and, when cooled, crystals separated.   These were in the form of octahedrons, somewhat larger than the cæsium salt.

	Analysis gave:		Calculated for $2RbCl.TeCl_4$.
Rb	33·50	33·83	33·59
Te	24·34	....	24·56
Cl	....	....	41·85

This salt remains permanent in the air.   From the dilute hydrochloric acid solution, concentrated hydrochloric precipitates it unaltered.   Water decomposes it, evidently in the same way as the cæsium salt.

Potassium tellurichloride, $2KCl.TeCl_4$.—To prepare this salt in a pure state an excess of tellurium chloride is necessary. The analyzed material was obtained by spontaneous evaporation of the constituents in a solution of dilute hydrochloric acid, twice as much tellurium chloride being present as required by the formula.   Under these conditions it was found to separate in the form of light yellow octahedrons, which, under the microscope, were shown to be free from potassium chloride.

	Analysis gave:	Ratio.	Calculated for $2KCl.TeCl_4$.
K	17·37	·44	18·79
Te	30·29	·24	30·03
Cl	49·47	1·39	51·18
	97·13		

The salt, therefore, has the formula $2KCl.TeCl_4$.   The crystals deliquesce somewhat in moist air and the analyzed material retained a small amount of water, as is shown by the deficiency in the above analysis.   It is not probable that the salt contains water of crystallization, for the crystalline form and optical properties show that it is isomorphous with the anhydrous salts.   This salt is the most unstable as well as the most soluble of the anhydrous double halides described in this article.   It is readily dissolved by dilute hydrochloric acid.

Strong hydrochloric acid separates potassium chloride. It therefore cannot be precipitated from its solutions by the addition of strong hydrochloric acid, as in the case of the other chlorides. Alcohol also separates potassium chloride. Water apparently effects the same decomposition as in the case of the cæsium and rubidium chlorides. The tendency of potassium chloride to separate along with the salt explains why Rammelsberg's analysis came high in regard to the potassium chloride. His results corresponded to a mixture of two molecules of KCl and three molecules of $2KCl . TeCl_4$. Experiments with the calculated quantity of the constituents invariably resulted in the separation of potassium chloride or potassium chloride mixed with the yellow $2KCl . TeCl_4$. Experiments with the method given by Ramsay[*] for the preparation of this salt, by mixing aqueous solutions of the constituents, resulted in the decomposition of the tellurium chloride, and the resulting white precipitate failed to dissolve until considerable hydrochloric acid was added. Attempts to prepare the compound by concentrating the mixture of the constituents by the aid of heat invariably resulted in failure. In certain cases, on cooling such solutions, a mass of colorless slender prisms was obtained, which will be described in a future article.

The Double Bromides.

The crystals of the anhydrous bromides have a brilliant red color resembling that of the mineral crocoite. The powders of the salts have a color that is similar to that of a mixture of equal parts potassium bichromate and red lead. The powder of the hydrous bromide has the color of mercuric oxide, but, by loss of water, this soon changes to that of the anhydrous salt.

Cæsium telluribromide, $2CsBr . TeBr_4$.—This double halide can easily be prepared by mixing finely divided tellurium with cæsium bromide in dilute hydrobromic acid, then adding bromine in excess. The presence of free acid is necessary to prevent the separation of tellurous acid. When the tellurium has disappeared, the solution is concentrated by the aid of heat, and, on cooling, bright red crystals of the pure salt are deposited. These are generally somewhat larger than the crystals of the double chloride.

	Analysis gave:			Calculated.
Cs	30·90	30·87	30·91	30·54
Te	14·29	13·60	14·03	14·35
Br	55·01	____	55·32	55·11

[*] loc. cit.

This salt remains unaltered in the air. It can be separated from its solution in dilute hydrobromic acid by the addition of concentrated acid. It does not melt below the boiling point of sulphuric acid. Attempts to prepare a hydrous salt according to the methods used for the preparation of $TeBr_4$. $2KBr . 2H_2O$ were without success.

Rubidium telluribromide, $2RbBr . TeBr_4$.—The directions given for the preparation of the corresponding cæsium compound apply also in the preparation of this salt. If the solutions are strong, the compound separates as a bright red precipitate, but if dilute, on concentrating by means of heat or spontaneous evaporation, it crystallizes in brilliant red octahedra.

	Analysis gave :	Calculated.
Rb	22·02	22·04
Te	----	16·11
Br	62·07	61·85

This salt is stable in the air. Like the corresponding cæsium salt, this separates from its solutions by the addition of concentrated hydrobromic acid. When it is dissolved in a little water and the solution is cooled slowly, colorless octahedrons of TeO_2 separate. The latter product was found to be impure, containing a small amount of bromine. On heating, the salt decrepitates slightly and melts at a high temperature. Efforts to prepare a hydrous salt according to the methods used for the preparation of $2KBr . TeBr_4 . 2H_2O$ were without success.

Potassium telluribromides, $2KBr . TeBr_4$ *and* $2KBr . TeBr_4 . 2H_2O$.*—For the preparation of these salts, a mixture of the constituents was made as described in the case of the cæsium double bromide. The solution invariably deposited crystals of the anhydrous salt when it had been concentrated by heat, but, by spontaneous evaporation of the filtrate, the hydrous salt was obtained. On recrystallizing either of these salts from water or from dilute hydrobromic acid, the anhydrous salt is obtained when the solution has been saturated by boiling and then allowed to cool, but if the solution is left to deposit crystals at ordinary temperature the hydrous modification is obtained. The crystals of these different compounds closely resemble each other in color and appearance. The anhydrous variety crystallizes in octahedrons modified by the cube. The orthorhombic crystals of the hydrous salt look like distorted crystals of the other. This being the case, and since

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* Described by Von Hauer as containing three molecules of water of crystallization.

the crystals of the hydrous compound can be obtained much larger than those of the anhydrous salt, both Von Hauer and Wills selected these for their work, while the more easily obtained anhydrous salt was overlooked.   The hydrous salt is readily distinguished from the anhydrous one by its deportment on exposure to a dry atmosphere.   The latter is stable, but under these conditions the hydrous compound rapidly effloresces, losing its luster, the faces of the crystals becoming superficially covered with a light reddish yellow and opaque layer of the anhydrous salt.   Crystals which had been exposed to dry air for several days and were completely covered with this layer were found, on crushing, to remain unaltered in the interior and to have still retained included water in addition to their water of crystallization.   This was shown by the fact that the crushed crystals gave a stain of the mother liquor to filter paper.   This property of the hydrous crystals explains why Von Hauer assigned three molecules of water to this salt instead of two.   The material for analysis of the hydrous salt was selected from crystals varying in size from 7 to 13^{mm} in diameter.   These were very rapidly crushed on smooth filter paper, to remove included water, and immediately corked up in the weighing tube and analyzed.   A close examination of the fragments, before and after weighing, gave no evidence of loss of water from the substance by efflorescence. The analyses were from three different crops.

	Analysis gave:			Calculated for $2KBrTeBr_4 . 2H_2O$.	Calculated for $2KBrTeBr_4 . 3H_2O$.
K	10·90	11·07	10·73	10·87	10·61
Te	17·59	17·29	17·46	17·38	16·96
Br	66·35	66·36	66·34	66·74	65·11
HO	5·33	5·53	5·73	5·01	7·32

These results make it evident that the salt contains two molecules of water, and not three as has generally been supposed.   The water in this salt was determined by heating it in an air bath to constant weight.   The temperature was maintained between 150°–160°, and finally, to be sure that all the water had been driven off, the residues were analyzed in two cases.

	Analysis gave:		Calculated for $2KBr . TeBr_4$.
K	11·71	11·52	11·44
Te	18·29	18·58	18·30
Br	70·25	70·09	70·26

Analyses of products obtained by cooling hot saturated solutions gave the following results :

				Calculated for $2KBrTeBr_4$.
K _____	11·67	11·70	----	11·44
Te _____	18·06	----	----	18·30
Br _____	70·24	70·20	69·40	70·26

The Double Iodides.

These salts are all black. The powder of the cæsium salt is pure black, that of the rubidium and potassium salts is grayish black.

Cæsium telluriiodide, $2CsI . TeI_4$.—In order to prepare this salt, and also in the case of the rubidium and potassium compounds, tellurium tetraiodide was made by treating tellurous oxide with hydriodic acid. The iodide of tellurium is sparingly soluble in hydriodic acid, but, on mixing this solution with a solution of cæsium iodide, an amorphous black precipitate was obtained, even in very dilute solutions.

		Calculated for $2CsI . TeI_4$.
Analysis gave :		
Cs _____	23·37	23·07
Te _____	10·51	10·84
I _____	65·17	66·09

This compound resisted all attempts to prepare it in a crystalline form. It is insoluble in cæsium iodide and in hydriodic acid, hence warming in the mother liquor failed to dissolve the salt. It is decomposed slowly by cold water, rapidly by hot, and apparently tellurous acid or anhydride separates. This generally is impure, being mixed with a dark colored residue containing iodine. On exposure the salt slowly loses iodine. In the open capillary it does not melt below the boiling point of sulphuric acid.

Rubidium telluriiodide $2RbI . TeI_4$.—This compound was prepared by mixing the constituents in the same manner as in the preparation of the corresponding cæsium salt. If the solutions are only moderately concentrated, a black amorphous precipitate is produced. Unlike the corresponding cæsium salt, it dissolves, to a slight extent, on warming in the mother liquor, and on cooling, black microscopic octahedrons are produced.

		Calculated for $2RbI . TeI_4$.
Analysis gave :		
Rb _____	16·83	16·17
Te _____	----	11·81
I _____	72·07	72·02

This iodide is stable on exposure. Water effects the same decomposition as in the case of the cæsium salt. A small portion of this salt dissolves in strong alcohol, giving the color of a weak iodine solution.

Potassium telluriiodide, $2KI . TeI_4 . 2H_2O$. — This compound can most conveniently be prepared by boiling tellurium iodide in a strong solution of potassium iodide in dilute hydriodic acid. The solution, filtered while hot from any undissolved tellurium iodide, deposits long black prisms on cooling. These crystals attain considerable size, about 30^{mm} in length, when a large excess of potassium iodide is used. The mother liquor, on evaporation in a desiccator, deposits more of the salt, but the crystals have a different habit.

	Analysis gave :			Calculated for $2KI . TeI_4 . 2H_2O$.
K	8·41	8·70	8·39	7·81
Te	12·25	12·95	12·30	12·48
I	75·97	----	76·68	76·11
H_2O	3.57	----	----	3·60

For the determination of water in this compound the crystals were rapidly pressed on paper and immediately analyzed. It was found that the salt could be dehydrated at a temperature between 110°–115°, the resulting anhydrous salt being stable at that temperature. This was shown by an iodine determination in the residue. Analysis gave 78·78 per cent. of iodine, calculated for $2KI . TeI_4$ 78·94.

This salt is far more stable in the air than the corresponding bromide, but the crystals lose their luster in dry air, becoming dull black on account of a superficial efflorescence.

Crystallography.

The crystallization of the anhydrous alkali-tellurium halides is isometric. The chlorides were obtained in octahedrons with little or no modification, the bromides in combination of octahedron and cube. The chlorides and bromides were measured and also proved to be isotropic by examination in polarized light. Of the anhydrous iodides, the rubidium salt was the only one obtained in crystals, and these were too small to measure, but appeared under the microscope as combination of octahedron and cube. They were so opaque that they could not be tested in polarized light.

The two hydrous salts, $2KBr . TeBr_4 . 2H_2O$ and $2KI . TeI_4 . 2H_2O$ although analogous to each other in their composition, differ in crystallization. The bromide is orthorhombic as has been shown by Baker[*] also by Grailich and Lang in Rammelsberg's Handbuch.[†] That the hydrous potassium tellurium bromide obtained in the present work is identical with that described by the above authors is shown by measurements of the crystals. The crystallization of the salt $2KI . TeI_4 . 2H_2O$ is

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[*] Loc. cit.   [†] Loc. cit.

monoclinic. Two different habits were observed; long prisms, developed in the direction of the clino axis were obtained from hot solutions (fig. 1). The mother liquor from these, on standing, gave shorter prisms in which the domes and clino-pinacoids were wanting (fig. 2).

1.   2.
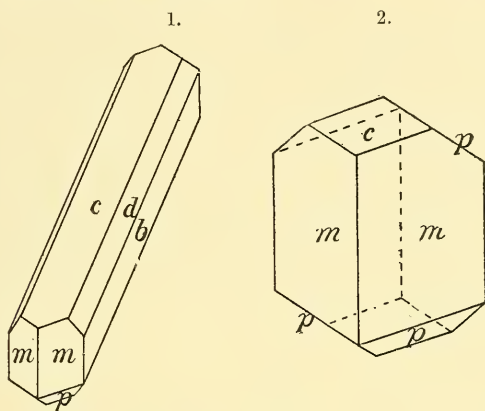
The forms observed were:

m 110	*c* 001	*d* 031
p 111	*b* 010	

The axial ratio is as follows:

$$\dot{a} : \bar{b} : \acute{c} \quad \cdot 7047 ; \ 1 ; \ \cdot 5688 \quad B = 100 \wedge 001 = 59°\ 7'\ 16''$$

The crystals gave fair reflections of the signal on the goniometer. Measurements chosen as fundamental are indicated by an asterisk.

		Calculated.	Measured.
$m \wedge m'''$	$110 \wedge 1\bar{1}0$	62° 20'	62° 26'
$m \wedge b$	$110 \wedge 010$	58° 50'	58° 50' *
$b \wedge c$	$010 \wedge 001$	90°	90°
$m \wedge c$	$110 \wedge 001$	63° 57'	63° 57' *
$m \wedge p$	$110 \wedge 11\bar{1}$	60° 42'	60° 42' *
$c \wedge p$	$001 \wedge \bar{1}11$	55° 21'	55° 22'
$b \wedge d$	$010 \wedge 031$	34° 20'	34° 25'
$b \wedge p$	$010 \wedge 11\bar{1}$	61° 42' 49''	61° 42' 30''
$m \wedge m'$	$110 \wedge \bar{1}10$	117° 40'	117° 33'
$c \wedge m'$	$001 \wedge \bar{1}10$	116° 3'	116° 11'

The crystals were too opaque for any optical examination.

In conclusion the author wishes to express his indebtedness, to Prof. H. L. Wells for valuable advice and for the interest that he has taken in this work, and to Prof. S. L. Penfield under whose direction the crystallography of these salts was investigated.

Sheffield Scientific School, January, 1893.

ART. XXXIII.—*Tungstous Oxide—a new Oxide of Tungsten
—associated with Columbous Oxide;*[*] by WM. P. HEADDEN.

IN an article on some tin and iron compounds, an abstract
of which appeared in this Journal,[†] reference was made to
certain products as iron bottoms whose formation was then
discussed at sufficient length.   This paper is practically a study
of the residues obtained from those bottoms.

The residues as obtained after having been freed from car-
bon and the portion which was so fine that it remained in
suspension for a longer time, consisted of two parts, a heavier
and a lighter.   The specifically lighter one was quite readily
attacked by hydric nitrate and the whole of the residues from
the first two bottoms were treated with this salt in order to
obtain the heavier portion as pure as possible.

The final residue from the first bottom was a brownish gray,
very fine, crystalline, and wholly non-magnetic powder which
under a magnification of 140 diameters, appeared to consist of
prisms.   It was examined after being ignited and found to
contain columbic acid with a small quantity of tungstic acid
and a very little iron and tin but no tantalic acid.

The residue from the second bottom was treated in a like
way.   The solution obtained by treating it with warm dilute
hydric nitrate indicated the presence of compounds of tin and
iron rich in the latter element.   The tin went into solution
and a small quantity of tungstic acid was formed; but it is
uncertain whether it was derived from the soluble compounds
or from the portion which remained as insoluble.   I think that
it was derived from the latter.   The gray, crystalline residue,
insoluble in warm dilute hydric nitrate was treated successively
with cold concentrated hydric nitrate, aqua regia, water, and
alcohol, and gave when subsequently treated with cold concen-
trated hydric chloride sp. gr. 1·2 a deep blue but clear solu-
tion, whose color was discharged by dilution with water and
also upon being heated.   The greater portion of this residue
was strongly magnetic, the rest of it, however, was not at-
tracted by the magnet.   I could observe no difference in the
form of the grains and crystals in the two portions.   These
were divided, by carefully washing them, into a finer crystal-
line and a coarser, well crystallized portion.   The crystals are
triangular prisms whose height is often several times the alti-

[*] Abstract of an article read before the Colorado Scientific Society, January
meeting, 1893.
[†] Vol. xliv, p. 464.

tude of their triangular bases but not always so, as the prisms are sometimes very short. The triangular base is apparently equilateral and I interpret the form as a hemiprism belonging to the hexagonal system; the color is gray to tin-white and the luster is brilliant metallic. These crystals are sometimes grouped in clusters and then the larger ones are often invested with an abundance of smaller ones. Cases of penetration are frequent but no surfaces other than those indicated have been observed. Some of the crystals are striated, which is probably due to interference.

The magnetic portion of this second bottom, as used for analysis, consisted for the most part of crystalline particles. It oxidized slowly and imperfectly when fused with potassic hydric sulphate, but when heated to dull redness in an open crucible it ignited and burned to a voluminous powder, yellow while hot but nearly white when cold. Complete oxidation is effected with some difficulty. The results of the analysis No. I were:

		At. eq.			
Cb	37·72	40·13	10 ⎫		
W	29·04	15·80	4 ⎭	14	1
Fe	19·62	35·10	9		
Sn	5·04	4·27	1		
O	8·78	54·90	14	14	1

100·20

This suggests a mixture of $10CbO + 4WO + Fe_9Sn$. Such a mixture would require 24·42 per cent of its weight of oxygen to completely oxidize it; the amount absorbed upon ignition was 24·88 per cent of its weight.[*]

The non-magnetic portion, analysis No. II, gave

[*] In separating tungstic and stannic oxides from columbic acid by digesting with ammonic sulphide and adding hydric chloride or sulphate to the alkaline solution, I have frequently obtained a yellow filtrate in which a further addition of hydric sulphate produced no precipitate. This reaction is due to the presence of potassic oxy-sulpho-tungstate $K_2WO_2S_2$ which is formed by the action of the ammonic sulphid on potassic tungstate formed during the fusion. The extent to which this salt may be formed is shown by the fact that in one instance I obtained rather more than one-third of all the tungstic acid present in this yellow filtrate from the mixed sulphide precipitate.

This salt is given in Gmelin-Kraut's Handbuch der Chemie, vol. ii, Part II, page 126, as being sometimes met with in the preparation of tungstic sulphide by fusing together potassic tungstate and sulphur—Berzelius; the same statement is given in Watt's Dictionary of Chemistry, vol. v, p. 914. But the reaction is not recorded anywhere, so far as I can find, as produced in the manner here given.

		At. eq.			
Cb	48·56	51·6	10·3 ⎫		
W	37·64	20·46	4·09 ⎭	14·39	1·14
Fe	3·22	5·75	1·15		
Sn	0·72	0·61	0·12		
O	10·08	63·00	12·60	12·60	1
	100·22				

The gain upon ignition amounted to 22·00 per cent of its weight. The formula suggested is the same as in the preceding case.

The third bottom showed, after a portion of it had been dissolved in hydric chloride, the triangular crystals disseminated throughout the mass and particularly abundant at the bottom. The residue in this case was not treated with warm hydric nitrate but was divided into three parts numbered 1, 2 and 3, beginning with the lightest.

PART 1. An analysis showed that this portion was a mixture of oxides and the ratio given for the metals to the oxygen was 1 : 1. When digested with cold hydric chloride, sp. gr. 1·2, it gave a clear blue solution whose color was discharged upon addition of water. The action of aqua regia upon it presented two phases, the first was very violent, while the second was quite slow; this was due to the fact that this reagent first dissolved the iron-tin compounds present, and then the tungsten or its compounds, which is evident from the following: some of this material was digested with two successive portions of aqua regia, each portion was evaporated to dryness after digestion at a gentle heat for about an hour; the first treatment gave $185 \cdot 7^{\text{mgm}}$ Fe_2O_3 and $81 \cdot 0^{\text{mgm}}$ WO_3, the second treatment gave $6 \cdot 7^{\text{mgm}}$ Fe_2O_3 and $51 \cdot 0^{\text{mgm}}$ WO_3. The residue from the first treatment consisted of triangular prisms, with a few crystalline grains, that from the second of remnants of such crystals, and after ignition consisted of tungstic acid with a small amount of columbic acid.[*]

PART 2. This consisted of crystalline grains and crystals. The latter were triangular prisms with an occasional six-sided plate; these plates which were relatively long and wide, were always pitted and had a much darker color than the prismatic crystals. The analysis of this showed 66·66 per cent of it to be difficultly soluble in aqua regia and emphasized the fact that the iron and tin do not belong to the triangular prisms which make up the larger part of the insoluble portion.

* In treating this portion with aqua regia containing a large excess of HCl, I obtained a clear yellow solution which gave upon addition of water a precipitate of tungstic acid; reference will be made to this reaction again.

The remainder of part 2 was persistently boiled with slightly diluted hydric nitrate, which attacks the iron and tin compounds much more readily than it attacks the crystals. The residue after being purified amounted to 42 per cent of the original quantity taken.

Neither the mixture itself nor the purified residue impart any color to a boiling concentrated solution of potassic hydrate, nor is there any evolution of ammonia or other reaction, but if the crystals are first digested with cold aqua regia and then potassic hydrate be added, the solution becomes brown upon standing, probably due to the formation of WO_2. The purified residue consisted very largely of the triangular prisms; some of the crystalline aggregations remained and the six-sided plates were still recognizable. When heated in the air it did not ignite but was slowly converted into a yellow powder. This residue was analyzed with the following results. Analysis III.

		At. eq.		
Cb	6·56	6·98	4·9 ⎞	
W	76·12	41·37	29·1 ⎠	1·21
Fe	9·06	16·18	11·4	
Sn	1·68	1·42	1·0	
O	6·34	39·63	28·0	1

99·76

The gain upon ignition equalled 20·66 per cent. If we calculate the columbinm, tungsten and oxygen to one hundred we obtain Cb 7·37, W 85·57, O 7·12 = 100·00.

Portion No. 3, that is, the coarsest portion of the residue, was passed through a 148 mesh bolting cloth and the small portion which remained on the cloth was reserved for subsequent study. The portion used for analysis consisted of triangular prisms, which constituted as much as and possibly more than 85 per cent of the whole mass; the rest was made up of crystalline aggregations with a few of the six-sided plates noticed in the last sample. When ignited in the air it oxidized without incandescence to a yellow powder; the gain equalled 19·10 per cent; the analysis No. IV gave:

		At. eq.			
Cb	1·46	1·55	1·34 ⎞		
W	86·64	47·09	40·94 ⎠	42·28	1·22
Fe	4·32	7·71	6·70		
Sn	1·36	1·15	1·00		
O	6·32	39·50	34·35	34·35	1·00

100·10

This and also the preceding analysis indicates an excess of tungsten over that required by the oxygen for the formation of tungstous oxide. But if there remained any metallic tungsten in the regulus we would expect to find it here; because of its high specific gravity and the fact that careful washing was the only available method for separating and purifying the portions into which the residues were divided. Boiling the material on which analysis No. III was made with hydric nitrate had no effect upon this point as columbous oxide and metallic tungsten are either only very slowly attacked or not at all acted upon by this agent.

Relative to the probability of the presence of metallic tungsten in these iron bottoms I would repeat the statement that they are closely related to cast iron and others have observed that metallic tungsten may exist as such in cast iron. Further, the result of much labor in an endeavor to obtain columbous oxide directly from a mixture of columbite, magnetite, and stream tin containing wolfram, was a series of iron bottoms which when melted together and subsequently dissolved in hydric chloride yielded a small quantity of a well crystallized residue in which, neglecting a minute quantity of iron, tungsten was the only metal. The crystals were octahedral, apparently quadratic, with some six-sided plates similar in color, luster, and in being pitted to those observed in portions two and three of the residue form the third bottom. Most of the octahedral faces were smooth but on some crystals these faces were depressed at the center. These crystals when kept at a bright red heat for half an hour in an open crucible were only very slightly oxidized and appear to be metallic tungsten.*

As the components of these various products could not be satisfactorily distinguished, even with the aid of the microscope, we are compelled to have recourse to the study of those ratios which remain constant while others vary.

We may divide the results obtained in analyses one and two into two groups, one containing the iron and tin, and the other, the columbium, tungsten, and oxygen. The iron and tin together constitute 25 per cent of the first sample and rather less than 4 per cent of the second, but the ratio of the iron to the tin is the same in each. If we calculate these elements found in each analysis to one hundred we obtain for

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* The ignited crystals themselves were not soluble in hot hydric chloride, sp. gr. 1·2, but the ignited mass gave with this salt a yellowish solution which solidified on being poured into a cold beaker, to a buttery mass, which proved to be pure tungstic acid. This is the second instance in which I have found tungstic acid to be soluble in hydric chloride. The statement in Gmelin-Kraut's Handbuch der Chemie, is that " Acids, even concentrated sulphuric acid, do not dissolve it," i. e. WO_3. Its solubility in acids has been observed but once before this so far as I can find, i. e. by J. W. Mallet.

number I : Fe 80·47 per cent, Sn 19·53 per cent, for number
II : Fe 81·72 per cent, Sn 18·28 per cent.   The ratios obtained for the remaining elements are quite as satisfactory and represented in the same manner are as follows :

No. I.		No. II.	
Cb	49·91	Cb	50·44
W	38·42	W	39·09
O	11·67	O	10·47
	100·00		100·00

The percentage composition required by the mixture
$10CbO+4WO$ is Cb 49·473, W 38·737, O 11·890.   The properties of this mixture agree closely with those of columbous oxide especially in burning with incandescence to columbic acid.   The presence of the triangular prisms is quite conclusive that the columbium and tungsten are present in separate compounds, which will appear more fully further on.

The two remaining analyses are not comparable to the same extent as those just given, still Nos. III and IV give 1 : 1·21 and 1 : 1·22, respectively for the ratios of the columbium and tungsten to the oxygen.

While it is inferable from the results of analysis III that the tungstic acid in the other analyses was derived from the prismatic crystals, the most conclusive proof that these triangular prisms are crystals of a compound of tungsten with only a very little or no iron or tin is afforded by the material designated part I of the residue from the third bottom ; for upon being treated with aqua regia in successive portions it yielded upon the first treatment a solution carrying ferric oxide equal to 2·3 times the amount of tungstic acid formed while the second treatment produced an amount of tungstic acid equal to 7·3 times the amount of ferric oxide which went into solution. The residue from the first treatment was very largely made up of these triangular crystals.   We conclude from all of this that this hemiprism is the usual crystal form of the compound of tungsten which occurs in these residues.   This conclusion is supported also by a comparison of the results obtained in analyses II, III and IV with the respective materials on which they were made.   The material serving for analysis No. II was a fine crystalline powder with some triangular crystals ; that serving for No. III contained very many of them, while in No. IV I estimated them as forming upwards of 85 per cent of the mass.   The results of the analyses are

	II.	III.	IV.
Cb	48·56 per cent.	6·56 per cent.	1·46 per cent.
W	37·64 "	76·12 "	86·64 "

Analyses Nos. I and II give the ratio of 1 : 1 for the atomic ratio of these metals to the oxygen, and Nos. III and IV give approximately the same, from which it appears that we have a mixture of columbous and tungstous oxide in these residues and that the triangular prisms are crystals of the latter.

Tungstous oxide—WO—as thus obtained crystallizes in the hexagonal system, mostly in hemiprisms having a light gray to tin white color, a metallic luster, a hardness greater than glass, and a dark gray streak. Hydric chloride, fluoride, and sulphate, also a boiling solution of potassic hydrate have no perceptible action on it, but hydric nitrate and aqua regia attack it, especially when heated, converting it slowly into tungstic acid. The crystals can be kept under water or exposed to the air at ordinary temperatures without change, but when heated to redness in the air they are gradually converted into tungstic acid; this change takes place without incandescence but is accompanied by a considerable increase in volume, less, however, than that which accompanies the corresponding conversion of columbous oxide into columbic acid which is accompanied by incandescence.

The tungstous oxide was probably formed in this case by the action of stannous oxide, formed in the repeated liquations of the tin, upon metallic tungsten which had been reduced in the original tin charge.

State School of Mines, Rapid City, S. D.

ART. XXXIV.—*A Sodalite-Syenite and other Rocks from Montana;* by WALDEMAR LINDGREN, *with Analyses* by W. H. MELVILLE.

AMONG the collections in the U. S. National Museum there is a suite of specimens, principally of eruptive rocks, collected in the northern part of Montana, by Dr. C. A. White and Mr. J. B. Marcou during the summer of 1883. The principal localities where the collections were made are the Moccasin Mountains, the Bear Paw Mountains, and Square Butte, near the Highwood Mountains. Rocks from these places have not been previously examined, as far as I know, and it is only proposed in this paper to describe in detail one which appears of particular interest; the general character of the collection, however, may be briefly noted. All of the igneous rocks collected appear to belong to the class of post-Cretaceous intrusive rocks which has such a wide distribution in the Rocky Mountains and which range from the most acid to the most

basic composition. Dr. C. A. White has had the kindness to furnish me with information regarding the occurrence in the field of the rocks and all the statements in the following pages in reference to this are from his unpublished notes.

The Moccasin Mountains form an isolated group about seventy miles southeast from Fort Benton on the eastern side of Judith river. They consist, according to Dr. White, of a central core of eruptive masses, probably laccolitic in character, surrounded by a ring of upturned sediments ranging from the Cretaceous to the Carboniferous. The rocks from the central core appear to belong only to one type. They are light colored, gray or yellowish porphyritic rocks with large phenocrysts of sanidine and soda-lime-feldspar, and smaller ones of brown hornblende; a greenish augite is occasionally seen. The groundmass is always holocrystalline of more or less fine grain and consisting of unstriated feldspar and quartz which sometimes are intergrown in such manner that each quartz grain contains numerous smaller feldspar grains of irregular optical orientation.*

These intrusive rocks from the Moccasin Mountains appear almost identical with the laccolitic masses in the Carboniferous of the Little Belt Mountains and the dikes in the Cretaceous east of Cadottes pass which I have described in previous papers under the name of dacites and diorites.†

Again, very similar rocks have been described in detail by Mr. Whitman Cross from Leadville and other localities in Colorado, and by Mr. Iddings from the Yellowstone Park region. It is apparent that this type of porphyritic intrusive rock is of wide-spread occurrence in the Rocky Mountains; the name of porphyrite or quartz-porphyrite‡ is now usually applied to them.

The Bear Paw Mountains are situated sixty miles northeast of Fort Benton and rise about 2500 feet above the surrounding plains. According to Dr. White, they are largely made up of igneous rocks intruded in Cretaceous strata. The specimens which are taken in the broad valley of Eagle creek at the south base of the mountains, mostly from dikes or dike-like masses, show a very different type from the one just described.

Prevailing is a dark fine-grained porphyritic rock with phenocrysts of greenish idiomorphic augite up to three milli-

* The name of *micro-poikilitic* has recently been suggested by Mr. Iddings for this structure.

† 10th Census, vol. xv, pp. 720 and 731. Eruptive rocks from Montana; Proc. Cal. Acad. Sci., series II, vol. iii, p. 39.

‡ The definition of porphyrite as applied to this type of rocks is given by Mr. Iddings in his paper on "The Eruptive Rocks of Electric Peak and Sepulchre Mountain." 12th Ann. Rep. U. S. Geol. Survey, p. 582.

meters long and flakes of a brown, slightly pleochroic mica with very small axial angle. The groundmass consists mostly of lath-shaped plagioclase crystals together with augite and mica. In some specimens with phenocrysts of olivine and augite the groundmass is glassy and contains no feldspar; this rock approaches closely to certain limburgites. The general appearance of the Bear Paw series and the absence of phenocrysts of feldspar in it points to its connection with the group which Rosenbusch has called the lamprophyric dike rocks.

The suite of specimens collected at Square Butte is of particular interest. Square Butte, which really forms the eastern end of the Highwood Mountains, is situated thirty miles southeast of Fort Benton and eighteen miles nearly due east of Highwood Peak. The rocks from this locality show a close relationship with those from the main group of the Highwood Mountains, and it may perhaps not be amiss to refer briefly to the character and rock types of the latter.*

The Highwood Mountains with their sharp and jagged peaks and ridges stand in isolated grandeur on the monotonous plains twenty miles south of Fort Benton on the Missouri river. They form an oblong group twenty miles from north to south and thirty miles from east to west and their highest peaks rise 3600 feet above the surrounding Cretaceous plateau which here consists of the nearly horizontal black shales of the Fort Benton group. The mass of the mountains is made up of a network of dikes and probably also of laccolitic masses between which are included contact metamorphosed and disturbed remnants of sediments none of which are believed to be older than the Cretaceous. Above the Fort Benton group once rested the whole thickness of the Montana and Laramie formations or at least 8000 feet of sediments. Volcanic activity began at this point at or after the close of the Cretaceous period. Great quantities of igneous rocks were forced into the sediments and on the surface the eruption was probably connected with the phenomena of a subaerial volcano. Subsequent erosion has removed nearly the whole thickness of the softer Laramie rocks, exposing the harder core of the ancient volcano and the abyssal rocks solidified under a pressure of many thousand feet of superincumbent sediments.

The Highwood Mountains are very similar in structure to the Crazy Mountains, also in Montana, recently described by

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* The general geology of the Highwood Mountains has been described by Prof. W. M. Davis in 10th Census, vol. xv, p. 697, and the petrography by W. Lindgren, *loc cit.*, p. 729. See also, " Eruptive Rocks from Montana," by W. Lindgren. Proc. Calif. Acad. Sci., series II, vol. iii, p. 40.

Mr. J. E. Wolff,* but the petrographical character of the two volcanic districts is somewhat different.

The intrusive rocks of the Highwood Mountains are in general basic in composition and holocrystalline in structure. There are a few coarsely granular rocks, principally dikes of augite syenites, but a much more common type of rock is of a porphyritic structure and closely allied to the trachytes.†

Augite-trachytes are frequent, usually containing two generations both of the orthoclase and the augite. The latter is characterized by a deep green color and evidently contains an admixture of the acmite molecule. The quantity of augite in these rocks is sometimes very large, and they grade over into basaltic rocks with orthoclase, plagioclase, olivine and augite.

Attention should be called to the great similarity of these rocks with the peculiar intrusive and extrusive masses recently described by Mr. Iddings from the Crandall basin and the Absaroka range in the National Park region.‡

Another interesting type in the Highwood Mountains is that of the analcite-basalts which, with holocrystalline porphyritic structure, consist of augite, olivine, brown mica and analcite. The latter mineral here appears under conditions strongly suggesting a primary origin.

Square Butte and vicinity was not visited by me in 1883, and I am again indebted to Dr. C. A. White for notes regarding it. As already mentioned, it forms the extreme eastern part of the Highwood Mountains with which it is connected by several lower buttes and ridges. The elevation of the flat top, about three-quarters of a mile in diameter, is 5600 feet above sea level according to the maps of the Northern Transcontinental Survey (Fort Benton sheet, U. S. Geol. Survey). The Butte is composed of a light gray eruptive rock with very distinct lamination. In the elevated table land surrounding its base are found several horizontal sheets of a dark gray or black volcanic rock interbedded with black Cretaceous shale belonging to the Fort Benton group. There are three distinct sheets of this dark rock, each about eight feet thick and separated by beds of shale of about the same thickness. Surrounding Square Butte there are numerous dikes apparently radiating from the central mass.

The dark volcanic sheets are represented in the collection by three types. Unfortunately, most of them are very much decomposed. The first is porphyritic and contains as phenocrysts augite of the Highwood type, olivine, usually brown

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* Bull. Geol. Soc. Amer., vol. iii, p. 445.
† This term is here used without restriction to surface flows.
‡ The Origin of Igneous Rocks, by J. P. Iddings. Phil. Soc., Washington, D. C., vol. xii, p. 169.

mica, and lastly white isometric crystals up to two millimeters in diameter. The original character of these white crystals cannot be made out as they are completely converted into secondary aggregates. The groundmass, which is quite fine-grained, contains much augite, besides other indeterminable minerals.

The second type is similar to the "analcite-basalts," but the specimens are not fresh and the white mineral is again completely decomposed. This type is more coarsely crystalline and not so pronouncedly porphyritic.

The third type is coarsely granular and in composition approaches the *theralite* described by Mr. J. E. Wolff from Martindale near the Crazy Mountains.

The main mass of Square Butte is represented by a light yellowish grey, rather coarse grained granular rock of miarolitic appearance (No. 28705, U. S. National Museum, Summit Square Butte). Macroscopically it consists of grains and broad lath-shaped crystals of feldspar, often five millimeters long, black glistening hornblende prisms reaching three millimeters in length, and sodalite which appears as small grains of a pale brownish color. Under the microscope the rock is shown to be hypidiomorphic granular and the following constituents are noted in their order of formation: *apatite, hornblende, orthoclase* (with some *plagioclase*), *sodalite*, and *analcite*.

Fig. 1.

Sodalite-syenite magnified **7** diameters. A hornblende, B orthoclase, C sodalite, D analcite.

The predominant constituent is orthoclase, occurring both as irregular grains and lath-shaped crystals; individuals partly or wholly imbedded in sodalite show terminal faces. Many of

the grains are very clear, but the larger part are somewhat clouded, not, however, by decomposition and the formation of muscovite and kaolin, but principally by irregular and elongated gas inclusions together with others of indeterminable character. Small crystals of apatite, as well as green and brown hornblende microlites, are noticed in the feldspars. A triclinic feldspar with very fine twinning lamellæ in only one direction occurs in intimate, almost microperthitic intergrowth with many of the orthoclase grains. This triclinic feldspar which usually is more pellucid than the orthoclase has every appearance of being albite.

Many of the feldspar grains are corroded in a peculiar manner as shown on the figures and are filled with faintly doubly refracting analcite. The same corrosion has been observed in an augite-syenite from the Little Belt Mountains,[*] although the enclosed mineral was not then recognized as analcite; a comparison with the Square Butte rock shows beyond doubt the identity of the two minerals. It has also been noted by J. Francis Williams in similar rocks.[†] This analcite is doubtless derived from the albite. It is a curious fact that although there is abundant sodalite present in the rock it should have remained fresh and undecomposed while the albite was attacked. There are no other zeolites or products of decomposition and it appears as if this conversion into analcite would have taken place very soon after the solidification of the rock. It certainly cannot here be regarded as a product of ordinary decomposition. Prof. Brögger[‡] and other authors have shown that analcite, in general, is the earliest of all the zeolites and that it must have been formed at a relatively high temperature, that is, perhaps between 200° and 400°. Friedel and Sarasin[§] for instance obtained analcite by heating the constituents of *albite* with water to 400°.

In order to test the character of the feldspars, fragments were introduced into a Thoulet solution. The feldspars began to sink at sp. gr. 2·57 and continued to fall until a sp. gr. of 2·45 was attained. Two portions were subjected to partial analysis:

	Sp. gr. 2·57	Sp. gr. 2·55
Na_2O	6·08	3·88
K_2O	8·91	11·03

It is evident that the first portion is orthoclase with a strong admixture of albite and equally so that the second is a nearly

pure orthoclase. The analcite which penetrates the feldspars is the cause of the lowering of the specific gravity; a mechanical separation of the two minerals is hardly practicable.

The hornblende occurs as slender black prisms bordered by ∞P and $\infty P\infty$; terminal faces are not seen. It is idiomorphic both against the orthoclase and the sodalite. The color in thin section is a very dark brown, so dark in fact that in slides of ordinary thickness many crystals are only faintly translucent. The pleochroism is very strong; the rays vibrating parallel to c and b are both very strongly absorbed, producing a dark brown color, while those vibrating parallel to the axis of maximum elasticity are less absorbed with a yellowish brown color, sometimes showing a tinge in green. The axis of minimum elasticity is inclined to the principal axis at an angle not exceeding 13°. In some places the brown hornblende is undergoing a peripheral conversion into a green modification with an extinction up to 25°.[*] The specific gravity of the hornblende was found to be 3·437. From the characteristics mentioned above the identity[†] with Prof. Brögger's barkevikite[†] seemed highly probable and to confirm this a quantity was isolated and analyzed.

	I. Square Butte.	II. Barkevik. Analyzed by G. Flink.
H_2O (above 100°)	0·24	
SiO_2	38·41	42·46[§]
Al_2O_3	17·65[‡]	11·45
Fe_2O_3	3·75	6·18
FeO	21·75	19·93
NiO	trace	
MnO	0·15	0·75
CaO	10·52	10·24
MgO	2·54	1·11
Na_2O	2·95	6·08
K_2O	1·95	1·44
	99·91	99·64

The mineral differs from barkevikite, an analysis of which is given under II, in containing somewhat less silica and alka-

[*] The conversion of brown compact hornblende into a green fibrous modification was first observed by Mr. G. F. Becker, in his "Geology of the Comstock Lode," Monogr. III, U. S. G. S., p. 36, Washington, 1882. The same change has been noted by Mr. F. Becke and Prof. G. H. Williams, Bull. 28, U. S. Geol. Survey, p. 45.

[†] Z. f. Kryst., u. Min., xvi, p. 412.

[‡] The titanic acid in (I) is contained in the alumina. The rock carries 0·29 per cent TiO_2 and contains 23 per cent. hornblende; hence, there being no other titanium minerals present, the TiO_2 in the hornblende may be calculated at 1·26 per cent which would reduce the alumina to 16·39 per cent.

[§] With some TiO_2.

lies, while the alumina is higher. The low percentage of CaO and MgO and the high amount of FeO show, however, that it is very closely related to it. In the absence of any crystallographic orientation the only way of distinguishing it from arfvedsonite is by its color and streak. I believe this is the first time that barkevikite has been identified in the United States. The hornblende in the *pulaskite*,[*] described by J. Francis Williams, also a syenitic rock, is probably closely related to barkevikite, but no analysis was made of it.

The sodalite forms irregular grains and partly developed crystals; it is allotriomorphic against the feldspar, but usually idiomorphic whenever bordering on the analcite. It sometimes fills triangular interstices between the lath-shaped feldspars. The period of its consolidation seems here to be decidedly later than that of the feldspar. The cleavage parallel to ∞ 0 is well indicated by the arrangement of very numerous inclusions in part of gas, in part of liquid with very large air bubbles; frequently these inclusions have the form of the enclosing minerals. Small moving bubbles do not often occur. The sodalite is perfectly isotropic and very fresh. Only very locally may a corrosion and decomposition into analcite be observed, such as shown on the large sodalite grain in figure 2.

Fig. 2.

Sodalite-syenite. Magnified 25 diam. A hornblende, B orthoclase, C sodalite, D analcite.

A little chlorite or serpentine is sometimes infiltrated from the hornblende. The sodalite is somewhat unequally distributed through the rock; the figures are taken from places where it

[*] Geol. Survey of Arkansas, Ann. Rep., 1890, vol. ii, p. 64.

is especially abundant and give a rather exaggerated idea
of the quantity of this mineral.

Besides the already mentioned occurrence of analcite in the
feldspar it also fills interstices between the feldspar and soda
lite grains in the manner shown in the figures.   It is very
clear and free from inclusions; a peculiarity of it is that con-
trary to the data usually given its refraction appears stronger
than that of the feldspar and sodalite.   It always shows a faint
double refraction in dark gray and bluish colors and each grain
usually divides into several sectors with different optical orien-
tation.   The form of the larger grains is triangular or poly-
gonal, being molded by the crystallographic faces of the feld-
spar and sodalite as shown in the figure.   The interpretation
of this analcite offers some difficulties.   It is not derived from
the sodalite; there is no direct proof to show that it has been
derived from nepheline; if it is an altered nepheline, then
this mineral must have been formed later than the sodalite.
No nepheline has been found so far, but it is by no means
impossible that other parts of the eruptive mass might con-
tain this mineral.   Another possibility is that the analcite fills
miarolitic cavities in the rock; it cannot then very well have
been derived from any other mineral than the feldspar.   The
specific gravities of the sodalite and analcite were found to
lie extremely close together.   They both fell between 2·27
and 2·23.   A special and repeated separation was made of this
mixture which resulted in the two minerals being obtained in
a relatively pure state.   The specific gravity of the sodalite
ranges from 2·27 to 2·255 while that of analcite extends from
2·26 to 2·24.   The two products were then analyzed:

	III. Sodalite.	IV. Analcite.
H_2O (at 100°)	0·45	
H_2O (above 100°)	3·73	(7·07)*
SiO_2	41·56	49·54
Cl	4·79	1·67
Al_2O_3	29·48	25·07
FeO	0·49	0·40
CaO	0·49	0·22
MgO	0·15	0·20
Na_2O	19·21	15·32
K_2O	0·91	0·89
	101·26	100·00
Excess O	1·08	
	100·18	

* By difference.

It is evident that both of these analyses are made of mixed material and equally plain that one of the constituents is sodalite.

In order to calculate approximately the composition of the two minerals let us assume an analcite composed as follows:

$$55 SiO, 23 Al_2O_3, 13 \cdot 5 Na_2O(+K_2O), 8 \cdot 5 H_2O = 100,$$
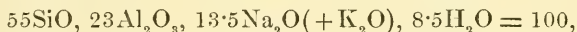
and a sodalite containing 37·5 per cent SiO_2. From the silica contents it follows then that (III) contains 76 per cent sodalite and 24 per cent analcite. Calculating further the remaining elements and disregarding for the present the small quantities of Fe, Ca and Mg, one obtains

$(37\cdot50\ SiO_2), 31\cdot50\ Al_2O_3, 22\cdot20\ Na_2O(+K_2O), 6\cdot30\ Cl, 2\cdot20\ H_2O$
    $= 99\cdot50$
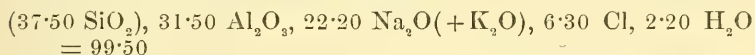
which, excepting the high percentage of water, is a normal sodalite.

On the other hand, assuming a sodalite composed as above and an analcite containing 55 per cent SiO_2, it follows that (IV) contains 68 per cent analcite and 32 per cent sodalite, and that the other constituents of the analcite are

$(55 SiO_2), 22\cdot04\ Al_2O_3, 13\cdot40\ Na_2O(+K_2O), 9\cdot37\ H_2O = 99\cdot81,$
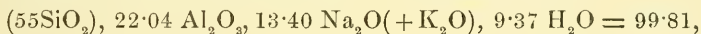
which corresponds very closely to a normal analcite. It does not seem possible to avoid the conclusion that a part of the water belongs to the sodalite. Under the microscope the sodalite appears perfectly pure and isotropic and no other zeolites such as natrolite or hydronephelite are present. If all the water belonged to the analcite it would have to contain about 15 per cent H_2O. The amount of H_2O in analcite is, however, very constant and varies only between 8 and 9 per cent. As a matter of fact, the majority of sodalite analyses do contain a small amount of water, and it has been suggested that a certain quantity of Cl may be replaced by (OH).

A quantitative separation of the rock was made and the following figures obtained for which only an approximate correctness is claimed:

> 66 feldspar.
> 23 hornblende.
> 8 sodalite.
> 3 analcite.
> ———
> 100

The proportion between albite and orthoclase could not be correctly ascertained on account of their very intimate intergrowth, but from the thin sections and from the separation it was estimated that the rock might contain 50 per cent ortho-

clase and 16 per cent albite. If it is further assumed, for the purposes of a calculation of the rock analysis, that the composition of the two minerals is

	Orthoclase.	Albite.
SiO	68	66
Al_2O_3	21	19
Na_2O	11	13
K_2O	--	2
	100	100

the composition of the rock may be calculated as follows:

	Horn-blende.	Ortho-clase.	Albite.	Soda-lite.	Anal-cite.	Calc. comp.	Rock analysis. V.	Difference.	VI.
H_2O*	----	----	----	----	----	----	0·26	----	----
H_2O†	0·06	----	----	0·16	0·29	0·51	1·51	+1·00	3·49
SiO_2	8·83	33·00	10·88	3·00	1·65	57·36	56·45	−·91	55·76
P_2O_5	----	----	----	----	----	----	0·13	----	----
Cl	----	----	----	0·48	----	0·48	0·43	−·05	----
TiO_2	0·28	----	----	----	----	0·28	0·29	----	----
Al_2O_3	3·77	9·50	3·36	2·52	0·66	19·81	20·08	+·27	21·61
Fe_2O_3	0·86	----	----	----	----	0·86	1·31	+·45	1·65
FeO	5·00	----	----	---	----	5·00	4·39	−·61	4·09
NiO	----	----	----	----	----	----	trace	----	----
MnO	0·04	----	----	----	----	0·04	0·09	+·05	----
CaO	2·43	----	----	----	----	2·43	2·14	−·29	2·26
MgO	0·58	----	----	----	----	0·58	0·63	+·05	0·74
Na_2O	0·69	1·00	1·76	1·72	0·40	5·57	5·61	+·04	6·94
K_2O	0·46	6·50	----	0·08	0·03	7·07	7·13	+·06	5·34
	23·00	50·00	16·00	7·96	3·03	99·99	100·45		101 88

Excess O.   ·10

100·35

The complete analysis of the rock is inserted under V in the third column from the right. The analysis agrees fairly well with the calculated composition in all except SiO_2 and H_2O; the former is very uncertain on account of no complete analysis having been made of the feldspars; the latter is too low in the calculated composition and the rock evidently contains more analcite than 3 per cent. A part of that amount which is not accounted for in the calculated composition doubtless fell together with the feldspars in the separation and some per cent of analcite should be substituted in the 16 per cent of albite. This would bring the calculated analysis closer to the actual composition, as the only effect would be to lower the SiO_2 and increase the H_2O. The analysis further shows that no plagioclase except albite is contained in the rock and also that there is about 0·3 per cent of apatite present.

* At 100°.   † Above 100°.

The absence of titanite is remarkable, but as only one speci-
men has been examined it is not unlikely that this mineral as
well as some of the rarer minerals frequently connected with
such rocks may be found upon closer examinations of more
abundant material.

The analysis agrees in general with that of many nepheline-
syenites, but differs from them all in the fact of containing
much more K_2O than Na_2O; it has also great similarity with
Prof. Brögger's augite-syenite (Laurvikite) except as to the
alkalies. Most of all it resembles the nepheline-syenite from
the Cape Verde Islands,* the analysis of which is copied in
the right column of the table (VI). The latter, however, con-
tains much less K_2O. From the ordinary syenite it differs in
the amount of silica, as well as in the low percentage of CaO
and MgO.

Only one sodalite-syenite appears to have been described
previously; it occurs at Kangerdluarsuk, Greenland, and its
minerals have been described in detail by Mr. Joh. Lorenzen,†
but I have been unable to find an analysis of the rock. It
consists of microcline, arfvedsonite and sodalite, while nephe-
line is only found in places.

I would finally like to call attention to the striking similarity
of the analysis of this rock with those of certain leucitophyres
from Rocca Monfina.‡ Under different conditions the same
magma, now crystallized as a sodalite-syenite, might have pro-
duced a leucite-feldspar rock.

Résumé.—The following rocks are described in this paper:

1) Porphyrites and quartz-porphyrites from the Moccasin
Mountains. They are intrusive, holocrystalline rocks of post-
Cretaceous age and consist of quartz, orthoclase, soda-lime
feldspar and hornblende.

2) Porphyritic, dark colored post-Cretaceous dike rocks from
the Bear Paw Mountains. They consist of augite, olivine,
biotite and triclinic feldspar and have a general resemblance to
the lamprophyric dike rocks of Prof. Rosenbusch.

3) A post-Cretaceous sodalite-syenite from Square Butte.
This rock consists of hornblende, orthoclase, albite, sodalite
and analcite. No nepheline is found but the interstitial anal-
cite, of which there is 3 per cent, might possibly have been
derived from such a mineral. It contains 8 per cent of
sodalite.

Washington, D. C., Dec., 1892.

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* C. Doelter. Die Vulcane der Cap Verden und ihre Producte; cited in Arkansas
Geol. Survey, 1890, vol. ii, p. 81.
† Mineralogical Magazine, vol. v, p. 49, 1882.
‡ Analyses cited in "The Origin of Igneous Rocks," by J. P. Iddings. Phil. Soc.
Washington, Bull., vol. xii, p. 199.

Art. XXXV.—*A Basic Dike near Hamburg, Sussex Co., New Jersey, which has been thought to contain Leucite;* by J. F. Kemp.

In June, 1888, the writer visited the exposures of basic igneous rock, near the Beemerville, N. J., elæolite-syenite and on the materials collected, published a short description in this Journal for August, 1889.[*] As stated in the paper, the available specimens were much decomposed, and yet as some plagioclase was noted they were called porphyrite. The presence of nepheline was strongly suspected, but although unusually large and abundant apatite appeared, no nepheline could be identified, owing doubtless to advanced alteration.

In the two or three years since the paper was published, there have appeared several descriptions of elæolite-syenite areas elsewhere, and in particular of the basic rocks associated with them ; so that we have come to recognize basic dikes as a quite invariable attendant upon this form of plutonic rock. This has proved true of the elæolite-syenite at Magnet Cove, Ark.[†] Montreal, Canada,[‡] and Salem, Mass.,[§] in this country ; of the exposures in the Serra de Tingua, near Rio Janeiro, Brazil,[||] in the Monchique Mountains of southern Portugal ;[¶] and near Christiania, Norway.[**] The basic dikes are analogous to basaltic rocks of various types, including augitite, limburgite, melilite-basalt, feldspar-basalt, and the like, but to preserve the special grouping of dike rocks by themselves, they have received individual names, fourchite, monchiquite, alnöite, etc.

When this literature became available, it was at once seen that the Beemerville dikes or bosses, (they appear more like the latter in instances) were analogous to these, and in the Arkansas Report, (Ann. Rep. 1890, vol. ii, p. 403), they were stated to be practically the same thing as the Arkansas rocks called ouachitite.

In September, 1890, the writer went again to the Beemerville syenite area,[††] and was fortunate in learning through Mr.

[*] On certain Porphyrite Bosses in Northwestern New Jersey, pp. 130–134.

[†] J. F. Williams and J. F. Kemp, Second Ann. Rep. State Geologist of Ark., vol. ii, pp. 290, 392.

[‡] B. J. Harrington, Geol. Surv. Cau. 1877–78, p. 429. F. D. Adams, this Journal, April, 1892, p. 269.

[§] J. E. Wolff, Geol. Soc. Amer., iii, p. 84.

[||] O. A. Derby, Quart. Jour. Geol. Soc., xliii, 457, and xlvii, 251, (especially 265).

[¶] Hunter and Rosenbusch, Tsch. Min. und Petr. Mitth., xi, 455, 1890. and still earlier by L. Van Werveke, Neues Jahrbuch, 1879, p. 451, and 1880, pp. 141–186, but especially 179.

[**] W. C. Brögger, Zeitschrift f. Kryst., vol. xvi, 1890, p. 79.

[††] Elæolite-syenite near Beemerville, N. J., Trans. N. Y. Acad. Sci., vol. xi, p. 60, Feb. 1892.

W. R. Van der Huff, of Deckertown, of another dike, near Hamburg. This was visited and from it a suite of specimens obtained, which are quite fresh, and which show several very peculiar and interesting features. The dike lies much farther

Fig. 1.
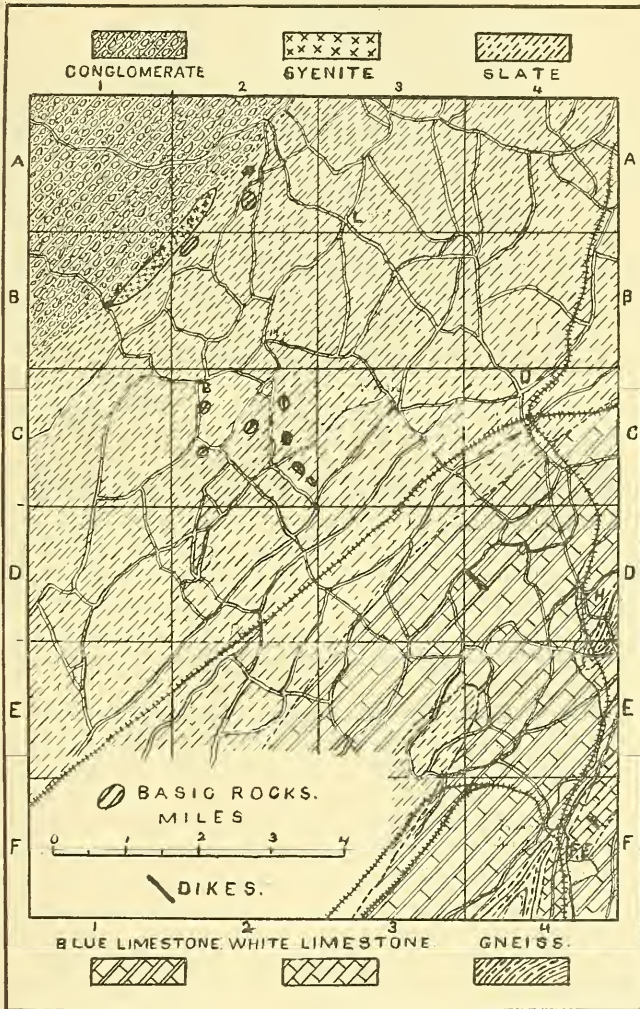
away from the syenite, than those earlier described and more than half way to Franklin Furnace, where Professor Emerson found years ago the peculiar mica-diabase.[*] The accompany-

[*] B. K. Emerson, this Journal, III, xxiii, p. 376. Still another dike has been discovered by F. L. Nason, at Rudeville, N. J. Geol. Surv. 1890, p. 35.

ing map, figure 1, illustrates the general geology and geography. Referring to the squares, the syenite occurs in B1, B2 and A2. It lies along the contact of the Kittatinny (Oriskany) conglomerate, and the Hudson River slates. The older described, basic rocks are all in the slate and outcrop in A2, B2, and C2. The dike here described is in undetermined, but probably lower Silurian, blue limestone, in D4. The Franklin Furnace dike is in white limestone in F4. Several initial letters are inserted to mark the towns: L, in A3, is Libertyville; B, in C2, is Beemerville; D in C4, is Deckertown; H, in D4, is Hamburg; F, F, in F4, is Franklin Furnace. The basic dikes appear at once to be in a general northwest and southeast arrangement, and it is natural to infer that they represent a series of outcrops along a common line of emergence. The Hamburg dike is on the farm of Lewis Havens (lately Zephaniah Havens) and the farm of Miles Harden lies just over the fence. A roadway runs near it. The dike cuts blue cherty limestone, which strikes N. 60 E. and dips 50 N., while the dike itself strikes N. 25 W., being nearly at right angles with the limestone. There are small veins of quartz along the contact, but otherwise no apparent metamorphism. The width of the trap is 15 to 20 ft. and the outcrop is about 50 yards long.

In the hand specimen, it is a dark rock, extremely tough, and thickly set with biotite. In portions some curious, spheroidal inclusions appear, which form one of the chief points of interest. They vary up to 10^{mm} in diameter and are filled with white minerals. They can be cracked out of the matrix, because they are surrounded by concentric scales of biotite. They attracted attention at once in the field and were brought to the laboratory as one of the features deserving special attention.

In thin section the dike rock is seen to be made up of biotite and pyroxene as its larger minerals, and these are set in a very feebly refracting, or entirely isotropic groundmass, that is chiefly analcite. Throughout the groundmass are abundant ægirine rods, apatite needles, magnetite and occasional plagioclase. In places titanite crystals are extremely numerous and the magnetite likewise shows the usual evidence of being titaniferous. Figure 2 is a drawing of the rock, the outlines of whose crystals were traced with a camera lucida. The endeavor was made to give as characteristic a portion as possible. The specific gravity of the rock is 3·040 to 3·049 as determined on several specimens.

The biotite is the deep brown variety characteristic of the nepheline rocks. It is nearly uniaxial and as noted by Professor Rosenbusch (to whom some specimens of the rock were sent and to whom the writer is indebted for a very kind letter)

it is the same as the mica of the theralites, with which rocks Professor Rosenbusch regards this dike as related.
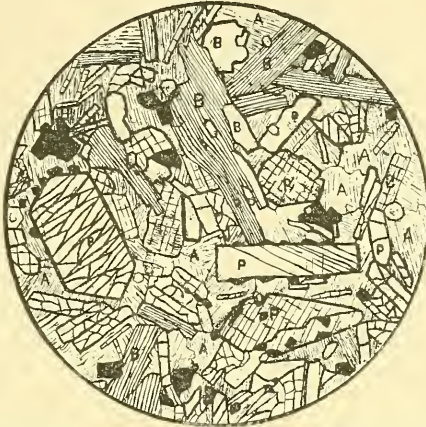
Fig. 2. Micro-drawing of normal dike rock. Actual field 3·5^{mm} in diameter, B, biotite, P, pyroxene, A, analcite. The general shading is uniform for each.

The pyroxene is faint yellow in color and affords extinctions up to 33° as measured. It is apparently identical with the one mentioned in the writer's paper on the elæolite-syenite, as occurring in an elæolite-porphyry (see paper on the Beemerville syenite, p. 66.) The basal sections show the emergence of an optic axis not much inclined to them. The plagioclase is in small rods but is not abundant. The analcite is almost or quite isotropic. It gelatinizes readily and stains a deep tint. Cracks showing the cubical cleavages are often to be seen. If the analcite is secondary after original nepheline, this mineral must have been very abundant. As all the other components of the rock are perfectly fresh, it would indicate that the nepheline has fallen an easy prey to atmospheric agencies.

The spheroidal inclusions offer the point of chief interest. This is heightened because they have been thought to indicate leucite. In the fall of 1890, Mr. O. A. Derby, of Brazil, spent several days with the writer, and on looking over the material from this dike, was at once impressed with its resemblance to certain Brazilian dikes, in which similar spheroidal masses occur, which he has regarded as alteration products after leucite. At his request a specimen was given him and on this are based the remarks upon the rock, which appeared in the Neues Jahrbuch, 1892, ii, p. 153, from Dr. E. Hussak. Dr. Hussak refers to the earlier paper on the "Porphyrite Bosses" already cited, but it should be noted that the materials, on which that contribution

was based, contained no trace of the spheroids, and that they
first appeared in the fresher material of this later discovered
and hitherto undescribed dike—which were shared with Mr.
Derby.   Dr. Hussak calls the rock a leucite-tephrite and adopts
the view originally taken by Mr. Derby.   I have since dis-
covered the same spheroids in some material from the dike in
the Buckwheat Mine at Franklin Furnace, but with different
mineralogical contents as will be noted later.   Inasmuch as the
existence or probable existence of so rare and interesting a
mineral as leucite in association with the Beemerville elæolite-
syenite is an important question, some especial care and delibera-
tion have been exercised in investigating the rock.

As opposed to the leucite interpretation, Professor Rosen-
busch, in a personal letter, remarks the perfect analogy which
the spheroids have with certain others which characterize the
" Kugel-minettes."   As is well-known to petrographers, the
lamprophyric dikes, that contain especially biotite, orthoclase
and some plagioclase and that are called minettes, show a
marked tendency to develop in certain cases spheroids or
" kugeln."   Such have been noted by Cohen* from Odenwald,
by Linck† from Weissenberg, and by Liebe and Zimmermann‡
from Thuringia.   Very nearly, if not quite, the same thing is
figured by Teall,§ in a rock from the island of Car Craig, near
Inchcolm, in the Frith of Forth.   The rock itself is described
as related to the teschenites, a description that fits the Hamburg
dike, perfectly.   The rocks described by Liebe and Zimmer-
mann are the only ones of the German references of great inter-
est here.   Some spheroids (kugeln) they regarded as variolitic
or perlitic structures, while others, that, like those of the Ham-
burg dike, possessed tangential veins of biotite, they rightly
inferred could have had neither an amygdaloidal nor a varioli-
tic origin.   These latter spheroids were formed of crystals of
feldspar irregularly grouped.

In the Hamburg dike the spheroids consist chiefly of anal-
cite.   This is illustrated in figure 3, in which nearly the whole
is of this mineral.   The analcite shows at times the faint cubi-
cal cleavage, as is indicated, and again it lacks it.   The sub-
stance is identical with the general groundmass of the rock.
A few minute specks of magnetite were in it, and one feldspar
rod.   In the upper portion a piece of analcite appeared to have
suffered a further alteration to a brightly refracting rim of cal-
cite and other small dots of the same mineral are seen through-
out the spheroid.   In other spheroids than the one drawn,

* Neues Jahrbuch, 1879, p. 858.
† Idem. 1884, ii, 194.   The reference is a review of the original, by H. Rosen-
busch.
‡ Jahrbuch d. k. Pr. Landesanstalt, 1885, 178–190, but especially 184.
§ British Petrography, p. 191.   Plate xxii, fig. 1.

titanite crystals are grouped about the rims in great numbers.
Dr. Hussak also mentions tiny muscovite scales as probably

Fig. 3.

Fig. 3. Micro-drawing of a spheroid. Lettering as in fig. 2. In addition C is
calcite, F is feldspar. Actual field 3·5ᵐᵐ.

present in the one examined by him. Around more than half
the spheroid are flakes of biotite arranged tangentially, but
neither in this nor in others do they entirely surround the
kernel, which shades out into the general groundmass. The
spheroids so far as observed are always rounded and show no
recognizable outlines of the tetragonal trisoctahedron. They
gelatinize readily and stain a deep tint with fuchsine. An
analysis of several by Professor L. M. Dennis, of Cornell Uni-
versity yielded the results in column I. The water was deter-
mined by direct weight. Column II, contains the same analy-
sis, recalculated after the CO_2 of I, had been combined with the
necessary CaO, to afford $CaCO_3$, and omitted. This reduces
the analysis to a nearer expression of the analcite present.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
H_2O	6·08	6·31	1·46	1·78	8·11	5·01	0·52	0·95
SiO_2	50·52	52·44	55·91	55·06	54·34	55·28	56·48	44·46
Al_2O_3	25·477	26·44	23·88 ⎫	25.26	23·61	21·21	23·14	30·97
Fe_2O_3	0·413	0·43	3·12 ⎭		0·12	0·93	....	2·09
CaO	4·05	1·94	1·22	0·60	0·21	3·70	....	0·66
MgO	....		tr.	0·28	....	0·39	....	....
K_2O	3·41	3·54	6·09	10·34	0·66	2·73	19·78	5·91
Na_2O	8·58	8·90	9·55	7·60	12·95	8·93	0·50	15·61
CO_2	1·71	....	....	....	....	....	....	....
Total	100·240	100 00	101·23	100·92	100·00	98·18	100·42	100·65

I. Analysis of spheroids from the Hamburg dike by Prof. L. M. Dennis of Cornell University.

II. Recalculation of I, 3,886 per cent $CaCO_3$ having been taken out.

III. By E. Hussak of "leucite-pseudo-crystals" from Brazilian Foyaite, Neues Jahrbuch, 1892, II, 146.

IV. By J. F. Williams, "pseudo-leucites" from leucite-syenite dike rock. Magnet Cove Ark. Ann. Rep. Dir. Geol. Surv. Ark., 1890, II, p. 270.

V. By Rammelsberg. Analcite from the Cyclopean Islands. Min. Chem., 804, quoted by Dana.

VI. By Nikolayev of massive analcite from Blagodatsk, Russ. Berg. Jahrb., II, 376, 1881. Zeitschr. Kryst., xi, 392, 1886. Dana's Mineralogy, new ed., 597.

VII. By Rammelsberg, Leucite of Vesuvius. Pogg. Annalen, xcviii, 142.

VIII. By Smith and Brush, Elæolite from Magnet Cove, Ark. This Journal, II, xvi, 371.

A comparison of II and V shows at once that the spheroids are practically analcite, for while the lime and alumina are high, and the silica rather low, the correspondence is extremely close, when it is remembered, that some little plagioclase is confessedly present, and a few other small impurities. The parallel between the soda and potash, and those of the massive analcite, Analysis VI, is very close. In respect to a change from leucite, we have to account for an immense accession of soda, and as regards the corresponding alteration from nepheline, a much smaller accession of potash. But the analysis of elæolite from Magnet Cove gave the alkalies in about the same ratio. In either change outlined above the alkalies have decreased in amount more than is compensated by the increase in water. On the whole, other things being equal, the analysis rather favors original nepheline, than original leucite.

Analcite as an alteration product is well known from both nepheline and leucite. Abundant literature on both changes is cited by Rosenbusch, and hardly needs repetition. It is especially interesting to mention the occurrence of this mineral in the teschenites, in which it is generally regarded as secondary after nepheline. The possibility of both these changes may be taken for granted.

On the one hand in the feldspathic rocks (minettes of Germany and in the mica-diabase or kersantite from Franklin Furnace), what appear to be essentially the same structural phenomena as the spheroids, occur with feldspar centers and biotite rims. No one has thought of leucite in these connections, nor does there seem any reason to do so. A group of feldspar crystals, irregularly aggregated have formed, and have attracted to their common border a tangential rim of biotite.

It is quite conceivable that nepheline crystals, with more or less feldspar might do the same, and subsequently alter to analcite.

On the other hand leucitic rocks in Brazil and elsewhere as cited by Hussak, present analogous phenomena. Leucite often tends to attract tangential rims and inclusions. It is, however, a mineral of comparatively restricted occurrence and although recently demonstrated in two new localities, Arkansas and Brazil, in association with elæolite-syenites, the probabilities are against it until unquestionably shown.

In the writer's judgment the question cannot be settled without the discovery of perfectly fresh material either of nepheline or leucite in the spheroids, and pending this, that the determination of the rock as a leucite-tephrite is premature, and should only be suggested as a future possibility. But if it should be demonstrated in New Jersey in association with the elæolite-syenite, it would form a most interesting addition to the geology of the region.

Geological Department, Columbia College.

Art. XXXVI.—*Underthrust Folds and Faults;* by
Eugene A. Smith, University of Alabama.

In the normal Appalachian fold, it has been repeatedly pointed out that one side of the fold is much steeper than the other, and that these folds have been produced by the action of a force coming from the direction of the Atlantic, and hence from the east and southeast, is very generally admitted. In the great majority of cases these folds have been pushed or lapped over towards the northwest, so that the more gently sloping strata dip toward the southeast, while those with the steeper dip are turned towards the northwest. So also when a fault occurs along the steeper side of the fold, the strata on the southeast of the fault are thrust up over those on the northwest side. Such faulted folds have been called by a variety of names; *overfaults, faulted overfolds,* etc., and the general term *overthrust faults* would also apply to these, especially where the over-riding has been very considerable.

A few instances have come under observation in Alabama, and are mentioned also in other States, where the steeper side of the fold lies to the southeast, and the more gently inclined side to the northwest, and where the fold has been faulted, the gently inclined northwest dipping strata *seem* to have been thrust up over the more highly inclined beds to the southeast.

It was suggested by Mr. A. M. Gibson of the Alabama Geological Survey some years ago, that this peculiar structure, the

very reverse of what we commonly see in the Appalachian
region, was to be explained on supposition that in the folding,
instead of the arch limb of the fold being, as is usually the
case, thrust up over the trough-limb, and lapped over toward
the northwest, the trough-limb was thrust under the crest or
arch-limb, the effect being the same as if, with a force acting
from the northwest, the fold had been lapped over in the usual
way, i. e. in the direction towards which the force was exerted,
or towards the southeast. Inasmuch as we could not easily
account for a force acting from the northwest, and since this
class of folds has demonstrably a common origin with the
folds of the regular Appalachian type, it has seemed to me
that the above explanation is the true one.

In the Appendix to Squires's Report on the Cahaba Coal
Field, I have discussed this type of structure, and have spoken
of the fault as a *reversed thrust fault* in contradistinction to
the thrust fault of the normal type which so greatly prevails
in the Appalachian region.

I have since thought that another name, which would more
clearly point to the mode of formation, would be preferable,
and therefore suggest the following terms, *under fault, fault-
ed under fold, underthrust fault*, as applicable to this type of
structure. These terms correspond with those used by Mar-
gerie and Heim in describing the common type of thrust fault.
In speaking of the causes that determine the direction towards
which a fold is overlapped, these authors say,[*] " Der Sinn, in
welchem eine Falte geneigt oder überschoben ist, hängt
nicht direct von der absoluten geographischen Richtung des
einseitigen Schubes in diesem Stück Erdrinde ab. Verschie-
dene locale Umstände bedingen die Richtung der Faltennei-
gung. Wenn, z. B. die Basis beiderseits einer beginnenden
Falte ungleich hoch ist, so ist die Falte geneigt, sich nach den
tieferen Seite ueberzulegen . . . . Wenn die Falten einer Zone
nicht mehr aufrecht sind, findet man fast immer die grosse
Mehrzahl derselben in gleicher Richtung geneigt oder über-
gelegt."

Fig. 1.   Overthrust.   Fig. 2.   Underthrust.
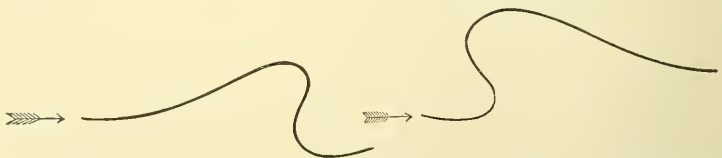
The sketches given, in which the arrows show the direction
of the folding force, will serve both to illustrate the remarks
of Margerie and Heim just quoted, and to show that the two
types of structure under discussion may result from the action
of the same force acting under slightly different conditions.

[*] Die Dislocationen der Erdrinde, p. 81.

Art. XXXVII.—*The Cretaceous Formations of Mexico and their Relations to North American Geographic Development;* by Robert T. Hill.

Mexican geology has been little studied in the light of the broader problems of continental development. In this paper it is proposed to present a few facts in its Mesozoic history which bear upon this relation and are based upon fragmentary literature and upon the observations of the author.

Mexico is a southern geographic continuation of the Cordilleran region of the United States. It consists of an interior plateau or basin enclosed upon the coastal sides by groups of marginal Sierras which are comparable to, although not genetically identical with, the Rocky Mountains and Sierra Nevada systems of our own country. These are known as the Sierra Madre of the east and the Sierra Madre of the west respectively; they unite into a common mass and terminate near the longitude of the City of Mexico. The profile of the southern union of the Cordilleras was the origin of the popular conception that the interior of Mexico is a great plateau; as several writers maintain, it is, really, an intra-mountain basin region between the crests of the Sierras, analogous to and continuous with the Great Basin of our own southern border. The present coastal plains of Mexico are but slightly developed and will not be discussed here.

The geological formations of Mexico may be classified in four general groups: 1. The Pre-Cretaceous rocks which were more or less completely buried beneath the earlier Cretaceous sedimentation and except possibly in Sonora are now only slightly exposed by the erosion of the later formations. 2. The two Cretaceous marine formations which constitute the prevailing sedimentary rocks of all the mountain structure. 3. The Post-Cretaceous eruptives which occur in associations with the Cretaceous formations in the mountain structure. 4. The detrital fresh water deposits which cover the intra-mountain plains and valleys. Of these the events connected with the Cretaceous and early Eocene history of Mexico are the most important.

Two contributions have lately been published upon the occurrence and relations of the Cretaceous formation in Mexico, both of which were founded upon personal observations by the writers in the southern half of the Republic. They differ widely in their conclusions, however, and show that their authors were not entirely familiar with the sequence of the

American Cretaceous beds so harmoniously developed in northern Mexico and in the Texas region. The first of these papers is the excellent monograph by Drs. Felix and Lenk, and summarizes the occurrence of the Cretaceous formation in Mexico as follows :* "The Cretaceous formation in Mexico is divided into two parts. 1. The Upper part (the 'Hippurite' limestone) is characterized by many Hippurites and Radiolite-like forms and numerous Nerineas. This is principally thick light gray sometimes flinty limestone. 2. Below this (they note no break) are light blue-gray sometimes black limestones with local intercalations of marly layers," which we shall hereafter allude to as the Monopleura beds of Tehuacan. The uppermost of these formations or 'Hippurites' limestone they do not describe at length, but passingly refer it to the Upper Cretaceous. The lower or Monopleura beds of Tehuacan, they refer to the Neocomian.

The second paper is by Prof. Angelo Heilprin† of Philadelphia, who, without giving any distinct subdivision or stratigraphic details recognizes only the Hippurites limestone and opposes the careful determination of the Neocomian by Felix and Lenk by saying: "No unequivocal deposits of Lower Cretaceous age—as equivalent of the Gault, Neocomian, etc., have yet been discovered in the Republic; the Mexico deposits represent a horizon not lower than the Cenomanian while the great bulk of the formation is of Turonian and Cenomanian age."‡

The diverse conclusions of these two papers can be explained, as I ascertained in Mexico, upon the ground that neither saw the regions of the full occurrence of the Cretaceous formations of Mexico or the sequence and relations of their divisions.

At most they describe only two of the many horizons in the great sequence of the Lower Cretaceous beds while the equally important but distinct Upper Cretaceous formation or Meek and Hayden series entirely escaped their observation.

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* Beiträge zur Geologie und Paleontologie der Republik Mexico, von Dr. J. Felix und Dr. H. Lenk: in two parts, Part I, Leipzig, 1890 ; Part III, Stuttgart, 1891 (Part II not published).

† The Geology and Paleontology of the Cretaceous Deposits of Mexico, by Prof. Angelo Heilprin, Proc. Philadelphia Academy of Natural Sciences, 1890, pp. 445–469.

‡ Prof. Heilprin also concludes that "No true Lower Cretaceous deposits exist or have so far been identified in either Arkansas or Texas, the Lower Cretaceous, so-called (Comanche Series, etc.) being not older than the Cenomanian (Middle or Upper Cretaceous)." I cannot here discuss this conclusion of Prof. Heilprin's concerning a region he had not seen and with whose unpublished paleontology his writings show unfamiliarity. While the upper part of the Comanche Series is undoubtedly of Middle Cretaceous affinities he seems unacquainted with the existence of the Lower Trinity division with its Glen Rose fauna of Neocomian mollusks and Potomac, or Wealden, plants.

The Lower Cretaceous Formation.

The Mountain Limestone.—The most common and striking material in the composition of the Mexican mountains is the firm stratified limestone which, with the eruptive rocks, forms the chief mass of all the Sierras. It constitutes the prevalent sedimentary rock of nearly all the mountains and in the southern States extends in intermittent patches from ocean to ocean. Its strata produce the peculiar scenic effects of the mountain topography and its products are the principal material of the later Basin deposits. Lithologically the lime stone consists of blue and grey, sometimes nearly black, beds of great hardness and density, and indistinguishable lithologically from the Paleozoic limestones of the Silurian and Carboniferous formations of the European and Appalachian regions to which they have frequently been referred from this resemblance.*

The strata vary in thickness from a few inches to a hundred feet. They are so broken and distorted by the mountain structure (fig. 1) and disconnected by the concealment of the

1.

Example of folding of Comanche limestone in Eastern Cordilleras.—Section northwest of Monterey.

basin deposits that it is impossible to give an idea of their total thickness or to obtain a complete section of the series in any one locality. In the eastern Sierra Madre in the valley of Miquehuana where the base of the series was studied by Mr. McGee and the writer, twenty thousand feet of the limestone could be seen in succession in the continuous strata between that point and the Hacienda El Carmen to the westward, all of which was only the lower portion of the great formation. This enormous thickness of the mountain limestone is further indicated by the frequent sections of 5000 feet of portions of the formations often visible in the tilted mountain fronts. Even at the Rio Grande near Presidio del Norte the same limestones as shown by White, attain a thickness of at least 4000 feet.† The persistent characteristics of this limestone with

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* The details cannot be given here of the innumerable references of the Cretaceous mountain limestone to Paleozoic age. Nearly always it was mistaken for Silurian or Carboniferous by mining engineers, and early writers on the country. With the exception of certain localities in Sonora given by R. Remond, it is exceedingly doubtful if there are any limestones in Mexico of Paleozoic age.

† This Journal, xxxviii, p. 440, 1889.

abundant paleontologic evidence show that it all represents the same great geological formation of Lower Cretaceous age instead of Upper Cretaceous and Paleozoic age, as frequently asserted, and that it is the southern continuation of the greatly altered, thickened and folded beds of the more chalky limestones of the Comanche Series of the Texan region.

The latter can be continuously traced from the region of their typical occurrence in the sub-coastal plains of central Texas to the mountains west of the Pecos (notably the Quitman mountains) where they are intensely folded and altered from their white chalky aspect into the firm blue limestones above mentioned. This limestone becomes the characteristic mountain rock from Trans-Pecos Texas southward into Mexico where they have been seen by the writer in the mountains in the States of Coahuila, Chihuahua, Nueva Leon, Tamaulipas and San Luis. From the writings of many authors the wide extent of the "Hippurite limestone," as it is called by Heilprin, can be traced over the States of Sonora, Coahuila, Nuevo Leon, San Luis Potosi, Hidalgo, Vera Cruz, Puebla, Mexico, Morelos, Guerro, Jalisco, Queretero, Colima, Aguas Calientes, and Mihoacan, which with the northern border States previously mentioned and Trans-Pecos, Texas, makes its distribution very general over the Republic of Mexico. From the abundant paleontologic evidence there is no doubt but the outcrops in northern Mexico are identical with similar masses described in the southern end of the plateau region by Barcena, Castillo, Virdet, Heilprin, and Felix and Lenk.

Owing to the great alteration the limestone has undergone the fossils, with the exception of a few genera, are usually much obliterated or converted into masses of calcite, but in most cases the form of some familiar Gryphæa, Exogyra, Nerinea, or Rudistes of the Comanche series can be determined. This alteration of the chalky Cretaceous rocks of Texas into the Paleozoic-looking limestone of northern Mexico was first noted in this Journal by Kimball[*] who called attention to the fact that the mountain limestones of northern Chihuahua were of Cretaceous instead of Paleozoic age as had been asserted by Wislizenus,[†] and others.

Subdivisions.—Notwithstanding the wide distribution of this formation throughout Mexico no detailed section of it has been presented and no attempt made to define its subdivisions with the exception of the recognition by Felix and Lenk of the two horizons: the "Hippurites" limestone and Monopleura (Tehuacan) beds above mentioned; while the latter

[*] Notes on the Geology of Western Texas and of Chihuahua, Mexico. This Journal, Nov., 1869.
[†] Quoted by Kimball.

division has escaped the observation of the other writers. Not only has the mountain limestone of Mexico these two subdivisions but I have found all the broader divisions of the Comanche Series represented in it.

The so-called "Hippurites limestone," however, may be accepted as a datum from which to trace the sequence of the overlying and the underlying horizons as shown in the table on page 324. Heilprin and other writers describe its characteristic fossils as consisting of the "Hippurites," Radiolites, and Nerineas—genera which do not range higher in the Comanche Series than the Caprina limestone of Shumard with which horizon the Mexican "Hippurites" limestone is largely identical.

The Tehuacan or Monopleura beds which Felix and Lenk show underlying the "Hippurites" limestone in Puebla are a distinct lower horizon of the Comanche series to which the writer has recently called attention in the Texas region under the name of the Glen Rose beds of the Trinity division.* From the lower bed they report twenty-eight genera of invertebrates (forty-six species) characterized by the corals. Pleurocenia, Cladophyllia and Astrocenia; a single echinoderm (Cyphosoma) and the Mollusca: Monopleura, Nerinea, and Tylostomas of the *Natica pedernalis* type. All these genera are abundantly found in the Texas Cretaceous and with the exception of Cyphosoma only in the Fredricksburg and Trinity or lower divisions of the Comanche Series and are its characteristic distinguishing forms. In both Texas and Mexico they occur below the "Hippurites" or Caprina limestone, as described in Mexico by Felix and Lenk, and under similar stratigraphic conditions except that in Mexico the limestones have been more altered by mountain movements. The molluscan genera are all strongly characteristic of the Neocomian of Spain and Portugal. These Monopleura beds are near but not quite at the base of the Mexican Cretaceous; northward they outcrop in several places. The writer has seen them ten miles east of Bustamente, in Nuevo Leon, on the Tropic of Cancer, and in the Santa Rosa mountain mass of Coahuila. Near the first mentioned locality about ten miles to the northeast in the valley of Miquehuana they are underlain by a series of still lower beds between which there is no stratigraphic demarcation. These lower beds consist of alternating strata of arenaceous calcareous clays becoming pack sands with quartz pebbles towards their base and rest unconformably upon the early Mesozoic red beds. These basement strata of the Comanche Series in Mexico strongly resemble in composition,

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* The Comanche Series of the Texas Arkansas Region, Bull. Geological Society of America, vol. ii, pp. 503–528.

arrangement and littoral characters the Trinity beds of the Comanche Series in Texas, but contain one genus, Rhynchonella, and many different species including several described by Felix and Lenk from southwest of Tlaxioco including *Hoplites tenochii, H. neocomensis* D'Orb., *Tylostoma princeps* White, and a large Terebratula very much resembling the form figured as *Inoceramus montezumi* by Felix.

Similar basement beds of the mountain limestone are reported at Catorce and near San Luis Potosi. From the latter locality Nikitin has noted[*] a fauna resembling that of Miquehuana, but also containing the California and Russian species of Aucella and refers the beds to the upper Jurassic. Near Bustamente these basement beds are metamorphosed into schists owing to the intense folds of the mountain as seen by McGee and the writer.

Felix presents strong arguments for the Cretaceous age of the basement beds, notwithstanding the somewhat Jurassic facies. The basement Trinity beds of the Texas region are clearly the Wealden phase of the Neocomian and these Miquehuana beds are this southward continuation and confirm the fact that the great littoral of the subsiding land in earliest Cretaceous time advanced from the south northward.

The " Hippurites" limestone is not the top of the Lower Cretaceous formation in Mexico, much less the top of the Upper Cretaceous or the equivalent to the Upper Cretaceous of the United States as supposed by Drs. Felix and Lenk, for in northern Mexico at various places I have found it overlaid by the beds of the Washita division of the Comanche Series and this in turn overlaid by the Upper Cretaceous of Meek and Hayden. Near Monclova and Santa Rosa in Coahuila the Washita beds appear as thinner limestone flags and shales overlying the lower limestones and contain the characteristic gryphæas and ammonitidæ of the division. The beds of this division cross into Mexico at several places along the Rio Grande. Opposite Del Rio Texas the *Exogyra arietina* zone of the Denison beds of the Washita division extends far into Mexico. West of El Paso at the international boundary the beds of the Washita limestone division occur on both sides of the river, the famous pass of the Rio Grande at that point being in rocks of the Fredericksburg and Washita division. The Washita beds here include both the Fort Worth and Denison subdivisions and are largely developed in the mountains of northern Chihuahua. Gabb[†] in 1863, before the stratigraphic identity of the Comanche Series had been made known, recognized the extension of the Texas Cretaceous into

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[*] Jahrbuch für Mineralogie, 1890, ii, pp. 273–274.
[†] Geological Survey of California, vol. ii, Sec. III, p. 255.

Sonora from a collection of fossils made by Remond. The fossils are the characteristic fauna of the latest or Washita division of the Comanche Series and resemble the variations seen at El Paso and Juarez and throughout the northern littoral of the latest beds of the Comanche Series and belong neither in the Upper Cretaceous formation nor below the Caprina (Hippurites) limestone, as Prof. Heilprin indicates in the paper previously mentioned.

From these data it is evident that the three prominent stratigraphic divisions of the Comanche Series are recognizable in Mexico as in Texas and when the whole region is studied more detailed resemblances of horizons will be discovered.

Age and Homotaxial relations of the Comanche Series in Mexico and Texas.—The diverse opinions concerning the age of the Mexican Cretaceous have been indicated. Felix and Lenk maintain the Neocomian age of the Tehuacan beds and have little to say concerning the so-called "Hippurites" limestone. Most of the Mexican geologists speak of the Hippurites limestone as probably Upper Cretaceous. Prof. Heilprin emphatically maintains the Upper Cretaceous age not only of the Mexican but of all the Texas Cretaceous. This conclusion is based upon the same evidence that caused Dr. Rœmer to make the same mistake in Texas, to wit: the occurrence of the alleged "Hippurites" and Nerineas in the limestone, and Prof. Heilprin's mistaken idea that the writer of this paper holds that the faunas of the Fredericksburg and Washita divisions of the Texas section represent the Neocomian instead of the Glen Rose and Trinity beds, with the faunas of which he (Prof. Heilprin) is evidently unfamiliar inasmuch as they have not been fully published. The writer has endeavored to reserve his views on the homotaxial relations of the North American Cretaceous for a future and exhaustive publication and can say but little concerning them now. In the first place the genus Nerinea which Prof. Heilprin and others consider a characteristic genus of the European Senonian, ranges in Europe from early Jurassic time to the top of the Cretaceous, while in America it extends no higher than the Caprina limestone of the Fredericksburg division of the Lower Cretaceous, not a single species appearing in the great Upper Cretaceous or Meek and Hayden section of the United States. Furthermore this genus has many sub-generic features each with its peculiar stratigraphic range and all the species described from Texas by Rœmer and Conrad and from Mexico by various writers are of the characteristic early Cretaceous type. The occurrence of the alleged "Hippurites," however, prevented Rœmer, Heilprin and others from understanding the true position of these beds, notwithstanding the testimony

of the associated faunas. This genus is characteristic of the Upper Cretaceous of the world, but unfortunately there are no true Hippurites in the Lower Cretaceous of the United States while their occurrence in Mexico is not proven. All the species so-called belong to the lower ranging genera Sphærulites and Radiolites which in Europe especially in Portugal* have the identical position they have in the Texas-Mexican region, i. e. they occur in a narrow zone between the true Monopleura and Caprina beds of the Neocomian and the Gault just as it ranges in Texas between the Monopleura and Caprina beds of the Glen Rose (Neocomian) and the Washita (Gault) division. Dr. Rœmer distinctly states in his description of "*Hippurites*" *texanus* that he is in doubt whether to refer it to the genus Hippurites or Radiolites, and from careful studies of abundant material in my collection it can be seen that the genus is clearly not Hippurites, but has strong resemblance to the Sphærulites of Portugal.

Felix and Lenk in their careful presentation of the Tehuacan or Monopleura beds (Glen Rose beds of my Texas section) show beyond doubt their Neocomian equivalency, and refrain from correlation of the "Hippurites" limestone with the beds of northern Europe.†

If those who doubt the Neocomian position of the faunas of basal half of the Comanche Series will compare my unpublished collections in the possession of the Texas Geological Survey and at my residence in Washington with the beautiful Cretaceous faunas of Portugal as illustrated by

* The so-called "Hippurites" of the Texan (Comanche) Cretaceous are entirely different in specific characters from the well known Hippurites of the Upper Cretaceous of Europe, but are of the genera Sphærulites and Radiolites of Lamarck which in Europe begin in the Lower Cretaceous. It is unfortunate that no systematic study of the biological relations of the American forms has been attempted None of the aberrant molluscan forms like Monopleura, Requienia, Plagioptychus, Caprina, Rudistes, and the alleged Hippurites range higher in the Texan Cretaceous than the Caprina limestone of the Comanche Series and only the entirely distinct generic form called *Radiolites Austinensis* type (Rœmer) has been found in the Upper Cretaceous, while no Hippurites especially of the European type of *H. cornu-vaccinum* have not been found in America.

† Dr. Rœmer, who committed the same error of placing the "Hippurite" bearing Lower Cretaceous of Texas in the Upper Cretaceous of Europe as others who have visited Mexico are now doing with the Hippurites limestone of that country, also wrongly concluded that the Monopleura fauna sent him from near Austin was from the Upper Cretaceous limestone instead of from the Caprina limestone and Glen Rose beds. See "Ueber eine durch die Haufigkeit Hippuriten Artigen Chamiden ausgezeichnet Fauna der Ober Turonienkreide von Texas. Palcontologischen Abhandlungen. IV Band. Heft 4. Berlin, 1887. Reviewed in this Journal by the writer in vol. xxxvii, 1889, pp. 318–319. Although admitting that it was different from anything he had known in Europe under the impression that it came from the Austin chalk, which has Turonian facies, he entitles it a Turonian fauna and so describes it. In all European palcontological treatises, notably Zittel and Steinman, these are shown to be characteristic genera of the Neocomian.

Choffat* they will no longer doubt the homotaxial identity of the beds but will be astonished at the wonderful and striking generic identity. The fossil beds of the Washita division or upper part of the Comanche Series from which Prof. Heilprin draws his conclusion that there is no Lower Cretaceous in America are Gault, and not Cenomanian as he alleges, although Marcou referred them to the Neocomian.† Until the writer's paleontological data can be published in full it will be difficult to eradicate the existing erroneous impressions concerning the North American Cretaceous but he strongly maintains that we have in this country in the Atlantic sedimentation of both Cretaceous Series a complete representation of the principal divisions of the Cretaceous period in Europe, presenting a remarkable homotaxial resemblance in many of their subdivisions, and which, instead of upsetting the canons of paleontologic and stratigraphic laws, as has been maintained, verifies the great principle that sedimentation and life on both sides the Atlantic basin presented in Cretaceous times the same generic resemblances and specific variations that it has in all time and that it does to-day, and that the American Cretaceous formations laid down in the open Atlantic waters present far more intimate resemblances to those of similar deposition in Europe than they do to those of the Pacific border only a few miles distant.

It is evident that the Lower Cretaceous or Comanche Series in Mexico verifies some of the principles already announced concerning it in our own country, to wit: that the deposits there are the deeper water sediments of an oceanic border which had its littoral across the southern end of our own republic, and that they record the progressive encroachment from the southward of the sea upon the Pre-Cretaceous (Jurassic) North American land accompanied by subsidence of the latter. As shown by the rapid shallowing of the sediments in the Washita sub-epoch at the close of Comanche time the profound Lower Cretaceous subsidence reached its culmination during the Fredericksburg sub-epoch and the northern littoral ferruginous beds of the Washita division probably marked the northern border of this Lower Cretaceous or Comanche ocean. This rapid elevation at the close of the Comanche also explains the disappearance of the aberrant Chamidæ and Rudistæ from sediments of later age in the Comanche series than the Caprina limestone, while some of the forms continue to the top of the Gault in Europe.

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* Recueil de Monographies Stratigraphiques sur le Système Cretacique du Portugal, par Paul Choffat. Lisbon, 1883.

Extent and History of the Comanche Sedimentation.

The Lower Cretaceous deposits of Mexico extend from the Pacific to the Atlantic and clearly show that during the Comanche sub-period the waters of the two oceans were united and separated the north and south continents into two islands. The southern shore line cannot be minutely traced at present owing to our indistinct knowledge of South American geology, but there is abundant evidence to show that it covered much of the western coast of Peru, Chili, Bogota, and the northern States of South America reaching far into the present area of Andean uplift against the nucleal Archæan and Paleozoic area of that continent, as shown by the occurrence of the typical and peculiar Comanche series, *Schlœnbachia peruvianus, Buchoceras pedernalis, Gryphœa pitcheri, Exogyra texana, Patellina (Orbitulina) texana* and other forms. The Comanche sedimentation extended into northeastern Brazil where its typical fauna has been described from Sergipe by Hyatt[*] but it does not appear in more southern faunas described by White.

The North American border of this Comanche sedimentation can be definitely located around the coastward margin of the old Appalachian region to near Marietta south of central Indian Territory, but west of this point it can be located at only widely separated places because of the overlapping of the Great Plains and basin formations and the disturbances of the Cordilleran region. In northeastern New Mexico the thin littoral beds of the Comanche are exposed in the strata of Tucumcari Mountain and the adjacent Llano Estacado.[†] They are next revealed at El Paso where the attenuated and highly tilted beds again outcrop against the foot of the Organ and Monument Mountains on both the Mexican and American sides of the Rio Grande. The most western localities recorded are Ariviche, and Sahuaripa in Senora from where Gabb described its characteristic uppermost or Denison fauna. Except a locality described on the southern line of Kansas no trace of the great Comanche sedimentation has been found and every possible interpretation of the littoral sediments shows that an adjacent land area must have existed over all the Appalachian Great Plains and Cordilleran areas north of a line connecting these points during that epoch, as shown upon the accompanying map.

The central portion of the Mexican plateau where the Comanche Series attains a thickness of more than twenty

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[*] Mentioned on pages 385–393 of Hart's Geology and Physical Geography of Brazil.

[†] See " On the Occurrence of Artesian and other Underground Waters," etc., by Rob't T. Hill. Final Report Artesian and Underflow Investigations. Senate Doc. 41, 52d Cong., vol. iii, p. 129, Washington, May, 1892; also Third Annual Report Texas State Geological Survey, pp. 152–154. Austin, Sept., 1892.

thousand feet was apparently the medial part of the wide oceanic strip that separated the two American continents in early Cretaceous times and probably the region of greatest deposition. This early Cretaceous subsidence and the accompanying accumulation of sediments was so great as to almost obscure the pre-Cretaceous history of the Mexican peninsula for to-day there are but few places where these limestones, even though aided by the enormous disturbance, have been eroded through to the pre-Cretaceous floor; yet by and of these there is enough evidence to show that the Mexican peninsula had its outline in even earlier geologic time.

The second great event in the history of the Mexican Cretaceous was the elevation of the sea-bottom and the return to land conditions of the region at the close of the Comanche sub-epoch,—an event most important in the interpretation of the history of all the American Cordilleran region and one which has been overlooked owing to the more distinct land making after the close of the Upper Cretaceous. The evidence of this mid-Cretaceous land is : (1) The unconformable deposition of the Upper Cretaceous upon the Comanche Series and consequent discordant overlaps of its western margin. (2) The entirely different outline of the western littoral of the Upper Cretaceous deposits of the Atlantic deposition in the Cordilleran region as shown upon the map, showing that there had been disturbances of the continental area in the Cordilleran region between the intervals of their deposition. (3) The evidence of an extensive land area during Upper Cretaceous time throughout the great basin region of Mexico and the United States, from which was derived the vast accumulation of Upper Cretaceous littoral plant-bearing sediments along the eastern margin of this mid-Cretaceous land. The entire dissimilarity and otherwise inexplicable difference between the faunas of the Atlantic and the Pacific Upper Cretaceous sedimentation south of the Canadian border indicate a continental barrier between them in Cretaceous time.

S. F. Emmons* has recognized in the Colorado division of the Rocky Mountains several areas of what he calls "Jurassic land" and cotemporary movements. These may have extended into the early Cretaceous, for the earliest marine datum of subsidence in that region by which he was able to fix the date of this land area was the basement littoral of Dakota of the Upper Cretaceous.

Between the two epochs the ocean over the Texan region no doubt receded nearly to its present outline as shown by the area traversed by the Dakota littoral from eastern Texas to

* Orographic movements in the Rocky Mountains, Bull. Geol. Soc. Am , vol. i, pp. 245–286.

Wyoming, preceding the Upper Cretaceous subsidence which covered the Great Plains and Rocky Mountain region, while the heart of the Great Basin and the central part of Mexico remained above sea level—apparently a continental divide traversing the heart of the entire central basin region of the Cordilleras from Tehuantepec to the British boundary—and possibly causing the great difference between the marine molluscan faunas of the Pacific region and the Atlantic during Upper Cretaceous times. This seldom appreciated and little understood western continental strip represents to the writer a most important stage in geological history, although but little topographic trace of it remains, for it was this land that furnished the vast sediments accumulated along its eastern front in Cretaceous and Laramie time which were folded up in the last grand epoch of Rocky Mountain making.

2.

DISTRIBUTION
of
Known Cretaceous Outcrops
in
MEXICO
By
Robert T. Hill

Montana Laramie
Colorado Benton
Comanche Series
Washita Division
Fredericksburg Division
Trinity Division

The data on above map are adapted, after slight modification, from Señor Antonio Castillo's excellent Geological Map of Mexico. Mexico, 1889.

The Upper Cretaceous Formation in Mexico.

All writers on the Cretaceous formation in southern and central Mexico have assumed that the mountain or "Hippurites" limestone was the top of the Cretaceous series of the country and have seemed unaware of the existence above it in northern Mexico of the true or Upper Cretaceous formation,

or Meek and Hayden's series, entirely different in lithological and paleontological aspects. Dr. C. A. White and the writer have frequently mentioned this formation in the Rio Grande region, but no attempt has been made to clearly define its geographic limitations.

In distinction from the characteristic mountain limestone of the Lower Cretaceous, the Upper Cretaceous formation in northern Mexico is characterized by its more shallow deposits of ferruginous limestones, clays, sands, and lignite all indicative of a more shallow origin than the purer lime beds of the main part of the lower series. The beds occur in the northeastern border States of Chihuahua, Coahuila, and Tamaulipas, and are at least 5000 feet thick ; the complicated structure of the region does not permit the entire section to be measured in any one locality. The areal development of this formation is principally along the mountains composing the east front of the Cordilleran region between Presidio del Norte at the great bend of the Rio Grande and Tampico and along the margin of the plains adjoining them on the Atlantic side as shown in fig. 2. They are upturned in the mountain structure with the Lower Cretaceous limestones, but owing to their softer nature they are usually degraded from the summits down to the level of the plain where they occur as foot hills of the Sierra de Santa Rosa, Sierra Candella, Sierra Lampazos and other ranges. It is especially developed in the Rio Grande embayment between the great Balcones fault of Texas and the eastern front of the Coahuila Cordilleras. It continues northward in the structure of the Trans-Pecos mountains of Texas and New Mexico and in the Rocky Mountain system as the typical Upper Cretaceous and Laramie series of western United States. Eastward it continues as the Cretaceous and Eocene Lignitic formations of the southern coastal plain.

The subdivisions of this series, which as a whole is a continuous deposition, are not distinctly differentiated in this southwestern region ; the deposits apparently represent the southwestern littoral of the great interior arm of the Atlantic in Upper Cretaceous time and do not extend across the Mexican peninsula to connect with the Pacific as did the Lower Cretaceous waters. The Dakota horizon has no true representative in the region, south of the 32nd parallel, but the Benton shales and clays with the typical *Inoceramus problematicus* and Scaphites occur near Juarez and in El Paso, Texas. The chalky beds of the Niobrara sub-epoch are also missing and the whole of the Niobrara-Pierre of the series is apparently represented by thinner ferruginous clays and impure limestones marked by a commingling of the characteristic fauna and the *Exogyra ponderosa* of the Southern States.

The Eagle Pass beds which White correlated upon good grounds with the Fox Hills stage have the characteristic aspects of that formation in northern Coahuila that they have in the Rocky Mountain region, and imperceptibly grade into the Laramie phase with its characteristic fauna.   The latter, in

3.

GEOLOGIC OUTLINE OF NORTHEASTERN MEXICO
Showing relation of Atlantic Coastal Plain, Cordilleran and Great Plains Region
BY
R T Hill

Topography modified from map by Mexican International Railway

turn, into the Eo-Lignitic beds of the Southern States, the whole having a unity of littoral lithologic features, thus indicating that the whole of the Upper Cretaceous and basal Eocene from the Dakota to the Claiborne inclusive, was a continuous epoch of sedimentation without any serious disturb-

ance of continuity until towards its close, and deposited at a marine base level now occupied by the eastern masses of the Rocky Mountains and eastern Sierra Madre.

None of the geologists—Schott, White, Penrose—or the writer, who have seen the continuous section of this formation exposed along the Rio Grande, from the unmistakable Ammonite horizon of the Cretaceous at Eagle Pass to the typical *Cardita planicosta* Claiborne Eocene horizon at Laredo, Mexico, have defined or recognized any distinct break in the continuity of sedimentation, but on the contrary every evidence of rapid estuarine or littoral deposition. In the midst of this section occur the fossiliferous horizons which White* has determined to be typical Laramie species, identical with those of the Colorado region. Some of these for instance, *Ostrea wyomingensis* Meek and *Anomia micronemia* Meek begin in the Ammonite-bearing Upper Cretaceous of Santa Rosa and Eagle Pass.

The Montana-Laramie Eocene portion of the formation occupies the vast synclinal basin of the Rio Grande, east of the great bend, which I have termed the Rio Grande Embayment, outcropping beneath the detrital deposits of late Tertiary and Pleistocene age. This synclinal is the contact of the Great Plains, Coastal Plains and Rocky Mountain regions as shown in fig. 3. The strata at the southern edge of the valley near Santa Rosa can be seen at the foot of the mountain upturned apparently conformably with the Comanche limestone which composes its mass, thus showing that the beds were involved in the great mountain movement of the east front of the Mexican Cordilleras. Likewise the strata of the Montana Laramie division are found across the front ranges of the Cordilleras, as shown upon the map, in the great enclosed intra-mountain basin between the Sierra Mercado of Monclova and the Sierra Candella, west of Lampazos, where three thousand feet of the strata occur in sub-vertical escarpments of hori-

4.
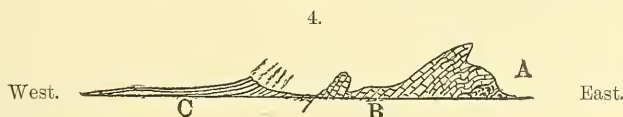
Cross section of the Sierra Candella west of Lampazos, Mexico, showing participation of Laramie strata in folding of the earlier Cordilleras. A, Intrusive Diorite. B, Comanche limestone. C, Laramie beds.

zontal or slightly dipping strata (see fig. 2). Around the edges of this synclinal basin the Laramie strata are again upturned as if they once extended over the mountain mass and

* This Journal, vol. xxv, 1883, p. 207.

contain the typical Laramie fauna of Corbiculidæ, *Ostrea wyomingensis*, and *Anomia micronemia*. Still southward, in another interior valley extending from Paderon—a village east of Venaditos—west to Jornos, the Montana-Laramie beds form similar foot hills against the interior border of the main mass of the Saltillo-Parras flank of the Eastern Sierra Madre.

On the east front of the Sierra Candella near Lampazos are two vast mesas of this formation—*Mesa Catahuana* and *Mesa Patrias*—the original Laramiè localities where White first studied this formation in Mexico. It occurs thence southeastward as far as Tampico.

The participation of the strata of the Upper Cretaceous-Laramie series in the mountain movements of the eastern Cordilleras is further shown to the southward in the great Rinconada passes of the eastern Sierra Madre between Monterey and Saltillo where thousands of feet of the medial and lower beds of the series are folded in the mountain structure. The writer was not able to collect minutely from these beds but found many of the characteristic Inocerami and *Exogyra ponderosa* of the Upper Cretaceous showing the participation of the medial beds of the Upper Cretaceous in the movement as well as that of the Laramie.

While there is no doubt that there were some upland bodies of water upon the western continent during the Upper Cretaceous and Laramie epoch, especially during the emergence of the land in the latter part of the epoch, it can hardly be said that these sediments are fresh water deposits in the sense that they were not laid down at marine base level, for there is every evidence that the larger part of the Laramie and Upper Cretaceous deposits along the whole front of the eastern Cordilleran region both in the United States and in Mexico were laid down at marine base level adjacent to the great western continent that existed over the nucleal Cordilleran region at that time, and that the idea of one great enclosed Laramie inland sea must be abandoned.[*]

This Upper Cretaceous Eocene (Laramie) deposit undoubtedly represents the last littoral of the Atlantic along the eastern front of the older Cordilleran region prior to the last great folding, for none of the Claiborne Eocene fossils such as occur in the same series of sedimentation above the Laramie

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[*] It is impossible here to discuss the Laramie question at length. Stanton and Cross in this Journal have both recently shown that several distinct formations have been confused under this name. In this paper the word is used to describe those sedimentations that insensibly succeed the last known beds containing unmistakable Cretaceous fossils and which like them were laid down at marine base level and containing estuarine, marine and fresh water fossils described by White and Meek under the name Laramie.

beds at Nuevo Laredo, are found in the folded mountain structure, as are those of immediately preceding beds, and it is probable that the age of the last folding of the Cordilleran eastern front can be accurately placed after the close of the Laramie, during the Eocene in Mexico, as it is in the Rocky Mountains. The movement no doubt began during the middle of the Upper Cretaceous, when an elevation of the shore line is indicated by the shallowing of the sediments, and was accelerated until the close of the Laramie, as is indicated in the enormous accumulation of littoral latest Cretaceous and Laramie sediments along the whole eastern half of the Rocky Mountain and eastern Sierra Madre region, finally culminating in the last great folding epoch immediately succeeding the latter time, thus completing the cycle of subsidence and elevation that took place between the Comanche, or mid Cretaceous and the Miocene. The waters of the arm of the Atlantic, or attenuated Gulf of Mexico receded from the present areas of the Great Plains for the last time, and the continental outline of to-day was practically defined.

How different is the land record of the Upper Cretaceous epoch from that of the Lower Cretaceous. It is true that during both periods the eastern margin of the continent again subsided and the waters of the ocean invaded large land areas; but the shore line of this Upper Cretaceous-Laramie was entirely different in the unstable Cordilleran region from that of the Comanche epoch. During the latter epoch it was the southern margin of the continent, or North American island, that subsided, but in Upper Cretaceous it was the Central or Great Plains region that went down, a great arm of the sea having extended inland between the Cordilleran and Appalachian lands, nearly severing our continent into two great islands, as has been shown by Prof. Dana, and culminated in the great littoral sedimentation of the Montana-Laramie epoch along the east front of the narrow land strip of the nucleal Cordilleran region. Nowhere in Mexico or the United States were the waters of the two oceans connected, and while the whole epoch was terminated in Eocene times by the last grand peripheral folding of the Cordilleras as seen in the Rocky Mountain front ranges from Montana to Mexico.

The accompanying table shows the sequence of the Cretaceous formations of Mexico, and their relations to those of the United States.

KNOWN POSITION OF THE CRETACEOUS AND RELATED FORMATIONS IN MEXICO.

Mexican occurrence.	Occurrence in United States.	Homotaxial Relations.
MIOCENE AND LATER. Detrital Upland deposits of Interior Basins and Cordilleran Slopes.	Genetically related to similar deposits of the Great Basin region, the Great Plains, and of the Texas Coast.	
EOCENE. Claiborne-Laramie beds of Nuevo Laredo, and Rio Grande Embayment.	Continuous on the American side of the Rio Grande.	Eocene and Transitional Cretaceous-Eocene, 7.
UPPER CRETACEOUS. Laramie-Montana beds of Eastern Cordilleras and enclosed basins of Coahuila.	Same as similar beds in Trans-Pecos, Texas, New Mexico, etc.	Transitional Cretaceous Eocene, and Senonian, 1, 2.
Beds at Juarez, and other points in Northern Chihuahua, Coahuila, and Carnero Pass, near Saltillo.	Continuation of Texas beds belonging to Colorado Division.	Turonian, 2, 4.
	(No beds of Dakota age have been recognized in Mexico.)	Cenomanian, 2, 3.
LOWER CRETACEOUS. Arivieh, Juarez, and south of Tampico. Foothills of Santa Rosa and Monclova Mountains	Washita Division, Denison beds c. " Fort Worth beds b.	Gault, (Albian) 6, b, d.
The so-called Hippurites Limestone of Mexico, together with adjacent barren limestones.	Fredericksburg Division. Caprina limestone, and associated Comanche Peak beds.	Transitional and Upper, 6, a.
The Monopleura beds of Tehuacan, Bustamante, Topo Chico, etc.	Trinity Division, Glen Rose beds.	Middle, 6.
The Miquihuana beds, and alleged Jurassie of Catorce, San Luis, etc.	" " Trinity beds.	Lower, 6.

Neocomian, 5, 6.

Authorities: 1, Sir Chas. Lyell; 2, F. B. Meck; 3, Leo Lesquereux; 4, F. Roemer; 5, Felix and Lenk; 6, the writer; 7, Dr, C. A. White. a, Senonian, Heilprin, Roemer. b, Neocomian, Mareou. c, Jurassic of Pyramid Mountain, Mareou. d, Cenomanian, Heilprin.

ART. XXXVIII.—*On Electrical Oscillations of Low Frequency and their Resonance;* by M. I. PUPIN, Ph.D., Columbia College.

Part I. *On the Production of Simple Harmonic Currents of Constant Frequency by Electrical Resonance.*

THE sensitiveness of the telephone for exceedingly small alternating currents is well known. It is probably as great as that of the most delicate Thomson galvanometer for direct currents. Just as this instrument, so the telephone is especially suited to zero-methods. But the telephone does not enjoy that popularity in the precision room which its direct current rival, the Thomson galvanometer, enjoys, although the field of physical research in which alternating currents must necessarily be employed is very extensive indeed. The fault lies with our alternating currents and not with the telephone. The alternating currents which the ordinary induction coil as employed in physical laboratories produces is far from being a simple harmonic current. The consequence is that in very many cases the zero method, for which the telephone is especially suited, has to be abandoned, and the minimum method substituted for it, which, of course, is a poor substitution.

Being engaged in a research in which I had to employ alternating currents I tried, for reasons just given, to devise some method of producing simple harmonic currents of constant frequency, the frequency to be easily and very accurately determinable. The following is my solution of this interesting problem:

A. *On the Production of Alternating Currents of Constant Easily and Accurately Determinable Frequency.*

My earliest solution of this problem consisted in producing an alternating current in the secondary of a very small transformer by making and breaking very rapidly and at a constant rate the primary. The interruptor of the primary current consisted of the following arrangement:

A stiff brass wire was stretched between the pole-pieces of a permanent horse-shoe magnet. The wire was supported, just as in a monochord, on two hard rubber bridges, and by varying the distance between the bridges and the tension of the wire it could be made to vibrate any note between about 60 and 1,000 complete vibrations per second. The middle part of the wire was between the pole pieces of the permanent magnet and carried just a short distance outside of the pole-pieces, a short, thin amalgamated copper wire which dipped into a mercury cup once during each vibration. At every dip it

closed the circuit of a gravity cell and the action of repulsion between the current now flowing through the stretched brass wire and the poles of the permanent magnet kept up the vibration of the wire when once started. In fact, when well adjusted the wire would start to vibrate of itself, making the primary current at every downward stroke and breaking it at every upward excursion. The current in the secondary was an alternating current, of course, of exactly the same frequency as the vibration of the wire. The frequency of the vibrating wire could be varied by varying the tension gradually until the vibration of the wire was in exact unison with a standard tuning fork. Varying the tension (in a manner which will be described below) of the brass wire did not interfere with its vibration, so that the tuning could be made very accurately by watching the beats. In this form, this what I call *electrodynamic interruptor*, was shown to Professors Abbe, Barker, Mendenhall, Michelson, and Rowland, during the autumn meeting of the National Academy of Sciences in New York, in 1891, and was very favorably commented upon by these scientists.

In the meantime experience suggested the form given in fig. 1, as best suited to the purpose for which the interruptor

Fig. 1.
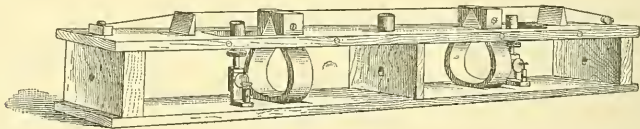
Fig. 2.
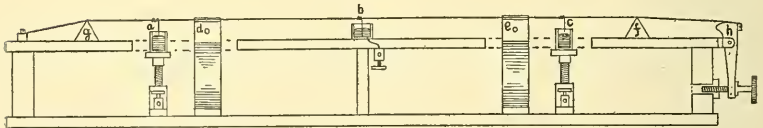
was first designed. The diagram of fig. 2 explains the construction of the apparatus more clearly. A stout aluminium, or phosphor-bronze wire, *the vibrator*, is stretched between the polepieces *d*, and *e*, of two permanent Weston magnets, such as this distinguished electrician uses in his voltmeters.

Fig. 3
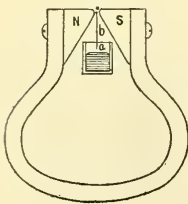
Fig. 3 gives the front view of one of the magnets. The cross section of the vibrator is seen there between the polepieces N S as a black dot. The short line, *a*, *b*, extending from the vibrator to the mercury cup below is the dipper, a short, thin amalgamated copper wire, which is soldered to the vibrator. The vibrator rests on two hard rubber bridges,

f, g. One of its ends is rigidly attached to the wooden frame of the apparatus, the other end is attached to a lever *h* which, worked by a micrometer screw, varies the tension of the vibrator. There are three mercury cups, *a, b, c,* and three dippers (which unfortunately do not appear in fig. 1). The middle cup, *c,* is fixed in position, and the middle dipper, being at the nodal point of the vibrator, makes a permanent contact there. The other two dippers make contact with mercury cups which can be raised or lowered by means of a nut and screw as represented in fig. 1, and indicated in diagram 2. The construction of the adjustable mercury cups and the stretching lever were copied from Dr. Max Wien's magnetic interruptor (Wiedem. Ann. 1891 and 1892). The middle cup (see fig. 4), is connected to one pole F, of the gravity or storage cell, the other two cups are connected one to one end, and the other to the other end of the primary of the small coil A, B. From the middle point, C, of the primary a wire leads to the other pole of the cell. Auxiliary small coils, E and D, and condensers, H and G, are inserted in the circuits as indicated. Their functions will be explained further below.

The vibrator vibrates with a node at the middle dipper as soon as the tension has reached a certain, by no means high, limit. A permanent contact is therefore maintained at this point, and the contact is made at one of the other cups just at about the same moment as it is broken at the other cup. Leaving the condensers out of consideration for the present, it is evident that this form of the current make-and-brake produces the same effect upon the iron core of the coil as an alternating current would. The advantage of this needs no comment; for although the iron core consists of the finest iron wire that can be obtained in the market, yet it must be remembered that the vibrator is expected to work sometimes at the rate of 512, or more, complete periods per second. Another immediate advantage which this interruptor offers is a considerable diminution of sparking. The addition of condensers, besides performing other functions which will be discussed presently, reduces the break sparks almost to invisibility, even when currents as large as half of an ampere are used. Each half of the primary coil consists of 532 turns of No. 22 silk-covered wire wound over an iron core of 30^{cm} in length, $4^{\square\,cm}$ in cross section, and consisting of very fine, soft iron wire.

The vibrator when at work gives a pure, but not objectionably loud, musical note in which the overtones are scarcely perceptible. The frequency ordinarily employed in my work is 256 complete periods per second, and it is obtained by bringing the vibrator in unison with a König standard tuning

fork.   The tuning is done in a few seconds, without any diffi-
culty, by simply stretching the vibrator gradually by means of
the lever and micrometer screw and watching for the beats.
The stretching does not interfere in the *slightest* with the
vibrations of the vibrator.

The secondary current is, of course, an alternating current
having the same frequency as the vibrator.   But it is by no
means a simple harmonic current.   On the contrary, it is a
very complex harmonic, its complexity depending on the fun-
damental frequency, on the ohmic resistances, and especially on
the self-induction and electrostatic capacity of the primary and
secondary circuits.   A telephone placed in shunt with a part
of the secondary circuit shows that without the condensers
sparking is rather strong, producing that peculiar rattling noise
which is full of those exceedingly high notes for which the
telephone is especially sensitive.   These high notes are due, as
is well known, to rapid electrical oscillations which accompany
the sparks.   If the condensers are put in as indicated in fig. 4,

Fig. 4.
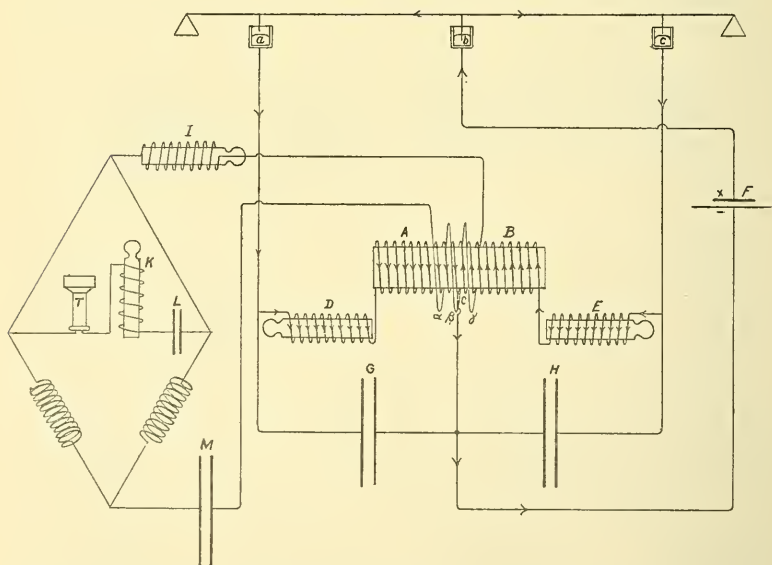
then the telephone shows that it is simply a question of ca-
pacity whether this or that overtone is particularly prominent.
These overtones mean, of course, that in addition to the alter-
nating current of the fundamental frequency there are also in
the secondary circuit higher harmonic currents.   In fact, the

telephone shows plainly that sometimes these upper harmonics are apparently much stronger than the fundamental current. The method of reducing the complex harmonic current obtained by the means just described forms the next part of this paper.

B. *On the method of weeding out harmonics by electrical resonance.*

If a coil, A, (fig. 5) is connected with a condenser B

Fig. 5
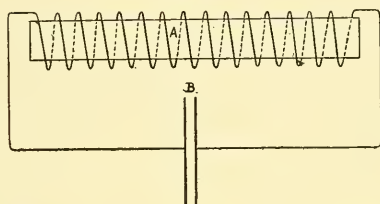
and an impulse starts an electrical disturbance in this system, then electrical oscillations will result from this disturbance. Electrical equilibrium is restored again after the electrokinetic energy produced by the impulse is partly radiated off and partly transformed into heat by the ohmic resistance of the circuit. Not to mention losses due to magnetic and dielectric hysteresis and to convection currents consisting of dust particles charged by contact with the systems. In Hertzian oscillations and in Tesla frequencies the period depends on the self-induction and the capacity of the system only, as is well known. But even in systems of large self-induction and large capacity, where *à priori* we can expect a long period of oscillation, this period can be easily shown to be independent of the ohmic resistance of the system in the majority of cases. An analytical discussion of this matter, as well as of other matters relating to resonance of slow oscillations is reserved for a future paper. Suffice it for the present to refer to these things, only in so far as they bear upon the subject of this paper.

The period of the system represented in fig. 5 is given (provided certain well-known conditions are fulfilled) by

$$T = \frac{2\pi}{10^3}\sqrt{LC}$$

where T is the period in seconds, L the coefficient of self-induction in Henrys, and C the capacity in microfarads. I shall refer to this period as the "*natural period*" of the system. By varying the capacity or the self-induction of the circuit we vary its natural period. I call this variation the *tuning of the electrical circuit.*

Let a complex harmonic, alternating electromotive force E act upon this cirucit.

By Fourier's theorem E can be represented by

$$\mathrm{E} = a_1 \sin pt + a_2 \sin 2pt + \ .\ . + a_n \sin npt + \ .\ .\ . \quad \text{where } p = \frac{2\pi}{\mathrm{T}}$$

T being the fundamental period. It is well to observe here that in complex harmonic e. m. forces as produced by ordinary methods the amplitude a_1, of the fundamental harmonic is largest and the amplitudes of higher harmonics diminish with the period of these harmonics.

The current produced in the circuit by the action of this complex e. m. f. will, of course, be a complex harmonic consisting of the same number of single harmonics as the e. m. f. and of the same periodicity ; but the ratio of the amplitudes will be different now. The various simple harmonic components have also different phases. In general every one of these harmonics is a forced oscillation of the circuit, but by tuning the circuit we can bring it (within certain practical limits) in *resonance* with any one of the harmonics.

In my work I generally bring the circuits in resonance with the fundamental harmonic. A resonant circuit behaves toward a complex harmonic e. m. f. just the same as an acoustical resonator toward a source of complex sound. It brings out prominently that harmonic with which it is in resonance. To express this numerically, say that the ratio of the amplitude of the fundamental harmonic e. m. force to that of the next higher harmonic (supposing it even to be no higher than an octave) is 2 to 1. Then the circuit can be easily brought into resonance with the fundamental harmonic, in such a way as to increase the ratio of the amplitudes of the corresponding simple harmonic currents to 60 : 1. Theoretically (and to a great extent practically also) that ratio can be made anything we please by increasing continually the coefficient of self-induction and diminishing the capacity without destroying the resonance. In other words, we can by proper single tuning weed out the upper harmonics as much as we please. But, as will be indicated later on, it is not always advisable to avail ourselves too much of the means of weeding out the upper harmonics by using very large self-induction. The best method of tuning depends on the nature of the problem before us. I propose to discuss two cases, after stating briefly the experimental method which I consider as the simplest in detecting resonance. Consider the circuit represented in fig. 5. Put a telephone in shunt with some part of the circuit between the coil and the condenser ; insert a small auxiliary coil with movable iron core in series with the large coil. Say the fundamental frequency

is 256 per second, make the condenser capacity larger and larger until the deepest note in the telephone (in our case 256), comes out strongest. It is easily recognized, for the difference between the sound of the telephone with the upper harmonics strongly represented and the sound without them, is just about the same as between the sound of a clarinet and that of a drum when playing the same note. Having done that, I then move the iron core of the auxiliary condenser until the telephone sounds loudest. The circuit is then in resonance with the fundamental harmonic.

An interesting phenomenon is observed during the first part of the tuning process. While plugging the condenser, so as to bring the capacity nearer and nearer to the point of resonance, a certain point is reached, when taking out a condenser plug is followed by a bright, snapping, spark. The spark is a sign that the point of resonance is very near, for resonance produces a difference of potential between the condenser plates which is many times higher than the amplitude of the impressed electromotive force. I proceed to consider this phenomenon a little more fully.

Case I.— Method of Tuning for the purpose of producing a high rise of potential at the Condenser plates.

When resonance is established the ratio of the amplitude E_o of the impressed e. m. f. to the amplitude $E_{\prime}$ of the difference of potential at the condenser plates is given by

$$\frac{E_{\prime}}{E_o} = \frac{10^6}{\frac{2\pi}{T} CR}.$$

Where C is the capacity of the condenser in micro-farads, R the resistance in ohms and T the period in seconds.

On the other hand,

$$T = \frac{2\pi}{10^3} \sqrt{LC}$$

Hence

$$\frac{E_{\prime}}{E_o} = \frac{2\pi L}{T R}. = \frac{\text{Inductance}}{\text{Resistance}}$$

If the priod $T = \frac{1}{400}$ and $E_o = 5$ volts, then

$$E_{\prime} = \frac{2\pi \times 400 \times L}{R} \times 5.$$

Hence to get the rise in potential as large as possible it is necessary to make the resistance as small, and the coefficient of self-induction as large as mechanical (and financial) considera-

tions will permit. It is not difficult at all to construct a coil whose L=5 and R=5, in which case E,=over 12000 volts.

In a circuit of this kind the amplitude of the fundamental harmonic would be at least 2000 times as large as that of any of the upper harmonics. In other words, we should have a simple harmonic current in the circuit. In such a circuit the condenser has very small capacity and can be replaced by vacuum bulbs partially coated with tinfoil on the outside and electrical discharges could be produced in them by this enormous rise in potential. Hence the interest attached to this method of tuning. I expect to take up this interesting subject in another communication as soon as time will permit.

Case II.—Method of Tuning for the purpose of supplying a Wheatstone Bridge with a simple Harmonic Current of constant frequency.

In this case the method of tuning is governed somewhat by the well known conditions under which the flow in a Wheatstone bridge system will have the highest sensitiveness. These conditions exclude the possibility of using self-inductions which are very much larger than those in the principal branches of the bridge. *Two kinds of apparatus can be employed. The first* and in a great many respects the most convenient kind of apparatus is the interrupter described above. In this case the most difficult, but at the same time the most interesting part of the tuning consists in establishing resonance between the circuits A D G C, B C H E (fig. 4) and the vibrator. It is done in the following way :

The vibrator is first tuned up to any frequency we wish, say, 256, in the manner described above, all the iron having been previously removed from the coils and a high resistance inserted between F and C so as to reduce sparking at the dippers. The iron cores are then gradually pushed in and the capacity of the condensers G and H varied until the sparking is reduced to a minimum. This process is continued until the iron core of the principal coil A B is entirely in the coil. The final touches to this part of the tuning are given by means of shifting the iron cores of the small auxiliary coils D and E. By watching the sparks in the cups *a* and *c* the point of maximum resonance can be determined with great accuracy. For at this point the sparks are scarcely visible. If there is any defect in this adjustment it shows up immediately when the current is increased, by gradually diminishing and finally removing the resistance which, as a matter of precaution, was inserted in the circuit between F and C. The voltage of the generator F does not (within reasonable limit) seem to cause a

variation in the size of the sparks if the adjustment is properly done. I have used as much as four storage cells in series as my exciter and have no doubt that with a properly constructed vibrator as much as 100 volts could be used without any annoyance arising from the sparks. But the interruptor must be kept in a place entirely free from jars or vibrations. For even with the storage battery just mentioned, when the voltage is only 8 volts, vibrations of the floor or table or singing a note which is nearly in unison with the vibrator will disturb its vibrations sufficiently to cause a dissonance between the vibrator and the circuits. This dissonance manifests itself at once by lively sparking which subsides as soon as the disturbance ceases. It is this very state of extreme sensitiveness of the electrically tuned up system which makes the work with the vibrator exceedingly instructive and interesting.

The secondary coil $a\beta\gamma$ (fig. 4) supplies the alternating current for the bridge. The number of its turns is small in comparison to the number of turns in the primary and the current in it is also small in comparison with the current in the primary, on account of comparatively high resistance in the bridge, so that the variation of the secondary current does not interfere with the established resonance in the primary. We can therefore tune this circuit without disturbing the adjustment of the primary. The tuning is performed by means of the auxiliary coil I, the condenser M, and a telephone placed in shunt with a part of the circuit whose resistance is high enough to give sufficiently intense sound in the telephone.

Finally, the bridge itself containing the telephone T is tuned by means of the auxiliary coil K and condenser L. This part of the tuning does not interfere with any of the previous adjustments on account of the extremely small value of the current which has to pass through the telephone to make the sound in it sufficiently intense.

It is needless to observe that the upper harmonics which the vibrator tends to produce are completely wiped out in the telephone circuit and that, therefore, with this arrangement we can employ the zero method of measurement, using as our detector the ordinary Bell telephone.

The second kind of apparatus that can be employed is a coil in series with a condenser as in fig. 5. A spark space is inserted in the circuit between the coil and the condenser and the extremities of this spark space are connected to the poles of an influence machine, or a high Voltage electromagnetic generator, and an air blast is applied to the spark space when the sparks begin to pass. An alternating current of any frequency may thus be generated in this coil-condenser circuit by a proper adjustment of capacity and self-induction and by gradual trans-

formation and tuning deprived of all its upper harmonics. This method is to be preferred when we wish to obtain a simple harmonic current of definite frequency to drive a synchronous alternating current motor, that is to say, a simple harmonic current, carrying with it a large quantity of power. I hope that I shall be pardoned for observing here that this last method was worked out by me some time ago. But in conversation with Mr. Nikola Tesla this distinguished experimentalist informed me that he obtained a patent about a year ago on the method of generating alternating currents of any frequency by means of disruptive discharges. The discovery that I was anticipated in a pretty invention caused me some disappointment at first, but I consoled myself very soon with the idea that a method patented by so excellent an experimentalist as Mr. Tesla, would enable me to obtain the object for which I invented it, the object being *to construct a synchronous alternating current motor which would spin around with great but perfectly constant angular velocity, the angular velocity to be just as adjustable and just as accurately determinable as the time of vibration of my vibrator, the motor to perform the function of a microphonograph.* I expect to be able to offer a favorable report on this matter very soon.

A communication of the results of some of my experiments with the simple harmonic currents obtained by the method described in this paper will be given as soon as time will permit.

Electrical Engineering Laboratory,
School of Mines, Columbia College, March 8th, 1893.

Art. XXXIX.—*On the Determination of Iodine in Haloid Salts by the Action of Arsenic Acid;* by F. A. Gooch and P. E. Browning.

Three years ago we demonstrated[*] the possibility of determining iodine in mixtures of alkaline chlorides, bromides, and iodides, with rapidity and exactness, by taking advantage of the behavior of arsenic acid toward the haloid salts in presence of sulphuric acid of definite strength. We showed in brief, that when amounts of potassium iodide ranging from 0·005 grm. to 0·5 grm. were dissolved in 100 cm³ of water containing 2 grm. dihydrogen potassium arseniate and 20 cm³ of a mixture of sulphuric acid with water in equal volumes, the entire amount of iodine was expelled on boiling down the solu-

[*] This Journal, vol. xxxix, p. 188.

tion from 100 cm³ to 35 cm³; and further, that arsenic, reduced to the arsenious condition to an amount the exact equivalent of the iodine liberated, remained in solution and was determinable, after neutralization of the acid, in presence of an alkaline bicarbonate, by titration against standard iodine according to Mohr's classical method. We studied carefully the behavior of alkaline bromides and chlorides under identical conditions and determined that 0·5 grm. of potassium bromide acted upon the mixture of arseniate and acid to the extent of reducing arsenic equivalent to 0·0008 grm. of iodine, and that 0·5 grm. of sodium chloride did not reduce arsenic but did cause, under the conditions, a volatilization proportional to the amount of arsenious oxide present, the loss amounting at the most — when 0·56 grm. of the iodide was present to exert its reducing action upon the arsenic — to 0·0011 grm. We showed, furthermore, that these maximum errors, due to the action of bromides and chlorides, though not large and tending to neutralize one another when both bromides and chlorides are present, may be eliminated by the application of a numerical correction to the results whenever the amounts of bromide and chloride present become known.

Recently Messrs. Friedheim and Meyer[*] have recognized the value of our reaction and applied it to the elimination of iodine from mixtures of haloid salts. They have, however, taken issue with us (unadvisedly, as we think) as to matters of detail. They have, in the first place, put themselves upon record as being unable to titrate arsenious oxide by iodine in alkaline solution under the conditions of our process. They account for their failure by the wholly unsupported hypothesis that the iodine reaction is unavailable in presence of the amounts of salts present, and modify the treatment by distilling, collecting the iodine in the distillate, and determining it by the thiosulphate method, thus introducing complexity of apparatus and manipulation, and sacrificing the simplicity and rapidity which are chief advantages of our process. Had they read our paper with intelligent care it must have been evident that we had given special attention to the question of the influence of the salts present upon the iodine reaction; for we expressly stated that " due correction was made for the amount of iodine necessary to develop the test-color in a solution prepared and treated similarly in all respects to the experimental solutions excepting the introduction of the iodide—the correction amounting to a single drop more of the decinormal iodine than was required to produce the end reaction in the same volume of pure water containing only the starch indicator." It

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[*] Zeitschr. f. Anorg. Chem., i, p. 407.

is obvious that such errors as 0·003 to 0·006 grm., which Messrs. Friedheim and Meyer found even in the absence of bromides and chlorides, are not explicable by the action of the salts which we used. Our errors ranged under like conditions from 0·0009 grm. − to 0·0003 grm. +, with a mean error in nine determinations of 0·0002 grm. −.

Everybody knows that the starch iodide test is most delicate in acid solutions and in presence of combined iodine, but Mohr's method of titrating arsenious oxide and iodine against one another in alkaline solution is sufficiently delicate for very exact work provided only that the alkali in excess is in the form of the bicarbonate, that the starch emulsion is used in abundance, and that the volumes of solutions titrated are regulated to low and uniform measure. In many determinations of iodine made by our method at different times and with different materials it has never been our ill-fortune to chance upon results so extraordinary as those of Messrs. Friedheim and Meyer, though we have met in the course of our work with potassium arseniate so contaminated with nitrates as to be unfit for use and with alkaline hydroxides too impure to employ. Most analytical processes depend for their exactness upon the use of proper materials: ours is no exception to the rule in this regard.

As to the correctness of the main reaction there appears to be no difference of opinion between Messrs. Friedheim and ourselves. We have, therefore, taken the pains, perhaps unnecessarily, to make experiments in which the estimation of the iodine of the same identical portions is effected both in the distillate and in the residue, in order that the two modes of estimation may be brought into direct comparison. It is scarcely needful to add that we took care to work with pure reagents. The potassium iodide, like that which we employed in our former investigation, was prepared by acting with resublimed iodine upon an excess of iron wire, pouring off the solution from the iron when the color of iodine had vanished, adding iodine equal to one-third the amount of that originally used, pouring the filtered liquid into a boiling solution of the calculated equivalent of potassium carbonate (from the bicarbonate), and filtering off the precipitated magnetic oxide of iron. The slightly alkaline solution thus made, containing approximately 2 grm. of potassium iodide in 100 cm³, and free from chlorine and bromine, was standardized by precipitating the iodine from weighed portions in the form of silver iodide and weighing upon asbestos. The other reagents—the sulphuric acid, the sodium hydroxide, the acid potassium carbonate, the dihydrogen potassium arseniate—when present in the proportions used in our process, and mixed with 5 cm³ of clear

starch solution prepared by Gastine's formula* (5 grm. starch, 0·01 HgI_2, 1 liter of water) gave the starch blue with a single drop of decinormal iodine at all dilutions below 300 cm³. The results of these experiments are given in the following table.

	Iodine taken in form of KI.	Iodine found in residue by our method.	Iodine found in distillate by As_2O_3.	Iodine found in distillate by $Na_2S_2O_3$.	Error in residue.	Error in distillate.
	grm.	grm.	grm.	grm.	grm.	grm.
(1)	0·4054	0·4052			0·0002 —	
(2)	0·4057	0·4055			0·0002 —	
(3)	0·4054	0·4052			0·0002 —	
(4)	0·4054	0·4052			0·0002 —	
(5)	0·4042	0·4046	0·4046		0·0004 +	0·0004 +
(6)	0·4050	0·4052	0·4040		0·0002 +	0·0010 —
(7)	0·4050	0·4052		0·4039	0·0002 +	0·0011 —
(8)	0·4058	0·4052		0·4051	0·0006 —	0·0007 —
(9)	0·4054	0·4046		0·4051	0·0008 —	0·0003 —
(10)	0·4042	0·4046		0·4039	0·0004 +	0·0003 —
(11)	0·4055	0·4052		0·4057	0·0003 —	0·0002 +

Experiments (1) to (4) were made exactly in accordance with the directions of our former paper, the mixtures being simply boiled in an Erlenmeyer flask trapped to prevent mechanical loss by hanging in the neck of the flask, with the larger end downward, a straight, two-bulbed drying tube cut off so as to leave the larger tube about 4 cm. in length. These four experiments all gave the same result, which differed from the theory by 0·0002 grm. —. The mixtures of the remaining experiments were treated in a flask connected with a cooled receiver and absorbtion tubes for condensing the distilled iodine (all joints being of glass and carefully ground) and carbon dioxide was passed through the apparatus in slow current to facilitate the transfer of iodine and quiet boiling. In experiments (5) and (6) the iodine was received in an alkaline solution of standard arsenious oxide and titration was effected with standard iodine after addition of starch. The residue was treated by our method. It will be observed that the residues, which contain the large amounts of salts, yield results by titration practically identical with those obtained by treating the distillates which do not contain the large masses of salts. In experiments (7) to (11) the iodine distilled was received in potassium iodide and estimated by standard sodium thiosulphate, itself standardized against the iodine whose value in terms of the standard arsenious oxide was also known. The residues were treated by our method. It is evident that the

* Bull. Soc. Chim., 1, 172.

errors of both processes of treatment are reasonably small, (respectively 0 0001 grm. – and 0·0004 grm. – in the average) with what difference there is in favor of our treatment of the residues.   Our process is incomparably the more convenient and rapid.   We do not doubt that Messrs. Friedheim and Meyer could have obtained equally good results had they worked with pure reagents.

Messrs. Friedheim and Meyer disagree with us also as to the degree of concentration of the liquid necessary to insure the complete expulsion of iodine and as to the effect of the concentration upon bromides present—points to which we gave particular attention in our former paper.   We showed that, in general, upon boiling a mixture of iodide with sulphuric acid and the arseniate diluted with water, the amount of iodine removed depended upon the proportion of the sulphuric acid to the final volume of the whole liquid, it being plainly shown that even after the liquid had lost the color of free iodine in the process of concentration it was still possible to detect combined iodine.   Further concentration and, to some extent, dilution and repetition of the concentration to the former point tend to set free the residual iodine.   In experimenting upon the proportions of acid most convenient for the work we found that a solution made up to contain 0·5 grm. of potassium iodide, 2 gram. of dihydrogen potassium arseniate, and 20 cm³ of the sulphuric acid mixture (1 : 1 by volume) retained when boiled down to 40 cm³ no determinable free iodine and but the faintest trace of combined iodine, while at 35 cm³ the liquid was free from iodine in any form.   Upon experimenting as to the behavior of mixtures of chlorides and iodides we found that 0·5 grm. of sodium chloride added to the mixture containing 0·5 grm. of the iodide occasioned at 40 cm³ a maximum loss of arsenious chloride equivalent to 0·0004 grm. of the oxide, or to 0·0008 grm. at 30 cm³; and that the loss as a matter of course, is less as the amount of iodide present (and consequently the arsenious oxide formed) is diminished.   We found that 0·5 grm. of potassium bromide treated in similar manner occasioned no loss of arsenious bromide but did induce at 35 cm³ reduction of the arsenic acid amounting to 0·0005 grm. of iodine.   Smaller amounts of bromide produced proportionately smaller effects, but concentration even a little below 35 cm³ was likely to be productive of serious error.   We fixed upon 35 cm³ therefore, as the ideal concentration for removing iodine from unknown mixtures with chlorides and bromides, but expressly stated that failure to concentrate below 40 cm³ introduces no appreciable error, while great care should be taken not to press the concentration below 35 cm³ on account of the

danger of bringing about the reduction of the arsenic by the bromide.

Messrs. Friedheim and Meyer contend that the reduction of volume under the conditions should not be pressed beyond 50 cm³ at the most, and cite in proof experiments in which potassium bromide in amounts less than half as great as those which we used caused an error on concentration to 35 cm³ equivalent to five or six milligrams of iodine. They recommend boiling from 150 cm³ to 50 cm³ to remove the iodine without disturbing bromine. Our former experiments are sufficiently definite upon these points. We have, however, determined directly and quantitatively the amounts of iodine remaining unexpelled when solutions are boiled from 150 cm³ to 50 cm³ and found, in certain experiments, in which the additional iodine expelled in concentrating from 50 cm³ to 35 cm³ was collected in potassium iodide and estimated with sodium thiosulphate, that about 0·0013 grm. remained when 0·5 grm. of potassium iodide was originally taken, and 0·0003 grm. when 0·25 grm. of the iodide was present at the first. It is evident, therefore, that concentration to 50 cm³ is not sufficient when the maximum amount of iodine may be present. We have also made certain experiments—recorded below—in which the bromine liberated at different degrees of concentration was collected in potassium iodide and estimated by the iodine set free. In our former work we inferred the loss of bromine from the effects upon the arsenic acid in the residues. In these experiments solutions of potassium bromine (free from iodine), with 20 cm³ of sulphuric acid (1 : 1), and 2 grm. of dihydrogen potassium arseniate were boiled down in a flask connected by ground glass joints with a cooled receiver containing potassium iodide, or the iodine set free was estimated by standard sodium thiosulphate.

KBr taken. grm.	Initial volume. cm³.	Final volume. cm³.	Bromine in distillate. grm.
0·5	150	50	trace
	50	40	trace
	40	35	0·0004
0·5	50	31	0·0010
	31	26	0·0064
	26	23	0·0072
0·25	45	40	none
	40	31	0·0004
	31	27	0·0010
0·25	50	35	0·0003
0·1	50	30	0·0003

From these results, which confirm very closely those ob-
tained by an examination of the residues and recorded in our
former paper, it is evident that the concentration may go under
the most unfavorable conditions—when the maximum amount
of bromide is present—to 40 cm³ without loss and to 35 cm³
with small loss.   As we stated in our former paper concentra-
tion below 35 cm³ should be avoided.

In our former paper we showed that the iodine could he de-
termined in unknown mixtures of sodium chloride, potassium
bromide, and potassium iodide taken in amounts not exceeding
1·5 grm. (in which, however, neither individual salt was present
in amount exceeding 0·5 grm.) with a maximum error ranging
from 0·0013 grm. − to 0·0016 grm. +.   We showed, further,
that when the amounts of chloride and bromide present were
known also a correction for the action of these salts might be
applied which reduced the maximum errors to 0·0010 grm. −
and 0·0008 grm. +, and gave a mean error of 0·0001 grm. −
for twenty-six determinations.

In conclusion we affirm the correctness of our former work
and reiterate our former directions without change.

ART. XL.—*The Radiation and Absorption of Heat by
    Leaves;* by ALFRED GOLDSBOROUGH MAYER, M. E.
    (Stevens Institute of Technology.)

THE present research was commenced in the Physical
Laboratory of the University of Kansas in the autumn of 1890,
and continued in the Jefferson Physical Laboratory of Harvard
University.

As plants must necessarily receive a considerable portion of
their energy by the absorption of the sun's heat during the
daytime, and then lose some of this heat by radiation during
the night, it becomes of some interest to the physiological
botanist to determine what may be the laws of this periodical
gain and loss.   Furthermore as by far the greater portion of
the land surface of the globe is covered by vegetation, the
laws of its radiation would become an important factor in a
determination of the radiation of heat by the earth.

Apparatus.—In the research use was made of a highly sensi-
tive thermopile in connection with a low resistance, reflecting
astatic Thomson galvanometer.   As it was feared that heating
the leaves to abnormal temperatures might alter the coefficients
of radiation of their surfaces, the form of apparatus shown
in fig. 1 was devised, by means of which the radiation from
leaves at the temperature of the air of the laboratory might

be determined. The essential parts consisted of two concentric boxes made of sheet tin (O I, fig. 1), drawn with their sides nearest the observer torn away in order to show the

Fig. 1.
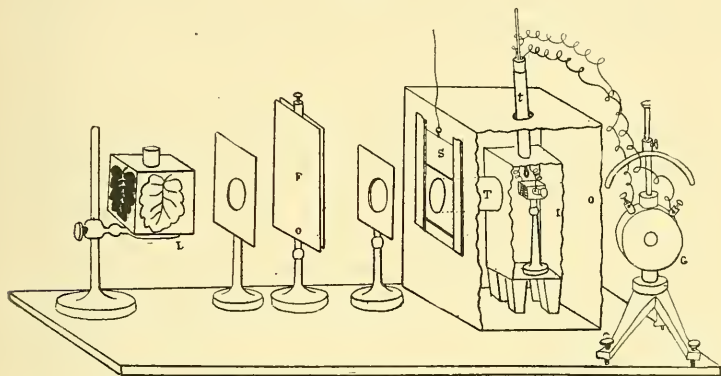
internal parts. The two boxes were connected by means of the tin tube (T) soldered into a perforation in the middle of a side of each.

The inner box which contained the thermopile was mounted upon wooden legs, and running out from its top and also through the top of the larger box was the tube (*t*). The wires which connected the thermopile with the galvanometer (G), ran through this tube (*t*), as did also a very delicate thermometer giving the temperature of the air surrounding the thermopile. The sliding metallic screen (S) could be dropped down over the opening of the tube T, thus shielding the thermopile from all radiant heat. The capacity of the larger box was about 850 cubic inches, that of the inner one being 150. The outer box was jacketed with a two-inch layer of cotton wool.

By filling the space between the two concentric boxes with cracked ice, the temperature of the thermopile, and of the air in the inner box which surrounded it, could be lowered, so that one might determine the radiation from leaves at the temperature of the air of the laboratory. This apparatus possessed also the very great advantage that there were no air currents impinging upon the thermopile, and as a consequence its readings were remarkably concordant.

Many determinations both of radiation and absorption of heat were made by the aid of this apparatus, but in the excellent constant-temperature room of the Jefferson Physical Laboratory it was found unnecessary to inclose the thermopile, and therefore it was mounted upon an ordinary Melloni's bench.

Of course, as the thermopile was then at the temperature of
the air of the room it became necessary to raise the tempera-
ture of the leaves which radiated to it. It was found, how-
ever, by numerous experiments, that the temperature of the
leaves might be raised to 45° C. without altering in the least
the coefficient of radiation from their surfaces.

Methods of Experimenting.

I. *Radiation of Leaves:*—Two leaves of the same species
of plant and as nearly alike as possible were procured, and
each was glued, flat, upon one of the polished tin sides
of the Leslie cube (L, fig. 1). One of the leaves was then
painted over with lampblack in alcohol, which caused it to
present a dull, dead black appearance. The Leslie cube was
then filled with water which was heated to about 40° C., at
which temperature it was maintained constantly by means of a
low luminous flame of a Bunsen burner. A side of the cube
bearing a leaf was turned so as to face the thermopile, and
after the temperature of the water had become steady, the
falling screen (F, fig. 1) was lowered, the slider S raised, and
the deflection of the galvanometer after five minutes exposure
to the radiant heat carefully observed. An exactly similar ex-
periment was then gone through with, upon the lampblacked
leaf, in order that the radiation from the green leaf might be
accurately compared with that from a similar surface of lamp-
black. Great care was taken in these experiments that the
thermopile cooled completely, so as to cause the galvanometer
to return to its zero reading before another experiment was
performed. As the deflections of the galvanometer were small
the radiation was assumed to be proportional to the deflection
produced.

II. *The Effect of Dew upon the Radiation of Leaves.*—As
a copious film of dew commonly forms upon the leaves of
plants during summer nights, it occurred to me to ascertain
whether their radiating ability was thereby altered to any per-
ceptible degree.

The experiments were conducted as follows:—A leaf was
glued to the polished side of the Leslie cube as in experiments
upon radiation. The cube was then filled with finely cracked
ice. This soon caused a film of dew to form upon the surface
of the cooled leaf. The temperature of the air of the room
and of the melting ice in the cube was then determined. The
leaf was placed facing the thermopile, the shielding screens
removed and the deflection of the galvanometer after five
minutes exposure observed. The Leslie cube was then filled
with water which was heated up and maintained at a tempera-

ture, as nearly as possible, as much *higher* than the temperature of the room as the melting ice was *lower* than that temperature. A five minute exposure was again given and the reading of the galvanometer taken. From the results of these two experiments it became possible to compare the radiation of the dewed leaf with the heated one. For example: let t_1 represent the temperature of the air of the room, supposed constant, t_0 that of the melting ice, T that of the heated water in the Leslie cube, d_0 the deflection produced by the dewed leaf, and d_1 that caused by the dry heated leaf. Then assuming the deflections of the galvanometer to be proportional to the radiation's we would have

$$(T - t_1) : (t_1 - t_0) = d_1 : x$$

Instead of x coming out equal to d_0 as it would do if the coefficient of radiation of the dewed surface were equal to that of the heated surface, it was always greater than d_0; thus proving that the coefficient of radiation of the leaf was *lowered* by the dew which had collected upon it.

III. *Absorption of Heat by Leaves.*—In performing these experiments the side of the Leslie cube was lampblacked, and the cube filled with water which was kept gently boiling. The reading of the galvanometer produced by five minutes exposure to the hot lampblacked surface of the Leslie cube was taken and compared with that produced when the heat from the Leslie cube was obliged to pass through a leaf, placed over a diaphragm, between the cube and the thermopile. Great care was taken to insure that all the heat which reached the thermopile had passed through the leaf. From the results of these two experiments it became a simple matter of ratio to calculate the percentage of heat absorbed by the leaf. Thus: Let D be the deflection produced when the heat passed uninterruptedly from the cube to the thermopile, and d that produced when the path of the heat was intercepted by a leaf, placed between the cube and the thermopile. Then the percentage of heat transmitted by the leaf would evidently be given by the expression $\dfrac{d \times 100}{D} =$ per cent transmitted. To find the per cent absorbed we have merely to subtract the per cent transmitted from 100. By causing the heat to pass through successively, one, two, and three leaves placed in its path, some facts relative to the selective absorption of leaves were obtained. By determining the heat-absorbing ability of a fresh green leaf, and then dissolving out its chlorophyl in alcohol or ether and testing the same leaf again, it became possible to ascertain how much of the absorption was due to the chlorophyl of the leaf.

Results of the Experiments.

In conducting the experiments upon radiation it was deemed wise to select leaves of widely different genera of plants; accordingly the leaves of a few forest trees, bushes, weeds living in both sunny and shady places, aquatic plants, cultivated plants and grasses were chosen. The results of a series of experiments upon the following leaves demonstrated that the coefficient of radiation of dark heat from both their upper and lower surfaces was *exactly* the same as that of lampblack.

The leaves tested were elm, oak, maple, horse chestnut, basswood (*Tilia Americana*), silver poplar, beech, lilac, mullein (*Verbascum thapsus*), plantain (*P. major*), lilly pads (*Nuphar advena*), cultivated grape, blackberry and clover. A single interesting exception, however, was discovered. The upper surface of burdock leaves (*Arctium lappa*) radiates exactly as do all other leaves, but the *under* surface radiates only 81 per cent of this amount.

These leaves are very broad and thick, and as they lie for the most part spread out horizontally very near the ground, the under surface is largely shaded from the sun's rays, and therefore receives but little direct heat. Moreover it is probable that being so near to the ground less dew would form upon the under surface than upon the upper. Both of these causes would combine, as we shall see later, to make it very advantageous to such leaves to possess a poorly radiating lower surface.

Of course, as leaves radiate exactly as lampblacked surfaces, they also possess correspondingly good absorbing surfaces. Numerous experiments were made by the method already described to ascertain the effect of dew upon the radiation of leaves. If we call the radiation from a dry leaf 100, that from a leaf covered by a thin film of dew is about 78, and if the dew stand out in beads over the surface the radiation is reduced to 66.

A polished tin surface which only radiated 14 per cent as much heat as a lampblacked surface, radiated 96·8 per cent of the lampblacked one when both were covered with beads of dew. The coefficient of radiation of the lampblacked surface was lowered, and that of the polished one raised until the radiation was nearly the same from both. So potent is a film of dew in altering the nature of a radiating surface.

Upon the importance of this remarkable fact we need hardly dwell. The surface of leaves being one of the best known radiators of heat, is therefore an equally good absorber of that heat. If then we imagine a forest in the tropics where the days and nights are of almost equal length the whole year round, very much of that heat which had been absorbed by the leaves during the day, would be lost by their great radiation

during the night, were it not for the fact that the blanket of dew which covers them cuts down this radiation to two thirds of its former value.

In the experiments upon the absorption of heat by the leaves, considerable individual difference was found in different specimens of the same species of leaf. In stating the results therefore I shall give the range of variation, where necessary. The following table gives the percentages of heat absorbed and transmitted by single leaves of the species named.

Name of Leaf.	Transmits	Absorbs
Ash	19·7 per cent	80·3 per cent
Elm	18–23	77–82
Maple	16–20	80–84
Wild Cherry	15–18	82–85
Horse Chestnut	19	81
Lilac	14–18	82–86
Mullein (V. thapsus)	17	83
Burdock (A. lappa)	14	86
Chicory (Chicorium intybus)	17	83
Rose leaves	28–31	69–72
Petals of red rose (cultivated)	33	67
" " White rose	27	73
" " Yellow rose	24	76
" " Oenothera speciosa	28	73
" " Tradescantia Virginica	31	69

The above table would seem to indicate that if dark heat be allowed to pass through a leaf, rather more than 80 per cent is absorbed by the leaf and somewhat less than 20 per cent transmitted. The heat passes through exactly as readily when it enters by the lower surface, as when it enters the upper.

The absorption of heat by leaves is highly selective. Thus a single elm leaf in the path of the dark radiant heat transmits 20 per cent of the heat which entered it. If now the heat which has passed through the first leaf be allowed to fall upon a second, it will be found that only 78 per cent of it will be transmitted. A third leaf will transmit over 83 per cent of the heat which passed through the second, and the effect of a fourth leaf is hardly noticeable. This may in some measure account for the somewhat remarkable fact that there is no very great difference between the absorbing abilities of such leaves as mullein and wild cherry, although the former are thick tough leaves and the latter very thin. By dissolving the chlorophyl out of leaves and again testing them, as has been explained under methods of experimenting, it was found that this substance absorbs but little of the dark heat. Thus, wild cherry leaves transmitted 9· per cent and chicory (*C. intybus*.)

4· per cent more heat when their chlorophyl was abstracted by ether or alcohol. In thick tough leaves such as lilac or elm, however, I was unable to detect its influence. It will be seen upon referring to the table that rather more heat seemed to be transmitted by the petals of flowers than by leaves. Natural selection has forced all leaves to the optimum as regards transmission and absorption of heat, and hence we find but little difference in the behavior of leaves of widely different genera of plants in this respect. Their surfaces have become the best known absorbers of heat, and in order to counterbalance the consequent disadvantage of being the best of radiators, the dew, which collects upon them at night, cuts that radiation down.

In conclusion, it gives me pleasure to acknowledge my great indebtedness to Professor Trowbridge, who kindly placed at my disposal the excellent apparatus and facilities of the Jefferson Physical Laboratory.

Cambridge, October, 1892.

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There appears to be no bibliography relating directly to the whole subject of the above paper. For reference to some of the few works relating more or less directly to it, I am indebted to the kindness of Professor Goodale.

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N. J. C. Müller, Handbuch der Botanik. Neunte Abtheilung: Einwirkung der Wärme, Heidelberg, 1880.

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SCIENTIFIC INTELLIGENCE.

I. CHEMISTRY AND PHYSICS.

1. *On an improved Boiling-point apparatus for determining Molecular Masses.*—Three effects are now made use of for determining molecular masses; (1) the decrease of vapor-pressure, (2) the lowering of the freezing point, and (3) the raising of the boiling point, of a solvent by dissolving in it the substance to be examined. SAKURAI has devised a simple and valuable modification of the apparatus described by Beckmann for determining the molecular mass of a substance by the elevation of the boiling point which a known quantity of it produces when dissolved in a known quantity of the solvent. The boiling vessel is a U tube of glass about 2^{cm} in internal diameter and 21^{cm} in height. Near the top of one of the legs is a lateral tube for attaching a

Liebig's condenser. An ordinary round bottom flask, placed by its side, is closed with a cork through which passes the stem of a tap-funnel and also a delivery tube. By means of a thick rubber tube, the end of this delivery tube is connected to the end of a similar tube passing through the cork of one of the legs of the U tube and terminating at its lowest part. Through a cork closing the other opening of the U tube, the thermometer passes. This reads to hundredths of a degree. The flask is surrounded with a tin plate vessel and the U tube with a box made of asbestus cardboard. To make an observation, the delivery tube is fixed in the U tube, and the bent portion of this tube is filled with glass beads. The solvent is now introduced till it rises 3 or 4^{cm} above the beads, and the thermometer is put in place. The flask, half filled with the same solvent, is then connected with the delivery tube and both it and the boiling vessel are heated by carefully regulated lamps. When the liquid in both vessels begins to boil, the tap in the funnel is closed and that connecting with the condenser is opened, and the boiling is continued for fifteen minutes or more. Then the thermometer is read by means of a telescope. The substance is introduced into the boiling tube by removing the thermometer, and the boiling point of the solution is determined again in the same manner. The thermometer used by the author read to hundredths, but by the telescope thousandths of a degree could be estimated. The device of the accessory flask enables the temperature to be made constant even to this limit. Results are given in which the solvents used were water, alcohol, ether, and carbon disulphide; and in which the substances dissolved were mercuric chloride, mannite, cane sugar, acetanilide, salicylic acid, naphthalene, iodine and sulphur. The molecular mass was calculated from the formula $m = B \times g / \varDelta$ in which m is the molecular mass sought, B a constant depending on the solvent, g the mass of the substance dissolved in 100 grams of the solvent, and $\varDelta$ the observed rise of the boiling point. B has the value $0 \cdot 02 T^2 / W$, where T is the absolute temperature and W the heat of vaporization of one gram of the solvent. In the case of water B has the value 5·2, alcohol the value 11·5, ether 21·0 and carbon disulphide 24·0. With respect to iodine the author finds its molecular mass in CS_2 from 247 to 261, and in ether from 255 to 261; thus confirming Beckmann's conclusion that its molecular magnitude is the same in both solutions. For sulphur in CS_2 the author finds the values 252 to 254; also confirming Beckmann as to the existence of a complex molecule consisting of S_8.—*Jour. Chem. Soc.,* lxi, 989, December, 1892.

<div align="right">G. F. B.</div>

2. *On the color of the Ions.*—An investigation has been made by OSTWALD on the absorption spectra of the solutions of several series of colored salts not only by measuring the position of the bands but also by photographing the whole spectrum. It appears from the results obtained that the spectra of dilute solutions of salts having the same colored ion are identical. In the case of

the permanganates for example, solutions containing the molecular mass in grams of the ion MnO_4 in 500 liters of water, give the same values for the absorption bands whatever the base. On the arbitrary scale employed, the four bands of potassium permanganate for example, were at 2600, 2697, 2803 and 2913; the positions of these bands in the twelve other permanganates examined not differing more than two or three units from these. In further proof of the fact that with this degree of dilution the metallic permanganates are completely dissociated, photographic reproductions of the several spectra are given side by side, in the paper, these spectra being identical for the different salts employed. The same conclusion was found to be true of the salts of fluorescein with sodium, lithium, benzylamine, potassium, methylamine, ammonia, piperidine, dipropylamine and trimethylamine; and also of the salts of eosin, both blue and yellow, of iodeosin, of dinitrofluorescein, of orcinphthalein and its tetrabromine derivative, of rosolic acid, of diazoresocin, of diazoresorufin, of safrosin and of the chromoxalates. To show that the law is equally true for positive ions as for negative the author gives the results obtained with the salts of para-rosaniline, aniline-violet, chrysaniline and chrysoidine, twenty different non-colored acids being employed. Generalizing from 300 cases examined the author regards the fact as established, that in dilute solutions, salts having the same colored ion give identical absorption spectra; the few exceptions being readily accounted for, either by the formation of insoluble compounds or by the hydrolysis of salts having feeble acids or bases.—*Zeitschr. physik. Chem.*, ix, 579; *J. Chem. Soc.*, lxii, 1137, Oct. 1892. G. F. B.

3. *Affinity-coefficients of Acids.*—The relative affinities of a number of acids have been measured by LELLMANN and SCHLIEMANN by means of a spectrophotometric method. This method is as follows: A measured quantity (25^{cc}) of a solution of two milligram-equivalents (0·448 grms.) of pure metahydroxyanthraquinone in a liter of 96 per cent alcohol, is mixed with a definite quantity of a solution of known strength of the pure barium salt of the acid, the mixture diluted to 50^{cc} and examined with the spectrophotometer; its absorption being compared with that of a solution of the same quantity of metahydroxyanthraquinone in excess of barium hydroxide. The alcohol and the water used in the preparation of the solutions are both carefully purified from basic substances by distillation over potassium hydrogen sulphate and even the glass vessels in which the solutions are kept are carefully freed from alkali by prolonged digestion with dilute sulphuric acid. In cases where the barium salt is not sufficiently soluble the potassium salt is employed. The results are given in terms of a constant k; this constant expressing the fact that when in the alcohol-mixture employed, equal equivalents of metahydroxyanthraquinone, of a given acid and of the base are contained, and when k equivalents of the salt of the acid are formed to one of a salt of metahydroxyanthraquinone, this fact

may be briefly expressed by saying that the acid is k times stronger than the metahydroxyanthraquinone. The value of k for formic acid for example is given as 61·97; of acetic acid 14·33; of benzoic acid 20·71; paramidobenzoic acid 7·60; lactic acid 39·94; propionic acid 11·68. The results obtained, even within very wide limits of concentration, are completely in agree·ment with the law of Guldberg and Waage; but they cannot be brought to accord with Ostwald's values of the affinity constants as determined by the electrical method, even when the same solvents are employed in the two cases. The authors regard the affinity coefficients as determined by the spectrophotometer method as expressing more simply and directly than can be done by the dissociation constants, the relation which exists between chemical change and the nature of the inter-acting substances.—*Ann. Chem. Pharm.*, cclxx, 204, 208; *J. Chem. Soc.*, lxii, 1269, November, 1892. G. F. B.

4. *On the Reaction of Hydrogen with Chlorine and Oxygen.*—Some time ago, in conjunction with Dixon, HARKER showed that contrary to the prevalent impression, hydrogen, when exploded with oxygen and excess of chlorine, does not unite wholly with the chlorine, but that water is formed at the same time. These experiments were left incomplete and Harker has now continued them with a view to determine whether the ordinary laws of mass action hold in this case. Much difficulty was encountered at first in carrying out the experiments, and special apparatus was devised for the purpose which is fully described in the paper. In all 18 experiments were made, in which the volume of chlorine added to 50 volumes of hydrogen and 50 volumes of oxygen varied from 9·08 to 95·83. The results show that in all cases a division of the hydrogen between the chlorine and the oxygen takes place. Moreover, this division takes place in such a way that the product of the number of molecules of hydrogen chloride and of those of oxygen divided by the product of the number of molecules of water vapor and of those of chlorine is practically constant, the mean value of this constant as given by the experiments being 23. The law of mass action laid down by Guldberg and Waage holds therefore in this as in other cases.—*Zeitschr. physik. Chem.*, ix, 673; *J. Soc. Chem.*, lxii, 1147, Oct., 1892. G. F. B.

5. *On the daily variation of Gravity.*—Professor MASCART, for several years has employed a barometric tube with a column of mercury four meters and a half in length, which counterbalances the pressure of a mass of hydrogen contained in a lateral vessel. The whole apparatus is sunk in the ground with the exception of a short column of mercury at the top. The level of the liquid is compared with a lateral division, the image of which is formed in the axis of the tube, and the points may be fixed to within the $\frac{1}{100}$ of a millimeter. The curves of variation present a very regular and slow course, due to changes of temperature, but on some days certain perturbations arise the duration of which is from

fifteen minutes to an hour. These do not seem explicable otherwise than by correlated variations of gravity. These perturbations often exceed $\frac{1}{20}$ of a millimeter. They seem to be undoubted and the author is arranging an apparatus constructed with great care for further observations.—*Phil. Mag.*, March 1893; *Comptes Rendus*, January 30, 1893.   J. T.

6. *Simple apparatus for the determination of the Mechanical Equivalent of Heat.*—C. CHRISTIANSEN describes with figures a simple apparatus for the determination of this important constant. Two trials gave J=42900, J=43060. The cost of the apparatus is 175 marks.—*Ann. der Physik und Chemie*, No. 2, 1893, pp. 374–376.   J. T.

7. *On a certain Asymmetry in Concave Gratings.*—Dr. J. R. RYDBERG discusses this subject and explains the asymmetry observed. Since the two sides of the gratings often give spectra of different brightness, the author believes that one can conclude that the furrows which the point of the diamond makes in the reflecting surface are not symmetrical in section. This explanation is not insisted upon, but is merely given as a possible explanation. The adjustments for getting rid of asymmetry are given in detail.—*Phil. Mag.*, March, 1893, pp. 190–199.   J. T.

8. *Potential of Electric Charges.* — Various investigations differ widely in their measures of the charge on spheres raised to different potentials. A. HEYDNEILER reviews the subject and appends a table in C. G. S. units which gives the charge on spherical electrodes of various radii, at variable distances apart of these electrodes.—*Ann. der Physik und Chemie*, No. 2, 1893, pp. 213–235.   J. T.

9. *Sensitive Galvanometer.* — H. E. J. G. DuBois and H. RUBENS describe a new form of astatic galvanometer which they believe excels other forms. Taking the nomenclature and classification recommended by Ayrton, Mather and Sumpner, (Phil. Mag., xxx, p. 58, 1890), current sensitiveness S_s is the deflection in scale divisions per micro-ampere, distance of scale being 2000 divisions and the full period of swing being 10 seconds.

The ballistic sensitiveness S_b is the deflection in scale divisions per micro-coulomb, distance of scale being 2000 divisions. The period of swing being 10 seconds with light suspensions. Ayrton's table gives as the highest value S_s=413. The authors obtain a value of S_s=800. Tables of the ballistic sensitiveness are appended.—*Ann. der Physik und Chemie*, No. 2, 1893, pp. 236–251.   J. T.

10. *Experiments with Currents of High Frequency.*—A. A. CAMPBELL SWINTON states that he has succeeded in passing through his body sufficient electricity to bring the filament of an ordinary 5 candle-power 100-volt incandescent lamp very nearly to full incandescence or to bring the filament of a 32 candle-power 100-volt lamp to full redness. No sensation was experienced. The apparatus consisted of an Apps coil, the primary of which was supplied with a powerful make-and-break current. The secondary

of the Apps coil included a step-up transformer constructed on the principle of those described by Mr. Tesla. The author thinks that the assumption that high frequency currents are harmless by reason of their high frequency is not correct. The true reason being the extremely small amount of current which accompanies the high voltage.—*Phil. Mag.*, February, 1893, pp. 142–145.

J. T.

II. Geology.

1. *Correlation Papers—Neocene* (*Bulletin of the U. S. Geological Survey, No.* 84, *Washington,* 1892); by William Healey Dall and Gilbert Denison Harris.—A part of the recent work of the Geological Survey in the classification of the formations of the United States for the purpose of constructing a general geologic map is represented by a series of memoirs showing the present state of our knowledge of the several systems of rocks, in America, the series being called " Correlation Papers." The memoirs represent not only bibliographic study but more or less field work. That pertaining to the Neocene (including the Pliocene and Miocene of the Lyellian classification) is especially rich in results of original field researches in both invertebrate paleontology and stratigraphy. The treatment of Florida and Alaska in particular is monographic, and so largely based on the personal observations of the senior author as to render the memoir the best source of information extant concerning the geology of these little known corners of our domain.

The Neocene formations of the country are considered as belonging to three natural geographic provinces, viz: the Atlantic and Gulf province, the Pacific coast province, and an interior province made up of terrestrial and freshwater basins. The principles of classification recognized are far-reaching and philosophic. In the first place, the deposits are classified by genesis as (1) marine sediments, (2) perizonal deposits (the deposits accumulated " between the neutral zone where sediments are dropped " by the sea " and the point where subaërial erosion terminates "— page 98), (3) lake beds, and (4) subaërial and fluvial deposits. These several classes of deposits are regarded as dynamic types. Proceeding on the basis of this physical classification, the applications and limitations of paleontologic correlation are next set forth. It is first shown that deposits of different dynamic types may be synchronous, as the life conditions are sometimes so diverse that synchrony can neither be assumed nor denied *à priori.* Then the more general conditions affecting deposition and organic existence are discussed, and it is shown that the distribution of fossils and thus the correlation of fossiliferous formations is affected by various conditions, notably sea-temperature. From a census of the shell-bearing marine mollusks in recent faunas of different temperature zones throughout the world, the authors " conclude that that part of the average mollusk fauna which is

capable of leaving traces in the shape of fossils, under conditions not greatly different from those of the present day, if situated in the arctic or boreal region, would comprise about 250 species; in the cool temperate region about 400 species; in the warm temperate, about 500 species; and in the tropical region, not less than 600 species" (page 27). The clear recognition of these local and general conditions as affecting the life of the globe prepares the way for a distinct advance in practical geologic correlation. Many years ago Barrande developed the conception of colonies, and subsequently Huxley wrought out the idea of homotaxis to explain the recurrence of allied faunas in different regions at different periods; and in this country Calvin, followed in greater detail by H. S. Williams, called attention to the changes in Paleozoic faunas evidently accompanying changes in character of sedimentation. These paleontologic researches, in common with modern researches in biology, show that life has not flowed in an even stream but has been constantly affected by local and general environmental conditions. Dall and Harris go further than their paleontologic predecessors and, thanks to the exceptional opportunity afforded by the study of relatively recent deposits, are able clearly to formulate a part at least of the homotaxial conditions. Thus their memoir is an important contribution not only to geology through paleontological method but also to general biology, and may be considered an exposition of the principles of homotaxy. The authors' final conclusion concerning the applications and limitations of paleontology as a basis for geological correlation is thus stated : "While paleontology holds the key to the problems of local and comparative stratigraphy, yet no study of paleontology that neglects the broad and general stratigraphic changes which accompany the development of the continental border as a whole is calculated to afford results of permanent value" (page 31).

The second chapter is a summary of knowledge concerning the Neocene of the Atlantic and Gulf coasts, arranged by states and illustrated by a special map of Florida and a general map showing the distribution of the Neocene formations of the country; while the third chapter is a general discussion of the relations of the Neocene deposits of the eastern province.

After showing that the Pliocene of North America, though homotaxial is probably not wholly synchronous with that of Europe and that the end of the American Miocene as generally understood, was marked by a great movement in elevation which united North and South America and joined the island of Florida to the mainland of Georgia, the authors adopt the culmination of this elevation as the physical event terminating the Miocene and from which the American Pliocene extends until, in its turn, terminated by the inauguration of the Glacial epoch.

Having thus limited the major divisions of the Neocene, the subdivisions of Miocene and Pliocene are discussed. The term Miocene in the United States has hitherto been understood to include the epoch covering the deposition of the well known

beds extending from New Jersey to Georgia which have been variously subdivided by Heilprin and others. It is now shown, however, that this Miocene, for which the name Chesapeake is adopted, represents only a part of the geological column between the Eocene and Pliocene. It was preceded by a division of at least equal importance, represented on the Gulf coasts by a greater thickness of strata, which encloses a fauna closely related to the Haitian and Jamaican Miocene, and of a distinctly tropical facies. Traces of this fauna are found in New Jersey, but it is in Florida and on the north shores of the Gulf of Mexico that it is found, uneroded, in its full development.

For the epoch covering its deposition and including the Chattahoochee and Tampa groups the name of Chipola has been proposed by Dall in a later publication.* The transition from the Chipola to the Chesapeake fauna is abrupt and is shown to involve a marked refrigeration of the Gulf of Mexico.†

The Pliocene of Florida shows a subtropical reaction in the matter of temperature, perhaps promoted by the closure of the strait which in Miocene times separated the peninsula from Georgia. The age of the South American fossil mammals which are found in Florida is determined by their discovery, as announced here, between mid-Pliocene shell limestones; and, incidentally, the peninsula of Florida is shown to consist of a central trough or ancient lake-basin, for which the name of De Soto is proposed, with low but unmistakable parallel folds on either side of the peninsula. The entire peninsula is built up of marine organic sediments and contains no minerals of other origin. Degradation has proceeded by solution rather than erosion, and reasons are given for supposing that the peninsula, since the Miocene, has maintained a remarkable stability and has not submitted to any serious changes of level.

Two chapters are devoted respectively to detailed description and general discussion of the Neocene formations of the Pacific coast of the United States and Canada, including Alaska; the latter being illustrated and elucidated by a convenient "Table indicating conditions existing during Cenozoic time in regard to changes of level" and the prevalence of volcanic emissions on the northwest coast (p. 278). The most interesting fact discussed is the age of the so-called Miocene leaf-beds of Alaska and the northwest coast which may probably turn out to be of Eocene age. The "Ground ice formation" of northern Alaska has also a peculiar interest.

* Trans. Wagner Inst., vol. iii, p. 307, Jan., 1892.

† This writing gives opportunity for the correction of an erroneous expression by the writer, printed before the appearance of the above memoir ("The Lafayette Formation," 12th Annual Report of the Director of the U. S. Geological Survey, 1892, page 411). The faunal change recognized by Dall and Harris has no connection with differences made by Heilprin the basis of a separation of the Atlantic coast Miocene into a "Marylandian" and "Virginian" series. The latter simply relate to proposed subdivisions of the Chesapeake formation, on the principle of percentages of survival.

The formations of the interior province, over 30 in number, are described in detail by states and correlated so far as the data permit by paleontologic characters coupled with dynamic conditions. The memoir is supplemented by an " Annotated list of names applied to Cenozoic beds and formations of the United States excluding the Laramie (pages 320–338), over 200 in number."

The work is slightly marred by clerical and typographical errors due to the absence of the authors while the matter was passing through the press; several of these are noted in a list of errata, but others may be noted by readers—e. g. the statement on page 189 that the Lafayette formation reaches "a *thickness* of 450 to 550 feet" should read "altitude." It should also be noted that nearly two years intervened between the submission and publication of the manuscript.   W. J. McGEE.

2. *Michigan Geological Survey—Report of the State Board of Geological Survey for the years* 1891 and 1892. 192 pp. 8vo, 1893. Lansing, Michigan.—Contains the Reports of Dr. CARL ROMINGER for the years 1881–2 and 1882–3; of Mr. CHARLES E. WRIGHT for the years 1885–8; of Dr. M. E. WADSWORTH for the years 1889, 1890, 1891, 1892, made to the State Board of Geological Survey for the years named; and also a Provisional Report by Dr. M. E. WADSWORTH, State Geologist, upon the Geology of the iron, gold and copper districts of Michigan.

3. *Geological Survey of Missouri*, ARTHUR WINSLOW State Geologist. Vol. II, 1892. *A report of the Iron Ores of Missouri*, by FRANK L. NASON, Assistant Geologist, for the years 1891 and 1892, 365 pp. 8vo, with maps, sections and other illustrations, 1892. Jefferson City, Mo.

Vol. III, 1892, 256 pp.—*A Report on the Mineral Waters of Missouri*, by PAUL SCHWEITZER, Assistant Geologist, embodying also the notes and results of the analyses of A. E. WOODWARD, Assistant Geologist, for 1890 and 1892. Jefferson City, 1892.

4. *Geological Survey of Texas*, 1892.—*Report on the Brown Coal or Lignite of Texas*, by E. T. DUMBLE, State Geologist, 232 pp. 8vo, with maps and other illustrations. Austin, 1892.

5. *The Journal of Geology:* A semi-quarterly Magazine of Geology and related Sciences. Vol. I, No. 1, pp. 1–112, January–February, 1893. The University Press of Chicago.—This new Journal opens with an interesting series of articles presented in particularly attractive typographical form; it promises to occupy a sphere of wide usefulness and influence. It is under able management : the senior editor is Professor T. C. Chamberlin of the University of Chicago, and the other editors are: R. D. Salisbury in geographic Geology; J. P. Iddings in Petrology; R. A. F. Penrose, Jr., in economic Geology; C. R. Van Hise in Pre-Cambrian Geology; C. D. Walcott in Paleontologic Geology ; W. H. Holmes in Archeologic Geology. There are also thirteen associate editors, six of these chosen from abroad.

The table of contents of this first number is as follows: The Pre-Cambrian rocks of the British Isles, by Sir Archibald Geikie; Are there traces of glacial man in the Trenton gravels? by W. H. Holmes; Geology as a part of the college curriculum, by H. S. Williams; The nature of the englacial drift of the Mississippi basin, by T. C. Chamberlin. The subscription price is three dollars per annum.

6. *Republication of Conrad's Works.*—Conrad's " Fossil Shells of the Tertiary Formations of North America" will be republished by Mr. G. D. Harris of Washington, D. C., as soon as 100 subscriptions can be obtained at $3.00 each, (about half the original cost of publication). The new edition will include Nos. 1, 2, 3 and 4 of the original edition, No. 3 of the so-called " republication of 1835," together with the different editions of Prefaces, Introductions, etc. Those desiring copies at the above rate should confer at once with Mr. Harris, care of Smithsonian Institution.

Conrad's "Medial Tertiary" is about to be republished by the Wagner Free Institute of Sciences of Philadelphia.

7. *Lines of Structure in Meteorites.*—Dr. Brezina has kindly called my attention to the discussion of the lines in stony meteorites given by v. Reichenbach in an article in *Poggendorff's Annalen*, vol. cviii, pp. 291–311 (1859), *Ueber das Gefüge der Stein-Meteoriten.*   H. A. N.

III. Botany.

1. *The localization of the perfumes of Flowers.*—Mesnard's method of examining floral odors is applicable to a wide range of micro-chemical studies. A ring of glass is cemented to a suitable glass-slide, and within this cell another smaller ring is glued, in such a manner as to leave between the two a clear annular space. In this space is placed pure chlorhydric acid. On a cover-glass, large enough to cover the whole of the larger cell, is put a drop of pure glycerine containing a good deal of sugar, and in this reagent is deposited the section of petal to be studied. The cover-glass is now to be inverted and applied to the outer ring. By the concurrent action of the vapor of the acid and the dehydrating activity of the glycerine, the essential or the fatty oil containing the perfume separates in minute drops.

A modification of the process directs that the central ring be covered by its own cover-glass. On this the drop of glycerine is to be put, and this is to hold the sections.

By this simple method, the localization of the perfume of the jasmine, rose, violet and tuberose, has been effected.   G. L. G.

2. *Botanical Prizes of the French Academy.*—For the year 1892, these prizes were assigned as follows : The *Prix Desmazières*, for the most useful work published during the preceding year, on any cryptogamic subject was given to Professor Pierre Viala, for his studies in regard to certain diseases of grapevines and fruit trees. The committee call particular attention to the

thoroughness with which these pathological researches have been conducted, and to the long period of nine years which they have covered. The *Prix Montagne*, for local cryptogamic floras, has been given to Auguste-Marie Hue, an Abbé, for his Lichens of of Canisy, (Manche) and neighborhood. A second prize, of five hundred francs, was awarded to Dr. F. Xavier Gillot for his catalogue of the higher fungi of the neighborhood of Autun. The *Prix de la Fons Mélicocq*, for the best work on the flora of the north of France, is given to M. Masclef for his Geographical Botany of Northern France. The latter work was submitted in manuscript. The *Prix Thore* was not assigned.   G. L. G.

3. *How blanched seedlings can be saved.*—CORNU communicates to the French Academy some very interesting notes in relation to a new method of bringing plants from distant tropical regions. The seeds of the plants in question are brought under conditions which reduce the chance of their germination during the voyage down to the smallest risk, but in spite of all precautions such seeds are likely to sprout and arrive as blanched, unhealthy and " drawn " seedlings which have hitherto been thrown away. Cornu has employed as a suitable mechanical support for the scanty roots of these unhealthy seedlings, a material known as fern-earth, that is, the detritus formed by the broken up rootstocks of *Polypodium vulgare.* This is a dry and somewhat porous mass which is almost free from any likelihood of any invasion by mould. Upon this polypod support, the isolated plants are placed with a little moisture, and are exposed to a small amount of light under a bell-jar. In a short time they resume their proper green color, and speedily take good root, after which they can be heaped up with common earth, or transplanted, as is thought best. By use of this simple means, it has been possible to save some very important plants which arrived at Paris in a wretched condition.

Not only are etiolated seedlings saved in this way, but it has been found possible to save also seedlings which have been injured by drying of some part or by mechanical injury. In some instances it has been the good fortune of Cornu to restore seedlings which had sprouted under soil and had come to hand in a perfectly hopeless condition.

The material which Cornu suggests is even better than coir, which has been employed for much the same purpose and in the same way. Coir is the firm fibre which surrounds the shell of the cocoanut, and which can be easily broken up into soft masses which are not at all affected by mould until a long time has elapsed.   G. L. G.

4. *Influence of moisture on Vegetation.*—E. GAIN (Comptes rendus, Nov. 21, 1892), has conducted experiments, which, though largely repetitions of investigations by others, are worthy of mention as showing a possibility of getting results from cultivation in an arid climate, under irrigation, which are unattainable elsewhere. Gain points out that a dry air and a moist soil are

very favorable to the blooming of plants, while a moist atmosphere is extremely unfavorable. This favorable effect was indicated in the former case especially by the precocity of the vegetation, which was so great as to allow of having three crops produced in a single season. From the researches of Gain, it would appear as if irrigation had advantages which have not hitherto been fully appreciated. G. L. G.

IV. Astronomy.

1. *Transactions of the Astr. Observatory of Yale University*, vol. i, Parts III and IV.

Part III. *Triangulation of Stars in the Vicinity of the North Pole;* by William L. Elkin.

This investigation was undertaken in consequence of a request from Prof. Pickering, of Harvard, to determine with the heliometer the relative positions of a few stars near the North Pole to serve as fundamental points for a photographic survey of that region. The author enlarged the plan to include 24 stars, nearly all of those bright enough to be well measured with the instrument within $1\frac{3}{4}$ degrees of the Pole in 1888. The plan of measurement adopted consisted in measuring all the intermutual distances between the 24 stars within the range of the heliometer, 145 of all the 276 possible combinations. These were observed each three times and a zone of stars ending with 51 *Hev. Cophei* and δ *Ursae minoris* was taken for an independent and simultaneous determination of the scale value. The adjustment of the measurement was carried out by a series of successive approximations, the system or coördinates used being that proposed by Fabritius, which offers great advantages for stars near the Pole. A first set of approximations revealed the existence of a systematic error in the measures, which being duly allowed for, a final system was derived, which was referred to the Pole by means of the Berlin Jahrbuch places of α and λ *Ursae minoris*. These final places are also given in the usual system of right ascension and declination together with tables for precessional changes. The probable errors were derived by a process suggested by Dr. Gill. The proper motions of the stars are small; approximate values can be inferred from the comparison given with Carrington's places for 1855.

Part IV. *Determination of the Orbit of the Comet* 1847, VI, by Margaretta Palmer.

This comet was discovered on Oct. 1, 1847, by Miss Maria Mitchell at Nantucket, Mass., and subsequently independently by de Vico at Rome, by Dawes in England, and by Madame Rümker at Hamburg. Its orbit had been investigated by Dr. George Rümker in a nearly exhaustive manner, but a slight improvement seemed possible by a new discussion of the places of the comparison stars, by introducing modern places of the sun and by taking the planetary perturbations into consideration. This, together

with the personal incentive derived from the fact of the author-ess's having been a pupil of Miss Mitchell at Vassar College, led to her undertaking a new determination.

Starting from Rümker's elements all the observations are com-pared with them, using star places derived from all available sources including the unpublished zones of the Astron. Gesell-schaft, and taking into consideration as far as possible the syste-matic errors of the various authorities. The perturbations by Venus, the Earth, Mars and Jupiter are applied to the normal places which are obtained by using places of the sun from Lever-rier's tables. The differential coefficients for the 6 normal places are computed by Schönfeld's formula and the normal equations are solved both for a parabola and an indeterminate conic section. In this latter case the eccentricity comes out $= 1{\cdot}0001727$, indi-cating a hyperbolic character of the orbit. The reduction of the sums of the squares of the residuals from $702{\cdot}11$ for the parabola to $171{\cdot}87$ for the hyperbola makes the conclusion seem well war-ranted that the observational data require this latter curve for their satisfactory representation, thus confirming Rümker's sim-ilar conclusion.

2. *Schreiner's Spectral-Analyse Der Gestirne.*—It is announced that a translation by Prof. E. B. Frost of Dartmouth College, of Dr. Schreiner's well known work, is to be issued in the autumn of 1893. Subscriptions ($5) are solicited by the publishers, Messrs. Ginn & Co., Boston.

V. Miscellaneous Scientific Intelligence.

1. *Observations in the West Indies;* by Alexander Agassiz. (In a letter to J. D. Dana, dated Steam Yacht "Wild Duck," Nassau, March, 1893).—Here we are back at Nassau for the third time, and thinking you might be interested to hear of my cruises, I send you a short sketch of our trip. The first time we left Nassau we entered the Bahama Bank at Douglass Channel and crossed the Bank to North Eleuthera, where we examined the "Glass Window" and the northern extremity of Eleuthera, we then sailed along the west shore of the island close enough to get a good view of its characteristics as far as Rock Harbor at the southern end. We steamed out into Exuma Sound through the Beach Channel and round the southern end of Eleuthera to little San Salvador, and the northwest end of Cat Island, where are the highest hills of the Bahamas. We then skirted Cat Island along its western face, rounded the southern extremity and made for Riding Rocks on the western side of Watling's Island. We cir-cumnavigated Watling, passed over to Rum Cay, then to north-ern part of Long Island, visiting Clarence Harbor; next we crossed to Fortune Island, and passed to the east side near the northern end of the island on the Crooked Island Bank. From there we crossed to Caicos Bank, crossing that bank from French Cay to Long Island, passed by Cuklum Harbor and ended our

eastern route at Turk Island; from there we shaped our course to Santiago de Cuba to coal and provision the yacht. We were fortunate enough to strike Cape Maysi a short time after daylight, and I thus had a capital chance to observe the magnificent elevated terraces (coral reef) which skirt the whole of the southern shore of Cuba from Cape Maysi to Cape Cruz and make so prominent a part of the landscape as seen from the sea. We were never more than 3 miles from shore and had ample opportunity to trace the course of some of the terraces as far as Santiago, and to note the great changes in the aspect of the shores as we passed westward due to the greater denudation and erosion of the limestone hills and terraces to the west of Cape Maysi, which seems to be the only point where five terraces are distinctly to be seen. The height of the hills back of Pt. Canete where the terraces are most clearly defined, I should estimate at 900 to 1000 feet; though the hills behind the terraces, which judging from their faces are also limestone, reach a somewhat greater height, perhaps 1100–1200 feet.

After coaling at Santiago de Cuba we visited Freayna, and next steamed to Hogstey Reef, a regular horseshoe-shaped atoll with two small Keys at the western entrance. There we passed three days studying the atoll. This to me was an entirely novel experience; to be at anchor in 3 fathoms of water 45 miles from any land with water 900 fathoms within 3 miles outside, surrounded by a wall of heavy breakers pounding upon the narrow annular reef which sheltered us. I made some soundings of the lagoon and of the slope of reef outside. From there we returned to Crooked Island Bank to the westward of which I also made some soundings to determine the slope of the Bank. We next again visited Long Island, taking in the southern and northern ends which I had not examined. From there we passed to Great Exuma, stopping at Great Exuma Harbor and sounding into deep water on our way out to Conch Cut when we sailed west crossing the Bank to Green Cay. From there we made the southward of New Providence, and before going in to Nassau Harbor made some trials in deep water in the Tongue of the Ocean with the "Tanner" deep-sea townet in 100 and 300 fathoms, depth being 700 fathoms—after which we returned to Nassau. I had on board a Tanner sounding machine kindly loaned me for this trip by Col. McDonald of the Fish Commission, and some deep-sea thermometers were also kindly supplied by him and by Professor Mendenhall, the superintendent of the U. S. Coast Survey. I supplied myself with a number of Tanner deap-sea townets and with a supply of drops and of townets and carried on board a Yale and Towne patent winch for winding the wire rope which I used in my dredging and towing in deep water. The yacht was provided with a steam capstan and by increasing its diameter with logging we found no difficulty in hauling in our wire rope at the rate of 8 min. to a 100 fathoms. I carried 600 fathoms of steel wire dredging rope with me

of the same dimensions which I had used on the "Blake" and which has also been adopted on the "Albatross." During our second cruise we steamed from Nassau for Harvey Cay crossing the Bank from north to south to Flamingo Cay and then to Great Ragged Cay, from which we took our departure for Baracoa. At Baracoa I hoped to be able to ascend the Yomque; unfortunately I had to give up my trip owing to the desperate condition of the roads. From Baracoa we steamed close to the shores to the westward, touching at Port Banes, Port Padre, Cay Confiles, Sagua, Cay Frances, Cardenas, Matanzas, and finally ending at Havana. This trip was a continuation of the observations we made on the south coast of Cuba and enabled me to trace the gradual disappearance of the terraces from Baracoa to Neuvitas, and their reappearance from Matanzas to Havana, from the same causes which evidently influenced their state of preservation from Cape Maysi west. I also got a pretty clear idea of the mode of formation of the fine harbors found on the northern coast of Cuba to the eastward of Neuvitas, and of the mode of formation of the extensive system of cays reaching from Neuvitas to Cardenas and which find their parellel on the south coast of Cuba from Cape Cruz to Cape Corrientes. After refitting at Havana we left for Nassau. Both on going into Havana and on leaving we spent the greater part of a day in towing with Tanner net. I thought I could not select a better spot for finally settling the vertical distribution of pelagic life than off Havana which is in deep water—900 fathoms—close to land, on the track of a great oceanic current, the Gulf Stream, noted for the mass of pelagic life it carries along its course. We towed in 100, 150, 250, and 300 fathoms and on the surface at or near the same locality, and I have found nothing to cause me to change the views which I expressed in my Preliminary Reports of the "Albatross" expedition of 1891. Nowhere did I find anything which was not at some time found also at the surface. At 100 fathoms the amount of animal life was much less than in the belt from 100 fathoms to the surface. At 150 fathoms there was still less and at 250 fathoms and 300 fathoms the closed part of the Tanner contained *nothing.* At each one of these depths we towed fully as long as was required to bring the net to the surface again. Thus we insured before the messenger was sent to close the lower part of the bar as long a pull through water as the open part of the net would have to travel till it reached the surface, giving the fauna of a horizontal column of water at 100, 150, 250 and 300 fathoms of the same or greater length than the vertical column to the surface for comparison of their respective richness. From Havana we steamed to Cay Sal Bank, visited Cay Sal, Double headed Shot Cays, Anguila Islands, and then crossed over to the Great Bank to the west of Andros Island. The bottom of this bank is of a most uniform level, 3 and $3\frac{1}{2}$ fathoms for miles and then very gradually sloping to the west shore of Andros, so that we had to anchor nearly six miles from the wide opening of the central part of Andros which we visited. The

bottom consists of a white marl, resembling when brought up in the dredge newly mixed plaster of Paris, and having about its consistency just as it begins to set. This same bottom extends to the shore; and the land itself, which is low where we went on shore not more than 10 to 15 inches above high water mark, is made up of the same material, which feels under foot as if one were treading upon a sheet of soft india rubber; of course on shore the marl is drier and has the consistency of very thick dough. It appears to be made up of the same material as the æolian rocks of the rest of the Bahamas, only that it has become thoroughly saturated with salt water and in that condition it crumbles readily and is then triturated into fine impalpable powder almost like deep sea ooze which covers the bottom of the immence bank to the west of Andros. After leaving Andros we crossed the Bank again to Orange Cay and followed the eastern edge of the Gulf Stream to see Riding Rocks, Guin Cay and the Beminis. We then passed to Great Isaac where we saw some huge masses of æolian rocks which had been thrown up along the slope of the cay about 80 fathoms from high water mark to a height of 20 feet. One of these masses was $15' 6'' \times 11'' \times 6'$. We then kept on to Great Stirrup Cay coasting along the Berry Cays, crossed over to Morgan's Bluff, on eastward of Andros down to Mastic Point on the same Sound, and then returned to Nassau.

The islands of the Bahamas (as far as Turks Island) are all of aeolian origin. They were formed at a time when the Banks up to the 10-fathom line must have been practically one huge irregularly shaped mass of low land, from the beaches of which successive ranges of low hills, such as we still find in New Providence, must have originated. After the islands were thus raised there was an extensive gradual subsidence which can be estimated at about 300 feet, and during this subsidence the sea has little by little eaten away the æolian lands, leaving only here and there narrow strips of lands in the shape of the present islands. Inagua and Little Inagua are still in the original condition in which I imagine such banks as the Crooked Island Banks, Caicos Banks and other parts of the Bahamas to have been; while the process of disintegration going on at the western side of Andros shows still a broad island which will in time leave only the narrow eastern strip of higher land (æolian hills) on the western edge of the tongue of the ocean. Such is the structure also of Salt Cay Bank which owes its present shape to the same conditions as those which have given the Bahamas their present configuration. My reason for assigning a subsidence of 300 feet is the depth of some of the deep holes which I have surveyed on the Bank and which I take to be submarine blow holes or cañons in the aeolian limestone of the Bahama hills when they were at a greater elevation than now. This subsidence explains satisfactorily the cause of the present configuration of the Bahamas, but teaches us nothing in regard to the substratum upon which the Bahamas were built. The present reefs form indeed but an insignificant part of the to-

pography of the islands and have taken only a secondary part in filling here and there a bight or a cove with more modern reef rock, thrown up against the shores so as to form a coral reef beach such as we find in the Florida Reef. I have steamed now nearly 3,300 miles among the Bahamas, visiting all the more important points and have made an extensive collection of the rocks of the group.

I hoped to have made also a larger number of deep soundings than I have been able to take; unfortunately the trades were unusually heavy during the greater part of my visit to the Bahamas, greatly interfering with such work on a vessel no larger than the " Wild Duck "—127 feet on the water line. For the same reason the number of deep-water pelagic hauls was also much smaller than I hoped to make, as in a heavy sea the apparatus would have been greatly endangered. It is a very different thing to work at sea in a small yacht like the " Wild Duck," or in such vessels as the " Blake" and the " Albatross" of large size and fitted up with every possible requirement for deep sea work. The " Wild Duck," on the other hand, was admirably adapted for cruising on the Bahama Banks, her light draught enabling her to go to every point of interest and to cross and recross the Banks where a larger vessel could not follow. I am under the greatest obligations to my friend Mr. John M. Forbes for having so kindly placed his yacht at my disposal for this exploration, and I hope soon after my return to Cambridge to publish more in detail the results of this examination of the structure of the Bahamas.

2. *The Barrier Reef of Australia: Its Products and Potentialities ;* by W. SAVILLE-KENT. (W. H. Allen & Co., 13 Waterloo Place, London.)—The publishers announce that this important work is now about ready. The specimen copies of the plates furnished give a high idea of the unusual beauty of the illustrations.

3. *Logarithmic Tables,* by Prof. GEORGE WILLIAM JONES of Cornell University. Fourth edition, 160 pp. 8vo. London (Macmillan & Co.) and Ithaca (George W. Jones).—There are many books of logarithmic tables, but this one is especially notable for its convenience and compactness of arrangement, clearness of typographical work and breadth of scope. Eighteen tables in all are given and the judicious selection and arrangement of these by the editor gives the student a much wider and more generous equipment for his work than can often be found within the limits of a small volume and one sold at the low price of seventy-five cents.

OBITUARY.

NICOLAS KOKSHAROV, the veteran and long honored Russian mineralogist, died on January 2, 1893, at an advanced age. His *Materialien zur Mineralogie Russlands,* of which the first volume was issued in 1853–54 and the tenth volume completed in 1891, is a monumental contribution to science and will always be a model of careful and accurate research.

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CONTENTS.

SCIENTIFIC INTELLIGENCE.

VOL. XLV.

MAY, 1893.

THE

AMERICAN

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THIRD SERIES.

VOL. XLV.—[WHOLE NUMBER, CXLV.]

No. 269.—MAY, 1893.

MINERALS, NEW ARRIVALS.

Large lots have been received from Sweden, France, Utah and other localities but the most remarkable are a series of Swedish, Norwegian and Finland minerals obtained in exchange from the Riksmusem at Stockholm through Baron A. E. Nordenschiold, the celebrated Arctic explorer. This is, as the Professor says, the finest collection of these minerals ever sent to this country. There are a number of duplicates of some of them and they supplement the collections made by myself last summer in many species.

The following are a few.

Well crystallized **Columbite**, 75c. to $5.00.

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EXTRA RARE AND VALUABLE BOOKS.

The following are among those received the past month. The first seven are the rare Wilkes Exploring Expedition Reports.

Dana, J. D. Crustacea. 2 vols. and atlas. 96 plates, (45 colored). 1855 ......$100.00

Dana, J. D. Geology. Vol. and atlas. 21 plates 35.00

Gray, A. Phanerogamia. Vol. and atlas. 100 plates 50.00

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Agassiz. Poissons d'Eau douce de l' Europe Centrale. 2 vols. 52 fine plates, many elaborately colored, and heightened with silver. 15.00

American Naturalist. First 19 vols. half roan 50.00

Wurtz. Dictionnaire de Chimie 25.00

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————•◆•————

Art. XLI.—*On the Deportment of Charcoal with the Halo-gens, Nitrogen, Sulphur, and Oxygen ;* by W. G. Mixter.

Charcoal containing the Halogens.

The difficulty in obtaining amorphous carbon fairly pure is a serious obstacle in an investigation of its properties. Kirwan[*] observed in the year 1785 that charcoal after prolonged and intense ignition contains hydrogen. The recent handbooks and dictionaries of chemistry state that the hydrogen may be removed by heating the charcoal in chlorine, while the older dictionaries contain nothing on the subject. The writer has been unable to learn who is the author of the method or to find any mention of analytical tests for chlorine in charcoal purified by ignition in chlorine. Berthelot and Petit[†] treated wood charcoal with hydrofluoric and hydrochloric acids, next with chlorine at a red heat, and finally calcined it in a Perrot furnace. Their charcoal was doubtless free from chlorine. Weber[‡] for his work on the specific heat of carbon prepared amorphous carbon by heating wood charcoal to bright redness for fifteen minutes in a stream of chlorine in order to remove hydrogen. It would be interesting to know that the distin-guished experimenter proved the absence of chlorine in the charcoal he used. Wright and Luff[§] heated sugar charcoal for two hours in chlorine and then ignited it for six hours in platinum over a blowpipe to remove chlorine. Their analyses of two preparations are as follows :

Carbon _____	96·17	95·13
Hydrogen _____	0·84	0·75
Ash _____ _____	1·56	1·68
Oxygen by difference___	1·43	2·44

These results are interesting as they show how tenaciously charcoal retains hydrogen even after ignition in chlorine.

While attempting to prepare for use in an investigation amorphous carbon free from hydrogen the writer observed that charcoal retains considerable chlorine at high temperatures. This fact has doubtless been observed but there appears to be nothing on the subject in the literature of chemistry except the statement by Schönbein[*] that charcoal absorbs chlorine and retains some of it when heated.

Experiments were made with amorphous carbon from various sources, but only the results will be given that were obtained with three varieties, viz: sugar charcoal, lampblack, which is finely divided charcoal, and gas carbon. The first was prepared by charring in an open platinum dish cane sugar which was almost free from ash. The charcoal was pulverized in an agate mortar, moistened with sugar syrup and then pressed in a hydraulic press. The pieces were next heated to redness and plunged into a thick syrup, and this treatment was repeated until the charcoal would sink in water without boiling to expel the air from the still porous coal. Finally, the sugar charcoal was heated intensely for several hours in a crucible by a charcoal fire in a wind furnace having a strong draught. The method employed for estimating hydrogen was as follows : the charcoal was heated to redness in a platinum tray, allowed to cool in a desiccator, then weighed and placed in the combustion tube and then, in order to drive off absorbed water, it was heated to faint redness for half an hour in a current of dry air in which it did not ignite. The combustion was made in oxygen dried by oil of vitriol, solid caustic potash, and finally, calcium chloride. An ordinary calcium chloride tube was used to absorb the water of the combustion. In a blank test of the apparatus the calcium chloride tube gained 0·2 milligram. One lot of sugar charcoal prepared as described yielded 0·13 per cent of hydrogen, 1·12 gram being used for the combustion. 1·25 gram of another preparation gave 0·126 per cent of hydrogen and 0·04 per cent of ash. The sugar charcoal burned with difficulty in oxygen, was hard enough to scratch glass, and was a good conductor of electricity.

The lampblack used was of a kind made from natural gas known as "Diamond Black." It is well described by Mallet.[†]

* Pogg. Ann., lxxiii, 326.   † Chem. News, xxxviii, 94.

My analysis of the lampblack gave 1 per cent of hydrogen, 0·04 of ash and in an air-dry portion 0·23 per cent of nitrogen by the absolute method. After igniting for two hours in dry nitrogen and allowing to cool in the gas, no nitrogen was obtained on burning with oxide of copper. This kind of lampblack when pressed into compact pieces conducts electricity, and when heated *in vacuo* it yields a small sublimate as observed by Mallet.

The gas carbon used was from the inner portion of a thick piece. A combustion of 1·742 gram of it yielded 0·035 per cent of hydrogen and 0·88 of ash.

The chlorine used in the experiments was made from salt, manganese dioxide and sulphuric acid, and was passed through one wash-bottle containing water and one containing oil of vitriol. The temperature in the experiments was the highest attainable in a gas combustion-furnace, that is, a bright red heat. A hard glass or porcelain tube was used to hold the charcoal during the ignition in chlorine.

Experiment 1.—10 grams of sugar charcoal were ignited in chlorine for three hours, then left for a day over solid caustic potash, and finally heated to redness for an hour *in vacuo*. The product weighed 10·304 grams and contained 3·7 per cent of chlorine.*

Another portion of 10 grams of the same charcoal was exposed at common temperature to a current of chlorine for three hours, then dry air was passed through the tube for 15 minutes. The gain in weight of the charcoal was 0·098 gram which was not diminished by exhausting the tube and then opening to the air. The results show that cold dense sugar charcoal takes up much less chlorine than when heated. Probably chlorine is simply occluded by cold charcoal; whether chlorine is chemically combined which is retained by hot charcoal will be discussed after the experimental results are given.

Experiment 2.—Sugar charcoal was heated to redness in a porcelain tube, then chlorine was passed through the tube for three hours, and while red hot the chlorine gas was displaced by nitrogen. The charcoal as it came from the warm tube gave off no chlorine, of which it was found to contain 4·6 per cent.

Experiment 3.—(*a*) Chlorine was passed for two hours over cold lampblack, and then (*b*) over glowing lampblack. Both preparations of chlorinated lampblack were left for a day over solid potash in a partial vacuum. 7·9 per cent of chlorine

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* The estimation was made by burning the chlorinated charcoal in moist oxygen and passing the products of combustion through dilute ammonia to absorb the chlorine, which was afterwards precipitated as silver chloride by the addition of silver nitrate and nitric acid It was found that chlorinated charcoal or lampblack burned with difficulty and often incompletely in dry oxygen.

was found in first. The preparation *b* gave 14·3 per cent of chlorine by the combustion method and 15·5 per cent by fusing with soda and niter. The low result by the method of combustion is due to the formation of carbon chlorides which form a slight sublimate and sometimes oily drops on the ammonia water. 3·75 grams of the chlorinated lampblack of *b* were placed in a glass tube, the anterior end of which contained lumps of caustic potash, and the air was exhausted by a Sprengel pump. The part of the tube containing the lampblack was heated to redness for two hours while the exhaustion was maintained by constant pumping. The evolution of gas not absorbed by potash was slow and 22^{cc} were obtained. The gas had a slight odor and burned with a blue flame. The lampblack after heating *in vacuo* contained 8·5 per cent of chlorine.

Experiment 4.—Lampblack in compact pieces* was heated in a current of chlorine for four hours in a porcelain tube to the highest temperature of a gas combustion furnace. The product after standing a day in the air contained 11·9 per cent of chlorine. 10 grams of the chlorinated lampblack were next placed in a porcelain tube which was connected with a tube containing calcium chloride and slaked lime to absorb water, chlorine and carbon dioxide. The air in the tube was pumped out so completely that after nine hours no more air was obtained by further pumping. The tube was then heated to bright redness for three hours while the Sprengel pump was in constant action. 30^{cc} of a gas were obtained which had a slight odor and burned with a blue flame. The chlorinated lampblack after ignition *in vacuo* contained 9·04 per cent of chlorine.

Experiment 7.—The lampblack of the preceding experiment with 9·04 per cent of chlorine was placed in a porcelain tube plugged with asbestos, and the sugar charcoal of experiment *2* containing 4·6 per cent of chlorine was put into a covered porcelain crucible. Both were heated in a covered clay crucible in a coal fire for fifteen hours, much of the time to a white heat. The porcelain was softened. No chlorine was detected in either carbon after the ignition. The test was made by cautiously heating the carbon with soda to which niter was gradually added and then testing for chlorine by the usual method. The ash of the sugar charcoal increased from 0·04 to 0·17 per cent, due undoubtedly to the absorption of vapors,

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* The lampblack was obtained in compact form by subjecting it to a pressure of about 2500 pounds to the square inch in a hydraulic press. Pressed lampblack is one of the best forms of charcoal for many kinds of experiments as it is uniformly porous and consists of very minute particles. That used in the experiments sank slowly in water, that is, its apparent density was 1 while the true density was according to Mallet 1·7.

perhaps chlorides, during the intense ignition. The following is the analysis of dechlorinated sugar charcoal for hydrogen: 1·4964 grams of the carbon which had been heated to dull redness and cooled in a desiccator were placed in a combustion tube and then heated again to dull redness while a slow current of dry air was passing through the tube to expel if possible all water. The carbon did not appear to burn. The chloride of calcium tube was then attached and the combination made with oxygen. 0·073 per cent of hydrogen was obtained. Another determination with 1·089 gram not heated until placed in the combustion tube gave 0·065 per cent.

Experiment 8.—Gas carbon in lumps was ignited in chlorine and then was allowed to cool in a current of dry nitrogen. Two tests failed to reveal any chlorine in the gas carbon thus treated. Finely pulverized gas carbon was also found to take up no chlorine at a red heat.

As gas carbon does not combine with chlorine the question was suggested: Will charcoal from which chlorine has been expelled by heat take up chlorine again? The following results show that it will.

Experiment 9. — The dechlorinated sugar charcoal of 7 was found to contain 3·24 per cent and the dechlorinated lampblack 2·82 per cent of chlorine after ignition in chlorine.

Experiment 10.—Lampblack and sugar charcoal were ignited for two hours in dry hydrochloric acid gas, and while hot the gas was displaced by dry air. The lampblack contained a minute trace and the sugar charcoal 0·26 per cent of chlorine.

Experiment 11.—Dry hydrogen was passed over the compact chlorinated lampblack of 4 At ordinary temperature no hydrochloric acid appeared, while at a temperature a little below redness the acid came off for three hours, and at a red heat more acid came off. A test showed that the charcoal still contained a little chlorine.

Experiment 12.—Lampblack and sugar charcoal were ignited for two and a half hours in bromine vapor which was finally displaced from the hot tube by a current of dry air. The lampblack was found to contain 3·04 per cent of bromine, and after exposure *in vacuo* to a red heat for two hours it contained 1·49 per cent of bromine. The sugar charcoal absorbed only 0 25 per cent of bromine, most of which it lost on ignition *in vacuo.*

Experiment 13.—This experiment was conducted like the preceding, iodine being used. The lampblack contained 2·04 and the sugar charcoal 0·63 per cent of iodine, both preparations retaining but a trace of iodine after ignition for three hours *in vacuo.*

Experiment 14.—9·6 grams of lampblack were chlorinated by heating for an hour in chlorine, and then allowed to cool in a current of gas. After standing for a day the product was burned in a current of dry oxygen. In the cool and narrowed part of the combustion tube a slight sublimate formed not sufficient for a quantitative analysis. It was found to contain chlorine and to burn with a smoky flame. The gaseous products of the combustion were passed through dilute ammonia on which a slight oily product collected. There was a little loss of chlorine in the fume which escaped from the ammonia which was found to contain, after the combustion was finished, 2·638 grams of chlorine, showing that the lampblack had taken up 27 per cent of its weight of chlorine.

Experiment 15.—Native graphite was ignited for two hours in chlorine, which was then displaced while hot by air. The graphite retained but a trace of chlorine, owing doubtless to impurities.

Experiment 16.—Half a gram of fragments of white diamonds remained unchanged in weight after ignition in chlorine for an hour.

Chloroform, benzene, alcohol and ether failed to dissolve anything from chlorinated lampblack. Boiling dilute ammonia water removed a little chlorine, but the lampblack after protracted digestion with ammonia retained chlorine. A portion of the chlorinated lampblack of *3* which had been heated *in vacuo* and contained 8·5 per cent of chlorine was mixed intimately with artificial alumina. The mixture gave no sublimate on heating in a glass tube in the blast lamp. The test was repeated with a new mixture and the tube containing it was heated in a combustion furnace for half an hour. No sublimate formed, but on passing chlorine over the mixture aluminum chloride appeared at once and was rapidly deposited in the cool part of the tube. Gas carbon, alumina and chlorine yielded at a red heat only slowly a small quantity of aluminum chloride.

The foregoing experiments were made to find whether chlorine held by charcoal at high temperatures is occluded, that is condensed in the pores and on the surface or is chemically combined with the carbon. It is not probable that the chlorine is occluded since gases condensed by charcoal are given off *in vacuo* on heating. If the chlorine were occluded then we should expect that bromine and iodine would be held in larger quantity by charcoal, as the more readily condensible gases are absorbed in the largest quantity, but glowing charcoal retains less bromine than chlorine and still less iodine. Charcoal facilitates combination of gases but when hydrogen

is passed over hot chlorinated charcoal hydrochloric acid, which is not retained by hot charcoal, is formed very slowly. Assuming that chlorine combines chemically with glowing charcoal, the question is, Does the chlorine unite directly with the carbon? Berzelius[*] stated, " In wasserfrei Chlorgas wird ein wohlausgeglühte Kohle bei keine Temperatur verändert." Nothing was said about testing the charcoal for chlorine. Recent writers state that carbon and chlorine do not unite directly, and the foregoing results with the diamond, graphite and gas carbon are in accord with this view. Chlorine, however, combines at high temperatures with charcoal which is not pure carbon but contains hydrogen and the latter is apparently replaced by chlorine in the chlorination of charcoal. Gas carbon containing 0·035 per cent of hydrogen does not take up chlorine, while sugar charcoal with 0·07 per cent of hydrogen does. Further experiments are necessary in order to determine whether sugar charcoal and gas carbon with a like content of hydrogen differ in their deportment towards chlorine.

Nitrogenous Charcoal.

Animal charcoal is known to contain nitrogen and to yield cyanogen to molten alkalies but the amount is not given, although doubtless known to manufacturers of animal charcoal and cyanides. It is stated on page 365 of this Journal that lampblack retains no nitrogen after ignition in dry nitrogen. This accords with the accepted fact that charcoal does not combine at high temperature with free nitrogen. The results of the following experiments show that charcoal not only retains nitrogen at very high temperatures when once combined with it, but also fixes it when ignited in an atmosphere of compounds of it such as ammonia and the oxides of nitrogen. In the decomposition of these bodies by glowing charcoal the nitrogen may be regarded as in the nascent state. The lampblack used in the tests was the " Diamond Black " variety described on page 364 of this Journal.

Experiment 1.—Lampblack was heated to redness for an hour and a half in dry ammonia gas, and while the tube was hot the ammonia was displaced by dry nitrogen. The product contained 3·17 per cent of nitrogen. On heating the nitrogenous lampblack for half an hour to a red heat *in vacuo* some ammonia came off owing to hygroscopic moisture, and the percentage of nitrogen fell to 2·68 per cent.

Experiment 2.—Hard-pressed lampblack was heated for an hour to the highest heat of a gas combustion furnace in a porcelain tube through which dry ammonia gas was passed. The

[*] Lehrbuch des Chemie, 1843, i, 301.

ammonia was displaced by dry nitrogen and the tube was exhausted. The product contained 2·22 per cent of nitrogen. In this and the preceding experiment considerable hydrogen was set free from the ammonia.

Experiment 3 was a repetition of *2* with the difference that the ignition in ammonia was maintained two hours. The escaping gases contained cyanogen. The lampblack contained 3·18 per cent of nitrogen.

Experiment 4.—Sugar charcoal, containing 0·126 per cent of hydrogen and 0·04 per cent of ash, was heated to a bright red heat and dry ammonia was passed over it for an hour, and then the ammonia was displaced by nitrogen and the tube allowed to cool. The hydrogen set free was collected over water and tested by burning. The charcoal after ignition in ammonia yielded 0·16 per cent of nitrogen on combustion. A portion of it was heated with sodium carbonate until it disappeared, the fused mass was dissolved in water and a mixture of ferrous and ferric chloride was added and the whole was warmed and then cooled. On acidifying with hydrochloric acid a small amount of prussian blue appeared.

As incandescent charcoal and ammonia react to form cyanogen it may be that the last is the compound taken up by the charcoal in the experiments with ammonia, since cyanogen reacts with charcoal producing a nitrogenous coal as shown by the following :

Experiment 5.—Pressed lampblack was placed in one end of a tube and mercuric cyanide in the other end, and the tube was gently heated while dry air was passed through it to remove moisture. Next the lampblack was heated to a red-heat which was sufficient to decompose paracyanogen, and the mercuric cyanide was gradually heated so that cyanogen gas passed for half an hour over the lampblack which was then allowed to cool in the gas. The lampblack was next heated, but not to redness, for half an hour in an exhausted tube to remove occluded cyanogen. Gas ceased to come off toward the end of the heating *in vacuo*. The product contained 6·48 per cent of nitrogen. It was finally heated *in vacuo* for one hour to redness when it gave off but little gas and no cyanogen. After the second heating *in vacuo* the lampblack was found to contain 6·46 per cent of nitrogen. When it was ignited in steam, ammonia was formed abundantly.

Experiment 6.—Animal charcoal of unknown origin but presumably from blood, as it left after burning only a small amount of red ash, was heated to redness in a covered platinum crucible, and then was found to contain 6·82 per cent of nitrogen.

Experiment 7.—Albumin from blood was charred in a covered platinum crucible, and the residue was exposed to the heat of a blast lamp five minutes after the escaping gases ceased to burn. The charcoal, which was very bulky and soft, contained 4·43 per cent of nitrogen. It gave off ammonia when heated in steam. A portion of the charcoal after heating for three quarters of an hour to the melting point of cast iron gave a distinct reaction for nitrogen by the test with molten sodium carbonate, etc.

Experiment 8.—Carefully washed and dried egg albumin charred as above yielded a charcoal containing 4·61 per cent of nitrogen.

In experiments described hereafter the charcoal used was not strongly heated and was made by charring sugar in a large platinum dish heated by a Bunsen burner.

Experiment 9.—10 grams of sugar charcoal were heated in a glass tube for a time to faint redness and then to the highest heat of a combustion furnace. During the heating 7 liters of pure nitric oxide* were passed over the charcoal. The charcoal did not glow as when burning rapidly, and about one-third of it was consumed. Carbonic oxide came off abundantly and with it small quantities of carbon dioxide, ammonia, and cyanogen. The charcoal after cooling was pulverized and then heated to incipient redness *in vacuo.* Thus treated it contained 3·44 per cent of nitrogen, but after heating for an hour in a Perrot furnace it was free from nitrogen. The complete removal of the nitrogen was doubtless due to the action of vapor of water from the burning of the gas.

Experiment 10.—This was conducted as nearly as possible like the preceding experiment with the exception that pure nitrous oxide was used. The product contained 1·09 per cent of nitrogen.

Experiment 11.—This was a duplicate of Exp. 10, with the difference that the charcoal was allowed to cool in dry carbon dioxide after the combustion in nitrous oxide was stopped. 3·85 per cent of nitrogen was found in the product. A part of this nitrogenous charcoal was heated for an hour to the highest temperature of a Perrot furnace. The charcoal was held in the middle of a porcelain tube by plugs of asbestos, and lower end of the tube which was not heated contained calcium chloride to dry the air in the tube. The charcoal after exposure to the intense heat was found by the absolute method to contain 0·46 per cent of nitrogen. The charcoal was also further tested by heating with sodium carbonate, dis-

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* The nitric oxide used in this and subsequent experiments was made from nitric acid by means of ferrous sulphate and was dried by sulphuric acid.

solving the saline mass in water and then adding successively a solution of ferrous-ferric chloride and hydrochloric acid. The prussian blue reaction showed the presence of more than a trace of nitrogen.

Experiment 12.—17 liters of nitric oxide were passed during an hour and a half through a tube containing 20 grams of charcoal heated to a dull red. 8 grams of charcoal were burned. The charcoal in the posterior end of the tube glowed feebly and mostly disappeared and the small portion remaining unburned contained 15·33 per cent of nitrogen, while the charcoal in the anterior end contained only 0 96 per cent. 0·092 gram of ammonia was obtained by passing the gases of the combustion through hydrochloric acid.

Experiment 13.—This was made as nearly as possible like the preceding, nitrous oxide being used. The charcoal burned more rapidly than in nitric oxide and with a yellow flame, disappearing completely in the posterior end of the tube. When, however, the heat was lowered to a faint red a small portion of unburned charcoal next the current of gas remained which contained 3·39 per cent of nitrogen, the charcoal from the anterior end yielding 0·26 per cent. The total amount of ammonia collected in the gaseous products of the combustion was 4 milligrams. When the nitrogenous charcoal of this experiment was heated in steam ammonia was formed.

Experiment 14.—30 grams of charcoal were kept at a dull red heat for three hours while 50 liters of nitric oxide were passed over it. The gas was dried by sulphuric acid in three wash bottles. The small portion of charcoal which remained in the posterior end of the tube contained 13·79 per cent of nitrogen. The nitrogen was not estimated in the remainder of the coal which was found to yield cyanogen to a hot concentrated solution of potassium hydroxide.

The charcoal used in the foregoing experiments contained considerable hydrogen and oxygen, when, however, charcoal nearly free from hydrogen is partly burned in nitric oxide no nitrogen is retained as the following shows:

Experiment 15. — Charcoal containing 0 126 per cent of hydrogen and no nitrogen was used. 10·5 grams of dense pieces were heated in a tube from which the air was displaced by dry carbon dioxide. 17 liters of nitric oxide dried by sulphuric acid in three bottles were passed over it in 35 minutes and the highest temperature of a combustion furnace was maintained. 3·7 grams of the coal were burned, the piece in the posterior end of the tube falling to a powder, which was found by the following test to contain no nitrogen: 0·2647 gram of the charcoal and 1·3 gram of potassium chlorate inti-

mately mixed with freshly ignited copper oxide were placed in
a combustion tube, and then copper oxide, a long roll of bright
copper gauze and hydrogen sodium carbonate were put in.
The tube was exhausted by a mercury pump and the combus-
tion was made as usual in the absolute method. 0.2^{cc} of gas
was collected, the amount repeatedly obtained in blank tests.
This method was employed in all the estimations of nitrogen
in charcoal, experience having shown that it is difficult to
burn charcoal with copper oxide alone, and that it is better to
mix the coal with 5 parts of chlorate than to place the latter
in the end of the tube. In none of the determinations of
nitrogen was the copper gauze perceptibly oxidized.

Experiment 16.—Uric acid was heated in a covered platinum
crucible over a large gas burner as long as combustible gases
came off. The resulting charcoal contained 34·06 per cent of
nitrogen.

Experiment 17.—Uric acid was charred by heating gradually
at first, then for half an hour to the highest temperature of a
Perrot furnace. The charcoal after this intense ignition
yielded 3·52 per cent of nitrogen.

Experiment 18.—Uric acid contained in a covered platinum
crucible was heated gradually and the charcoal formed was
kept at a dull red heat for 15 minutes after the escaping gases
ceased to burn. This product had 39·62 per cent of nitrogen.
It was an exceedingly bulky black powder which gave off
ammonium cyanide when heated in a current of dry hydrogen.

Experiment 19.—1 gram of paracyanogen left 6 milligrams
of black residue after heating for two minutes in a covered
platinum crucible over the same lamp that was used in *16*.

Nitrogenous charcoal which has been intensely heated does
not contain paracyanogen as this is converted into gaseous
cyanogen by heat. It is possible that the charcoal from uric
acid with the large content of nitrogen is composed in part of
paracyanogen.

Charcoal containing Sulphur.

Berzelius* made the following statement regarding a solid
sulphide of carbon : " Die Kohle, welche zur Darstellung dieser
Verbindung (carbon disulphide) angewandt worden ist, enthält
Schwefel in chemischer Verbindung, der nicht durch Glühen
ausgetrieben werden kann, wenn dabei der Zutritt der Luft
verhindert wird." This fact, not mentioned in recent works on
chemistry, must be familiar to manufacturers of carbon disul-

*Lehrbuch der Chemie, 1843, i, 300.

phide. Solid compounds of carbon and sulphur formulated as $CS . C_2S_3$, and C_2S_5 have, however, been described.

Experiment 1.—30·9 grams of air dry soft sugar charcoal were kept at the highest temperature of a combustion furnace for an hour and a half, and during this time the vapor of 30 grams of sulphur was brought into contact with it. No sulphur passed unchanged over the charcoal but hydrogen sulphide came off abundantly during the first half of the time of heating. When all the sulphur had been distilled from the end of the tube containing it dry hydrogen was passed in and hydrogen sulphide was again formed. The charcoal after cooling in a current of hydrogen weighed 30·1 grams and contained according to two estimations 20·02 and 19·95 per cent of sulphur. The sulphurized charcoal gave up no sulphur when treated for five minutes with a boiling solution of potassium hydroxide having a density of 1·5. The charcoal sank in the solution and hence had a density higher than 1·5. A portion of the charcoal gave off at the heat of a combustion furnace a little hydrogen sulphide and sulphur but no carbon disulphide, while another portion gave off the last at a bright red heat in a Perrot furnace. A third portion of the sulphurized charcoal was placed in a porcelain crucible surrounded by sugar charcoal in a clay crucible and was heated to the highest temperature of a Perrot furnace which melted cast iron readily. The charcoal after the intense ignition retained 3·4 per cent of sulphur. It was free from ash and, when burned in a current of moist oxygen in a combustion furnace, left a small amorphous black coal which disappeared when the tray holding it was heated over a blast lamp.

Experiment 2.—Vapor of carbon disulphide was passed for an hour over soft sugar charcoal at a red heat. The carbon disulphide was displaced by dry hydrogen in which the charcoal was allowed to cool. Hydrogen sulphide was formed abundantly at first, while during the latter part of the time of heating but little was detected. The charcoal sulphurized by carbon disulphide was found to contain 11·14 per cent of sulphur.

Experiment 3.—1·2632 gram of sugar charcoal containing 0·126 per cent of hydrogen and 0·04 per cent of ash was exposed for twenty minutes to sulphur vapor at the highest heat of a gas combustion furnace and then was allowed to cool in a current of dry hydrogen. The charcoal lost 0·0055 gram in weight and was found to be free from sulphur.

Experiment 4.—Charcoal such as used in the preceding test was subjected to sulphur vapor at the temperature of a Perrot furnace. It was next heated to redness in a crucible to drive

off occluded sulphur and was then found to contain 0·29 per cent of sulphur. Carbon disulphide was not produced in this experiment nor was it likely to be formed since the temperature of the furnace was sufficient to decompose it as was proved experimentally.

Experiment 5. — Filter paper nearly free from ash was charred at a dull red heat in vapor of sulphur and the latter was displaced by hydrogen. The product contained 29·1 per cent of sulphur.

Experiment 6.—Filter paper in loose rolls was placed in a large glass tube and was then wet with a saturated solution of sulphur in carbon disulphide. The latter was driven off and a considerable quantity of solution of sulphur was poured into the tube. After the carbon disulphide was expelled from the tube again the paper was charred by gradually heating to incipient redness, and dry hydrogen was passed through the tube during the heating and cooling. Two estimations of sulphur in the charcoal gave 46·46 and 46·60 per cent. This sulphurized charcoal yielded nothing to boiling carbon disulphide and gave up no sulphur to a boiling solution of potassium hydroxide.

Experiment 7.—This was made as nearly as possible like the preceding. The product contained 43·64 per cent of sulphur and exhibited the same negative deportment towards carbon disulphide and potassium hydroxide.

The results show that nearly pure amorphous carbon takes up but little sulphur, while a soft charcoal containing much hydrogen and oxygen takes up considerable even from carbon disulphide. The sulphur is chemically combined as Berzelius held, for it is not removed by solvents even from charcoal which is nearly one half sulphur.

Combustion of Charcoal in Oxygen.

The paper by H. B. Baker[*] on combustion in dry oxygen suggested a lecture experiment to show that charcoal will not burn in dry oxygen as readily as it does in the gas containing water. For this purpose Hoffman's experiment[†] was modified by allowing the oxygen in the apparatus shown in fig. 1, to dry for a day or longer by contact with phosphorous pentoxide contained in a short tube just below the bulb. The charcoal was hung on the small wire above the spoon and was intensely heated, cooled in carbon dioxide and then placed in the apparatus. To carry out the experiment the wire was heated by electricity until the charcoal was glowing at the point of con-

[*] Jour. Chem. Soc., xlvii, 349.
[†] Berichte der deutsch. chem. Gesellsch., ii, 251.

1.

tact with the wire. In many of the trials the charcoal ceased to glow as soon as the current of electricity was stopped, burning readily, however, when ignited in moist oxygen. The failures in the experiments led to an investigation of the burning of charcoal. Baker* in his experiment used charcoal previously ignited in chlorine. Such charcoal contains chlorine unless heated for a long time to a white heat,† and the writer has frequently observed that chlorinated charcoal only partly burns at the temperature of a combustion furnace in oxygen dried as for organic analyses, and that after the coal has ceased to glow it ignites again on admitting moist oxygen and burns completely. Dubrunfaut‡ failed to burn sugar charcoal mixed with copper oxide in a current of dry oxygen. Other chemists have alluded to the difficulty attending combustions in dry oxygen; Dumas,§ however burned graphite in oxygen dried by solid caustic potash and sulphuric acid.

A Hoffmann apparatus, such as shown in fig. 1, was used in the investigation. It held about 350^{cc} of gas and had heavy platinum wires passing through the stopper to the small wire which held the charcoal. To prepare it for use sufficient mercury was poured in to fill the tube at the bend below the stopcock and a short wide tube containing phosphorous pentoxide was placed in the neck below the bulb which was then closed. Next the charcoal and all the platinum below the stopper were heated in a blast lamp. The charcoal used in *1, 2, 3* and *4*, was allowed to cool in carbon dioxide, but the sugar charcoal of the other experiments was put into the apparatus while glowing as it did not burn in air. The apparatus was then filled with oxygen by passing through it about two liters of the gas dried as for organic analyses. In *1, 2, 3* and *4*, the supporting wire passed through a hole in the charcoal, thus giving only one point of contact, in the other experiments it was placed in an inverted cone of platinum wire.

Experiment 1.—0·033 gram of dense wood charcoal previously heated to redness for an hour was taken, and the gas was allowed to dry a day. The charcoal ignited when heated by a current of electricity through the wire and burned completely without further heating. The volume of the gas at

* Loc. cit.
‡ Comp. rend., lxxiii, 1395.
† This Journal, p. 364.
§ Comp. rend., lxxiv, 137.

the temperature of the room, which was constant, was 1.8^{cc} greater than before the combustion.

Experiment 2.—0.0337 gram of same charcoal as used in *1*, gave the same results, except that the volume of gas increased 2.4^{cc}.

Experiment 3.—Another lot of hard burned charcoal was tried in gas dried for a day. Three times the coal failed to burn after it had been heated at one point to incandescence, burning, however, brilliantly when ignited by prolonged heating.

Experiment 4.—The charcoal from the same piece as used in *3*, did not burn when first heated to redness at one point but when heated a second time it burned well.

Experiment 5.—Dense sugar charcoal containing 0.126 per cent of hydrogen ignited promptly when the wire cone holding it was heated, and burned brilliantly and completely in oxygen which had been in contact with phosphorus pentoxide thirteen days.

For the remaining experiments with the Hoffmann apparatus the sugar charcoal described on page 366 was used. It contained 0.07 per cent of hydrogen and 0.17 per cent of ash. The amount weighed off for each trial was 0.04 gram, which was somewhat reduced by heating as already described. The gas was allowed to dry for two days in each case.

Experiment 6.—The charcoal did not burn after it was heated to faint redness, but when heated hotter it continued to burn after the current from the battery was broken. The volume of the gas increased 1.5^{cc}.

Experiment 7.—The charcoal after it was first ignited burned a few seconds. Ignited a second time it partly burned, and it did not burn completely until it was heated intensely. The volume of the gas was 2^{cc} greater than before the combustion.

Experiment 8.—The charcoal burned completely after the battery current was broken. In this and the following tests the apparatus stood in a cylinder of water having the temperature of the room. The pressure of the gas when it had attained the temperature of the water was 2.4^{mm} of mercury greater than before the combustion.

Experiment 9.—The result was the same as in *8*, except that the pressure increased 2^{mm}.

Experiment 10.—The charcoal was heated gradually until it was ignited. The pressure increased 3^{mm}.

Experiment 11.—The charcoal ceased to burn after the first heating by the hot wire and when ignited again it burned completely. The pressure increased 2^{mm}.

The increased volume of gas after a combustion can only be explained on the assumption that some carbonic oxide was

formed, although the oxygen largely exceeded the amount required for the complete oxidation of the carbon. To prove that the increase was not due to heating the wires passing the stopper, the wires were repeatedly heated by an electric current and the gas in all cases returned on cooling to its original volume. Nor could any air have passed in by the stopper for the pressure in the apparatus was greater during the combustions than that of the atmosphere.

The above results throw no light on the question of the burning amorphous carbon in dry oxygen, as charcoal containing 0·07 per cent of hydrogen and upwards was used, which would yield water. It is evident, however, that dense charcoal must be intensely heated before it will burn in dry oxygen. When such charcoal ceases to burn after having been ignited at one point it may be that the temperature of the part burning falls below the point of ignition owing to the dense coal conducting heat from it. Charcoal even of the densest variety when burning rapidly in oxygen is surrounded by a small flame which may be due in part to the incandescence of carbon dioxide and oxygen about the piece, but the flame is chiefly that of burning carbonic oxide, which formed in the reaction between the oxygen and glowing carbon, as the latter is in excess in the limited space where the reaction occurs. Carbonic oxide is formed either by the direct union of oxygen with carbon or by the reduction of carbon dioxide. Carbonic oxide, as Meyer[*] has shown, burns when mixed with dry oxygen only when intensely heated by a powerful electric discharge, and carbonic oxide mixed with air or with an excess of oxygen not dried burns with difficulty and ignites only at a high temperature. In order then that charcoal may continue to burn in oxygen the temperature must be maintained sufficiently high to ignite the carbonic oxide. Rapid combustion will do this while slow combustion will not, as the following results show:

Experiment 12.—A piece a centimeter thick of dense charcoal having 0·126 per cent of hydrogen was placed in a glass tube and a rapid current of oxygen was passed in, the gas being dried as for organic analysis. The charcoal was heated by one burner until it began to glow. It then rapidly became hotter and in a few seconds there was a slight puff, flame passing 20 or 30 centimeters through the tube, after which the charcoal burned brilliantly with a slight flame surrounding it. This result has been attained many times, not, however, without failures.

Experiment 13.—A piece of dense wood charcoal a centimeter thick and three centimeters long when heated in a rapid

[*] Berichte der deutsch. chem. Gesellsch., xix, 1099.

current of moist oxygen commenced to burn without any puff. It was allowed to cool until black on the outside and the gas in the tube was replaced by air. When the oxygen was turned on again the coal began to glow and in four or five seconds there was an explosion accompanied by a distinct click, flame passing from the coal through the tube for a distance of 40 centimeters. The experiment was repeated a number of times. If the oxygen was turned on when the charcoal was incandescent on the outside there was no puff and no flame passed along the tube. A soft porous charcoal gave no puffs.

2.

Experiment 14.—The glass tube shown in fig. 2 contained charcoal at *b* which was kept hot during the experiment. At *a* was a piece of dense wood charcoal a centimeter thick and three long. The two pieces were 40^{cm} apart. Oxygen not dried was supplied through the small tube. When the charcoal at *a* was first heated it took fire without any puff. The oxygen was then turned off and as soon as the coal at *a* ceased to glow air was passed into the tube to displace the gas in it. On turning on the oxygen again the charcoal at *a* commenced to glow and the charcoal at *b* burned brilliantly, showing that the other piece had not consumed all the oxygen. After a few seconds there was a slight explosion. The experiment was repeated many times until the piece at *a* was mostly consumed. The flame accompanying the explosions usually passed from *a* to *b*, but sometimes it passed from *b* to *a*.

In *12* the amount of hydrogen and water present was very small and the explosive mixture of gases may be regarded as consisting of oxygen and carbonic oxide and possibly some carbon dioxide. When the charcoal was glowing feebly carbonic oxide was formed and together with oxygen passed beyond the coal and when the temperature of the burning coal reached the point of ignition of carbonic oxide there was an explosion, and the coal then burned with a flame. In *13* and *14* the gas was used moist and the charcoal also yielded water when burned. But in these experiments the slow oxidation in presence of an excess of oxygen yielded a combustible gas that required a higher temperature than that of feebly burning charcoal to ignite it.

ART. XLII.—*Note on some Volcanic Rocks from Gough's Island, South Atlantic;* by L. V. PIRSSON.

THE rocks which are the subject of this note were gathered as beach pebbles from the shore of Gough's Island, South Atlantic Ocean, lat. 40° 20′ S., lon. 9° 44′ W., by the captain of a whaling vessel from New London, Conn., and they came into possession of the writer through the kindness of Prof. C. E. Beecher of the Peabody Museum in New Haven.

While in general the mere petrographical description of rocks disconnected from their geological occurrence and relationships has little value or interest, the fact that nothing so far as the writer can learn has ever been published on this remote locality, and also that the material developed several points of interest are the reasons for the publication of this note.

Gough's Island was discovered in the sixteenth century by Gonçalo Alvarez, and later by Gough, an English navigator, after whom it is generally called. The island seems to be little known and a search through the literature has given only the information that it is a craggy mass rising to a height of 4350 feet and about eighteen miles around, of a generally agreeable climate, with streams which present several fine cascades and several valleys green with turf and bushes.* Tristam da Cunha, the group of islands lying 240 miles N.W., are of volcanic origin, as others of the detached oceanic islands of the South Atlantic, and from what has been given and the evidence afforded by the present investigation it is probable that the island represents a volcanic cone.

The material consisted of a small number of rounded pebbles, all of which represent very fresh volcanic rocks or tuffs which may be referred either to trachytes or basalts.

Basalt.

This is represented by two varieties, one of which is a rock of a dark gray color thickly dotted with black phenocrysts of augite, yellow olivines and white feldspars of the microtine habit   The groundmass is dense and cannot be resolved by the eye alone. The augites are the largest phenocrysts, attaining at times a length of 5^{mm}; the feldspars and olivines are much smaller. In thin section under the microscope the rock is seen to be beautifully fresh and unaltered and the usual minerals to be present, viz: iron ore, apatite, olivine, augite and plagio-

* Cf. Earth and its Inhabitants; Africa, vol. iii, pp. 97. New York, 1888. Appleton & Co.

clase, the last two in two generations. The *augite* is of a pale brownish color, non-pleochroic and shows a marked dispersion of the optic axes emerging from extinction, on one side bluish, on the other yellowish in color. In the second generation it is similar and scattered through the feldspar staves in rounded, irregular granules and often attached to iron-ore grains. The *feldspar* phenocrysts are tabular on *i-i* (010), and from their high extinction angles in the zone $100 \wedge 001$ and on the clinopinacoid (010) it is seen that they are to be referred to labradorite. On the other hand the lath-like feldspars of the groundmass are to be referred to andesite. The usual laws of twinning abound. The other minerals present nothing worthy of mention. In structure the rock is an interwoven mesh of feldspar laths in which the other minerals lie imbedded. It is rather of an andesitic habit owing to the prevalence of the feldspar but from the abundance of olivine and the basicity of the rock, a determination of silica having given 48·61 per cent, it should undoubtedly be referred to basalt. Its specific gravity is 2·890.

The second type of this rock is macroscopically of a dark grayish brown color, weathering to a brown, porous in texture and thickly dotted with white broad lath-like phenocrysts of feldspar which frequently attain a length of from 5–6^{mm} and often group themselves into radial starlike clusters. In thin section iron ores, apatite, olivine, augite and feldspars are disclosed. The *olivine* exists in two forms, in large irregular phenocrysts attaining 1^{mm} in diameter and in small crystals averaging about ·05^{mm}. The larger phenocrysts are undergoing a process of alteration into an orange-red colored mineral. This proceeds inwardly along the edges and cracks and seems to be in two stages which are best observed under crossed nicols. The first stage seems fibrous and gives a rolling extinction, until the second stage is reached where the mineral again becomes apparently homogeneous and extinguishes as such. In this product the orientation of the axes of elasticity are different from the original. In the smaller olivines mentioned the process has been entirely completed and they all appear of this orange-red color but appear otherwise homogeneous and extinguish parallel. A somewhat similar case is mentioned by Michel Lévy[*] as occurring in the basalts of Mont Dore. It is probably conditioned by a change of ferrous to ferric oxide and is somewhat like the coloration in the olivines in the limburgite of Sasbach.[†]

[*] La Chaine des Puys et le Mont Dore, Bull. Geolog. Soc. France, 3d serie, xviii, 1890.
[†] Rosenbusch, N. J., 1872, pp. 59 ; also Physiog. d. Min., 1892, pp. 472.

The *augite* as a phenocryst is rare but presents nothing remarkable. The *feldspar* phenocrysts are of labradorite as indicated by their optical properties and by their sp. g. 2·708 taken with a heavy solution and Westphal balance. There is the usual albite and pericline twinning. The *groundmass* consists of fine feldspar laths in character near andesite, the small olivines referred to and between these globulitic material, augite microlites, iron ore, glass, etc. This interstitial material is of a dark grayish brown color in which the colorless feldspar laths lie, looking like slits in the section.

A determination of silica in this rock gave 49·55 per cent and its sp. gr. is 2·643, the lowness of which is no doubt due to the glass of the groundmass. From these and the mineral composition it is evidently to be referred to basalt.

Trachyte.

This is represented by trachytic tuffs and obsidian. The latter is macroscopically, a black, pitchy looking glass filled with pores which by their extension in one direction indicate flow movements in the viscous fluid. Rarely small feldspar phenocrysts are to be seen. Before the blowpipe this glass melts readily, puffing up into a grayish pumice which then melts to glass with the utmost difficulty, a small amount of water present increasing the mobility and lowering the melting point as noted previously by other observers on acid glasses. The chemical analysis of this glass gave the following composition :

Sp. gr. $= 2·210$

SiO_2	61·22
TiO_2	·42
Al_2O_3	18·01
Fe_2O_3	1·32
FeO	4·51
MnO	tr.
MgO	·44
CaO	1·88
Na_2O	6·49
K_2O	5·93
H_2O	·46
Total	100·68

From the moderate amount of silica, low lime and magnesia and high alkalies, it is evident that this glass is to be referred to trachyte, perhaps of the phonolithoid type.

In thin section it appears as a fresh unaltered glass of a deep brown color scattered through which are a few grains of iron ore, apatite crystals, an occasional sanidine or olivine pheno-

cryst, and as the final products just before consolidation globulites and small sanidine microlites.

The *olivine* occurs very rarely indeed. It is fresh and of a pale yellow color and shows magnetic resorption. That it is indeed olivine is shown by its optical behavior, its high double and single refraction, its extinction parallel to two cleavages at about right angles, one of which is more pronounced than the other, and its general outline and habit.

This was confirmed by treatment of the powdered rock by hydrofluoric acid according to Fouqué's method of isolation and in the residue the lens disclosed a number of the olivines which were carefully picked out and subjected to qualitative analysis. This proved the mineral to be a silicate soluble in hydrochloric acid and in the solution were only iron and magnesia, lime not being present. The mineral is therefore undoubtedly an olivine and one rich in iron. The method of isolation also showed that it was very scarce in the rock. The crystals attain a size of ·5 to 1^{mm}.

The presence of olivine in trachytic rocks is not unknown. It is mentioned by Mügge[*] as occurring in the trachytic lavas of the Azores, by Michel Lévy[†] in augite trachyte of Monte Dore which is however of an andesitic type, and by Fuchs[‡] as an accessory component of the trachyte of the Arso stream on the island of Ischia. Its occurrence in the present case in a magma containing less than ·5 per cent of magnesia is, however, remarkable and to be paralleled with its presence in the rhyolite of Iceland as shown by Bäckström,[§] and that of fayalite in the rhyolitic obsidian of the Yellowstone Park,[||] and of the Lipari Islands[¶] as shown by Iddings. The latter author parallels such occurrences with that of sporadic quartz grains in basalt[**] and refers their origin to the mineralizing tendency of included water vapor in highly heated magmas under conditions of great pressure. In the present case the corroded state of the olivines evinces that in the later chemical and physical conditions under which the magma consolidated, the compound as a chemical one was incapable of existing and that it was therefore formed under different ones. The fact that the magma chilled as a glass proves that it was ejected and cooled with comparative rapidity, and it is reasonable to infer that such ejection through comparatively long and narrow conduits must be accompanied by varying degrees of pressure and with

[*] N. J., 1883, ii, pp. 217.
[†] Bull. Geol. Soc. France, 3d series, xviii, pp. 812.
[‡] Tschermak Mitth., 1872, pp. 224.
[§] Geol. Fören. Förhandh., xiii, No. 7, pp. 644.
[||] This Journal, vol. xxx, p. 58, 1885; cf. also 7th Ann. Rep. U. S. G. Surv., pp. 270, 1888. [¶] This Journal, vol. xl, p. 75, 1890.
[**] This Journal, vol. xxxvi, p. 208, 1888.

comparatively slight variations of temperature. Such increase of pressure may be sufficient to condition the crystallization of compounds which later under lower pressures would be incapable of existing, the mobility of the magma being increased by the presence of water vapors as shown by the author cited and thereby conditions more favorable for the production of the compound.

Feldspar is scattered freely through the glass in small microlites of sanidine in flat tables of excessive thinness and twinned according to the Carlsbad law. They are outlined by the base (001), clinopinacoid (010) and positive hemidome ($\bar{2}$01) and appear as in the annexed figure. They are sometimes solitary and sometimes grouped into somewhat spherical aggregates and thus exhibit the only tendency toward spherulitic structure observed in the rock.
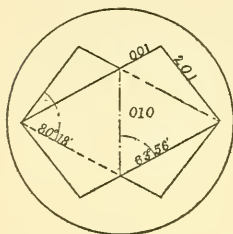
Globulites are present composed largely of minute specks of iron ore as is shown by the colorless zones surrounding them, from which they have extracted the ferruginous coloring matter of the glass.

Tuffs are represented by several specimens. They are soft, light brown in color and enclose fragments of volcanic rock. In thin section they are seen to be composed of fragments of glass which are generally very fresh, mingled with broken crystals of sanidine and augite.

In conclusion it is of interest to note that in thus establishing, as is evinced by the material investigated, the recent volcanic nature of this solitary island, there is one more added to that line of mid-Atlantic volcanoes, which sweeping southward through the Azores, Cape Verde Islands, Ascension, St. Helena, Tristam da Cunha, and Gough's Island, terminates its volcanic fires on Bouvet Island on the confines of the Antarctic Ocean.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, Jan., 1893.

ART. XLIII.—*On a Champlain (?) deposit of Diatomaceæ belonging to the Littoral Plain;* by ARTHUR M. EDWARDS, M.D.

ON the 30th of March, 1859, F. C. S. Roper read a paper by me before the meeting of the Microscopical Society of London, and which was published in volume vii of the Transactions, "On Diatomaceæ collected in the United States." In it there is spoken of a gathering made at Hoboken, N. J., in which eighty-six species of Diatomaceæ, from fresh, brackish and salt water are mentioned as coming from that locality. This gathering, or rather these gatherings, for there were more than one hundred made at that time, were mostly from a large brook, the mud of which yielded the shells of the dead Diatomaceæ. At that time I did not try to work out the geology of the deposit, only pointing out that the mixture of marine, brackish and fresh water forms in the deposit was curious. Since that time I have kept the matter in view and am now prepared to assert what I believe to be the geology of the deposit. I shall show that the Diatomaceæ in it, and by which its geology is determined, are widely spread.

It is the first time that Diatomaceæ are found at all in the geological scale and referred to the brackish, although they are indicated by Ehrenberg in the Mikrogeologie, 1854, as coming from Norwich, Conn. This I will show is the same as those.

They are known to be marine and are referred to the Eocene, Oligocene or Miocene Tertiary. These are from Paita, Peru; San Pedro (or farther south in Southern California) to Sub Little Mines, Del Norte Co., in California; Petersburg, Virginia, to Atlantic City, New Jersey; Oran, in Africa; Mors, in Denmark; Simbirsk, in Russia; Sentz Peter, in Hungary; Moron, in Spain; Nicobar Island, in the Bay of Bengal; Cuba, Trinidad and Barbadoes, in the West India Islands; Sandai, Kobe and Netanai, in Japan; the Island of Sicily and Omaru, in New Zealand.

On the 18th of December, 1871, I read a paper before the Lyceum of Natural History, New York, "On a deposit of marsh-mud upheaval by superincumbent pressure and containing the remains of shells of Mollusca and microscopic organisms," which was not then published, but is now for the first time in the microscopic notes for January 1, 1893. As this records the instance of the shells of marine and brackish Diatomaceæ in this deposit also, it now sees the light. The third instance of marine, brackish and fresh-water Diatomaceæ mixed I have now to publish. This deposit I have studied for over three years past. Besides the many spots on the

Newark meadows, N. J., where I have collected the Champlain (?) deposits, I will mention the following as typical, and from which I have gathered the clay, blue, gray or white, and made slides: Harrison, near the bridge; opposite Athar's factory; opposite Lister's factory; by Hillingsworth's factory; between Hillingsworth's factory and the P. R. R. bridge; Frank Creek, half way across the meadows; near the P. R. R. No. 1 and No. 2; near the bridge over the Passaic River; on the extension of the P. R. R.; raised meadows on the P. R. R.; Woodruff's Creek, near Elizabeth; near Linden Park No. 1 and No. 2, Elizabeth; back of Jersey City; in Jersey City, at the third street from New York Bay; Elizabethport; Bay Way, Elizabethport; Kingsland; Sewarren; Kearney; Peddie Street Ditch; Signal post on the L. V. R. R., Bound Creek; and Arrowchar, S. I., N. Y. Besides these I have the same clay from near New Haven, collected by myself, and also sent to me by Mr. W. A. Terry, of Bristol, Conn.; near Boston, Mass., from Mr. F. F. Forbes and Mrs. S. A. Fuller; also from Mr. L. Woolman, as clay, water works, Absecon, N. J.; Bingham House, No. 1 and 2, Philadelphia, Penn.; 11th and Market streets, Philadelphia; Spreckel's Refinery, Reed Street Wharf, Philadelphia; abutment Walnut Street Bridge, Philadelphia; Gray's Ferry, B. & O. R. R , and he records in the Microscopical Bulletin for October, 1892, "Fossil Diatoms in Philadelphia beneath the girls' new Normal School buildings." And I am also indebted to Mr. C. L. Peticolas for a slide from Cornfield Point, St. Mary Co., Md. I have also to record that Professor J. W. Bailey discovered in the earth of the rice fields at Savannah, Ga., Diatomaceæ. This I received at the same time, about forty years ago, from Dr. W. C. Daniels, Savannah, Ga. Bailey records it in his Microscopical Observations made in South Carolina, Georgia and Florida, and published in 1850 in the Smithsonian Contributions to Knowledge, Vol. II, page 5. Dr. F. W. Lewis records the finding of Diatomaceæ in the blue clay of the Delaware River, Philadelphia, Penn., in his Notes on new and rarer species of Diatomaceæ of the United States seaboard, 1861.

We now come to mention the species of Diatomaceæ found in the Champlain (?) deposits of the Littoral Plain. They include the following:

Achnanthes hirta, O. F. M., lanceolata, A. de B.
Actinocyclus ternarius, C. G. E.
Actinoptychus biternarius, C. G. E.
Amphiprora alata, C. G. E., lepidoptera, W. G., pulchra, J. W. B.
Amphora cymbifera, W. S., lanceolata, P. T. C., pellucida, W. G., robusta, W. G., undata, H. L. S.
Amphitetras antediluviana, C. G. E.
Brebissonia lanceolata, C. A. A.

BIDDULPHIA aurita, A. de B., lævis, C. G. E., pulchella, S., radiata, F. C. S. R., rhombus, C. G. E., turgida, C. G. E.

CAMPYLODISCUS clypeus, C. G. E., echeneis, C. G. E.

COCCONEIS diaphana, W. S., distans, W. G., limbata, W. G., major, W. G., occanica, C. G. E., placentula, C. G. E., scutellum, C. G. E., undulata, C. G. E.

COCCONEMA cistula, H., lanceolatum, C. G. E.

COLETONEMA eximium, F. T. K., vulgare, T.

COSCINODISCUS asteromphalus, C. G. E., excentricus, C. G. E., lacustris, A. G., nitidus, W. G., radiatus, C. G. E., sol, G. C. W., subtilis, C. G. E.

CYCLOTELLA carconensis, S. G., operculata, F. T. K., kützingiana, T.

CYMBELLA stomatophora, H. G., truncata, W. G.

CYMATOPLEURA elliptica, A. de B., quinquepunctata, F. T. K.

DIPLONEIS apis, C. G. E., elliptica, F. T. K.

DENTICULA minor, A. G.

DORIPHORA amphiceros, F. T. K.

ENCYONEMA paradoxum, F. T. K., prostratum, J. R.

EPITHEMIA Jurgensii, C. A. A., gibba, F. T. K., gibbula, F. T. K.

EUNOTIA arcus, C. G. E., gracilis, C. G. E., incisa, W. G., lunaris, A. de B., pectinalis, S. R.

FRAGILARIA Pacifica, A. G., virescens, S. R.

GOMPHONEMA acuminatum, C. G. E., cupitatum, C. G. E., constrictum, C. G. E.,? curvatum, F. T. K., cristatum, S. R., mamilla, C. G. E., marinum, W. S.

HYALODISCUS scoticus, F. T. K., stelliger, S. W. B.

LYRADISCUS ovalis, R. K. G.

MASTOGLOTA lanceolata, W. S., Smithii, T.

MERIDION circulare, C. A. A.

MELOSIRA crenulata, F. T. K., grandis, M. P., granulata, C. G. E., Jurgensii, C. A. A., nummunloides, C. A. A., punctata, A. G., sulcata, C. G. E., undulata, F. T. K., varians, C. A. A.

NAVICULA Americana, C. G. E., bacillum, C. G. E., borealis, C. G. E., cancellata, A. S. D., Couperi, T. W. S., cruciformis var. brevior, P. T. C., cuspidata, F. T. K., dactylus, C. G. E., Dariana, A. G., elegans, F. T. K., esox, C. G. E., firma, F. T. K., gigas, C. G. E., gibberula, F. T. K., gracilis, C. G. E., granulata, A. de B., Henedyii, W. S., interrupta, F. T. K., Lewisiana, R K. G., lyra, C. G. E., major, F. T. K., maxima, W. G., minutula, W. S., Mexicana, C. G. E., nobilis, C. G. E., oblonga, F. T. K., peregrina, C. G. E., radiosa, F. T. K., spherophora, C. G. E., stauroneiformis, W. S., (tenuis Grey var. ?) sublineais, W. G., trinodis, W. S., viridis, F. T. K., viridula, C. G. E.

NITZSCHIA, acicularis, F. T. K., amphioxys, C. G. E., Brightwellii, F. K., bilobata, W. S., constricta, F. T. K., compressa, J. W. B., fasciculata, A. G., obtusa, W. G., Peruviana, C. G. E., paradoxa, G., reversa, W. S., scalaris, C. G. E., sigma, F. T. K., sigma, var. major, A. G., sigmoidea, C. G. E., subrecta var. rigida, A. G., tryblionella, H., (tryblionella var. ?) littoratis, A. G.

PLAGIOGRAMMA Gregorianum, R. K. G.

PLEUROSIGMA angularis, W. S., Balticum, C. G. E., delicatulum, W. S., oximium, F., elongatum, W. S., fasciola, F. T. K., hippocampus, C. G., obscurum, W. S.

PODOSIRA monilformis, C. G. E., Montagnei, F. T. K.

PYXILLA ? Baltica, A. G.

RHABDONEMA Adriaticum, L., arcuatuaum, F. T. K.

SYNEDRA affinis, F. T. K., lunaris, C. G. E., pulchella, F. T. K., salina, W. S., tabulata, F. T. K., ulna, F. T. K.

STICTODISCUS craticula.

STEPHANODISCUS corona, C. G. E., Niagaræ, C. G. E.

STAURONEIS acuta, W. S., anceps, C. G. E., aspera, W. S., salina, W. S., legumen, C. G. E., maculata, J. W. B., phœnicenteron, C. G. E., pteroidea, C. G. E., gracilis, C. G. E., fenestra, C. G. E.

SURIRELLA acuta, C. G. E., Brightwellii, W. S., crumena, A. de B., cardinalis, F. K., Davidsonii, A. S., Fastuosa, C. G. E., gemma, C. G. S., gracilis, A. G., linearis, W. S., Molleriana, A. S., ovalis, A. de B., Ratrayii, A. S., recedens, A. S., robusta, C. G. E., splendida, C. G. E., salina, W. S., Suevica, Z.

SCHIZONEMA cruciger, W. S., divergens, W. S., hyalina, W. S., Smithii, C. A. A.

TETRAGRAMMA Americana, T. W. B.

TABELLARIA fenestrata, F. T. K., flocculosa, F. T. K.

TRICERATIUM alternans, T. W. B., favus, C. G. E., reticulum, C. G. E.

VAN HEURKIA rhomboides, A. de B.

We now come to the geology of the Newark Champlain (?) deposit. I understand the Champlain deposit to be formed when the melting of the glacier which succeeded the Tertiary age. The first were glaciers forming the glacial period and then they melted and formed the Champlain period. When the glaciers were nearly melted, the Diatomaceæ lived in the fresh water, and their shells were deposited when the stream of the Champlain period rushed down from the North. The deposit was mostly clay and covered the states where it is now found. From New Brunswick to Pennsylvania on the Atlantic coast of North America it is formed covering the whole country. The clay was of course fresh water, and the Diatomaceæ were also fresh water. By and by salt water flowed in and formed brackish pools on the coast. As this was raised a brackish clay was formed, and this I call the raised or sunken beach. Dr. J. S. Newberry calls it the Littoral Plain. He describes it in the geological history of New York Island and harbor in the Popular Science Monthly, vol. xiii. The fresh-water deposits are innumerable, but really are one and form the clay at the bottom. Upon this is the raised coast. The raised coast forms two deposits in the Newark meadows. Upon this is a clay of fresh water Diatomaceæ, and lastly comes the recent clay now forming.

Art. XLIV.—*Refraction of Light upon the Snow ;*[*] by
Albert W. Whitney.

Under certain conditions involving the character of the
snow and the altitude and brilliancy of the sun, the glitter of
the snow is not uniform. Make these conditions, then, a cold,
clear, winter afternoon, about half an hour before sunset, and a
rather fresh field of snow, and the following description becomes
general.

Two roughly V-shaped paths, of especial, not exclusive, bril-
liancy, open away from the observer and towards the sun; the
apex of one is perhaps six feet away, its angle 90°; the apex
of the other is perhaps 15 feet away, its angle 60°.

The following facts are to be noted :

First, the light is not diffused ; it is made up of many sep-
arate brilliant points.

Second, the paths are broad, several degrees in width.

Third, the inner margin is rather sharply defined; there is
no such clear outer limit.

Fourth, the path nearer to the sun is brighter—the separate
points of light are visible twice as far away as those in the
nearer path.

Fifth, while the general glimmer of the snow is apparently
colorless, the points which lie in the paths glow most brilliantly
with prismatic colors; blues pure and clear as the bluest sky,
greens as delicate as the emerald, reds as glowing as the fiery
opal. With a movement of the head which brings a blue crys-
tal towards the inner edge of the path, its color passes through
all the tints of the spectrum ; a movement in the other direc-
tion reverses the succession of colors. Within the limits of
the path, the colors at first seem to be scattered promiscuously ;
more careful observation, however, leads one to feel that there
is a slight tendency in the reds to keep to the inside.

A large number of measurements with the sextant have made
it evident that the angle between the eye, the glowing point,
and the sun, is not only constant as regards all other points
of like position on the path but also for varying altitudes of the
sun. The supplement of this angle, measured from the part of
the greatest brilliancy, is for the nearer path about 46°, for the
further path about 22°. Let us call this in general δ.

Without seeking a cause for the condition, it is easy to deter-
mine what, under this condition, the path must be. The
locus of points at which a constant angle is made between

parallel lines and lines to a given point is the surface of a cone. In this case, the eye is the apex, the axis the line of sunlight, the angle at the apex is 2∂. It will be seen at once that the snow-surface is a plane which cuts this cone. The conic section produced depends upon the relation of the altitude of the sun and ∂. In both cases, where $\partial = 22°$ and $46°$, the figure on the snow is evidently a hyperbola. When the altitude of the sun $= \partial$, the figure is at infinity; the sun has an altitude of more than 22° till about the middle of the afternoon; hence before this time the inner hyperbola is invisible. As even at noon the sun is not higher than 37°, the outer hyperbola is visible at all times. The effect of the going down of the sun is evidently to broaden the figures and bring them nearer.

We have now proved inductively that ∂ is constant, and deductively that, ∂ being constant, the figure is an hyperbola. It remains to find a cause for the constancy of ∂.

The light from the snow is evidently due either to reflection or refraction; most of it is doubtless reflected. Several facts already mentioned seem to prove, however, that the light of the hyperbolas is not due to reflection.

First, the only intrinsic law of reflection, that of the equality of the angles of incidence and reflection, is seen to be no path-discriminating condition—for the facets of the snow-crystals may be tilted at any angle.

Second, reflection cannot account for the color. Therefore this phenomenon must be due to refraction. The difference is apparent between the light from the crystals lying in and out of the path. As one turns his head, those crystals lying outside flash for an instant, and as quickly subside; those in the path, on the other hand, linger to run through their little life of color. At noon the altitude of the sun is about 37°; the complement of the polarizing angle of ice is 37° 20'. Hence at this time the reflected light near the vertex of the hyperbola should be nearly all polarized. Experiments with Nicol's prism and tourmaline prove that nearly all the general glimmer is cut off, while the light of the hyperbola is undisturbed.

The problem is now simplified to that of finding a phenomenon of refraction to correspond with the constancy of ∂. The angle of minimum deviation seems to promise a solution; it will evidently give a maximum, for at this point the refracted light is greatest. It will also give a sharp inside limit to the path and an indefinite outside limit, which exactly corresponds with observation.

Now ice belongs to the hexagonal system; it may form in right hexagonal prisms. Consequently a snow-crystal may offer to the light angles of 60°, 90°, and 120°. There will evidently be no emergence in the case of the 120° angle.

The formula, $\delta = 2 \sin^{-1}\left(n \sin \dfrac{A}{2}\right) - A$, gives for the angles of minimum deviation, where n, the refractive index of ice, is 1·31, and A is first 60° and then 90°, the angles 21° 50′ and 45° 44′, which correspond very closely with observation.

The greater brilliancy of the 22° hyperbola corroborates the theory also, for evidently less light is transmitted through a 90° prism, than through one of 60°, owing to the greater obliquity of the incident rays in the former case.

To sum up, in a field of snow crystals tilted at all possible angles, not one can send a refracted ray to the eye unless, first, it lies in the path of the hyperbola, and, second, it is tilted at just the right angle.

The resemblance of this theory to that of halos, or, in fact, the real unity of the two, is manifest. The halo and the snow-hyperbola are respectively the aerial and terrestrial portions of the same phenomenon; the comparison in detail is very interesting.

Some rays of light doubtless experience internal reflection. Hence other conic sections are within the range of possibility. The simplest such case, that of one internal reflection, where the maximum is given by the critical angle, would give angles corresponding to δ of about 87° and 116°. Some color may be seen throughout this region, but I have not been able to detect anything definite enough to be called a path.

The perspective of these snow-hyperbolas forms concentric circles upon a plane normal to the path of the sun's rays, which is also evident from the fact that they are the completion of the halos. On a vertical plane the perspective forms ellipses.

Another interesting fact concerns the relation of the other limb of the hyperbola to that upon the snow. If the observer walks so as always to keep one certain point in the path of light, his track will be an hyperbola; if now, from the apex of the hyperbola which he has traced, he advances a distance equal to his height multiplied by the cotangent of the angle, the altitude of the sun plus δ, the figure which he now sees and the figure which he has traced upon the snow are the two limbs of the same hyperbola.

The difference between the refractive indices for red and violet light gives theoretically a dispersion of 46′ in the case of the hyperbola of 22°, and of 2° 10′ in the case of the hyperbola of 46°. It may be noticed that the colors in the nearer figure are more conspicuous. I do not understand, however, why the arrangement of color is not more regular. It may be due to an inability of the eye to sum up this discrete color. The hyperbola is produced by a single layer of crystals, the

halo by a mass of crystals perhaps hundreds of feet in depth; hence in the latter case the summation is already made.

Refraction upon the snow is largely, perhaps mostly, due to frost-crystals. They form more slowly, hence more regularly, than snow-crystals; they are inconspicuous upon a snow-surface. Snow-hyperbolas are usually more obvious in late afternoon than in the early morning. I have thought that possibly the following may be in the line of an explanation of this: the frost-crystals need a certain amount of clearing up by sun and wind of minute secondary accumulations of frost upon themselves, to make them fit for transmitting light.

ART. XLV.— *Value of the force exerted by a current of Electricity in a circular conductor on a unit magnetic pole at its center;* by S. T. MORELAND.

THE following method of finding this value is new so far as I know.

Let i = strength of current

r = mean radius of the conductor supposed to make one turn.

So far as magnetic effects are concerned it is known that such a current produces the same result as a *magnetic shell* having its boundary in the circle and satisfying the condition

$$i = It$$

where I is the uniform surface density of the magnetism and t is the thickness of the shell. Substitute a *hemispherical magnetic shell* for the current in this case having plus magnetism on the inner surface and minus on the outer, the total quantity on each of the two surfaces being equal.

Let $\sigma_{,}$ = surface density on inner surface.

$\sigma_{,,}$ = " " " outer "

$r_{,}$ = radius of inner surface.

$r_{,,}$ = " " outer "

Then $r_{,,} - r_{,} = t$, a very small quantity, and $r = \sqrt{r_{,} r_{,,}} = \frac{r_{,} + r_{,,}}{2}$ very nearly, and $I = \sqrt{\sigma_{,} \sigma_{,,}} = \frac{\sigma_{,} + \sigma_{,,}}{2}$ very nearly.

Also
$$\sigma_{\prime} : I = \frac{1}{r_{\prime}^{2}} : \frac{1}{r^{2}}$$

$$\therefore \sigma_{\prime} = I \frac{r^{2}}{r_{\prime}^{2}}.$$

Similarly
$$\sigma_{\prime\prime} = I \frac{r^{2}}{r_{\prime\prime}^{2}}.$$

The resultant repulsion of the magnetism of the inner surface on the unit pole at the center is $\pi\sigma_{\prime}$ and the attraction of the outer surface is $\pi\sigma_{\prime\prime}$. Hence,

Resultant force of magnetic shell $= \pi(\sigma_{\prime} - \sigma_{\prime\prime})$

$$= \pi I r^{2} \left(\frac{1}{r_{\prime}^{2}} - \frac{1}{r_{\prime\prime}^{2}} \right) = \pi r^{2} \frac{(r_{\prime\prime}^{2} - r_{\prime}^{2})}{r_{\prime}^{2} r_{\prime\prime}^{2}}$$

$$= \pi I \frac{r^{2}}{r^{4}} (r_{\prime\prime} + r_{\prime})(r_{\prime\prime} - r_{\prime})$$

$$= \frac{\pi I}{r^{2}} 2rt = \frac{2\pi i}{r}$$

which is the result sought.

We see too that in the equation

$$I = it$$

I is the mean of the two surface densities which must necessarily differ in value unless the shell is a plane.

ART. XLVI.—*On Cookeite from Paris and Hebron, Maine;* by SAMUEL L. PENFIELD.

THIS mineral was first described as a new species in 1866 by Professor George J. Brush,[*] and only a limited supply of pure material could be obtained at that time for the chemical analysis, which was made by Mr. Peter Collier. In the summer of 1891 Professor Brush visited the localities of Paris and Hebron and obtained there some excellent specimens of Cookeite, from which abundant material suitable for analysis could be obtained, and at his suggestion the mineral has been reëxamined.

Cookeite is related to the chlorites and micas, having a distinct basal cleavage and crystallizing like them in the monoclinic system. The largest crystals that the author has observed are not over 3^{mm} in diameter and are hexagonal in habit. Dis-

[*] This Journal, II, xli, p. 246.

tinct six-sided prisms are rarely found; the crystals are usually radial as if made from a series of wedge-shaped hexagonal plates, fig. 1, grouped with their thin edges together, fig. 2. The form is something like that of prochlorite, figured on page 653 of the sixth edition of Dana's Mineralogy, only more bent. The exterior of the crystals is rather rough, so that they look almost hemispherical or globular. The cleavage plates are naturally wedge-shaped like fig. 1, which interferes somewhat with making exact optical determinations. When examined in polarized light they appear divided up very symmetrically into sectors fig. 3. The inner portion *a* is uniaxial and shows a weak, positive double refraction. The outer por-

tion or rim is composed of six segments, the opposite ones extinguishing simultaneously in directions indicated in the figure, showing that this outer portion may be regarded as a trilling, composed of penetrating individuals. In each segment the acute bisectrix is about at right angles to the section and the plane of the optical axes is parallel to the edge of the hexagon, corresponding to the clinopinacoid. The bisectrix is also slightly inclined in the same plane. The divergence of the axes is large, considerably greater than that of muscovite, although it could not be measured exactly owing to the small size of the sections. The double refraction is positive and not very strong, being about like that of the chlorites. The uniaxial central portion *a*, fig. 3, may be considered as composed of biaxial plates, superimposed on one another in twin position according to Tschermak's law of twinning for the chlorites.[*] The relative proportion of center and rim varies. In some sections the center is almost wanting, the rim, however, is always prominent and shows with the microscope a faint striated structure, the striæ running at right angles to the edge of the hexagon, as represented in the figure. Except for the uniaxial center the above method of twinning is exactly like that of the clinochlore from Texas, Lancaster Co., Pa., described by Professor J. P. Cooke,[†] after whom this mineral was named.

[*] Sitzungsber. d. kais. Akad. d. Wissenschaften in Wien (1), xcix, p. 174, 1890.
[†] This Journal, II, xliv, p. 201.

Cookeite is associated with quartz, lepidolite and tourmaline (especially the variety rubellite) and apparently has resulted from the alteration of the latter, as suggested by Professor Brush. One of the best and most interesting specimens of the mineral in the Brush collection is a deposit of the mineral on a large tourmaline crystal. This latter has a triangular prismatic habit, terminated by a basal plane and is over 4^{cm} in diameter. As a subsequent process the tourmaline has been mostly removed, leaving a cellular interior, containing cookeite, a few quartz crystals and remnants of the original tourmaline, etched out into slender prisms and spicules reminding one of the etched beryls (aquamarines) from Mt. Antero, Colorado.[*] The cookeite here is plainly a secondary mineral and in this respect, as well as in its crystalline habit, mode of twinning and optical properties it is related to the chlorites. It is also like some varieties of vermiculite in its pyrognostic properties. When heated before the blowpipe it exfoliates prodigiously, giving at the same time a lithia color to the flame.

The material for analysis was carefully selected from a specimen from Paris where the cookeite was associated with quartz and tourmaline, thereby avoiding any contamination with lepidolite. The results of the analysis are given below together with the original analysis of Mr. Collier.

	Author.			Ratio.		Collier.
Specific gravity	2·675					2·70
	I.	II.	Mean.			Mean.
SiO_2	34·00		34·00	·567	4·00	34·93
Al_2O_3	45·13	44·98	45·06	·442	3·11	44·91
Fe_2O_3	0·45		0·45			
CaO	0·04		0·04			
K_2O	0·11	0·16	0·14	·001 }		2·57
Na_2O	0·20	0·17	0·19	·003 } ·138	0·97	
Li_2O	4·14	3·89	4·02	·134 }		2·82
H_2O	14·85	15·06	14·96	·831 }		13·79
F	0·46		0·46÷38	·012 } ·843	5·94	SiF_4 0·47

O equivalent to the F 99·32   99·49
                          19

                        99·13

The ratio in the author's analysis corresponds closely to $SiO_2 : Al_2O_3 : Li_2O : H_2O = 4 : 3 : 1 : 6$ giving the formula $H_{12}Li_2Al_6Si_4O_{24}$, or simplified to that of a basic metasilicate,

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[*] This Journal, III, xl, p. 488, 1890.

$Li[Al(OH)_2]_3Si_2O_6$. Below will be found the author's analysis simplified by regarding all of the alkalies as represented by their equivalent of Li_2O, the Fe_2O_3 as Al_2O_3 and the F as OH and the whole calculated to one hundred per cent, also the percentage composition from the proposed formula.

	Analysis as adjusted.	Theory.
SiO_2	34·46	35·09
Al_2O_3	45·95	44·74
Li_2O	4·21	4·38
H_2O	15·38	15·79
	100·00	100·00

The agreement is certainly satisfactory and the discrepancy is probably the result of some slight impurity, which it is hard to avoid in micaceous minerals. Most of the water is expelled from cookeite at a high temperature, showing that it is probably formed from hydroxyl as assumed in the formula given above. The analysis was made on air-dry powder and the following fractional determinations were made:

Twenty hours over sulphuric acid in a desiccator, 0·82 per cent loss.
One hour at 100° C. _____ 0·09 "   "
One hour at 300° C. (to constant weight) __ __ 0·91 "   "

          Total _____ 1·82 "   "

If this small amount of water is deducted from the analysis the ratio of $SiO_2 : H_2O$ is nearer $4:5$ but the formula then becomes much more complicated.

The essential difference between the author's analysis and that of Mr. Collier is in the alkalies, and it is impossible to give any explanation of his potash determination except that the material for the same was possibly contaminated with lepidolite.

Mineralogical Laboratory of the Sheffield Scientific School,
          New Haven, January, 1893.

Art. XLVII.—*Mineralogical Notes;* by Samuel L. Penfield.

The author takes this opportunity of expressing to the Director of the U. S. Geological Survey his obligations for the privilege of presenting the results of the following mineralogical studies, which have been made upon material collected by the writer during the summer of 1892, while engaged in survey work.

1. *Zunyite from Red Mountain, Ouray Co., Colorado.*

In 1884 Mr. W. F. Hillebrand[*] described a new mineral zunyite from the Zuñi Mine, near Silverton, San Juan Co., Colorado. It is interesting to know that a second locality has been found for this rare mineral, at the Charter Oak mine, situated on the hill, only a short distance east of the village of Red Mountain. This is about five miles north of the original locality and on the same mountain chain.

When visiting the mine, my attention was called by the superintendent, Mr. C. A. Taylor, to a very hard rock which had been taken from the shaft. This is fine grained, of a grayish white color, and with the lens one can readily detect the little bright tetrahedrons of zunyite, about 1^{mm} in diameter, sometimes scattered sparsely, sometimes abundantly, through it. An examination of thin sections with the microscope shows that the rock is a porphyrite, very much altered by steam and fumerole action, so that only remnants of the original minerals are left. The zunyite crystals are fresh and clear and show no double refraction with polarized light.

The pulverized rock was almost an ideal one to treat with the Thoulet solution. An approximate separation of the zunyite crystals was first made. This product was then further purified by digesting with dilute hydrochloric and hydrofluoric acids, which have no appreciable solvent action on the zunyite, and then again separated with the heavy solution, giving a very pure product. Most of the mineral had a specific gravity between 2·904 and 2·876 and only this portion was used for the chemical analysis, the results of which are given below, together with the original analysis of Mr. Hillebrand.

	I.	II.	Average.	Ratio.		Hillebrand.
SiO_2	24·11	24·10	24·11	·402	3·00	24·33
Al_2O_3		57·20	57·20	·561	4·18	57·88
Fe_2O_3		·61	·61			·20
Cl	2·61	2 62	2·62	·074 ⎫		2·91
F	5·92	5·70	5·81	·306 ⎬ 1·616	12 06	5·61
H_2O	11·06	11·18	11·12÷9=1·236 ⎭			10·89
P_2O_5		·64	·64			·60
CaO		·11	·11			K_2O ·10
Na_2O		·48	·48			·24
			102·70			102·76
O equivalent to Cl and F			3·03			3·02
			99·67			99 74

The analysis was made on air-dry material which lost only 0·06 per cent by drying for one hour at 100° C. and an additional 0·15 per cent by heating for one hour at 300° C. The water is therefore regarded as formed from hydroxyl, with

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[*] Proc. Col. Soc., i, p. 124, 1884. Also Bulletin No. 20, U. S. Geological Survey, p. 100.

which the Cl and F are isomorphous. Disregarding the small amounts of P_2O_5, CaO . Na_2O and Fe_2O_3 the ratio of SiO_2 : Al_2O_3 : (Cl . F.OH) is nearly 3 : 4 : 12, which is required by the formula suggested by Professor P. Groth[*] $[Al(Cl.F.OH)_2]_6$ $Al_2Si_3O_{12}$. The agreement between the author's and Mr. Hillebrand's analyses is very satisfactory. Especially the percentages of Cl, F and hydroxyl, which are regarded as isomorphous, are very close and yet there seems to be no definite proportion in which these constituents are related to one another. The relation of Cl + F : OH in the author's analysis is ·380 : 1·236 or 1 : 3·25.

Besides the occurrence of zunyite in the rock, as just described, it also occurs at this same mine in a pulverulent form. This material resembles some kinds of kaolin, is pure white and consists of minute crystals, so loosely aggregated that they can be disintegrated by rubbing between the fingers. Other minerals found at the mine are enargite, pyrite, scorodite and sulphur. The latter in small but highly modified crystals showing the faces, 100, i-$\bar{\imath}$; 010, i-$\check{\imath}$; 110, I; 101, 1-$\bar{\imath}$; 103, $\frac{1}{3}$-$\bar{\imath}$; 011, 1-$\bar{\imath}$; 111, 1 ; 113, $\frac{1}{3}$; 115, $\frac{1}{5}$ and 133, 1-$\bar{3}$.   The scorodite was determined by proving it to be a hydrous ferric arseniate of specific gravity 3·209. It is not crystallized but has formed as a green, botryoidal incrustation on the enargite and decomposed rock.

The author also visited the Zuñi mine near Silverton where the zunyite occurs intimately mixed with the sulpharsenite of lead, guitermanite, and an earthy decomposition product containing lead sulphate, as described by Mr. Hillebrand. Some crystals were also found in the wall rock, which, like that from Red Mountain, is a decomposed porphyrite. At both localities zunyite is plainly a secondary mineral and has probably been formed by fumerole action upon the silicates of the rock.

The author takes pleasure in expressing to Mr. C. A. Taylor of Red Mountain, and to Mr. R. H. Williams of Silverton, the discoverer and owner of the Zuñi mine, his obligations for their kindness in supplying him with specimens and information.

2. *Xenotime from Cheyenne Mountain, El Paso Co., Colorado.*

The occurrence of this mineral from the tysonite and bastnaesite locality of El Paso County has already been noted by Mr. W. E. Hidden.[†]   His description was confined to a single crystal, measuring over one centimeter in diameter, weighing 5·1 grams and which had suffered some superficial alteration. The crystal to be described in the present article was given to

[*] Tabellarische Uebersicht der Mineralien, 1889, p. 104.
[†] This Journal, xxix, p. 249, 1885.

the writer by Mr. J. G. Hiestand of Manitou, Colo. It is over one centimeter in diameter and is implanted on a gangue of quartz and feldspar. Associated with it are crystals of hematite and astrophyllite. The xenotime is very fresh and pure, has a brown color and in thin splinters is pale pink. The form of the crystal is the unit pyramid with its middle edges slightly modified by the prism and a steeper pyramid, probably 331, but the faces of the latter were too dull to measure on the reflecting goniometer. The faces of the unit pyramid were bright and the following measurement was made, $111 \wedge 1\bar{1}1 = 55° \ 32'$, agreeing very well with the measurements of G. vom Rath* and C. Klein,† 55° 30'. The prismatic cleavage was very well shown by cracks running through the crystal.

Without destroying the specimen a little over 0·2 gram was removed for a quantitative analysis, the results of which are as follows:

Specific gravity	5·106			Ratio.
P_2O_5	32·11	÷ 142 =	·226	1·00
$(Yt, Er)_2O_3$	67·78	÷ 284 =	·238	1·05
Ignition	·18			
	100·07			

The only metals that were found were those of the yttrium and erbium group and the joint molecular weight of the oxides was found to be 284, equivalent to a joint atomic weight of 118. A solution of the oxides tested with the spectroscope showed the absorption bands of erbium and the atomic weight indicates that yttrium is also present. The ratio of $P_2O_5 : (Yt, Er)_2O_3$ is almost 1 : 1 showing that the mineral is a normal phosphate.

The author desires to express his thanks to Mr. J. G. Hiestand for giving him this interesting crystal which is now in the United States National Museum.

ART. XLVIII.—*The Influence of Free Nitric Acid and Aqua Regia on the Precipitation of Barium as Sulphate;* by PHILIP E. BROWNING.

THE fact demonstrated by Dr. F. W. Mar‡ in an interesting series of experiments, that free hydrochloric acid even in large quantities does not interfere with the complete precipitation of barium as sulphate when sulphuric acid is present in

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* Pogg. Ann., 1864, B. 123, p. 187.   † Jarb. Minn., 1879, p. 536.
‡ This Journal, xl, 283.

sufficient excess, but rather renders the precipitate more crystalline, and therefore more easily and quickly filtered, suggested a similar series of experiments having as their object an investigation of the influence of free nitric acid on the same precipitation. Certain qualitative preliminary experiments showed a similar effect to that brought about by hydrochloric acid as regards the crystalline form and rapid settling of the precipitate. It therefore remained to determine whether the nitric acid present had any solvent effect upon the precipitate. Accordingly a standard solution of barium nitrate was prepared, free from alkali, by precipitating a soluble barium salt with ammonium carbonate, washing thoroughly with hot water and dissolving in nitric acid, care being taken to avoid an excess of the acid, and making up to measure. Definite portions of this solution were drawn from a burette into counterpoised beakers, and weighed as a check on the burette reading. Several precipitations of the barium in the form of sulphate were made, both in the presence of free hydrochloric acid and in neutral solution, and the mean of closely agreeing determinations was taken as the value of the standard solution. The mode of procedure in the testing was simple and may be outlined as follows:—Into a counterpoised beaker a definite amount of the standardized solution of barium nitrate was drawn and the weight taken as before described, the amount of nitric acid to be used was then added, and the whole volume brought up to 90 cm^3 by the addition of water. This acid solution was then brought to the boiling point and 10 cm^3 of the dilute sulphuric acid added, and the whole was allowed to stand for the length of time shown by the table before filtering on asbestos, igniting and weighing. . It will be seen that the total volume of liquid taken in each determination was uniformly 100 cm^3, the percentage of acid by volume being thus easily regulated. In no case did the amount of barium salt present exceed 0·4 gm. considered as the sulphate, and consequently the uniform amount of 10 cm^3 of dilute (1:4 by volume) sulphuric acid employed was always enough to assure the excess which Fresenius[*] has shown to be necessary in the precipitation of barium as the sulphate in the presence of hydrochloric acid. By reference to Series I it is evident that in the presence of five per cent of nitric acid very little solvent action is shown, and it appears also that the sulphate may be safely filtered after an hour's time. In the presence of ten to fifteen per cent of the acid the solvent effect is very small when the solution is allowed to stand six hours or more. With twenty to twenty-five per cent of acid present we find the solubility to be slightly increased, but even then the average loss is less than 0·001 grm.

[*] Zeitschr. f. anal. Chem., xxx, 455.

SERIES I.

	BaSO₄ equivalent to Ba(NO₃)₂ taken. grm.	BaSO₄ found. grm.	Error in terms of BaSO₄. grm.	Averages. grm.	Time between precipitation and filtration. hours.	Per cent by volume of strong HNO₃.	Total volume. cm³
(1)	0·2540	0·2336	0·0004 −		12	5	100
(2)	0·2489	0·2483	0·0006 −		"	"	"
(3)	0·2495	0·2489	0·0006 −	0·0006 −	"	"	"
(4)	0·2492	0·2482	0·0010 −		"	"	"
(5)	0·2486	0·2483	0·0003 −		6	"	"
(6)	0·2490	0·2490	0·0000	0·0002 −	"	"	"
(7)	0·2555	0·2546	0·0009 −		1	"	"
(8)	0·2538	0·2534	0·0004 −	0·0006 −	"	"	"
(9)	0·4067	0·4057	0·0010 −		12	10	"
(10)	0 2540	0·2533	0·0007 −		"	"	"
(11)	0·2492	0·2489	0·0003 −	0·0006 −	"	"	"
(12)	0·2493	0·2488	0·0005 −		"	"	"
(13)	0·2494	0·2488	0·0006 −		"	"	"
(14)	0·2492	0·2492	0·0000		6	"	"
(15)	0·2490	0·2489	0·0001 −	0·0002 −	"	"	"
(16)	0·2489	0·2484	0·0005 −		"	"	"
(17)	0·2540	0·2524	0·0016 −	0 0016 −	1	"	"
(18)	0·2529	0·2515	0·0014 −		12	15	100
(19)	0·2534	0·2522	0·0012 −		"	"	"
(20)	0·2533	0·2531	0·0002 −		"	"	"
(21)	0·2538	0·2532	0 0006 −	0·0007 −	"	"	"
(22)	0·2497	0 2490	0·0007 −		"	"	"
(23)	0·2489	0·2487	0·0002 −		"	"	"
(24)	0 2542	0·2528	0·0014 −		6	"	"
(25)	0·2486	0 2486	0·0000	0·0006 −	"	"	"
(26)	0·2492	0·2487	0·0005 −		"	"	"
(27)	0·2547	0·2532	0·0015 −	0·0015 −	"	"	"
(28)	0·2489	0·2478	0·0011 −		12	20	"
(29)	0·2486	0·2475	0·0011 −		"	"	"
(30)	0·2548	0·2546	0·0002 −	0·0008 −	"	"	"
(31)	0 2548	0·2542	0·0006 −		"	"	"
(32)	0·2496	0·2486	0·0010 −		"	"	"
(33)	0·2539	0·2527	0·0012 −		6	"	"
(34)	0·2488	0 2475	0·0013 −	0·0008 −	"	"	"
(35)	0·2497	0 2497	0·0000		"	"	"
(36)	0·2486	0·2477	0·0009 −		12	25	"
(37)	0·2491	0·2490	0·0001 −		"	"	"
(38)	0·2494	0·2484	0·0010 −		"	"	"
(39)	0 2538	0 2535	0·0003 −	0·0008 −	"	"	"
(40)	0·2492	0 2484	0 0008 −		"	"	"
(41)	0·2487	0·2471	0·0016 −		"	"	"
(42)	0·3414	0·3407	0·0007 −		"	"	"
(43)	0·2489	0·2481	0·0008 −		6	"	"
(44)	0·2485	0·2478	0·0007 −	0·0007 −	"	"	"

Having shown that free nitric acid even though present in considerable amount has only a slight solvent influence upon barium sulphate it seemed interesting to try the effect of the combination of nitric and hydrochloric acids mixed in the proportion to form aqua regia (3HCl : 1HNO₃). The experiments

recorded in Series II show that aqua regia has even less effect as a solvent than nitric acid alone. In fact it seems to act like hydrochloric acid alone, which practically has no solvent effect, as shown by Dr. Mar's work previously cited.

Series II.

	BaSO₄ equivalent to Ba(NO₃)₂ taken. grm.	BaSO₄ found. grm.	Error in terms of BaSO₄. grm.	Averages. grm.	Time between precipitation and filtration. hours.	Per cent by volume of strong aqua regia. (3HCl : 1HNO₃).	Total volume. cm³
(1)	0·2539	0·2534	0·0005 —		12	5	100
(2)	0·2540	0·2538	0·0002 —	0·0002 —	"	"	"
(3)	0·2490	0·2490	0·0000		"	"	"
(4)	0·2491	0·2492	0·0001 +		"	"	"
(5)	0·2488	0·2484	0·0004 —	0·0001 —	6	"	"
(6)	0·3419	0·3421	0·0002 +		"	"	"
(7)	0·2491	0·2487	0·0004 —		12	10	"
(8)	0·2486	0·2482	0·0004 —	0·0006 —	"	"	"
(9)	0·2549	0·2539	0 0010 —		"	"	"
(10)	0·2543	0·2538	0·0005 —		"	"	"
(11)	0·2487	0·2485	0·0002 —	0·0002 —	6	"	"
(12)	0·3416	0·3415	0·0001 —		"	"	"
(13)	0·3417	0·3420	0·0003 +	0·0003 +	1	"	"
(14)	0·2547	0·2544	0·0003 —		12	15	"
(15)	0·2492	0·2492	0·0000	0·0003 —	"	"	"
(16)	0·2489	0·2479	0 0010 —		"	"	"
(17)	0·3412	0·3412	0·0000		"	"	"
(18)	0·3418	0·3417	0·0001 —	0·0001 —	6	"	"
(19)	0·3413	0·3412	0·0001 —		"	"	"
(20)	0·3411	0·3402	0·0009 —	0·0009 —	1	"	"
(21)	0·2492	0·2484	0·0008 —		12	20	"
(22)	0·2486	0·2480	0·0006 —	0·0005 —	"	"	"
(23)	0·2491	0·2485	0·0006 —		"	"	"
(24)	0·3412	0·3411	0·0001 —		"	"	"
(25)	0·3417	0·3418	0·0001 +	0·0000	6	"	"
(26)	0·3417	0·3417	0·0000		"	"	"
(27)	0·3414	0·3404	0·0010 —	0·0010 —	1	"	"
(28)	0·2491	0·2485	0·0006 —		12	25	"
(29)	0·1701	0·1697	0 0004 —	0·0003 —	"	"	"
(30)	0·1708	0·1705	0·0003 —		"	"	"
(31)	0·1710	0·1710	0·0000		"	"	"
(32)	0 3415	0·3410	0·0005 —	0·0003 —	6	"	"
(33)	0·3418	0·3418	0·0000		"	"	"
(34)	0 3412	0·3405	0·0007 —	0·0007 —	1	"	"

In this connection I append the results of a few experiments made to determine the effect of the presence of a considerable amount of free nitric acid, on the precipitations of barium as sulphate in cases where certain substances are present which under ordinary conditions tend to hold up the precipitate. Fresenius[*] has demonstrated this property in the case of ammonium nitrate, Scheerer and Rube,[†] have shown that

* Zeitschr. f. anal. Chem., ix, 62.   † Erdm , Jour. prakt. Chem., lxxv, 113–116.

metaphosphoric acid acts similarly, and Spiller* notes the
same general effect where alkaline citrates are present.   Series
III shows the results obtained by precipitating definite portions
of the standard solution of barium nitrate in the presence of
stated amounts of the substances just mentioned.   The total
volume in every case was 100 cm³, the amount of dilute sul-
phuric acid used 10 cm³, and the time between precipitation
and filtration twelve hours.   Upon filtering, igniting and
weighing the barium sulphate an excess of weight, due un-
doubtedly to contamination of the precipitate, was found.   It
became necessary, therefore, to purify the precipitate as first
weighed in order to determine whether all the barium was
actually precipitated or whether a partial loss was covered by
the amount of included impurity.   The method of purification
employed was that successfully applied by Dr. Mar in the work
previously mentioned.   The contaminated sulphate, collected
on paper and treated according to the familiar method (on
account of the difficulty attending the complete removal of the
precipitate from asbestos for purposes of purification), was dis-
solved in warm concentrated sulphuric acid, and evaporated
quickly and without spattering by means of the Hempel
burner, the barium sulphate being left after this treatment in
coarse granular crystals.   The crystallized sulphate was warmed
with a little water containing a drop of sulphuric acid, filtered
upon an asbestos felt contained in a perforated platinum cru-
cible, the crucible and felt having been previously ignited and
weighed.

SERIES III.

Impurity present to the amount of 5 grm.		BaSO₄ equiva- lent to Ba(NO₃)₂ taken.	Apparent amount of BaSO₄ found.	BaSO₄ after purifica- tion.	Error after purifica- tion.	Percentage of strong HNO₃ by volume.
		grm.	grm	grm.	grm.	
(1) Ammonium nitrate		0·1710	0·1800	0·1702	0·0008 —	10
(2) " "		0·3415	0·3440	0·3410	0·0005 —	"
(3) " citrate		0·3412	0·3442	0·3407	0·0005 —	"
(4) Sodium "		0·1360	0·1730	0·1366	0·0006 +	"
(5) Metaphosphoric acid		0·3461	0·3511	0·3470	0·0009 +	"

The results show that in the presence of nitric acid amount-
ing to one tenth by volume of the entire liquid these salts
exert no apparent interference with the precipitation of the
barium.

The entire work would seem to show that the presence of
an excess of nitric acid or aqua regia amounting to ten per
cent by volume of the liquid treated is not only not to be
avoided in estimating barium as the sulphate, but is actually
beneficial.   Ordinarily the advantage is found in the tendency

* Chem. News, viii, 280–281.

of the precipitate to fall coarsely crystalline under the conditions. In certain special cases in which certain substances mentioned, which would otherwise exert solvent action, are present the precipitation is made complete. The contaminating effect of such substances when complete precipitation is induced may be corrected by dissolving the precipitate in sulphuric acid and recrystallizing by evaporation.

ART. XLIX.—*On a Rose-colored Lime- and- Alumina-bearing Variety of Talc;* by WM. H. HOBBS, Madison, Wis.

THE crystalline dolomite of the vicinity of Canaan, Conn., is well known as a locality for white pyroxene and white and pale green tremolite. Some of this tremolite has recently been shown to be pseudomorphic to the white pyroxene.* Small amounts of quartz and colorless mica, and isolated crystals of pyrite, are present in the rock at many localities, and veins of calcite are occasionally met. Except near the boundaries of the horizon, where the rock passes by gradations toward a gneiss or schist, these are the only common minerals. Phlogopite I have found in clear brown scales a millimeter or more in diameter on the road running south from Rattlesnake Hill. The numerous openings which are made in the dolomite for supplying the lime-kilns of the vicinity, furnish opportunities for the discovery of any less common constituents that may be included in the rock. Mr. J. S. Adam, former analyst of the Barnum and Richardson Company of Lime Rock, has in his mineral collection at Canaan, several minerals of this character which have not been carefully studied. I am under obligations to him for the material which is here described. It was met with in the Adam Quarry which is located a mile southeast of the village of Canaan. The specimens given me are enclosed in the white crystalline dolomite whose grains average two millimeters in diameter.† Scattered through the dolomite

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* Wm. H. Hobbs, Notes on some Pseudomorphs from the Taconic Region, Am. Geol., x, 44 (1892).

† I am permitted by Mr. Adam to publish analyses by him of the dolomite of the vicinity, which show it to contain calcium and magnesium carbonates in the proportions of normal dolomite:

	Canaan Lime Company's Quarry. Granular.	Cleavage Pieces.	Calculated for $CaCO_3 . MgCO_3$.
$CaCO_3$	52·62	54·40	54·35
$MgCO_3$	46·25	45·12	45·65
Fe_2O_3 } Al_2O_3 }	0 24	0·25	·
Insoluble residue	0·17	0·08	
	99 28	99·85	100·00

are simple pentagonal dodecahedrons of pyrite about a millimeter in diameter, which are colored brown from superficial alteration to limonite. On lines evidently corresponding to fracture planes in the rock, is developed a talcose mineral. Other fracture lines are occupied by vein dolomite, one cleavage surface extending several centimeters. In one of the specimens the talcose mineral has a deep rose color, somewhat deeper than that of the margarite from Chester, Mass. In the other specimen the color is white or nearly so, but Mr. Adam informed me that when found it had the same rose hue as the first mentioned specimen. The rose color has faded through exposure to the light, resembling in this respect rose quartz.

The scales of this talcose mineral lie with entire lack of any regular orientation, completely filling the fissure. Scales one-half a centimeter across can be obtained having roughly hexagonal outlines, but which are too poor for accurate measurement. They are very flexible but entirely inelastic. They have the softness and unctuous feel of ordinary talc. After treatment with dilute hydrochloric acid to remove any possible trace of calcite, nearly a gram of the material gave a specific gravity of 2·86 by determination with the pyknometer. In the closed tube the powdered mineral yields considerable water. Ignited before the blowpipe it resembles talc in exfoliating, whitening and glowing intensely. It is, however, much more fusible, falling below 5 in v. Kobell's scale. It is also more readily decomposable than common talc. When digested for only a short time in hydrochloric acid, the solution yields a considerable amount of alumina and calcium.

Between crossed nicols in convergent light, scales of the mineral show a negative bisectrix perpendicular to the plane of cleavage. The optical angle, which is very small, lies in the plane perpendicular to one of the bounding planes, and also perpendicular to a side of the hexagon of the percussion figure. It therefore corresponds to a mica of the first class. $2E$ was measured in sodium light as $15\frac{1}{2}°$.

I am indebted to my friend, Mr. Louis Kahlenberg of the University of Wisconsin, for a chemical analysis of this mineral. His results are given below in the first column. In the last column is given the theoretical composition of ordinary talc:

			Calculated for $H_2Mg_3Si_4O_{12}$
SiO_2	61·48	64·52	63·52
Al_2O_3	3·04		
MgO	25·54	30·50	31·72
CaO	4·19		
FeO	0·77		
MnO	trace		
H_2O	5·54		4·76
	100·56		100·00

The mineral contains no nickel.

The analysis corresponds to a normal talc in which the magnesia is in part replaced by lime and the silica by alumina. The trace of manganese accounts for the rose color of the mineral which is lost on exposure to sunlight. The large amount of lime present is doubtless the cause of the unusual fusibility and decomposability by acids. Small amounts of lime in talc are not altogether unusual, though I have been unable to learn of but three analyses of the mineral, which have yielded more than one per cent of lime. These are given by Hintze in the list of sixty-seven analyses of talc printed in his Handbuch der Mineralogie.[*] The three occurrences referred to are Plaben, Bohemia (CaO, 1·09 per cent); Bergen Hill, New Jersey (CaO, 1·41 per cent); and Campo Longo (?), Tessin (CaO, 3·70 per cent.) The presence of alumina in talc would not seem to be so unusual, since the same list includes four occurrences of talc characterized by as large an amount of alumina as the Canaan mineral. They are, Plaben, Bohemia (Al_2O_3, 3·27 per cent); Gasteinthal, Salzburg (Al_2O_3, 5·37 per cent); Mainland, Shetland Isles (Al_2O_3, 4·14 per cent); and Fahlun, Sweden (Al_2O_3, 4·69 per cent). No occurrence is mentioned by Hintze which like the Canaan mineral contains considerable amounts of both alumina and lime.

As regards the color of the mineral, it seems to be altogether exceptional. Nearly all the text-books mention a rose talc from Cooptown in Harford County, Maryland, but I am informed by Dr. G. H. Williams that the authority for this is a statement made by Tyson as long ago as 1837, the mineral being not talc but kaemmererite or rhodochrome. Hintze mentions in his Handbuch[†] beside the Cooptown locality, two others where rose-colored talc occurs, viz: in granite at Fischbach near Hirschberg, Silesia,[‡] and with magnesite in clay slate at

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[*] Leipzig, 1892, pp. 824–6.   [†] Loc. cit., pp. 819–821.
[‡] Traube, Min. Schles,, 1888, 224.

Wald in Styria.* The original reference to the first has not been accessible to me, and the second contains no mention of the mineral's properties.

The Canaan mineral is thus shown to belong to the talc family by its chemical composition as well as by most of its physical and optical properties. That it is a somewhat distinct variety is shown by its high percentages of lime and alumina, by its low fusibility and easy decomposability by acid, and by its exceptional rose color.

University of Wisconsin.

ART. L.—*The Magothy Formation of Northeastern Maryland;* by N. H. DARTON, U. S. Geological Survey.

CONTENTS: *Introductory. General relations. The Magothy Formation.* Distribution. General features. East of Chesapeake Bay. Magothy River region. Severn River region. Odenton region. Patuxent River region. Original extent and thickness. Definition. Synonomy. Economic Geology. History.

Introductory.

IN this paper there is described an arenaceous formation not heretofore discriminated, lying between the Potomac and Severn formations in the upper Chesapeake Bay region.

Up to 1891, when I published my memoir on the Mesozoic and Cenozoic formations of eastern Virginia and Maryland,† I had given but little attention to the details of the geology of northeastern Maryland and believed that there was but one physical gap between the Potomac and Severn formations. Later studies in this region have led to the discovery that a series of sands and brown sandstones which I formerly supposed to be a local upper member of the Potomac formation, is separated from it by a continuous erosion plane, and constitutes a distinct formation.

As this formation is excellently exposed on the Magothy River, and partly for want of a better name it has been designated the Magothy formation. The general features of its distribution in Maryland are shown on the accompanying map. In the course of a few weeks a geological map of Maryland will be published by the State on which the lower boundary of this formation will be represented on a larger scale, and later its distribution west of Chesapeake Bay will be shown in detail on atlas sheets now in course of publication by the U. S.

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* Rumpf, Ueber krystallisirte Magnesite aus den nordöstlichen Alpen, Tschermak's Min. Mittheil., 1873, p. 271.

† Geological Society of America, Bull., vol. ii, pp. 431–450, pl. 16.

Geological Survey. Finally, I will describe the formation more fully in a Monograph on the Geology of the Chesapeake Bay region now in preparation.

General Relations.

The coastal plain of eastern Maryland is underlain by a series of later Mesozoic to Pleistocene deposits lying on an east-sloping floor of crystalline rocks. These deposits are widely extended sheets of sands, clays, and marls inclined and thickening to the southeast and separated into formations by erosion breaks. In the following table there is given a list of these formations and breaks, an explanation of their age and a brief description of their general characters :

	Formation.	Characters.	Paleontologic position.
Pleistocene.	*Columbia* ----	Loams, sands, and gravels. On terraces.	
		Erosion interval. Development of outlines of present topography.--------	————
Neocene.	*Lafayette* ----	Gravels, sands, and loams.-----	Pliocene ?
		Erosion interval. Base levelling over Coastal plain and westward ------	————
	Chesapeake ----	Sands, clays, infusorial earths, and marls.------------- -------	Miocene.
Eocene.		Erosion interval, planing of surfaces of preceding deposits ------------	————
	Pamunkey ----	Glauconitic marls and sands ..	Eocene.
Cretaceous.		Erosion interval, planing of surface of Severn and Potomac formations ----	————
	Severn ----	Black, argillaceous sands, mainly--	Cretaceous.
		Erosion interval, planing of surface of Magothy and Potomac formations---	Cretaceous.
	Magothy ----	White sands and brown sandstones, also gravels ----------------	Cretaceous.
		Erosion interval, planing of surface of Potomac formation-----------------	Cretaceous.
	Potomac ----	Clays and sands, also gravels and sandstones -------------------------	Early Cretaceous.

Great erosional and stratigraphic break following Jura-Trias deposition.

The Potomac formation lies directly on the crystalline rocks and outcrops over a wide belt eastward. Its western border extends westward on the ridges and the crystalline rocks extend eastward in the intervening depressions. It is succeeded eastward by the younger formations outcropping in succession in irregular northeast and southwest belts which are deflected westward of the ridges and eastward down the de-

pressions. The Lafayette and Chesapeake formations form a partial exception to this general statement for they overlap the other formations in some localities, and their western extension is now represented by small outliers occurring mainly in the higher lands to the northwest. The Columbia terraces extend across the other formations from the crystalline rocks in the depressions westward, to the Lafayette in the lowlands far to southeastward.

In southern Maryland the typical Coastal Plain topography of the south Atlantic region prevails, an elevated east-sloping plain capped by Lafayette formation, and holding sharply depressed drainage basins lined with low Columbia terraces which extend eastward into a wide low belt adjoining the ocean. This east-sloping Lafayette plain has also a gradual tilt northward and with increasing altitude it is more and more widely eroded. Near the latitude of Washington it finally terminates, except for a few small outliers, and through northeastern Maryland the region west of the bay, although still elevated, is rolling in contour in the higher lands and occupied by areas of Columbia terraces in the moderately elevated and low districts. The entire country east of Chesapeake Bay is a Columbia terrace relatively low throughout but gradually increasing in altitude to the north and northwest.

MAGOTHY
AND
ASSOCIATED FORMATIONS
IN
NORTHEASTERN MARYLAND

N H DARTON.
U S. Geological Survey

Scale 16 miles to an inch

1893

LEGEND

Lafayette
and
Chesapeake

Pamunkey

Severn

Magothy

Potomac

The Magothy Formation.

Distribution.—As is shown on the accompanying map the Magothy formation extends from the Delaware line to a point just southwest of Bowie, where it disappears in the overlap of the Severn onto the Potomac formation. I have not traced its eastward continuation through Delaware but the formation undoubtedly extends some distance at least, probably included in the sand marls described by Chester as the base of the glauconitic series.

East of Chesapeake Bay the Magothy formation extends in a nearly straight line from near Chesapeake City to below Worten's Point and outcrops below the Columbia deposits in the face of river and bay bluffs and in stream cuts. Its range of altitude is not great except in the outlying area of Maulden Mountain where it lies in greater part above one hundred feet above tide. Its dip is to the east-southeast at from 20 to 30 feet per mile.

West of the bay the formation begins a short ways below Bodkin Point at the mouth of the Patapsco, and crosses the rolling country and three or four intersecting valleys, south-westward to its termination. Its inclination of from 30 to 40 feet per mile carries it far westward up the long slopes of the ridges in irregular sheets and outliers but it descends below the Severn formation at tide level eastward along a line essentially continuous with its course on the eastern shore of the bay. The altitudes attained in the ridges westward are 130 feet on the neck between the Magothy and Patapsco Rivers, 240 feet in a far western outlier near Severn Station on the Magothy-Severn divide, 250 feet east of Odenton, 160 feet between the forks of the Patuxent and 190 feet on the ridge just east of Bowie.

General Features.—The Magothy formation consists mainly of white and buff sands with local beds of brown sandstone, and limonitic streakings both in plates and discolorations. Southwestward it becomes gravelly for some distance and some portions are locally lithified into loose conglomerates or harder, more or less pebbly, brown sandstones. The ferrugination which gives rise to the brown sandstones is by no means confined in this region to the Magothy formation for brown sandstone and limonitic masses and crusts are scattered locally in the Potomac, Pamunkey and Columbia formations and also but more rarely in the Severn, Chesapeake and Lafayette formations. The sands of the Magothy formation are moderately coarse and at some localities they are very coarse. They consist of quartz grains which vary in shape from rounded to subangular with a greater or less admixture of angular grains.

They lie loosely—a characteristic feature, in beds usually quite thin and regular but locally cross-bedded, sometimes to an extreme degree. The thickness varies from 10 to 30 feet but about 15 feet is the usual amount. An admixture of carbonaceous materials is often present in the form of grains but several thin beds and interbeddings of lignite have been observed. A few thin streaks of pale gray clays occur interbedded in the formation in the Bohemia River region.

The unconformities between the Magothy and Potomac below and with the Severn above are planes of erosion everywhere distinct and participating in the general southeastward inclination of the Coastal plain deposits.

East of Chesapeake Bay.—The northeasternmost exposures of the Magothy formation, which I have observed, are in the vicinity of Chesapeake City near the eastern terminus of the Chesapeake and Delaware canal. The cuts of the canal begin about two miles east of Chesapeake City and are in the marls and black sands of the Severn formation of which they afford a superb exposure. At the western end of these cuts and in several small stream depressions in the vicinity there are showings of the Magothy sands overlain by the black Severn beds. The sands are white, gray, and buff, streaked irregularly with light brown. The entire thickness of the formation was not observed in this region but in one exposure twenty feet of its sands were seen, capped by weathered, gray-brown Severn beds along an undulating plane of unconformity.

Between Chesapeake City and Bohemia Creek small exposures of Magothy beds are frequent in the deeper stream cuts. They are overlain directly by the Columbia gravels and loams westward, and the feather-edge of the Severn sands eastward.

On the south shore of Bohemia Creek near its mouth there is a long, high bluff in which the Magothy and adjacent formations are finely exposed. The basal beds are typical Potomac variegated clays, pink and red predominating, but in part buff and dark lead color. These clays extend to an altitude of about 30 feet at the western end of the bluff but this upper surface dips gently eastward and finally sinks below the water in about a mile. This upper surface is an undulating plane presenting no marked irregularities of contour and it is clearly a product of aqueous erosion. It is overlain by the Magothy sands which have a thickness varying from fifteen to twenty-five feet. These sands are mainly white or light gray but in places they are stained with buff and pinkish streakings. The materials are moderately coarse quartz grains quite uniform in size, rounded or subangular in greater part and lying loosely compacted in thin beds with but little cross-bedding. Near their base they sometimes contain a

small amount of clay fleckings and intermixture, derived from the subjacent clay formation, and discontinues streaks of limonite. Towards the western end of the bluffs they include two elongated lenses of tough, laminated, gray clay. The lower mass is near the base of the formation and is about six feet thick; the upper one is near the top and has a maximum thickness of three feet. These clay streaks merge into the adjoining sands, but the transition is quite abrupt at most points. Overlying the Magothy formation eastward is a thin wedge of weathered Severn sands separated by an east dipping erosion plane similar to the one below. The Severn beds attain a thickness of 15 feet at the eastern end of the bluffs but are cut out westward by an overlap of the overlying Columbia formation onto the Magothy beds. The Severn beds are dark gray, argillaceous, carbonaceous, fine, laminated sands with some portions less argillaceous slightly glauconitic, more massive and lighter gray in color with buff mottlings. They are sharply contrasted from the Magothy beds and even without the separating unconformity could never be classed with them. The Columbia capping on these bluffs has a thickness of from four to seven feet. It consists of a basal bed of pebbles, bowlders and slabs with local beds of conglomerate and an upper bed of red-brown to buff, columnar loam with a few scattered pebbles.

The next notable Magothy exposures southward are in the long high bluffs extending north from Grove Point. Towards the point the bluffs are of Severn beds overlain by Columbia deposits both superbly exposed.* About 1000 yards north of the point the Magothy formation comes up on a low southern dip and soon attains prominence in the bluffs in which it continues to the end. The formation consists of coarse, loosely compacted, cross-bedded gray sands with irregular masses and streaks of brown sandstone and sandy limonite. The erosion plane separating the Severn formation is well exposed and is seen to be less regular in contour than usual. The ferrugination of the Magothy beds is here very irregular and predominates near the summit. Below are many scattered masses consisting of reticulated plates and tubes of sandy limonite, some of which are several feet in length and as much as a yard in thickness.

On the peninsula between Elk River and the head of Chesapeake Bay there is a high ridge on which there remains an outlier of Magothy with overlying Severn formation constitut-

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* Detailed descriptions of the Columbia formation in these and many other bluffs in this region are given by McGee in a memoir on "The Geology of the head of Chesapeake Bay. U. S. Geol. Survey, Seventh annual report of the Director, pp. 537–646, pls. 1888.

ing two local eminences known as Maulden Mountain and Bull
Mountain.   The western sides of these so-called mountains
are cut by the bay giving rise to very prominent bare bluffs
120 to 130 feet in height, in which the Potomac and Magothy
formations are well exposed.   The Potomac beds in this region
are the typical variegated clays in which pink and buff colors
predominate but some reds and purples also occur.   In the
upper part of the Potomac here there is a local bed of white
sand with more or less pink clay admixture which extends
for some distance along the bluff.   The Magothy beds lie on
the usual erosion plane and are distinct from the Potomac
sands and clays below.   They consist mainly of coarse, loose,
pure sands, regularly bedded except at a few points where
cross-bedding was observed.   Several thin, local streaks of
clay are included and many large masses of brown sandstone.
Loose masses of this sandstone, in part pebbly, are prominent
in sandy areas between the higher portions of the ridge.   The
Severn outliers are of weathered beds, consisting of dark gray,
fine, argillaceous sands below and more arenaceous, gray buff
members above, attaining in all a thickness of about forty feet.
Their entire separateness from the Magothy beds is exhibited
in several exposures.   The higher summits about Maulden
Mountain are from 150 to 180 feet above tide level, and are
capped by outliers of Columbia of the high level series.

The high bluffs along the south shore of the Sassafras River
near its mouth, expose the Severn beds in great force.   Ap-
proaching Howell's Point the gentle southeast dip brings up
the Magothy beds which soon displace the Severn formation,
and extend westward nearly to the Point.   They are the usual
moderately coarse sands but vary in color from pink to flesh col-
ored in greater part, with light brown streakings locally.   Their
thickness is about twenty-five feet.   They are loosely bedded,
with some cross-bedding.   The underlying Potomac beds come
up in turn about 600 yards west of the first appearance of the
Magothy beds and the two formations continue to the end of
the bluffs, a short distance westward.   The Potomac beds are
typical variegated clays comprising white, buff, pink, red, and
dark lead colors.   Their surface is quite uneven and the clays
are separated from the Magothy sands by a thin, interrupted,
layer of impure limonite and coarse sand with a few scattered
quartz pebbles.   The bluff is capped with Columbia members
which constitute about two-thirds of its height.

Howell's Point is a tide marsh area, but a short distance
south the bluffs again extend to the bay shore and thence
continue to Still Pond.   The Columbia formation extends
down to tide level for considerable distances in these bluffs but
the upper part of the Magothy beds is well exposed in the

intervals. The formation consists of the usual coarse, loosely bedded sands generally white but in places stained buff or pinkish. Several short thin streaks of light colored clays occur and a few thin, discontinuous layers of ironstone. In the base of the overlying Columbia are several masses of coarse brown sandstones and conglomerate but they are sharply separated from the Magothy beds. Near the entrance to Still Pond a change of trend in the bluffs to southeast, carries them into the Severn belt, bringing in Severn beds between the Columbia and Magothy formations. In the next half mile the dip carries the Magothy formation below tide level and soon after, the Columbia deposits come down to the base of the bluff. The Severn beds in the exposure are weathered at their base to gray and lead colored clays with sandy layers; an unusual character. Higher up they are the typical black argillaceous, carbonaceous sands, covered superficially with green and gray sulphurous incrustations from decomposing pyrite, a common feature at this region. Their relations to the Magothy beds are particularly well exposed here and the gently undulating erosion plane extends along the bluff in plain view for a considerable distance. At their southeasternmost exposure in the bluff the Magothy sands are steeply crossbedded, some of the bedding planes having an inclination of 25°.

South of Still Pond there are no notable exposures of Magothy beds, the prominent bluff on Worton Point lying west of their outcrop belt and exposing only Potomac and Columbia deposits.

Magothy River region.—The Magothy formation appears first on the western shore of Chesapeake Bay on the bay shore 1½ miles south of Bodkin Point. The exposure is in a low bluff and consists of an irregular mass of brown sandstone in buff sands in all about fifteen feet thick of which the greater part is sandstone. It is underlain by typical yellow and pink Potomac clays along an irregular plane and dips below weathered, but unmistakeable Severn beds exposed a short distance south but not in contact.

On the north side of the Magothy River the formation and its relations are well exposed in a small side inlet, Broad Creek, about three miles above the mouth of the river. To the east on Gibson, and Dobbin islands and in the adjoining higher lands notably Eagle Hill the Severn beds are extensively exposed with all their usual characteristics. To the west up the river the underlying Potomac clays and sands comes out. In the inlet above referred to the contact with the Potomac formation is exhibited in a long low bank and the line of unconformity is seen to be unusually irregularly and strikingly distinct. The Magothy beds are the usual coarse gray, loosely

bedded sands containing more or less brown sandstone. The Potomac formation here is a densely packed, moderately fine, "sharp" sand with more or less disseminated clay particles, a member which is first seen in this vicinity and extends for about twenty miles southwestward. This Potomac member merits some special description here on account of its unusual characters, relations to the Magothy formation and some misapprehensions which exist regarding it. Its sands grade into and give place to white and pink sandy clays at some localities but they are usually characterized by their purity and extreme compactness. At some points they are lithified in greater or less part into white or gray sandstones or quartzites, and less frequently brown sandstone. This sandstone constitutes the "White Rocks" out in the Patapsco River near its mouth and there are a number of other occurrences of it. This arenaceous Potomac member is, I suppose, the upper part of the "Albirupean formation" of Uhler, but as it grades into typical Potomac clays and sands and is unquestionably not separated by any stratigraphic break I see no grounds for its separation as a distinct formation.*

On the neck between the Magothy and Patapsco Rivers the sands and brown sandstones of the Magothy formation extend inland for several miles covering the higher areas and capping several small outlying knobs.

Severn River region.—In the bluffs along the north shore of the Severn River at Round Bay and for some distance above, the Magothy formation and its relations are finely exposed. Just south of the Round Bay hotel there is a bluff which with the steep slopes above expose 140 feet of beds from the top of the Magothy some distance up into the Pamunkey formation. The Pamunkey beds here are weathered to brown, buff and red sands with ferruginated masses, containing Eocene fossils. Lying unconformably below the Pamunkey formation are 90 to 100 feet of the black micaceous, argillaceous and carbonaceous sands of the Severn formation. Near the base of the bluff the base of the Severn beds is exposed for several yards lying unconformably on very coarse, white Magothy sands along an east-dipping plane extending to a few feet above water level.

In the next five hundred yards west these sands rise rapidly and some low bluffs exhibit a thickness of twelve feet with a

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* The term Albirupean was proposed by P. R. Uhler in 1888 to the American Philosophical Society (see Proceedings, vol. xxv, page 42). The fossils exhibited and reputed to have been obtained from the "Albirupean" were shown by Heilprin and Lewis to be of Upper Silurian age and were probably fragments from the Columbia formation. Its taxonomy was never clearly defined and its author now includes under the name the greater part of the upper Potomac formation of Maryland, all the sand lenses in the Potomac from top to bottom, apparently, and I take it, the great Potomac series in Virginia.

thin capping of weathered Severn beds. The coarseness of the upper part of the Magothy is not so pronounced in this exposure and the sands for some distance below are of the usual moderately coarse, loosely bedded type. Near their base, thin, interbedded carbonaceous layers gradually come in and finally form an irregular lignitic layer with white sand streaks. Below this are irregular layers of brown sandstone two or three feet thick exposed along the beach.

In the next bluff up the river, Potomac, Magothy and Severn beds are exposed in a section thirty feet in height. The Severn caps the bluff to a thickness of from six to nine feet and consists of fine, argillaceous sands weathered to a gray-buff color. They lie on a very even but clearly defined erosion plane exposed for nearly a hundred feet along the bluff. The Magothy beds average twenty feet in thickness but are several feet thicker at several points. They consist of regularly bedded, loosely compacted, gray sands with light buff streaks and blotchings containing thin streaks of brown sandstone above, and large masses of brown sandstone below. They lie on a very uneven surface of the densely packed sands and clays which as before stated characterizes the upper part of the Potomac formation in this region. One of the most notable irregularities of this surface is an old channel four or five feet in depth in which the Magothy beds come down nearly to water level. The Potomac deposits lying next below the Magothy formation are very densely packed, gray sands, in part lithified. They also contain a short streak of carbonaceous materials. Below, they give place abruptly to a series of lenses of very tough pearl-gray sulphurous clay with sulphur crusts on its surface. Underlying this clay are several masses of sandstone which outcrop at the base of the bluff. A person unfamiliar with the complicated stratigraphic relations in the coastal plain formation would be puzzled by this exposure with its several exceptional features in the Potomac formation, and their apparent unconformities, and by the two horizons of brown sandstones.

Ascending the river the dip brings up in succession lower and lower beds which exhibit very plainly the true general relations. There are several bluffs on the north shore exposing the very compact sands and clays of the Potomac, unconformably overlain by the loosely bedded coarse, white Magothy sands here constituting the surface formation. In a bluff about a mile and a half above Round Bay the Potomac beds attain an elevation of twenty-two feet and are overlain by from eight to ten feet of Magothy sands. This exposure is the key to the horizon of the compact sands and gray sulphurous clays for they are finely exhibited, *grading* laterally and downward into looser white

sands with streaks of red and pink clay of the usual Potomac type. A short way west these sands are exceptionally pure and they are quarried for use in the arts but in the western part of the quarries and beyond they are seen to grade into variegated sandy clays and then pure clays of typical Potomac character. There can be no doubt of the Potomac age of these compact sands and clays lying immediately below the Magothy formation in the district.

North of the Severn River in this region the Magothy gray and buff sands with brown sandstone fragments cap the higher summits over a considerable area and at many points are seen lying on Potomac clays westward and the compact sand and clay member eastward. The northwesternmost Magothy exposure is a brown sandstone cap on a very small, shaly elevated knob a mile east by south from Severn station.

On the south side of the Severn River the banks are lower and present no notable Magothy exposures. In the slopes south ascending westward nearly to Odenton there are frequent outcrops in which are seen gray and buff sands with brown sandstone masses. They lie on a gentle undulating plane of unconformity with local irregularities, and dip southeastward at the usual rate of about thirty feet per mile.

Odenton Region.—In the hills east of Odenton the Magothy beds attain an elevation of 220 feet and cap the higher lands over an irregular area of considerable extent. They are overlain by several small outlying areas of weathered Severn beds westward and the northwestern edge of this formation extends along the eastern slopes of the Magothy hills.

In the southwestern extension of the Magothy formation the light colored sands give place to darker colored and coarser sediments in which brown sandstones, gravels and conglomerates prevail. The gravels are most conspicuous a mile and a half east of Odenton in the cuts of the Annapolis railroad, and on the adjoining hills. The relation to the Severn sands is plainly exposed in these cuts and at several points in stream and road cuts in their vicinity and southwestward. The gravels are more or less cemented into a loose conglomerate and intermixed with sand and brown sandstone. The aggregate thickness is variable but it amounts to 23 feet in the railroad cuts. Two and a half miles southeast of here towards Millersville in the cuts for the Drum Point railroad a somewhat greater thickness is seen of buff sand, and brown sandstone, in part sparingly pebbly. Typical Potomac clays and sands are exposed underlying the Magothy formation at many points in the Odenton region and the usual unconformity is always very distinct.

Patuxent River region. — South of Odenton the Magothy formation gradually thins but it extends to some distance beyond the Patuxent River before terminating.

In the ridge just east of Bowie and again on the ridge between the two forks of the Patuxent there are outliers of Magothy brown sandstones in turn capped by small areas of weathered Severn beds. The Potomac formation in the adjacent slopes are typical variegated clays in greater part, but there are also lenses of compact gray sands locally silicified to white quartzites.

The southwestern termination of the Magothy formation is not clearly exposed and the outcrops along the Patuxent are obscure. In the hills southwest of Bowie the Severn beds lie directly on Potomac clays and are themselves cut out at intervals westward by Pamunkey beds as far south as Washington.

The thinning may be due to an actual decrease in thickness of the original deposit or an overlap of its shore lines by a later formation, but it appears to have resulted from an increase southward of the erosion to which its surface was subjected in the interval preceding Severn deposition.

Original extent and thickness.—How far south the Magothy formation may have extended is not known, and as its surface has been eroded the original thickness is not determinable. The location of the northwestern shore line of the formation is not defined but it was probably very near the gravelly deposits extending from Bowie to beyond Odenton.

Definition.—The Magothy formation is a thin series of arenaceous deposits lying between the Potomac and Severn formations and separated from both by erosional unconformity and great dissimilarity of character. There are local unconformities at various horizons in the Potomac formation at the base of some of its sand lenses but these unconformities are due solely to current action and exist only within a restricted area. I have studied many of these Potomac sand lenses and found the sands grading laterally into clays or clays and sands and these merging downward across the horizon of unconformity into clays below. The unconformity at the base of the Magothy formation is clearly not of this character nor is the break at its summit, but both are in every way similar to the erosion planes which bound all the other members of the Coastal plain series.

The age and equivalence of Magothy formation is not known with any degree of precision but its stratigraphic position places it in the early Cretaceous. It contains plant remains at several localities notably in the lignitic members on

the Severn River at Round Bay, but they have not been studied.

The formation is not divisible into individual members, for the variations in character which it presents are local features not characterizing definite horizons.

Synonomy.—The Magothy formation has never before been discriminated or at least with any degree of definiteness. Mr. P. R. Uhler in his several papers* has referred more or less definitely to some of its features at several localities but he does not set forth its true relations.. He has separated a member, which he terms "alternate sand series" beginning somewhere at this horizon and extending up into the Severn formation, but its definition is so vague and moreover so variable in each succeeding publication of his that the name cannot be adopted without confusion.

Economic geology.—The Magothy formation has not as yet yielded any great amount of economic products. Its sandstone members have been employed locally to some extent as building stone and its gravels are used for railroad ballast. Some portions of its sands are, I believe, sufficiently pure for use in the arts notably on the Magothy River and at several points on the bay shore south of Howell's Point.

History.—The Magothy formation is a product of littoral deposition following the uplift and erosion of the Potomac deposits. It represents a time when currents and beach action were sufficiently active to sort out moderately coarse sands and spread them in beds, regular where the currents were gentle, and crossed where currents were more powerful. A few thin lenses of clay indicate that slack waters existed locally and the gravels westward indicate proximity to a shore line. The materials were probably all derived from the Potomac formation and the shore line was located within the Potomac area throughout. The far eastward extension of the Magothy beds now deeply buried below the Severn deposits, undoubtedly consists of the finer sands and clays which were carried farther off shore before being deposited.

Magothy deposition was succeeded by a general uplift and erosion interval during which the surface of the Magothy deposit was planed off in greater or less measure and degradation of the Potomac surface westward was continued. This epoch was followed by Severn deposition.

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* Maryland Acad. Sci. Trans., vol. i, 1888–1892.

ART. LI.—*On Electrical Oscillations of Low Frequency and their Resonance;* by M. I. PUPIN, Ph.D., Columbia College.

PART II. THEORETICAL DISCUSSION WITH SPECIAL REFERENCE TO THE THEORY OF RISE OF POTENTIAL BY RESONANCE.

I. *Introduction.*

A very faithful mechanical picture of the periodically varying flow in an electrical circuit possessing *localized** capacity and self-induction is obtained by considering the motion of a torsional pendulum, that is a heavy bar, say of cylindrical form, suspended on a stiff elastic wire. The moment of inertia of the bar and the elasticity of the suspension wire correspond to the coefficient of self-induction and the capacity of the circuit. The frictional resistance of the air corresponds to ohmic resistance, internal friction in the bar and the elastic suspension correspond to magnetic and dielectric hysteresis; angular displacement of the torsional pendulum corresponds to the electrical charge of the condenser, and therefore torsional reaction of the suspension to difference of potential between the condenser plates. Angular velocity in the one case stands for the current in the other, kinetic energy for electrokinetic energy, potential energy of the torsional forces stands for the electrostatic energy of the condenser charge.

In slow mechanical vibrations the decrement of the kinetic energy is chiefly due to external and internal frictional resistances. But as the frequency of the vibration increases other losses causing this decrement become more prominent ; so the losses due to radiation in form of sound waves. Similarly in electrical oscillations of very high frequency ; the decrement of the electrokinetic energy due to radiation in form of electromagnetic waves becomes considerably larger than that due to dissipation in consequence of ohmic resistance, magnetic and dielectric hysteresis. The analogy, therefore, supplied by mechanical vibrations is by no means a poor guide in the study of *even very rapid* electrical oscillations. *For slow vibrations the analogy is very striking and instructive.* To return to the torsional pendulum :—

Let I = moment of inertia of the bar,
θ = angle of displacement at any moment.

* The term *localized* is employed to distinguish the circuits considered in this paper from those electrical circuits in which self-induction and capacity are more or less uniformly distributed over the whole circuit, as, for instance, in the case of a Herzian Resonator.

Let the torsional force be as ordinarily assumed proportional to angle of displacement and the frictional resistance to angular velocity. An impulse having set the pendulum in motion it is required to describe the motion. The differential equation of motion is obtained by writing down the symbolical statement of the principle of moments, viz:

Rate at which the moment of momentum about the line of suspension varies _ } $=$ { Moment of all the forces about the same line.

That is

$$-\frac{d}{dt}\left(I\frac{d\theta}{dt}\right) = \alpha\frac{d\theta}{dt} + \beta\theta \quad \ldots \ldots \quad (1)$$

or

$$I\frac{d^2\theta}{dt^2} + \alpha\frac{d\theta}{dt} + \beta\theta = 0 \quad \ldots \ldots \quad (2)$$

Certain well known conditions being fulfilled the following integral is readily obtained:

$$\theta = A e^{-\frac{\alpha}{2I}t} \sin\frac{2\pi}{T}t \qquad (3)$$

where $T = natural\ period$ of the pendulum $= \dfrac{2\pi}{\sqrt{\dfrac{\beta}{I} - \dfrac{\alpha^2}{4I^2}}}$

The arbitrary constant A depends on the energy of the impulse and can be easily determined by well known rules. When $\dfrac{\alpha^2}{4I^2}$ is small in comparison to $\dfrac{\beta}{I}$ then

$$T = 2\pi\sqrt{I\cdot\frac{1}{\beta}} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

that is, *the natural period of the pendulum is independent of the frictional resistance.*

I venture to discuss briefly this rather familiar mechanical problem; for, the discussion seems to throw a strong light upon some of the electrical problems which form the subject of this paper.

Let $T_1 =$ natural period calculated by (3)
$T_2 =$ " " " " (4)

By a simple transformation it is easily shown that

$$T_1 = T_2\left(1 + \frac{1}{8\pi^2}r^2 - \ldots + \ldots\right) \quad . \quad (5)$$

where $r = \dfrac{\dfrac{T_2}{2}\,\alpha}{L}$

= ratio (approx.) of frictional loss during any half period to the amplitude of the kinetic energy during the same half period. I shall call it the *dissipation ratio*.

It follows therefore that whenever the dissipation ratio is smaller than $\frac{1}{4}$ then T_2 differs from T_1 by less than $\frac{1}{10}$ of one per cent. But since on the other hand

$$e^{-\frac{R}{2L}t} = e^{-r\frac{2t}{T_2}}$$

It follows that when the dissipation ratio $r = \frac{1}{4}$ then the pendulum will be practically reduced to rest after 16 complete oscillations. *This simple calculation shows, therefore, that even in very damped oscillations the period can and in most cases will be practically independent of the frictional resistance.*

The following observations are too well understood to need a mathematical commentary:—*a.* If a periodically varying force is applied to a torsional pendulum the oscillations will be *free oscillations* if the period of the force is the same as the natural period of the pendulum, that is if the force and the pendulum are in *resonance* to each other. When this resonance does not exist the oscillations are forced.

b. Of two periodically varying forces of the same mean intensity the one which is in resonance with the pendulum will produce the largest maximum elongation. The maximum elongation is reached when the work done by the resonant force during a complete period is equal to the frictional losses during that time.

c. The torsional force of the suspension varies periodically, its period being the same as that of the impressed resonant force, but differing from it in phase by a quarter of a period. The *amplitude of the torsional force can be much larger than the amplitude of the impressed force, especially when the frictional resistances are small, the moment of inertia large and the oscillations rapid,* that is the torsional coefficient large. For in this case that part of the work of the impressed force which is stored up in the kinetic energy of the pendulum will become large before the maximum elongation has been reached. But since this large kinetic energy has to be stored up in the potential energy of the torsional forces once during each half oscillation it is evident that a large torsional force will be called into action. *The amplitude of the tor-*

sional force is evidently an accumulative effect of the impressed force, and can easily be made so large as to break the suspension. This is a complete analogy to the breaking down of condensers due to a great rise in potential produced by resonance described further below.

The analogy can be carried further by considering the motion of a torsional pendulum A which is acted upon by a periodically varying force F, not directly, but through another torsional pendulum B to which A is suitably connected. The study of the motion of this system under different conditions as regards resonance between A, B and F gives a complete mechanical picture of the electrical flow in an electrical system consisting of a primary and a secondary circuit, each circuit having localized self-induction and capacity, when a periodically varying e. m. f. acts upon the primary circuit. An analytical discussion of the motion of this mechanical system would lead far beyond the limits of this paper. It seems sufficient to point out, that the analysis is almost identical with the following mathematical discussion of the electrical flow in resonant circuits and that it is possible to imitate in a mechanical model most of the electrical effects discussed below, by properly constructed torsional pendulums connected to each other in a suitable manner.

II. *On the Natural Period of an Electrical Circuit Possessing Localized Capacity and Self-induction.*

The circuit consists of a coil, whose coefficient of self-induction is L henrys, connected in series to a condenser of capacity C farads. Let the ohmic resistance be R ohms. An electrical impulse having started the electrical flow it is required to describe the flow. Let Q be the positive charge of the condenser in coulombs, at any moment, then the differential equation of the flow is obtained by writing down a symbolical expression of the generalized form of Ohm's law (disregarding losses due to magnetic and dielectric hysteresis)

$$-\frac{d}{dt}\left(L\frac{dQ}{dt}\right) = R\frac{dQ}{dt} + \frac{1}{C}Q \quad \ldots \ldots \quad (1^a)$$

or

$$L\frac{d^2Q}{dt^2} + R\frac{dQ}{dt} + \frac{1}{C}Q = 0 \quad \ldots \quad . \quad (2^a)$$

Comparing these equations to (1) and (2) we see that certain well known conditions being fulfilled the familiar integral first discussed by Sir W. Thomson, can be written down as follows:

$$Q = A e^{-\frac{R}{2L}t} \sin\frac{2\pi}{T}t$$

where T = natural period of the circuit

$$= \frac{2\pi}{\sqrt{\dfrac{1}{LC} - \dfrac{R^2}{4L^2}}}$$

When $\dfrac{R^2}{4L^2}$ is small in comparison to $\dfrac{1}{LC}$ then

$$T = 2\pi\sqrt{LC}$$

that is *the natural period of the circuit is independent of the ohmic resistance.*

To show that it is only under very exceptional circumstances that this condition is not fulfilled, I shall consider a circuit consisting of a large Bell telephone connected in series with a condenser of 1 microfarad capacity. The resistance of the telephone is 100 ohms, very large indeed, considering that its coefficient of self-induction is only about 0·5 henrys. Making this circuit a part of the secondary circuit of the small transformer excited by the electro-dynamic interrupter described in part I of this paper* it is found that the sound of the telephone is loudest when the frequency of the vibrator is about 225. The pitch of the sound is not sensibly altered by changing the resistance within very large limits; a result required by theory. For the period calculated from formula

$$T = 2\pi\sqrt{LC}$$ gives 224,4 vibrations per second.

Adding the correction given by formula (5) we get for the corrected period $T_1 = 224,9$ a difference of only about $\frac{1}{4}$ of one per cent. Since the dissipation ratio $r = \dfrac{1}{2,25}$ we get for the damping factor $e^{-\frac{1}{2,25}\frac{2t}{T}}$, that is to say the electrical oscillations would disappear almost completely after only 10 complete oscillations, which shows that the ohmic resistance produces a very strong damping and yet the period is practically independent of it.

In circuits consisting of well made coils with finely divided but split iron cores the dissipation ratio r is very small even for frequencies as low as 100 periods per second. The period, therefore, will be independent of the dissipation losses even if

* This Journal, April, 1893.

hysteresis and Foucault current-losses approach the order of magnitude of the losses due to ohmic resistance. The natural period of such circuits, especially when tuned up to a frequency of over 200 periods per second will be given *very accurately* by the formula

$$T = 2\pi\sqrt{LC}$$

To such circuits only the following discussion refers.

III. *On the Electrical Flow in a Resonant Circuit.*

Let a simple harmonic e. m. f. of period T act upon a circuit having localized self-induction and capacity, coil and condenser being connected in series. By the generalized form of Ohm's law we have in the usual notation

$$L\frac{dx}{dt} + Rx + P = E \sin pt \qquad (6)$$

The integral obtained by well-known rules is

$$x = \frac{p\,CE}{\sqrt{(1 - p^2\,CL)^2 + p^9\,C^2\,R^2}} \sin(pt - \varphi) \qquad (7)$$

where
$$\tan\varphi = \frac{1 - p^2 CL}{pRC}$$

which can also be written

$$x = \frac{E}{\sqrt{p^2 L_I^2 + R^2}} \sin(pt + \varphi_I)$$

$$\tan\varphi_I = \frac{pL_I}{R}$$

The integral written in this last form shows, as Oliver Heaviside first pointed out, that a condenser of capacity C in series with a coil changes the impedance of the circuit in such a way as if the condenser had a negative coefficient of self-induction equal to $\frac{1}{p^2 C}$.[*] It produces also a shifting of phase. *The impedance is reduced to ohmic resistance* when $L_I = 0$ or $p^2 LC = 1$, that is when the period of the impressed e. m. f. is equal to the natural period of the circuit, or in other words, *when the two are in resonance.*

The current and therefore the amplitude of the charge of the condenser reach then their maximum value.

[*] It is well to observe here that later on in the analysis of more complicated circuits possessing localized self-induction and capacity, I simplify my calculations very much by substituting $L_1 = -L + \frac{1}{p^2 C}$ for the coeffic. of self-induction and treating the circuit then as if it had no capacity.

The resonant flow consists in a conversion of electrokinetic into electrostatic energy, and *vice versa*, during each semi-oscillation, accompanied by a loss due to ohmic resistance which is the only work which the e. m. f. does. The amplitudes of the electrokinetic and electrostatic energies must therefore be equal to each other, hence

$$\tfrac{1}{2}\,L\left(\frac{E}{R}\right)^2 = \tfrac{1}{2}\,P_0{}^2\,C$$

where $P_0 =$ amplitude of the potential difference in the condenser.

The last relation gives, remembering that owing to resonance $p^2 LC = 1$,

$$P_0 = \frac{E}{pCR} = \frac{pL}{R}\,E = \frac{\text{Inductance}}{\text{Resistance}} \times E \quad (8)$$

If L and p are large and R small the rise in potential can be made as large as we please, or rather as large as the condenser will stand.

The analogy between this rise of potential due to resonance and the torsional reaction of the suspension in the resonant swinging of the torsion pendulum mentioned above is striking. In both cases the reaction is produced by an accumulative effect of the impressed force.

A rough experiment only, bearing on this point and which can be easily repeated in a few minutes in every electrical laboratory, will be briefly described here.

Two large choking coils and a Marshall condenser were connected in series with the secondary of a transformer. The core of the smaller of the two choking coils consisted of a removable bundle of soft iron wire. The condenser terminals were connected to a Thomson Electrostatic Voltmeter. The frequency of the impressed e. m. f. was about 100 periods per second. The capacity of the condenser was adjusted until the removal of the plug was accompanied by bright snapping sparks, which was a signal that resonance was near. Then the removable iron core of the smaller choking coil was moved up and down gradually until the Voltmeter gave the largest deflection. A rise from 60 volts (generated in the secondary and indicated by a Cardew Voltmeter) to about 900 volts in the condenser was easily obtained. When the impressed e. m. f. was raised to 80 the condenser indicated about 1200 volts, which showed that the rise in the condenser was proportional to the impressed e. m. f., as the theory requires.* The rise of potential is practically

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* I feel that it is only just to mention here that Mr. Marshall's ordinary condensers stood these voltages very well indeed, considering that they are guaranteed to stand a 1000 volts as their upper limit.

confined to the condenser, for the voltage on the line, indicated by the Cardew Voltmeter, does not change sensibly when resonance is established. *There is a large and rapid change in the current with the approach of resonance* which can be studied in a rough way by the pull which the choking coil exerts upon the removable iron core when the core is moved up and down during the process of tuning. The variation of this pull indicates very plainly that the curve expressing the relation between the current and the self-induction (resistance, capacity and frequency being constant), has a very steep crest which is in perfect accordance with the carefully plotted curve of equation (7) in Bedell and Crehore's volume on alternating currents.[*]

There are, however, several large maxima in this curve, each corresponding to a different capacity and self-induction; the simple experiment just described shows their presence very forcibly. The maximum corresponding to the largest capacity with about the same self-induction being however considerably the highest. With the condensers that I had at my disposal at that time I did not dare to tune the circuit for the highest maximum. The existence of several maxima will be seen presently to be a necessary consequence of the theory.

IV. *Electrical Resonance in a Circuit with a Complex Harmonic Electromotive Force.*

By Fourier's theorem a complex harmonic alternating e. m. f, can always be represented by the following series:

$$E = a_1 \sin pt + a_2 \sin 2pt + \ldots\ldots a_n \sin npt \ldots\ldots$$
$$= \sum_1^\infty {}_a a_a \sin \alpha pt$$

In this expression I shall call $a_1 \sin pt$, $a_2 \sin 2\, pt$, ... the *component harmonics*, $a_1 \sin pt$ is the *fundamental harmonic*, its frequency, the *fundamental frequency*. The other harmonics will be referred to as the *upper harmonics*. The order of magnitude of their amplitudes is $a_1 > a_2 > a_3 > \ldots\ldots > a_n > \ldots\ldots$

The symbolical expression of Ohm's law is this:

$$L\frac{dx}{dt} + Rx + P = \sum_1^\infty {}_a a_a \sin \alpha pt$$

Comparing this to (6) it is seen from the integral in (7) that this differential equation has the following expression for its integral:

[*] See Bedell and Crehore's treatise: Alternating Currents, p. 138, published by W. J. Johnston Co., New York.

$$x = \overset{\infty}{\underset{1}{\Sigma}}_a \frac{\alpha p C a_a}{\sqrt{(1 - \alpha^2 p^2 CL)^2 + \alpha^2 p^2 C^2 R}} \sin (\alpha pt - \varphi_a)$$

Where $\tan \varphi_a = \dfrac{1 - \alpha^2 p^2 CL}{\alpha p CR}.$

If we make $1 - p^2 CL = 0$, then the *circuit is brought in resonance with the fundamental harmonic* and the current is given by

$$x = \frac{a_1}{R} \sin pt + \overset{\infty}{\underset{2}{\Sigma}}_a \frac{\alpha a_a}{\sqrt{p^2 (1 - \alpha^2)^2 L^2 + \alpha^2 R^2}} \sin (\alpha pt - \varphi_a).$$

If the coefficient of self-induction is large then it is perfectly evident that the amplitude of the fundamental harmonic current is by far the largest especially when the frequency of the fundamental harmonic of the impressed e. m. f. is high.

For instance,   let $L = 2$, $R = 5$, $p = 2\pi \times 100$.

I select these values so as to be near the conditions under which the above experiment was performed. Under these conditions we should have for the amplitude of the next harmonic, supposing it to be an octave

$$\frac{a_2}{6\pi \times 10^2} \text{ (very nearly).}$$

The amplitude of the fundamental is therefore at least 360 times as large. In all probability this ratio is considerably larger, considering that a_1 is generally several times larger than a_2.

The higher harmonics have even much smaller amplitudes. *The rise of potential in the condenser is therefore just the same as if a simple harmonic e. m. f. of amplitude a_1 and pulsation p, acted upon the circuit.*

The tuning of the circuit produces therefore two distinct effects: 1st, It produces a rise of potential in the condenser, and 2nd, It weeds out the upper harmonics.

It may happen, however, that the circuit is tuned to one of the upper harmonics, as for instance when $\alpha^2 p^2 CL = 1$.

In this case the current is given by

$$x = \frac{a_a}{R} \sin \alpha pt + \Sigma \frac{a_\beta}{\sqrt{(\alpha^2 - \beta^2)^2 p^2 L^2 + \beta^2 R^2}} \sin (\beta p - \varphi_\beta)$$

β to take integral values from 1 to ∞ except the value α.

It is evident that now the fundamental harmonic with all the upper harmonics excepting the harmonic a is practically weeded out on account of the strengthening of the harmonic

$\frac{a_a}{R}$ *sin αpt by resonance.* The rise of potential according to formula (8) is given by

$$P_a = \frac{\alpha p L}{R} \cdot a_a.$$

To show how this rise of potential compares to the rise obtained by resonance to the fundamental harmonic, let $\alpha = 5$ and let the coefficient of self-induction be the same as before.[*]

$$P_1 = \frac{p L}{R} a_1$$

$$P_5 = \frac{5 p L}{R} a_5$$

Hence
$$\frac{P_1}{P_5} = \frac{a}{5 a_5}.$$

It is a well known fact that well made alternators are constructed in such a way that a_1 is generally larger than $5\,a_5$; hence, P_1 will be generally considerably larger than P_5. This was confirmed by the above experiment.

(It is well to observe that this suggests a rather interesting method of analysing a complex harmonic e. m. f. into its component harmonics *and of determining the relative value of the amplitude of each component.*)

The bearing of this on the method of producing a simple harmonic current by electrical resonance, described in the first part of this paper (l. c.) needs, I venture to say, no further discussion.

The study of resonance in electrical systems consisting of a primary and a secondary circuit with localized self-induction and capacity presents several features which deserve careful attention; a brief discussion of these together with a description of several experiments bearing upon the theory of low frequency resonance will be given in my next paper.

Electrical Engineering Laboratory, School of Mines,
Columbia College, April 15th, 1893.

[To be continued.]

[*] In the experiment described above the capacity was the principal variable; for, the first approximation to resonance was obtained by plugging the condenser until the vicinity of resonance was reached. The maximum point was finally obtained by a, comparatively speaking, slight variation of the coefficient of self-induction.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Properties of free Hydroxylamine.*—A further paper on the properties of hydroxylamine has been published by Lobry de Bruyn. In the solid state it forms white inodorous scales or hard needles which melt at about 33·05° and remain in the surfused state on cooling, even at 0°. At 58° and under a pressure of 23^{mm}, it boils; and when heated to 90°–100° it decomposes evolving gas. At a higher temperature it detonates. The crystals have a density of 1·35 as determined by the method of suspension in a mixture of chloroform and benzene; while in the liquid state the density is 1·23. According to Eykmann the refractive index at 14° for sodium light is 1·44123 and at 40° 1·43359. Its molecular mass by Raoult's method is 33. The crystals liquefy on exposure to air, increase in weight and volatilize completely. In a current of dry chlorine, hydroxylamine inflames; but bromine and iodine decompose it without flame. In the solid state it is oxidized on exposure to the air; a white substance is formed containing nitrous acid and ammonia. When dry oxygen is passed through the fused hydroxylamine white fumes of nitrous acid are produced with but little evolution of heat. Sodium attacks it with the production of flame. When added to its solution in dry ether, hydrogen is evolved, and a voluminous white amorphous substance is formed probably a compound of hydroxylamine with sodium hydroxylaminate. Crystals of potassium permanganate, of chromic acid, of potassium and sodium chromates and of ammonium dichromate produce decomposition with a white flame; while potassium and sodium dichromates cause a sharp violent explosion. With certain chlorides, hydroxylamine forms compounds analogous to their hydrated salt. The most probable formula the author thinks is $NH_2.OH$.—*Rec. Trav. Chim.*, xi, 18; *J. Chem. Soc.*, lxii, 1391, Dec. 1892. G. F. B.

2. *On the Trisulphide and the Pentasulphide of Boron.*—According to Moissan boron trisulphide may be formed (1) by acting on boron iodide with melted sulphur, (2) by acting on amorphous boron with the vapor of sulphur, (3) by the action of hydrogen sulphide on pure boron at a bright red heat, (4) by the action of pure carbon disulphide vapor on boron at a red heat, and (5) by the action of tin, antimony or arsenic sulphide on amorphous boron at a red heat. When condensed in a large receiver, boron trisulphide forms white slender needles which are very unstable and are decomposed by water with the evolution of hydrogen sulphide and without separation of sulphur. The crystals begin to melt at 310° and pass through a pasty condition. Their density is about 1·55. It is slightly soluble in phosphorus trichloride, from which it crystallizes in slender colorless needles.

Hydrogen does not reduce it at a red heat. It burns with a green flame in chlorine, forming boron and sulphur chlorides. Sodium and potassium decompose it below dull redness with incandescence. Water decomposes it violently, the reaction being $B_2S_3 + (H_2O)_6 = (B(OH_3))_2 + (H_2S)_3$. Ammonia combines with it to form a yellow powder, evolving great heat. Organic compounds react energetically with it.

Boron pentasulphide is a light white crystalline powder, fusing sharply at 390° and having a density of 1·85. It is best made by heating boron iodide with sulphur in a carbon disulphide solution for 24 hours at 60°. The precipitated product is washed with the disulphide to remove the iodine, with which it forms an additive compound. It is hydrolysed by water into boric acid, hydrogen sulphide and sulphur. When heated to its fusing point in a vacuum it dissociates into the trisulphide and sulphur, and is similarly decomposed when heated with mercury or silver. — *C. R.*, cxv, 203, 271 ; *J. Chem. Soc.*, lxii, 1393, Dec. 1892.

G. F. B.

3. *On the Oxidation of Different forms of Carbon.*—WIES-NER has examined different varieties of carbon under the microscope while being subjected to the action of a mixture of sulphuric acid and potassium dichromate. Charcoal obtained by heating soot in chlorine and hydrogen successively is rapidly attacked owing to its finely divided state. Lignite consists of brown transparent particles, becoming colorless by treatment leaving a skeleton of cellulose. Anthracite, bituminous coal, wood charcoal, soot and graphite, contain a small quantity of an easily oxidizable substance which is readily dissolved by the chromic solution, leaving a residue which is only very slowly attacked. The black lung pigment acts like soot and hence must be derived from the outer air.—*Monatsb.* xiii, 371 ; *J. Chem. Soc.*, lxii, 1273, Nov. 1892.

G. F. B.

4. *On the Rise of Salt-solutions in Filter paper.*—It was long ago observed by Schönbein that, when a piece of filter paper is immersed in a saline solution (1) the water rises more rapidly than the dissolved salt and (2) the height to which the latter rises is different for different salts. So that by this means it is possible to recognize the different constituents of a complex solution. E. FISCHER and SCHMIDMER have investigated this phenomenon more closely and have reached the conclusion that the result is due to the differences in the diffusibilities of the dissolved substances, that salt which has the greatest velocity of diffusion rising most rapidly in the paper. Hence diffusion phenomena can be studied in this way quite as well as by the use of membranes; the new method having the advantage that it is applicable to all liquids which moisten filter paper. The authors used in their experiments a glass tube 2 cm. in diameter and 70 cm. long, containing six rolls of filter paper, each about 10 cm. long and weighing about 7 grams. The paper had been purified by washing with hydrochloric and hydrofluoric acids and the rolls

were fitted rather tightly into this tube, so as to make good contact with the walls of the tube and with each other. The tube was then placed upright in the solution to be examined, its lower end being immersed two or three centimeters deep, and it was allowed to remain in this position until the fifth roll of paper was completely moistened by the rising liquid ; requiring from 3 to 4 days. To ascertain the composition of the liquids at the several levels, the tube was cut across opposite the ends of the adjoining rolls, and the rolls separately extracted with water. Using a solution containing 10 grams sodium chloride and 10 grams barium chloride in 100 c. c. water, the authors found the ratio of $BaCl_2$ to NaCl to be in the fifth roll 1: 1·364, in the third 1: 1·230 and in the first 1: 1·022; showing the greater diffusibility of the sodium chloride. With a solution of 10 grams crystallized ammonium-ferrous sulphate in 100 c. c. water, 87 hours were required to reach the sixth roll, and the ratio of the Fe to the NH_3, which in the double salt is 1:1, was found to be in the 4th roll 1: 1·686. When a saturated solution was used, the ratio in the fourth roll, after 96 hours, was only 1: 1·004, and in the fifth 1: 0·993. Potassium-ferrous sulphate and potassium-nickel sulphate gave similar results; a considerable dissociation taking place in dilute solutions, while in saturated solutions it is scarcely appreciable. Further experiments showed that aqueous solutions of the double chlorides of mercury with sodium and with lithium are decomposed by diffusion, while alcoholic solutions are not ; and that the ammonium double chloride is permanent even in aqueous solution. No splitting was observed with the double salts $HNa(NH_4)PO_4(H_2O)_4$, (KCy, AgCy), and $KNaC_4H_4O_6$ $(H_2O)_4$ in aqueous solution; but the compound of sodium chloride with grape sugar $(C_6H_{12}O_6)_2NaCl$ is partially dissociated. No decomposition was observed with naphthalene picrate or methyl-ketol picrate. Making a comparative experiment with Rüdorff's apparatus, the authors found that though the dissociation was more effective in a given time with ammonium-ferrous sulphate and with the sodium chloride compound of grape sugar by the membrane diffusion method, the filter paper method was the better for the sodium mercuric chloride.—*Ann. d. Chem.*, cclxxii, 156, 1892.

G. F. B.

5. *On Chemical Inactivity at low Temperatures.*—Some instructive experiments have been made by RAOUL PICTET confirming his view that all chemical action ceases at very low temperatures. Sulphuric acid solidifying at −56° and containing 89 per cent H_2SO_4 was brought into intimate contact, in the solid condition and at a temperature −125°, with finely powdered sodium hydroxide, at the same temperature. No chemical action took place between them even when strongly compressed. Even when electric sparks were passed through the mass, no effect was produced except in the line of the sparks. On warming to −80° action suddenly began, evolving great heat and fracturing the vessel. With a weaker acid containing 35 per cent H_2SO_4

solidifying at —88°, the results were similar. In like manner potassium hydroxide remains unacted on below —90°. Concentrated ammonia and sulphuric acid do not act at all on each other below – 80°; while above this temperature, a limited action takes place by means of electric sparks, complete reaction suddenly occurring at from —80° to —65°. Sulphuric acid does not react on common salt below —50°; though at about this temperature a limited reaction begins which becomes complete at —25°. No action takes place between sulphuric acid of 35 per cent and sodium or calcium carbonates at —80°. Gas bubbles make their appearance first at —56° with sodium carbonate and at —52° with calcium carbonate; the reaction becoming turbulent at – 15° with the latter and at —30° with the former carbonate. With nitric acids chemical action begins at a slightly lower temperature. Metallic sodium undergoes no change when brought into contact with aqueous alcohol at —78° containing 84 per cent alcohol; the action beginning only at —48° and then being active. Sodium may be mixed with 35 per cent H_2SO_4 at —85° without any action; but at —50° a violent reaction occurs, the hydrogen taking fire. With potassium, the action begins at —68°. At – 85°, sulphuric acid may be mixed with an alcoholic solution of barium chloride without precipitation, the reaction first occurring at – 70° and becoming complete at —40°. An alcohol solution of silver nitrate was mixed at —125° without reaction; precipitation beginning at —90° and being complete at —80°. Potassium hydroxide dissolved in alcohol was mixed with phenol-phthaleim at —135° without action; a faint red tinge appearing at —100° and the color being distinct at – 80°. Litmus in contact with acids remains blue at —120°, a sudden change to red taking place with sulphuric acid at —105° and with hydrochloric acid at —110°. Hence the author concludes that no chemical action whatever takes place at temperatures between —125° and —155°.— *C. R.* cxv, 708, 814; *J. Chem. Soc.*, lxiv, ii, 112, March, 1893. G. F. B.

6. *Berzelius und Liebig, Ihre Briefe von* 1831–1845. 279 pp., 8vo. Munich and Leipsic, 1893. (J. F. LEHMANN).—The correspondence of these illustrious chemists has been well edited by Justus Carrière; it is published under the auspices of the Royal Bavarian Academy of Sciences. The book gives fascinating glimpses of the personality of both these famous men—the fire and enthusiasm of the younger Liebig and the calmer sagacity of the Northern philosopher. The letters contain much that is of historical interest to the student of chemistry, in giving many descriptions of the experiments and discoveries of both these celebrated investigators, many discussions of views and theories, and numerous criticisms of the work of other chemists of the time. The chief charm of the book, however, lies in the fact that the letters are given literally and in full, even where written in excitement and bitter animosity. These letters are supplemented by extracts from others between Liebig and Wöhler, so introduced as to give a most effective form of explanation.   H. L. W.

7. *Carl Wilhelm Scheele—Briefe und Aufzeichnungen heraus-gegeben von* A. E. Nordenskiöld. Roy. 8vo, 491 pp. Stockholm, 1892.—In thus preserving in permanent form and making public the scientific letters and laboratory notes of Scheele, Professor Nordenskiöld has rendered a great and lasting service to the historical literature of science. There seems to be a period of retrospection in chemistry at present and a desire to place its historical foundations on a sure basis, and thus the appearance of this publication is particularly opportune.

Among the crowd of eager and gifted searchers of the last half of the previous century, with whom the modern era of chemical science began, no figure stands out more luminous or conspicuous than that of Scheele. When we consider the particularly unfavorable conditions under which he worked, compared with the magnitude of the results he achieved, by the force of skill, energy and intellect, he must at once take place in the front rank of scientists of all ages. His claim to this position is materially strengthened by this publication of his notes and letters. To him must be ascribed the prior discovery of oxygen, chlorine, manganese, baryta, and many other discoveries which would have entitled a chemist to renown. Of particular importance were his researches in the line of organic chemistry, which are now for the first time fully set forth.

It is certainly true, as Professor Nordenskiöld remarks, that these letters will be read with interest and pleasure by every chemist and thinker, engaged in original research. They are chiefly addressed to Scheele's friends, Retzius, Gahn and Bergmann. Besides the notes and letters which have been carefully turned into modern German and are accompanied by critical notes, there is an able sketch of Scheele's life and facsimiles of his writings. The volume is moreover a beautiful specimen of the typographical art. L. V. P.

8. *Simple apparatus for measuring the Index of refraction of Liquids.*—H. Ruoss immerses a mirror vertically in the liquid, leaving a portion not immersed. The mirror can be turned about a vertical axis. At a suitable distance, about four meters, is placed a scale and telescope. The reflection of the scale in the air and in the liquid are then observed. One can make many observations at different angles of refraction by turning the mirror. The mean error of a single determination of index of refraction of water at 22·9° C. with sodium light was 0·00011 to 0·00005.— *Ann. der Physik und Chemie,* No. 3, 1893, pp. 531–535. J. T.

9. *Electromagnetic Theory of Color dispersion.* — H. von Helmholtz points out that no satisfactory explanation of color dispersion by the electromagnetic theory has been given. He accordingly submits the question to mathematical analysis, combining his own theories of electrically charged molecules with the general equations of Maxwell, and is led to a satisfactory explanation of the subject by means of the electromagnetic theory of light.—*Ann. der Physik und Chemie,* No. 3, 1893, pp. 389–405. J. T.

10. *Penetration of thin metallic screens by Phosphorescent rays.* —LENARD, at a recent meeting of the Berlin Academy, described some experiments upon this subject. Rays from an aluminum cathode disc were projected on a thin aluminum window 0·003^{mm} thick. The cathode rays passed through the window and made the air faintly luminous. There was a strong smell of ozone. Other gases, besides air were tried. Oxygen and carbonic acid were less penetrable than air. "One may say that hydrogen molecules cause less turbidity in the ether than those of oxygen and the latter less than those of carbonic acid."—*Nature*, March 30, 1893. J. T.

11. *Representation of Equipotential lines due to a current flowing through a metallic plate.*—E. LOMMEL, in a preliminary communication, has described a method of showing these equipotential lines. He now publishes photographs of these lines and gives an explanation of Hall's phenomenon by means of these photographs. A current of twenty ampères is passed through a thin copper plate and magnetic filings are distributed on the plate. These filings distribute themselves in the direction of the equipotential lines. If 2ε represents the potential difference between two points on the copper plate, M the strength of the magnetic field perpendicular to the direction of the current in the plate, (Hall's method), we have 2ε =KJM, where K is a species of friction coefficient which depends upon the material of the plate employed. J is the strength of current flowing through the plate. The resistance of the plate K is proportional to its section and also to its thickness δ. Calling K a constant and r the resistance of the galvanometer, we have

$$\varepsilon = \mathrm{K} \cdot \frac{\mathrm{IM}}{r\,\delta}$$

which expresses the law, Lommel believes, of the Hall effect.— *Ann. der Physik und Chemie*, No. 3, 1893, pp. 462–466. J. T.

12. *Alternating Currents: An Analytical and Graphical Treatment for Students and Engineers;* by FREDERICK BEDELL and ALBERT CUSHING CREHORE. 325 pp. 8vo. New York, 1893. (The W. J. Johnston Co.).—The subject of alternating currents is one which has come into great prominence in electrical engineering in the present time, and this fact gives especial value to a work like the one in hand, in which the whole matter is perhaps for the first time presented systematically and fully. The volume is divided into two parts; the first of which gives after some introductory statements, the solution of problems for the various cases supposed. These include circuits with resistance and self-induction, with resistance and capacity, with resistance, self-induction, and capacity; the general solution of this last case is followed by a discussion of the various cases, (1) of discharge, (2) of charge, (3) for harmonic electromotive force, and (4) for any periodic electromotive force. The latter half of the work contains the graphic treatment of a great variety of cases, which the fulness of illustrations makes very clear. The work is a very

important contribution to our knowledge of the subject, and reflects much honor upon its authors. The execution of the mechanical part of the volume by the publishers leaves nothing to be desired.

13. *Die physikalische Behandlung und die Messung hoher Temperaturen*, von CARL BARUS. 92 pp. 8vo. Leipzig, 1892. (John Ambrosius Barth–Arthur Meiner).—Dr. Barus has had rare experience in the measurements of high temperatures, and hence this general discussion of the subject, which is not only historical but also practical as based upon his own extended observations, is of very high value. The method to which he gives the preference in pyrometry is the use of the thermo-element of the platinum metals, the application of which he discusses with admirable fulness.

14. *Hülfsbuch für die Ausführung elektrischer Messungen*, von Dr. AD. HEYDWEILLER. 262 pp. 8vo. Leipzig, 1892. (Johann Ambrosius Barth–Arthur Meiner).—Brief descriptions are given in this volume of the various methods of electrical measurements, particularly those which have been introduced during the last decade or two. They include the measurements of current-strength, of resistance, capacity, and so on. Some of the most important numerical results obtained are given in the series of twenty tables at the end, and these are preceded by an extended index of authors and papers. The book brings together much valuable matter only to be found otherwise scattered through recent periodical literature.

15. *Practical Physics ;* by R. T. GLAZEBROOK and W. N. SHAW. Fourth edition, revised. 633 pp. 12mo. London and New York, 1893. (Longmans, Green & Co.).—The excellent volume on " Practical Physics " by Glazebrook and Shaw is too well known and widely appreciated to need commendation here. It has done valuable service in many physical laboratories for nearly ten years. The fourth edition now issued contains some important additions and changes, called out particularly by the experience of the authors at the Cavendish Laboratory.

16. *Elementary Treatise on Physics, Experimental and Applied*, for the use of Colleges and Schools. Translated and edited from Ganot's Éléments de Physique (with the author's sanction); by E. ATKINSON. Fourteenth edition, revised and enlarged. Illustrated by 9 colored plates and maps and 1028 woodcuts. 1115 pp. New York, 1893. (William Wood & Co.).—Thirty years have passed since the first English translation of Ganot's Physics, and in this time no less than fourteen editions have been given to the public. Perhaps no other general text book has played so important a part in the education of students in this branch of science. While appreciating its many excellent features, it is impossible not to wish that the English editor might attempt an entire re-construction of the work, so as to make it homogeneous throughout, and in accordance with the methods of the Physics of to-day.

II. Geology and Mineralogy.

1. *Additions to the Palæobotany of the Crectaceous Formation on Staten Island;* by Arthur Hollick. Trans. N. Y. Acad. Sci., vol. xii, pp. 1–12, pl. 1–iv.—Dr. Hollick adds seven new species to the flora of the Lower Cretaceous of the United States, and finds on Staten Island several of the unpublished ones of the Amboy clays described by Dr. Newberry. There can be no longer any question as to the parallelism of these two series of beds. The beautiful *Platanus Aquehongensis* here figured (pl. iv) may belong to Vitis or Grewiopsis. It is hardly a Platamus. The name *Myrica grandifolia* which he gives to the fine leaf figured on plate iii (fig. 1), is unfortunately preoccupied. It may be renamed *Myrica Hollicki,* an honor richly deserved by the discoverer.

In his effort to avoid making too many new species on insufficient material, so laudable in itself, Dr. Hollick has clearly gone too far in this paper. *Laurus primigenia* is a wide-spread Tertiary species and has never been found in the Cretaceous, except perhaps in the Laramie group. It is unlike the present figures, which are too fragmentary for safe determination. Almost the same may be said of his *Rhamnus Rossmässleri,* and Dr. Hollick is mistaken in saying that it is described by Heer from the Cretaceous of Greenland. Both these leaves have a Cretaceous aspect and differ essentially from the Tertiary species to which they are referred. Again, his claim to have discovered *Sequoia Couttsiæ* in the Cretaceous is not sustained by his figure (pl. 1, fig. 5). It is a Tertiary species, and the form here figured belongs to the older type *S. Reichenbachi.* L. F. W.

2. *On the Organization of the Fossil Plants of the Coal-Measures,* part xix; by W. C. Williamson. Phil. Trans. Roy. Soc. London, vol. clxxxiv, B, 1893, pp. 1–38, pl. i–ix.—This is one of the most important of this valuable series of memoirs. It deals entirely with *Lepidodendron Harcourtii* of Witham, originally described in 1833, subsequently treated by Lindley and Hutton and by Brongniart, and more recently by Bertrand and Hovelacque. But this is the first time that Prof. Williamson has approached the subject on account of the difficulty in finding the original types and such other material as he deemed necessary to throw any additional light upon it. Harcourt's original specimen was at length discovered in the museum at York, and much new material was supplied by the trusty collectors who have so long assisted Prof. Williamson in his researches. Although unable to prove that this species ever developed a secondary xylem, or exogenous zone, as he has shown so many Lepidodendroid forms to do in their later stages, he was still in condition to add much to what was already known of this historic plant. Perhaps the most important part of this information is that which relates to the Halonial and Ulodendroid attachments of this species. The author had shown ten years earlier from the study of other

species that the forms called Halonia were the terminal divisions of Lepidodendroid branches. This discovery is confirmed in the present case, and proof advanced that not only Halonia, but Ulodendron as well, is a state belonging to branches that either bore fruit or were destined ultimately to do so. He concludes that the Ulodendron scars were produced by the pressure of strobiles which were borne at the ends of lateral branches arrested before fairly issuing from the parent branch, and that the distinction between the Halonial and Ulodendroid condition is chiefly that in the former, owing to the presence of a short peduncle, the strobile produced no pressure disk but only a tubercular scar. All these conditions are thoroughly illustrated in the plates.

<div align="right">L. F. W.</div>

3. *Fossil Plants as Tests of Climate ;* by A. C. Seward. xii + 151 pp., 8°, London, 1892.—This is the Sedgwick prize essay for the year 1892, and the award was undoubtedly a just one. Geologists usually admit the value of plants as tests of climate, whatever they may think of their value in determining age. And yet this work, which probably makes the most of this subject, shows what a difficult one it is and how unsatisfactory most of the evidence really is. We can indeed say with certainty from the existence of vegetable remains in the early Tertiary of the arctic regions, similar in their general character to those now growing in temperate climes, that a great change has taken place there since that time. This is because we are dealing with forms so well known to us that we feel that inferences based on the assumption of their similarity in respect to the effect of temperature are tolerably safe. But when we go back to Carboniferous time the force of such arguments is greatly reduced by our ignorance as to whether similarity of form implies similarity in hardiness at such widely separated periods. There are, nevertheless, many facts that indicate a much warmer climate over the whole globe in Paleozoic time than that which has since prevailed, among the strongest of which is the complete disappearance of the leading types at the close of that period, which is now generally believed to have been marked by a great fall, temporarily at least, in the general temperature. The work is chiefly a compilation of facts bearing on the problem, and the author wisely refrains from sweeping deductions. The historical sketch and discussions of distribution, temperatures, annual rings, etc., are attractive features. The literature covered shows great research.   L. F. W.

4. *Flora Tertiaria Italica*, auctoribus A. Meschinelli and X. Squinabol. 1 vol., 8°, pp. lxii + 578. Patavii, 1893.—This exhaustive and scholarly work has been announced some time and is highly welcome. It enumerates 1759 fossil plants, or all that are known to the authors to have been reported from any of the Tertiary deposits of Italy, and it aims to give all the information that exists relative to every such plant. That is to say, the names are followed by full bibliographical references, synonymy and brief descriptions, as well as a statement of the exact locality and

geological horizon. They are arranged in systematic order, beginning with the lowest in organization. The classification is in line with modern discovery, the Gymnosperms standing at the base of the phanerogamous series, the Monocotyledons being classed as Angiosperms coördinate with the Dicotyledons, and these latter being divided into Archichlamydæ (equal to the Apetalæ and Polypetalæ of most authors) and Sympetalæ (=Gamopetalæ), culminating in the Compositæ. In short it is substantially the classification of Engler and Prantl. The genera are also described and the species numbered for each genus. In addition to this there is a running number to all the species irrespective of genera. The systematic part is preceded by a historical sketch occupying thirty pages and giving an able review of the progress of paleophytology in Italy from the earliest times, and a complete bibliography covering 425 titles. These and other features will make this work a constant handbook for all who are engaged in the study of fossil plants. It is written wholly in Latin and is without illustrations, but the typography and general appearance are in all respects praiseworthy.   L. F. W.

5. *The Correlation of Early Cretaceous Floras in Canada and the United States ;* by Sir J. W. Dawson. Trans. Roy. Soc. Canada, vol. x, Section iv, pp. 79–93.—The history of our knowledge of the lower Cretaceous deposits in western North America since they were first made known by Richardson in 1872, is succinctly given in this paper as introductory to the description of certain plant remains collected by Mr. H. M. Ami and by Dr. Hayden in Canmore, Alberta, in the Kootanie district. The material was very fragmentary and the determinations are for the most part doubtful, much more so than those treated in 1885, but taken in connection with these and with the forms now known from the Great Falls of the Missouri, in Montana, referred by Newberry to the Kootanie, they help to indicate the probable nature of the vegetation of that epoch. Twenty-one distinct forms are recognized, thirteen of which are given specific names, and of these seven are referred to species occurring in the Potomac formation of Virginia. A summary of the plants of the Kootanie group is given at the end indicating those found elsewhere. The absence of Dicotyledons (" Angiosperms ") thus far is taken as negative evidence that the Kootanie may be older than the Potomac, and the conclusion from the plant remains is expressed that there can " be scarcely any doubt as to their general reference to the Neocomian Group of the Lower Cretaceous, and to the lower part of the earlier or Lower Cretaceous as held by the Canadian Geological Survey." The figures in the text are very poor, and the proof reading was carelessly done, e. g. "Pagophyllum" for Pagiophyllum.   L. F. W.

6. *A New Tæniopterid Fern and its Allies ;* by David White. Bulletin Geol. Soc. of America, vol. iv, pp. 119–132, pl. i.—The discovery of a new species of Carboniferous fern is not usually a very important event, but in this case its relationships, as shown

by Mr. White, give the *Tæniopteris missouriensis* an especial interest from the point of view of phylogeny. It supplies a sort of " missing link " in a chain of development already pretty clearly marked out leading from the ancient Devonian Megalopteris stock through the Alethopterids and the pinnate Tæniopterids, culminating in the Jurassic Danæites and living Danæa. The present form seems to be in the direct line of descent, but there was a lateral branch of the Megalopteris stock which led through Lesquereux's American genus Lesleya and the simple forms of Tæniopteris to Fontaine's Macrotæniopteris, the most characteristic plant of the Richmond and North Carolina coal fields and Connecticut valley Trias, or Newark system. It is with this branch that the Glossopteris flora seems to have its nearest affinities in the northern hemisphere. Should these relationships ever be successfully worked out a great light will be thrown upon the geological history of plants and the early climatic conditions of the earth. The new plant was collected near Clinton, Henry county, Missouri, in the Lower Coal Measures, and if it is a Tæniopteris it is the most ancient species of that genus. The copious references given to the literature show that the author is complete master of his subject, which takes this paper entirely out of the class of mere speculations.   L. F. W.

7. *The Bryozoa of the Lower Silurian in Minnesota ;* by E. O. ULRICH. 4to, 332 pp., 23 plates, 1893. From vol. iii, of final Report of the Minnesota Geological Survey.—This report of the Minnesota Geological Survey by Mr. Ulrich is one of the most valuable contributions to the subject that has thus far been made. The illustrations are unsurpassed in any of the Paleontological publications of the country. The Bryozoan corals have great importance in the geology, as stated in the following paragraph from the introduction.

" The Bryozoa must be accorded the first rank among the various classes of fossils that are represented in the Lower Silurian rocks of Minnesota. They are entitled to this distinction, first, because of the great variety of form and structure among them; and, secondly, because of their exceeding abundance in the way of individuals. In both of these respects their representation exceeds that of the Brachiopoda, which doubtless held the second rank, in the approximate ratio of two to one. So plentiful are their remains in some of the beds, particularly in the shaly members, that they may be said to constitute no inconsiderable part of the strata. In the Trenton shales, the intercalated plates of limestone are literally covered with them, and they are not rare even in the massive limestones above and beneath the shales, which were deposited under conditions much less favorable to their development. In short, of every impartial collection of the Lower Silurian fossils of Minnesota, the Bryozoa necessarily constitute a large portion, not only of the number of species and specimens, but of its bulk as well.

The importance of the Bryozoa from the view of the stratigraphical geologist, is again second to no other class of fossil remains. Many of them have a wide geographical distribution, and as they usually occur in greater or less abundance, and are very persistent in their characters, their value as data upon which to base correlations of strata of widely separated localities cannot be overestimated. Many of them, especially of the suborder *Trepostomata*, are serviceable even where other fossils are too imperfect, since with the aid of thin sections, mere fractions can often be identified with certainty."

8. *The Tertiary Mollusks of Florida.*—The second part of Mr. W. H. DALL's "Contributions to the Tertiary Fauna of Florida, with especial reference to the Miocene silex-beds of Tampa and the Pliocene beds of the Caloosahatchie river," has appeared in the transactions of the Wagner Free Institute of Science. (Vol. 3, Part II, December, 1892, pp. 201–473, with Plates 13–22).*—This part discusses the streptodont and other Gastropods. One hundred and eighteen new species are described belonging to fifty-one distinct genera. In addition to the purely descriptive portions of the work, in several cases the author has given a comprehensive review of all the species of the generic group discussed, and has commented upon the relations of the species to each other and their natural associations into subgeneric and generic groups. H. S. W.

9. *Petrographische Untersuchungen an argentinischen Graniten.* J. ROMBERG, Berlin. (N. J. M. B. B. VIII).—The material upon which this investigation has been carried out was collected by Prof. Brackebusch during his geological explorations in Argentina. Besides the descriptions of rocks the work contains a full discussion of many points of petrographical interest relating to dynamic processes. The rocks are grouped and the components treated separately with regard to special details. A description of a new mineral with an analysis on rather impure material by Jannasch is given. It seems to be between andalusite and dumortierite and is marked by a blood-red pleochroism. No name is proposed. L. V. P.

10. *Phonolite in Great Britain.*—In a brief description of some lower Carboniferous volcanic rocks of East Lowthian DR. HATCH mentions a new occurrence of phonolite, the second recorded for the British Isles, composing a hill called Traprain Law. There are also some basalts and trachytes described and a limburgite which would seem to be rather a nephelite-basalt.— *Trans. Roy. Soc. Edin.*, vol. xxxvii, pt. I, No. 8. L. V. P.

11. *Catalogue of American Localities of Minerals;* by EDWARD S. DANA. 51 pp. large 8vo. New York, 1893 (John Wiley & Sons).—Pages 1053 to 1104 of Dana's System of Mineralogy have been reprinted and issued separately for the convenience of those desiring the Catalogue of Mineral Localities in a small volume by itself.

* See this Journal, p. 351, April, 1893.

12. *Repertorium der Mineralogischen und Krystallographischen Literatur vom Anfang d. J.* 1885 *bis Anfang d. J.* 1891, *und Generalregister der Zeitschrift für Krystallographie und Mineralogie.* Band xi–xx. Herausgegeben und Bearbeitet von P. Groth und F. Grünling. I. Theil (Repertorium von P. Groth). 206 pp. 8vo. Leipzig, 1893. (Wilhelm Engelmann). —This is a very complete literature of all the mineralogical and crystallographic publications issued between 1885 and 1891. It has been prepared by Professor Groth, to whose rare industry and ability as editor we owe the twenty volumes of his " Zeitschrift," of which this marks the completion. The second part, the index of vols. xi to xx, by Dr. Grünling, is nearly ready.

III. Miscellaneous Scientific Intelligence.

1. *Hodgkins Fund Prizes.*—The Smithsonian Institution announces the establishment of a series of prizes to be given from the income of a fund established in October, 1891, by Thomas George Hodgkins of Setauket, N. Y., " for the increase and diffusion of more exact knowledge in regard to the nature and properties of atmospheric air in connection with the welfare of man." The prizes include one of \$10,000, another of \$2,000, and a third of \$1,000. A medal is also to be established under the name of the Hodgkins Medal of the Smithsonian Institution, in connection with the same subject. Full information in regard to the subjects for which these prizes are to be given, special conditions, etc., may be obtained from the Secretary, Professor S. P. Langley, at Washington.

2. *The Mechanics of the Earth's Atmosphere.*—A collection of translations by Cleveland Abbe. 324 pp. 8vo. Washington. Smithsonian Miscellaneous Collections, 843.—Professor Abbe has done a great service to meterologists, and to all interested in the physics of the atmosphere, in thus preparing and editing this valuable collection of papers. They are twenty in number, and the authors are as follows: Hagen, Helmholtz, Kirchhoff, Oberbeck, Heitz, Bezold, Rayleigh, Margules, and Ferrel.

3. *Manual of Irrigation Engineering*, by Herbert M. Wilson. 351 pp. 8vo. New York, 1893. (John Wiley & Sons).—The subject of irrigation is one in which a large part of our country has a vital interest, and this method promises to do a great work in reclaiming land long considered of no value. This volume is a timely and comprehensive treatise on the subject, discussing the subject of precipitation and evaporation, and also very fully, the construction of dams at many points in the West. A large number of illustrations adds to its value.

4. *Jean-Servais Stas.*—Subscriptions are solicited for a fund to be used for the publication of the works of, and the erection of a monument to, the great Belgian chemist, J. S. Stas. They will be received by M. L. Errera, 1 Place Stéphanie, Brussels.

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MINERALS BOLEITE.

Mr. Cumenge has just returned from a visit of several months to his mines in
Southern California. I have purchased the specimens collected by him during
this time and saved during several previous months. They were almost entirely
obtained by working over the old dumps and he is very confident no more will be
found. While no very large crystals were obtained this time, there were quite a
number of small ones, so that I can offer crystals from 10c. upward.

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ART. LII.—*Electro-Chemical Effects due to Magnetization;*
by GEORGE OWEN SQUIER, Ph.D., Lieut. U. S. Army.

Introduction.

THE influence of magnetism on chemical action was the
subject of experiment by numerous investigators during the
first half of the present century.* Up to 1847, we find, by
no means, a uniformity of statement in regard to this subject,
and secondary effects were often interpreted as a true chemical
influence. Among the earlier writers who maintained that
such an influence exists, may be mentioned Ritter, Schweigger,
Döbreiner, Fresnel, and Ampère, while those of opposite view
were Wartmann, Otto-Linné Erdmann, Berzelius, Robert Hunt
and the Chevalier Nobili.

Professor Remsen's discovery in 1881, of the remarkable
influence of magnetism on the deposition of copper from one
of its solutions on an iron plate, again attracted attention to
the subject, and since then considerable work has been done
directly or indirectly bearing on the question.

Among other experiments by Professor Remsen† were the
action in the magnetic field of copper on zinc, silver on zinc,
copper on tin, and silver on iron, in all of which cases the
magnet evidently exerted some influence. With copper sul-
phate on an iron plate the effects were best exhibited, the
copper being deposited in lines approximating to the equipo-
tential lines of the magnet, and the outlines of the pole being
distinctly marked by the absence of deposit.

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* Wartmann, Philosophical Magazine, III, xxx, p. 264, 1847.
† American Chem. Jour., vol. iii, 157, vol. vi, 430. Science, vol. i, No. 2, 1883.

Messrs. Nichols and Franklin* were the next to conduct experiments bearing on this subject. They found that finely divided iron, which has become " passive " through the action of strong nitric acid, suddenly regains its activity when introduced in a magnetic field, and also that when one of the two electrodes immersed in any liquid capable of chemically acting upon them, is placed in a magnetic field, a new difference of potential is developed between them due to this magnetization. They ascribe these effects to electric currents in the liquid produced indirectly by the magnet, which currents go in the liquid from the magnetized to the neutral electrode.

Professor Rowland and Dr. Louis Bell† were the first to note the " protective action " of points and ends of magnetic electrodes, and to give the exact mathematical theory of this action. Their results were *directly opposite* to those of Messrs. Nichols and Franklin, who found, as stated above, that points and ends of bars in a magnetic field acted like zincs to the other portions, or were more easily dissolved by the liquid.

The method of experiment adopted by Professor Rowland was to expose portions of bars of the magnetic metals placed in a magnetic field to reagents which would act upon them chemically, and study the changes in the electro-chemical nature of the exposed parts by fluctuations in a delicate galvanometer connected with the two bars. Iron, nickel, and cobalt were experimented upon and nearly thirty reagents were examined in this manner. The results are summed up in the following statement: " When the magnetic metals are exposed to chemical action in a magnetic field, such action is decreased or arrested at any points where the rate of variation of the square of the magnetic force tends towards a maximum."

Other investigations in this field are those of Andrews,‡ who employed iron and steel bars from eight to ten inches long with their ends immersed in various solutions, and one bar magnetized by means of a solenoid. The protective action was not noted, but, on the contrary, the magnetized bars acted as zincs to the neutral bars, thus indicating that they were more easily attacked.

Practically the same results were obtained by Dr. Theodor Gross;§ soft iron wires 8^{cm} long, and 3^{cm} in diameter coated with sealing wax, except at the ends, were exposed to various

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* This Journal, xxxi, 272, xxxiv, 419, xxxv, 290.

† Philosophical Magazine, xxvi, 105.

‡ Proceedings of the Royal Society, No. 44, pp. 152–168, and No. 46, pp. 176–193.

§ Ueber eine neue Entstehungsweise galvanischer Ströme durch Magnetismus. —Sitzungsberichte der Wiener Akademie, 1885, vol. xcii, '85, p. 1373.

liquids. When one electrode was magnetized a current was obtained going in the liquid from the magnetized electrode to the non-magnetized electrode.

It thus appears that there is at least an apparent inconsistency between the protective results of Professor Rowland and Professor Remsen, and those of Nichols, Andrews, Gross and others, who find the more strongly magnetized parts of iron electrodes more easily attacked than the neutral parts, and it was with the object of endeavoring to reconcile these results, and of studying the *exact nature* of the influence exerted by the magnet, that the experiments recorded in this paper were undertaken.

Apparatus and Method of Investigation.

The method of investigation was that adopted by Professor Rowland in his previous work on the subject, since its facility and delicacy permitted the effects of the magnet to be observed whenever there was the slightest action on the electrodes by the solution examined, and the investigation could thus be carried over a wide range of material.

A large electromagnet was employed to furnish the magnetic field, and, at a distance sufficient to prevent any direct influence due to the magnet, a delicate galvanometer of the Rowland type was set up. Small cells were made of iron electrodes of special forms, coated with sealing wax, except at certain parts, and immersed in a liquid capable of acting chemically on iron. The whole was contained in a 50^{cc} glass beaker, and when joined to the connecting wires of the distant galvanometer was firmly clamped between the poles of the electromagnet.

In the course of the examination of a number of substances it was found necessary to use two galvanometers, one specially made by the University instrument maker and very sensitive, which was employed with acids which evolve hydrogen, the other much less sensitive was best suited to the violent "throws" with nitric acid and iron. The samples of iron used throughout the experiments were obtained from Carnegie, Phipps & Co. of Pittsburg, and were practically pure.

In order to insure a uniform density of surface, the electrodes were turned from the same piece and polished equally with fine emery cloth. The magnet could be made or reversed at the galvanometer, and its strength varied at will by a noninductive resistance. The electro-chemical effects due to the magnetic field could thus be studied with facility by the fluctuations of the galvanometer needle. The original difference of potential which always existed between the electrodes was compensated by a fraction of a Daniell cell, so the

effects of a variation of the magnetic field could be observed when no original current was passing between the electrodes.

The standard cells were made with care, and under uniform treatment possessed at 20° C. an electromotive force of 1·105 volts. The connections with the compensating circuit, which contained a finely divided bridge, were so arranged that from its readings the difference of potential between the distant electrodes became known at once without involving the resistance of the cell or of the galvanometer.

Since quantitative measurements of the effects observed were desired, a preliminary step was to calibrate the electromagnet for a given distance apart of the pole-pieces. The method employed was the well-known one of comparing the galvanometer deflections produced by a test-coil in the field with those of an Earth Inductor in series in the circuit. Since the effect of the sudden addition of a certain strength of field was wanted instead of its absolute value, the deflections with the test-coil were taken for simple " make " or " break " and not for reversed field, thus eliminating the residual magnetism of the pole-pieces.

In the formula applicable, viz : $\dfrac{H}{H'}\dfrac{\pi na^2}{\pi n'a'^2}=\dfrac{d}{d'}$ nearly, in which d and d' represent the deflections due to the Inductor and test-coil respectively; H and H' the earth's field and the field to be measured; n and n' the number of turns and a and a' the radii of the coils, the particular values were

$$\pi na^2 = 20716^{\text{sq cm}}$$
$$\pi n'a'^2 = 6\cdot788^{\text{sq cm}}$$
$$d = 4\cdot697$$

Distance between pole-pieces $3\cdot5^{\text{cm}}$.

$H' = 1299\cdot48\ d'H$, and as d' varied from $\frac{1}{20}$ to 16, the range of field employed was from 65 to 20,800 H.

A curve was constructed so that from accurate ammeter readings in the field circuit, the strength in absolute measure could be read off at once.

Experimental Results.

Preliminary.—The first experiments were made with very dilute nitric acid and iron electrodes, one a circular disc of 5^{mm} radius, and the other a small wire 1^{cm} long and 1^{mm} in diameter turned to a sharp point at one end. The point was placed opposite the center of the disc, at a distance of 1^{cm} from it, and the whole placed so that the cylindrical electrode coincided with the direction of the lines of force. When the minute point and the center of the disc were exposed to the

liquid, and the magnet excited, a momentary "throw" of the galvanometer was observed in the direction indicating the point as being protected or acting as the copper of the cell.

When the pointed pole was slightly flattened at the end, and the insulation so cut away that the surfaces of exposure on the two electrodes were exactly the same, the throw of the galvanometer on making the field was very much diminished, although still perceptible, since the disposition of lines of force would still be very different over the two plane surfaces of exposure.

With ball and point electrodes precisely similar phenomena were observed as with a disc and point, except to a less degree.

The gradual reversal of the current shortly after exciting the field; the independence of the throw of the direction of the current through the magnet; the disappearance of the throw when the nature of the magnetic field at the exposed parts became the same; and the effects of artificially stirring the liquid were observed exactly as described by Messrs. Rowland and Bell.

In the course of a large number of preliminary experiments with nitric acid, it was soon observed that under certain conditions the effect of suddenly putting on the magnetic field, was to produce a less rapid deflection of the galvanometer in the *opposite* direction, or indicating the point as acting as a zinc. Plainly this irregular behavior, due to the magnet, required a more systematic study than it had yet received. It had been found that the reversal of the current which regularly followed the "protective throw" was decreased or destroyed by anything which prevented free circulation in the liquid, and that an acidulated gelatine, which was allowed to harden around the poles, was best suited for this purpose. The great irregularity observed in any one experiment made it necessary to eliminate everything possible which might mask the true phenomenon, if any accurate comparisons were to be drawn between the effects observed in the different cases, accordingly a standard form of experiment was adopted which was carefully repeated many times. The cell found best suited for this purpose was composed as follows :

Disc electrode, diameter _____	$14 \cdot 4^{mm}$
thickness _____	$2 \cdot 6^{mm}$
Point electrode, total length _____	$15 \cdot 2^{mm}$
. diameter _____	$4 \cdot 4^{mm}$
length of point _____	$5 \cdot 2^{mm}$
Distance of point from center of disc _____	$10 \cdot$ ^{mm}

The same electrodes were used throughout any set of experiments, being carefully cleaned and polished each time.

With nitric acid the liquid was finally made up, as follows :

> Distilled water _____ 10 grams
> Hard gelatine ____ _____ 1 gram
> C. P. nitric acid (sp. gravity, 1·415), 0·533 grams

The gelatine and water were allowed to stand until the former had dissolved without the application of heat, when the acid was added, and the whole thoroughly mixed. Too strongly acidulated gelatine would not harden at all.

In some cases, in order to protect the point from the *beginning*, the electrodes, secured as usual at the ends of two small glass tubes containing the connecting wires, were firmly clamped in the proper position between the poles of the magnet, and the magnetic field put on before the cell was completed by pushing the beaker containing the solution up in position around the electrodes.

With this cell a series of parallel experiments were conducted to obtain the variation of the effects with time, or the amount of iron salts present ; the fluidity of the solution, and with constant and variable magnetic fields.

A. *Behavior of the cell with time, in the Earth's field.*

The cell was placed entirely outside the magnetic field, and galvanometer readings taken at intervals of one minute for three hours. The curve fig. 1 (I) shows these results. Positive ordinates indicate a current from the point to the disc, and negative ordinates the reverse current. Other experiments with fresh solutions, same electrodes, same exposed area, and every condition as nearly as possible the same, gave curves of practically the same character, and the one given is selected to illustrate.

The curve indicates that the original current was to the point electrode, this gradually decreased due to polarization until after an hour and five minutes it reversed slightly, but again reversed thirty-five minutes later, and after a little more than two hours the deflection became perfectly constant, remaining so indefinitely.

The iron salts formed could not move with facility from the exposed surfaces through the hardened gelatine, and were easily outlined from their brown color, as the whole apparatus was placed in a strong light.

B. *In a uniform magnetic field.*

The cell was next placed in the magnetic field which was kept practically uniform (about 15,650 H) for three hours, and galvanometer readings taken as before.

The electrodes were magnetized before being introduced into the solution, so as to protect the point from the beginning. In order to prevent the influence of the rise of temperature due to the heating of the field coils of the electromagnet, the whole cell was packed with cotton wool between the poles. As Gross and Andrews observed the temperature effect was small, the solution rising but 0·7° C. in half an hour.

Fig. I.

Fig. 2.

Fig. 3.
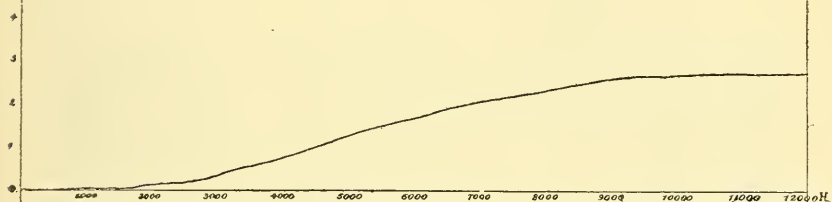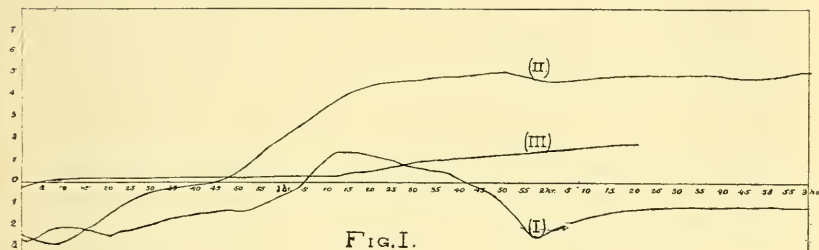
The curve fig. 1 (II) shows the result of these observations. It is seen that the original current was as before to the point electrode, and about the same in value. This reversed after forty-five minutes, and rapidly increased to approximately twice its original value at the end of one hour and twenty

minutes, and instead of again reversing, remained indefinitely with the point electrode as a zinc. The distribution of the iron salts in this case was quite unlike the former. Notwithstanding the gelatine, the powerful magnetization of the exposed point gradually drew the iron salts from the disc as fast as they were formed, and concentrated them symmetrically about the point, giving the solution in this region an almost black appearance.

After waiting a sufficient time to be assured that further presence of iron salts would not effect the permanency of the existing electromotive force, the magnetic field was gradually decreased *without ever breaking circuit*, by increasing the liquid resistance in the field current. This change of resistance was necessarily made more or less suddenly, and the deflection experienced at each increase of resistance, a not very sudden throw toward reversal, in every respect the same as had been repeatedly observed in the preliminary experiments, and very different from the characteristic "protective throw" which is always sudden and in one direction.

By simply varying the field current with care, as explained above, the deflection could be reversed again and again at will, and could also be held at the zero of the scale indicating no current at all, as long as desired. When once the field was entirely broken the iron salts were released from the control of the exposed pole, seriously disturbed by gravity, and putting on the field again failed to reproduce the results noted above.

The only elements of difference in the two cases are, (*a*) the magnetized condition of the metal, (*b*) the distribution of the iron salts formed by the reaction.

Although, as the curves indicate, the average electromotive force with the magnetic field was much greater than in the former case, yet this electromotive force is due to the difference of action at the two exposed surfaces, and, as will be pointed out later, the total amount of iron dissolved and passing into solution in the two cases is probably not very different.* Quantitative experiments are wanting on this point.

The influence of the magnetized condition of the metal and its magnitude is exhibited in the phenomenon of the "protective throw" which is always observed with apparatus sufficiently delicate and unless it is masked by other secondary phenomena.

Since the electrodes were embedded in hardened gelatine, there could be no convection currents in the liquid and this can be eliminated. Evidently the great difference in the

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* Fossati, Bolletino dell' Elettricista, 1890.

behavior of the cell in the two experiments described is principally due, either directly or indirectly, to the distribution of the iron salts formed by the reaction in the two cases.

The principal *time* effects of the magnet were:

(*a*) To produce a higher potential at the point of greater magnetization.

(*b*) To increase the rate of change of the potential between the electrodes and the absolute value of this potential difference.

(*c*) It also appears from both curves that after a certain distribution of iron salts is reached, further presence of the same does not effect the permanency of the current established.

Since the time effects of the magnet were so marked, it was thought possible that a " cumulative " effect, due to the Earth's field alone might be detected after a sufficient time had elapsed. The apparatus was made as delicate as possible, and parallel experiments conducted, the electrodes first being placed in the magnetic meridian, and afterwards perpendicular thereto. No positive difference could be detected.

C. Convection currents in the liquid.

As has already been stated, the reversal of the current which regularly followed the " protective throw " was found by Messrs. Rowland and Bell to wholly disappear when hardened acidulated gelatine was substituted for the dilute acid solution, so that when the magnet was put on, a permanent deflection of much less magnitude was obtained instead of a transitory throw. This indicated that currents in the liquid cannot be neglected, and their study was next undertaken. Since hardened gelatine completely prevented the reversal of the current, and with no gelatine it regularly appeared after a short time, a large number of experiments were made, in which the amount of gelatine was varied continuously between these limits. As expected the effects also varied, the greater the fluidity of the solution, the more quickly the reversal occurred.

In the light of what was already known concerning the presence of iron salts, some of the experiments were continued over a considerable time, and in others iron salts were introduced artificially, to increase the effects. It was soon found that by starting with a fresh hardened gelatine, with which the " protective throw " was the only feature, and gradually increasing the fluidity of the solution and the amount of iron salts present, both effects were exhibited at the making of the field, first, the sudden throw of the needle always in the direction to protect the point, and immediately thereafter the comparatively slow " concentration throw " in the opposite direc-

tion. By making the conditions still more unfavorable for the
"protective throw," it gradually diminished until entirely
masked by the second effect, so that making the field produced
a deflection in the direction indicating a current from the
point.

With the proper conditions both of these effects could be
studied with the greatest ease: first, one made prominent, then
both equal, then the other made prominent at will.   The "pro-
tective throw" could be traced until it became a mere sta-
tionary tremor of the needle at the instant of its starting on
the "concentration throw."   This latter, though called a
"throw," can be made to vary from an extremely slow continu-
ous movement of the galvanometer deflection, as in experiment
B, already described, to a comparatively rapid deflection at the
instant of making the magnet.

By using simply a dilute nitric acid solution with no gelatine,
and inserting a thick piece of glass between the electrodes, the
concentration effect was delayed enough to allow the "protec-
tive throw" to first appear, with considerable iron salts in the
solution, and on making the field both effects were observed
as described above.

It now appears that the reversal of the current uniformly
observed in the experiments of Messrs. Rowland and Bell was
but a form of the "concentration throw" mentioned above,
and that we can regard the substitution of the hardened acidu-
lated gelatine for the dilute acid, as merely separating these
effects, so that the former can be studied by itself; in other
words, the reversal of the current would have occurred just
the same after a sufficient time had elapsed.

Turning to the experiments of Drs. Gross and Andrews,
they employed but one magnetized electrode which was not
pointed. In this case the nature of the magnetic field at the
two exposed surfaces would be very much more nearly the
same than when a pointed electrode is employed. This arrange-
ment is not therefore suited to bring out the delicate "protec-
tive throw," and it is not surprising that the concentration
effect was the prominent feature observed.

We have now a complete reconciliation of the *directly op-
posite results* referred to in the introduction. The "protec-
tive throw" is due to the actual attraction of the magnet for
the iron, and is always in the direction to protect the more
strongly magnetized parts, while the "concentration throw"
is always in the opposite direction, and depends upon the dis-
tribution of the iron salts present in the solution, and the con-
vection currents in the liquid. The concentration of the
products of the reaction about the point, would tend to pro-
duce a ferrous reaction instead of a ferric reaction, and experi-

ment shows that a higher electromotive force is obtained with cells in which a ferrous reaction takes place than with those in which a ferric reaction occurs, and this change in the *character of the reaction* produced by the concentration probably accounts, at least in part, for the increased electromotive force at the point.

D. *The iron salts about the point electrode.*

The effect of artificially stirring the liquid, and the direct influence of the fluid condition of the solution on the deflections observed, at once suggested movements of the liquid, produced indirectly by the magnet. In order to locate these currents, and determine their potence, a small cell was made of two rectangular pieces of glass held by stout rubber bands to thick rubber sides. Perforations in the sides admitted the electrodes which were point and disc as before. The cell, between the poles of the electromagnet, was in a strong light, and the movements in the liquid were easily perceptible from the displacements of suspended particles introduced for the purpose. When very dilute nitric acid was placed in the cell, and the magnet excited, some interesting phenomena were observed.

The liquid, at first colorless, almost immediately assumed a pale brown color about the point, but nothing appeared at the disc electrode. The iron salts were drawn as soon as formed towards the point electrode, since here the rate of variation of the square of the magnetic force is a maximum.

As more iron was dissolved, a surface approximating to an equipotential surface of the pointed pole, and enveloping the colored iron salts, was observed enclosing the point, and at some distance from it. The outline of the surface became darker in a short time, and finally two or more dark contours, separated by lighter portions and symmetrical with the outer one, appeared between it and the point, indicating maxima and minima of density. When the magnetic field was gradually increased, this surface usually enlarged without breaking up and holding the iron salts within it. On further strengthening the magnetic field to about 16,000 H the ridges merged into one thick black envelope around the point.

This phenomenon is best studied with but little iron salts present, and by watching the point electrode with a microscope while the strength of the magnetic field is increased and decreased continuously. The sections, fig. 3 (p. 449), show the general form of these contours with different strengths of field.

Upon breaking the field, everything dropped from the point suddenly to the bottom of the cell, and on making the field again, it required a few seconds for the salts to reappear at the

point. This, at least partially, accounted for the sudden effects often noticed at breaking the field circuit, and the comparatively small ones at "make" especially with certain salt solutions, such as copper sulphate.

The outer envelope which held the iron salts together, and limited the immediate influence of the magnetized point, was distinctly defined within the liquid, and easily observed by the reflection of the light from its convex surface.

The persistency with which the iron salts were held about the point was shown by moving the cell with respect to the electrodes, when the contour remained approximately intact, passing bodily through the liquid without being broken up.

E. Electromagnetic rotations.

The small dust particles present in the liquid were drawn radially toward the point until they reached the surface described, when they pierced it and began to revolve rapidly about the point inside this surface, in the opposite direction to the currents of Ampère. Reversing the poles of the magnet, produced surfaces of the same appearance, but opposite rotations.

When the current from a Daniell cell was sent through, it seemed to have very little effect upon the rotations, showing them to be controlled by the powerfully magnetized point.

The electromagnet was arranged with its field vertical, and the point electrode along the lines of force as before. This arrangement gave better control of the surfaces formed, since gravity now acted symmetrically about the point.

When a single iron rod about 3^{mm} in diameter, and placed vertically in the cell, was substituted for the two electrodes, two rotations were observed, which were uniformly dextro about the north-seeking pole of the rod, and lævo about the south-seeking pole. About the central neutral portion no rotations were observed. When the rod was covered with a thin coating of vaseline, the rotations entirely disappeared as expected. Wartmann[*] observed similar rotations about soft iron cylinders adhered to the poles of a magnet, and he ascribed them to electric currents in the liquid which proceed from the periphery of the cell radially to the surface of the rod.

The explanation of these rotations follows at once from what we know of the time effects produced by the magnet. A higher potential is always produced at points of greater magnetization, causing electric currents in the liquid from the more strongly magnetized to the weaker parts of the iron.

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[*] Philosophical Magazine, xxx, 1847, p. 268.

Applying this fact to the exposed conical point electrode, we see that local electric currents exist from its vertex to the other parts of the surface, returning by way of the metal. In the case of the vertical rod, these currents pass from the poles at its ends, through the liquid, to the neutral portions, returning as before.

These currents* under the influence of the poles themselves, would cause electromagnetic rotations of the liquid, as we find them. The mere mechanical influence of these rotations, as in the case when the liquid is artificially stirred, is to increase the chemical action upon the point, causing it to tend to act more like a zinc.

F. Acids which attack iron with the evolution of Hydrogen.

Professor Rowland had observed the "protective throw" with such acids to be extremely small and difficult to detect, except by very sensitive apparatus. The sensitive galvanometer was set up, and every precaution taken against inductive effects. A telescope and scale were used in this part of the work.

Several substances were first examined, among them being hydrochloric acid, acetic acid, perchloric acid, chlorine water, copper sulphate, ferric chloride, sulphuric acid, etc., but as these observations added nothing to the results already obtained, they are not given here.

After several trials a standard sulphuric acid solution was made up as follows:

$$
\begin{array}{ll}
\text{Distilled water} & \text{10 grams} \\
\text{Gelatine} & \text{1 gram} \\
\text{C. P. Sulph. acid (sp. gravity 1·826)} & \text{1·062 grams}
\end{array}
$$

More strongly acidulated gelatine would not harden, and weaker solutions gave too small effects.

The "protective throw" was detected, but the point very soon became completely covered with minute bubbles of hydrogen, so that the electrodes had to be cleaned constantly.

The effect of adding hydrogen dioxide to the solution was next tried, since this would facilitate the removal of the hydrogen as soon as formed,† which was thought to act merely mechanically.

When about 1^{cc} of H_2O_2 was added to the solution, the "protective throw" became much more prominent, and the

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* The rotations produced in liquids by axial currents, e. g. currents coinciding with the direction of the magnetic lines of force as distinct from radial currents, have been studied by Dr. Gore, Proceedings of the Royal Society, xxxii, p. 151.

† J. M. Weeren, Berichte der Deutschen Chemischen Gesellschaft, No. 11, 1891.

gas bubbles only appeared in small quantities after a considerable time, further addition of small quantities of the dioxide showed the " protective throw" to be very decided with sulphuric acid when the hydrogen is removed from the surface of the electrodes in this manner.

G. The electromotive force.

Several attempts were made to obtain the relation between the strength of field and the electromotive force developed in the " protective throw," but it was difficult to obtain consistent readings owing to the trouble of balancing the original deflection, and the small absolute values of this electromotive force when hardened gelatine was employed.

A curve was constructed, however, showing the variation of the galvanometer deflection with the strength of field, using nitric acid solution without gelatine.   This is shown in fig. 2, p. 449.

The readings were taken one after another, as rapidly as possible, to eliminate the damping effects of the iron salts formed.

The curve exhibits the general character of the variation. In the region from about 3,500 H to 8,000 H the greatest rate of change occurred, and beyond 10,000 H the curve became nearly horizontal for the particular electrodes used.   Curves were also constructed for the " concentration throw " on making the field under different conditions, and they were approximately right lines more or less inclined, according to the amount of iron salts present.

With the sulphuric acid solution already given, the electromotive force varied from 0·0033 to 0·0078 of a volt, while with the nitric acid solution it became as great as 0·036 of a volt. In making all the solutions used with the different substances, amounts were taken proportional to their particular molecular weights, and then halved or doubled until of a suitable strength to give results with the galvanometer.   It was thought possible at the beginning, that this might lead to some relations between the protective results and the strengths of the particular solutions, but the general irregular character of the whole phenomenon prevented comparisons in this respect, and all that can be stated is, that both the " protective throw " and the concentration effect, in general, increased rapidly with the strength of the solution.

H. Influence of a periodic magnetic field upon the cell.

An experiment was made to determine the behavior of the standard nitric acid cell when the magnetic field was made and

broken at regular intervals over a considerable time, and curves were drawn showing the variation of the "throw" with time, and the fluctuation of the original deflection caused by this treatment. The strength of field was about 11,000 H, and the experiment was conducted without compensating the original deflection, and by making the field for one minute, then breaking for one minute, and so on.

One of the curves is shown in fig. 1, (III) in which positive ordinates are values of the concentration throw at "make," and negative ordinates the values of the "protective throw."

Experimenting was not begun until the gelatine had completely hardened, and since the electrodes would tend to become polarized while the gelatine was hardening, the "protective throw" was very small, and soon masked by the concentration effects. After about five minutes, making the field had very little effect at all, but began to show decided "concentration throws" ten minutes later, and these rapidly increased with time, as the curve indicates.

Considering the fluctuation of the original deflection, the effect of this periodic field was to tend to reverse it, just as in the case of the uniform field in experiment B, but much more slowly, since the field was on but half the time in this case.

The cell also showed the iron salts almost entirely about the point, forming a thick black envelope.

I. Summary.—The principal results of this investigation may be summarized as follows:

Whenever iron is exposed to chemical action in a magnetic field, there are two *directly opposite* influences exerted.

(*a*) The direct influence of the magnetized condition of the metal, causing the more strongly magnetized parts to be *protected* from chemical action.

This is exhibited in the phenomenon of the "protective throw" which is always in the direction to protect the more strongly magnetized parts of magnetic electrodes. The "protective throw" is small, often requiring delicate apparatus to detect it, and is soon masked by the secondary concentration effects.

As to the absence of the "protective throw" with acids which attack iron with the evolution of hydrogen, the hydrogen acts merely mechanically, and when removed by adding to the solution small quantities of hydrogen dioxide, the "protective throw" becomes very decided.

In the curve, fig. 2 (p. 449), representing the variations of the "protective throw" with the strength of the magnetic field, we trace at once the magnetization of the point electrode. Since only the minute point was exposed to the liquid, it would

become saturated for comparatively small magnetizing forces, and the curve indicates that this occurred at about 10,000 H, beyond which the curve becomes practically horizontal. This further establishes the direct connection between this "throw" and the variation of the magnetization of the exposed point, and confirms the explanation of Professor Rowland, that it is due to the actual attraction of the magnet for iron, and not to any molecular change produced by magnetization.

(*b*) The indirect influence of the magnet caused by the concentration of the products of the reaction about the more strongly magnetized parts of the iron.

This tends to produce a higher potential at the more strongly magnetized parts, and finally establishes permanent electric currents, which go in the liquid from the more strongly magnetized to the neutral parts of the iron. This concentration effect increases rapidly with the amount of iron salts present and the fluidity of the solution.

The convection currents in the liquid are themselves a consequence of this same concentration, being electromagnetic rotations produced by the action of the magnet upon the local electric currents between different parts of the iron.

As to the permanent current, due to the magnet which is finally set up between the electrodes as shown in fig. 1 (II), it is probably due to a change in the character of the reaction produced by the concentration of the iron salts about the more strongly magnetized parts, which would tend to cause a ferrous instead of a ferric reaction to take place, and thus increase the electromotive force.

Physical Laboratory, Johns Hopkins University, May, 1892.

Note.—Since the completion of the above investigation, a number of experiments have been performed similar to those of Professor Remsen. Starting with the known existence and direction of the electric currents in the liquid, it was thought that these might lead to some explanation of the peculiar form of deposit in equipotential lines. A number of interesting facts have been noted, but they are withheld for further experiment.   G. O. S.

Art. LIII.—*Nikitin on the Quaternary Deposits of Russia and their relations to Prehistoric Man;* by A. A. Wright.

At the international Congress of archæology in Moscow, in 1892, the Russian geologist, Mr. S. Nikitin, presented an elaborate paper upon the above subject. A summary of his views will be of interest in connection with the pending discussion upon the continuity of the Glacial epoch. The paper opens as follows: "The terms 'Quaternary Period' or 'Post-tertiary' with their subdivisions and geological equivalence in the series of deposits, are far from being definitely settled by science. At the latest sessions of the International Geological Congress at London and Washington there was much debate upon these questions without arriving at any definite results."

It will be recalled by those present at the Washington session that two distinct glacial epochs in Germany were argued for by Dr. Wahnschaffe,* and similarly by Baron De Geer for Sweden. On the other hand Professor Credner thought that the stratified beds between deposits of till were only local, indicating some retreat and re-advance of the ice-sheet, but no interglacial epoch. Dr. Carl Diener suggested that intercalated beds of sand were no positive proof of interglacial epochs, as moraines, in the Austrian Alps, no more than twenty years old, were covered with pasture. Dr. Holst of Sweden, mentioned two moraines separated by interpolated sand, and thought that they might both have been formed by the same ice-sheet. A blue ground-moraine and a yellow upper-moraine were deposited even in northern Sweden, where there is no indication of the retreat of the ice. Professor Hughes of Cambridge, expressed his opinion that the Ice age was a single continuous cold period, in England at least, except for slight and unimportant oscillations in the extent of the ice-sheet.

Mr. Nikitin continues: "I do not pretend to solve this complicated question; but will confine myself to giving a brief analysis of the signification and the meaning which I attribute to this terminology. Under the name of Quaternary period or Post-tertiary I include all the time since the close of the Pliocene up to our day. I divide this period into two epochs, the Pleistocene (earlier) and the modern epoch. The close of the Pleistocene is characterized, as I conceive, by the disappearance of the mammoth, the rhinoceros, and other large mammals which are now wanting within the limits of Russia. This subdivision coincides with that of many archæologists

* Am. Geol., viii, 241.

that is to say, with the subdivision into the *palæolithic* and *neolithic* epochs. . . . . I think that this subdivision will stand, even though, along with the remains of the mammoth, there should be found some polished stones as the first indications of a more perfect industry." . . . .

" As to the time of the disappearance of the mammoth . . . it is certain that wherever the glacial deposits are developed in their entirety, the remains of the mammoth are not found above the morainic deposits of the so-called second glaciation ; or at least they are very rare.   The time of the greatest development of the mammoth and rhinoceros in Europe corresponds to the period called interglacial, and to the second glaciation of northern Europe.   In northern and central Russia, which exhibits everywhere but a single moraine, the remains of the mammoth and rhinoceros are found principally in loessiform deposits, in old lake and river deposits covering the moraine, or the products of its alteration.   These facts prove that the morainic deposits of Russia belong to the first glaciation, and that by analogy with the west our loess, and the ancient alluviums where the remains of the mammoth and rhinoceros are found, are sediments corresponding to the interglacial epoch, and the second glaciation."

" There are two questions whose solution is important for the subject of which I am treating : first, that of *two glaciations* in middle Europe, and then, that of the so-called *interglacial deposits* of Germany, England and Scandinavia.   You know, gentlemen, that the idea of two epochs of glaciation (and even of several, according to some investigations) has been suggested by the discovery, upon the great expanse of the countries mentioned, of two morainic deposits, separated by heavy, stratified beds, in which are occasionally found numerous traces of the Pleistocene fauna and flora.   At the same time, the partisans of this theory affirm that the second glaciation was less powerful than the first, and that it could not cover all the region occupied by the primary and principal glaciation.   You know also, gentlemen, that this theory, adopted by the larger number of those who have studied the Quaternary deposits, is far from being irrefutable.   I will remark in the first place, that the supposition of three and even four distinct glaciations instead of two, indicates the possibility of diverse explanations, and diverse opinions upon the genesis of these interglacial deposits.   For several countries, there has recently been demonstrated the weakness of the proofs which have been used in affirming the existence of several Glacial epochs, separated by periods whose climatic conditions have been entirely different.   Contemporary geological literature furnishes us with some examples which demonstrate that there has been an error,

even in the case of certain classical sections of interglacial deposits, so that these have now lost the importance that was formerly accorded to them." . . . .

"In 1885 I made a visit to Germany, for the purpose of comparing these Post-tertiary deposits with the corresponding deposits of Russia. The results of my journey were then published in Russian, and later were compiled by Mr. Sjögren in German and in Swedish, so that they have become accessible to the savants of western Europe. Among other things, I prove in those reports a complete analogy between the Russian Quaternary deposits and the German types; with only this difference, that over a vast expanse in central and northern Russia there is a complete absence of traces of interglacial deposits, and of the moraine of the second glaciation; and that the eastern limit of the second glaciation must pass through Lithuania and the Baltic region. It is true, that in the detailed geological literature of Russia we frequently find announcements of the discovery of interglacial beds at one point or another in middle Russia, or even in southern. Nevertheless, none of these cases can be taken seriously, as I believe. Often they are called forth only by the false idea that all the details of the Quaternary deposits of northern Germany ought to be discovered everywhere in Russia." . . .

Proceeding to describe with more detail the deposits of certain districts, he enumerates the four following as the principal strata in Finland:

(*a*) Old stratified sands and clays, intercalated in a few places between the crystalline rocks and the moraine.

(*b*) Unstratified clays, clayey sands and pebbly moraine, mostly blue (*grises*) with polished, sub-angular, striated blocks —the *moraine profonde* of the first glaciation, according to the Swedish classification.

(*c*) Stratified sands and clays, with some rounded gravel— the "interglacial" beds.

(*d*) Unstratified, clayey gravel, sand and clay, mostly yellow, with morainic pebbles and bowlders—the *moraine profonde* of the "second glaciation." In discussing the age of these deposits he says:

"As to the advance of the glacial epoch in Finland and the time of the formation of the two morainic clays, the terminal moraines and osars, nothing is yet known with certainty. However, we have as yet no reason to distinguish here, as a fact irrevocably proved, the deposits of the first glaciation, interglacial deposits, and those of the second glaciation, as in Germany and Scandinavia. All the phenomena known up to the present time connected with the glacial deposits of Finland can easily be explained by a single, continued glaciation,

and by a single glacier subject to oscillation. In short, no interglacial deposits are here known containing animal and vegetable remains. The morainic clay of the type (*b*) alone is distributed over the interior of the country, and only in the border portions of the country does it seem to be separated into two types (*b*) and (*d*)."

The author gives summary accounts of the deposits in seven different regions, as follows :

1. Finland, and the government of Olonetz.
2. The Baltic region and the Waldaï Mountains.
3. Poland and Lithuania.
4. Central Russia.
5. The region of morainic deposits near the limits of their distribution.
6. The region of steppes in southern Russia, beyond the limits of glaciation.
7. The southeastern region of Russia.

The whole makes a pamphlet of thirty-four large octavo pages. It is, however, only the summary of a more detailed report which he is soon to publish. It closes with the following :

" *Principal Theses.*"

1. " The subdivision of the stone age into palæolithic and neolithic epochs should be preserved for European Russia, because it here coincides with the geological divisions into Pleistocene and modern, which are in their turn based upon palæontological data.

2. " The study of the glacial deposits of Finland and of the western region furnishes no proof of the existence of two distinct glacial epochs and an interglacial epoch. All the facts can be explained by the phenomena of the oscillation of the glacier at the time of its gradual, but irregular, retreat.

3. " If however one accepts the Swedish and Prussian theory of the subdivision of the glacial period into two epochs and an interglacial epoch, the second glaciation cannot have extended beyond the western region, in a certain part (comparatively restricted) of the Baltic region, of Finland and of the government of Olonetz.

4. " The other portion of Russia subjected to glaciation, has only one morainic stage, corresponding to the deposits of the first glacial epoch of the Swedes.

5. " At the epoch of the more extended glaciation the major part of Russia presented the aspect of a desert of ice, similar to that of Greenland, carrying no moraine upon its surface, and presenting no elevation free from ice, where forest vegetation could be preserved.

6. " The time corresponding to the interglacial epoch and the second glaciation of the Swedes, was probably, for the greater part of Russia, the epoch of the formation of the ancient lake deposits, the loess, and the upper terraces of the rivers, which constitute the principal repository for the bones of the mammoth and other extinct mammals, which abounded here while Scandinavia and Finland were still covered by the glacier.

7. " In accordance with the composition and genesis of her Quaternary deposits, European Russia may be divided into a series of typical regions which are very characteristic, although resting upon differences which are scarcely recognizable, but which illustrate none the less the life of the immense Russian plain during the Quaternary period, and the formation of her superficial deposits.

8. " In the second portion of the Glacial epoch, or of the pleistocene, the mammoth and other large mammals inhabited southern and eastern Russia in great numbers. As the glacier retreated these animals advanced toward the north and north-west ; toward the close of the pleistocene they reached Finland for a very short time, and then disappeared entirely throughout the whole extent of European Russia, but probably later in its northeastern part and in Siberia.

9. " Man lived contemporaneously with the mammoth during the second part of the glacial epoch along the limits of glaciation, possessing an industry well advanced, and making use of fire among other things, but producing implements solely of flaked flint. As the glacier retired, man advanced toward the north and northwest : he arrived in Finland and the Baltic region after the close of glaciation and after the disappearance of the mammoth ; but man himself possessed already the more advanced culture of the neolithic age, and besides implements of trimmed flint, he knew how to make implements in polished stone, pottery, etc.

10. " European Russia shows no traces of man in the first part of the Pleistocene, or of any more ancient man."

Art. LIV.—*Rigidity not to be relied upon in estimating the Earth's Age ;* by Osmond Fisher, Cambridge, England.

It is impossible not to admire the ingenious argument by which Mr. Clarence King[*] reasons that, assuming the earth to be rigid, the temperature gradient must be such that, within the first few hundred miles at least, it cannot intersect the curve which he uses to express the fusibility of igneous rock under the pressure corresponding to the depth. Placing this before his mind, he was led to obtain an examination of the rock diabase at high temperatures to be made by Dr. Barus ;[†] and we owe a debt of gratitude to both these gentlemen for an interesting addition to our scanty store of knowledge of this obscure class of subjects.

On comparing Dr. Barus's results with those obtained by Professors Rücker and Roberts-Austen for the dolerite of Rowley Regis, we are struck by the considerably higher value of the melting point of diabase, which is about 1170° C., whereas that of the dolerite was found to be under 920° C. On the other hand, Dr. Barus makes the latent heat of fusion of the diabase to be 24, whereas that of the dolerite is 49 ;[‡] thus the latent heat of the rock which has the lower melting point is more than double that which has the higher.

When, however, by means of the above considerations Mr. King endeavors to fix a limit within which the age of the earth must lie, it is clear that the rigidity of the earth must be first established. In proof of this he refers to the "unshaken results of Ld. Kelvin (Sir W. Thomson) and Professor G. H. Darwin," and to "the further arguments for rigidity advanced by Professor S. Newcomb[§] from the data of the lately ascertained periodic variation of terrestrial latitude, as together warranting a firm belief in the rigid earth."

I hope it will not be thought presumptuous if I endeavor to point out what these authorities have really determined. And first of Professor S. Newcomb's discussion of the periodic variations of latitude.

On referring to the article in the monthly notices of the Royal Astronomical Society,[§] it will be found that he proposes two modes of explaining the phenomena. The first hypothesis which he examines is an elastic yielding of the solid earth, and he comes to the conclusion, that the phenomena recently dis-

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[*] This Journal, Jan., 1893.   [†] *Ibid,* Jan., 1892.
[‡] Appendix to the writer's "Physics of the Earth's Crust." 2d ed., p. 18, 1891. See also the account of the experiments, Phil. Mag., Oct., 1891.
[§] For March, 1892.

covered may be accounted for in that manner, if the earth is slightly more rigid than steel; but he does not stop at this explanation. He goes on to say, " we have next to consider the effect of viscosity of the earth. Those geologists, who have given special attention to the subject, regard it as well established, that the earth yields under the weight of deposits, as if it were a thin crust floating upon a liquid interior, and must therefore be a viscous solid, if a solid at all." He then states, that the phenomena observed might in such a case be produced, if some disturbing cause acted, adding, " a *vera causa* was pointed out some years ago by Sir William Thomson in the motions of the winds and oceans, and especially in changes in the polar ice cap." Thus it appears that Professor Newcomb does not consider that there may not be a possible alternative to the hypothesis of steel-like rigidity; and evidently he does not regard the question as settled, for the concluding words of his paper are, " but under the actual circumstances we must await the results of further investigation into the whole subject."

Professor Newcomb tells us that, in the case of a viscous earth, " the poles [of rotation and figure] would eventually appear to meet, unless separated from time to time by [disturbing] causes changing one or both of them." A geologist acquainted with the flow of solid rock would hardly recognize a condition of the interior so elastic, and so devoid of viscosity, that during geological ages the elasticity would be constantly maintained, so that this coincidence of the poles should not by this time have been accomplished. If this be so, then the action of disturbing causes is still needful to account for their separation at present, and there is no stronger argument from variation of latitude for an elastic earth than for a viscous or liquid interior.

While referring to authorities it is worth while to mention that Professor Harkness, in his exhaustive work "On the Solar Parallax and its related Constants including the Figure and Density of the earth," remarks, that, " Notwithstanding the difficulties which arise in connection with the rigidity of the earth under the action of the forces which generate precession, nutation, and the tides, the theory of a comparatively thin crust resting in approximate hydrostatic equilibrium upon a denser substratum is favored by enough facts to render it very plausible."[*]

Let us now turn to what Mr. King describes as " the hitherto unshaken results of Ld. Kelvin and Professor G. H. Darwin" as to the tidal rigidity of the earth. It is no doubt a very serious matter to hold an opinion opposed to such high author-

[*] Washington, Government printing office, 1891, p. 143.

ities in physics, especially when backed by experienced geologists like Messrs. Clarence King and G. F. Becker: nevertheless I pray *audi alteram partem*.

It will, I think, be at once admitted that these objections to a yielding earth have been based upon the equilibrium theory of the tides. It does not seem impossible that the equilibrium theory may give a fairly good approximation to the truth in the case of the bodily tides of the earth itself, although the moment of inertia, and the forced period of oscillation differing from the gravitational, must give rise to deviations from the exact equilibrium value of the tidal distortion. But let us assume that the bodily tide agrees with the equilibrium theory. Then the pith of the objection to a yielding earth is well summarized in Ld. Kelvin's words, "Had the solid part of the earth so little rigidity as to allow it to yield in its own figure very nearly as much as if it were fluid, there would be very nearly nothing of what we call tides—that is to say rise and fall of the sea relatively to the land, but sea and land together would rise and fall a few feet every twelve lunar hours. This would, as we shall see, be the case if the geological hypothesis of a thin crust were true."* But this statement of the question rests on the equilibrium theory of the tides, and takes no account of the horizontal motion of the water to which its accumulation at high and diminution at low tide are due. As Airy wrote, "the problem of the tides, it is evident, is essentially one of the *motion* of fluids;"† and again (one almost hesitates to quote the words), "it must be allowed that it is one of the most contemptible theories that was ever applied to explain a collection of important physical facts. It is entirely false in its principles, and entirely inapplicable in its results."‡

The hydrodynamical problem has never been treated fully on account of its complexity, but for tides of short period the canal theory is thought to give results most nearly in accordance with nature. Now, the only investigation of the tide upon a yielding earth according to the canal theory with which I am acquainted is given by Professor Darwin§ but he has left his result in general symbols without reducing it to a numerical estimate. It is, however, perfectly easy on certain assumptions to supply this desideratum, all the quantities involved having known astronomical values except two. These two are the height of the bodily tide, and the amount of its lag. Let us then suppose the earth's interior to consist of a liquid of small viscosity, which is the case in which the ocean tide ought to be most diminished. In that case the bodily tide

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* Thomson and Tait's Natural Philosophy, § 833.
† Encyclopædia Metropolitana, "Tides and Waves," § 14.
‡ Ditto, § 64.   § Phil. Trans. Part I, 1879, p. 23.

may be taken at the equilibrium value, which for a large body like the earth is very much more suitable than it is to a layer of water like the ocean. The height of such a lunar tide is estimated to be about 1¾ feet from highest to lowest,* and the lag would be small. The diminution of the tide from its normal amount is caused by the attraction of the two bodily protuberances, and these must be taken as of half the mean density of the earth. Introducing these values into Darwin's formula I have obtained the result† that the tide would be diminished by only one-fifth of what its height would be on a rigid earth. If for instance the height would be fifty inches on a rigid earth, it would still be forty inches if the earth was liquid. Now, since we do not know what the precise height of a tide on a rigid earth would be, it is quite possible that the tides we actually experience may be of the height appropriate to a liquid interior, seeing that the diminution would be so small.

If there is no flaw in the above reasoning, the rigidity of the earth has not been established by the argument from the tides of short period, and no estimate of the earth's age can be based upon a belief in such a condition of the interior derived from their existence. If, however, the argument is transferred to the fortnightly tide, the reply may be made that there is no certain evidence from observation of the existence of such a tide; for " it is certain that, if at a given port a tide exists, the average height of that tide ought to be always the same year by year, and its lag ought to be the same. But in fact the average annual height of the fortnightly disturbances of the sea at Karachi, in India, which is the port where the necessary observations have been carried out for fifteen years, does not maintain anything like a constant value. This appears to show that no conclusion can be drawn from the observations to decide the question whether there is such a tide or not. The disturbances may be wholly due to meteorological causes. At any rate, if such a tide exists, it is so masked by meteorological disturbances as to be unrecognizable. The irregularity of the times of disturbances is equally noticeable

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* Thomson and Tait's Nat. Phil., 2d Ed. § 804. Mr. King, p. 17, writes as if the tidal deformation of the earth would be five feet if it is not rigid, but does not give his authority. Possibly he may be referring to the observed height of the tide at oceanic islands, which on the assumption that the tide would be obliterated by a yielding earth would afford a measure of the yielding. The only numerical estimate I have been able to find is in "Thomson and Tait," and is that which I have given above. If any larger one is mentioned I have overlooked it.

† See a paper by the writer on "the hypothesis of a liquid condition of the earth's interior considered in connection with Professor Darwin's theory of the Genesis of the moon." Proc. Cam. (England) Phil. Soc., May 30, 1892.

with the irregularity of their amount."* The mean of all the heights is 0·396 inch. The least annual mean is 0·072 and the greatest 0·936; the difference between them, 0 864, is more than double the mean of the whole series of observations, which indicates the existence of a disturbing cause of the same order of magnitude as the quantity to be measured, so that we can draw no inference either way.

I submit, therefore, that the title of this article has been justified, and that it has been shown that rigidity cannot be relied upon as affording a datum towards estimating the earth's age.

Art. LV.—*On the Treatment of Barium Sulphate in Analysis;* by J. I. Phinney.

In a recent paper by M. Ripper† entitled "Beiträge zur Gewichtsanalyse der Schwefelsäure" the method discussed is the precipitation of barium sulphate from an excess of the chloride and differs from similar methods only in the manner of purification of the precipitate. Purification according to Ripper, is accomplished by oxidizing with bromine water whatever sulphate may have been reduced by the ignition of the filter, then treating the entire precipitate with dilute hydrochloric acid until the impurities are removed. In the course of his investigation Ripper made the attempt to eliminate the possible source of error in the reduction of the sulphate by the use of the asbestos filter-crucible, but finding it impossible to bring asbestos to a sufficiently constant weight either by itself or when treated with dilute acid, he abandoned it as impracticable, and substituted the treatment of the reduced precipitate with bromine. Ripper accepts without investigation the old method of purifying barium sulphate by hydrochloric acid.

Inasmuch as the asbestos crucible has been employed successfully even in processes so delicate as atomic weight determinations, sufficient confidence was felt in it to warrant testing by its use the accuracy of the hydrochloric acid process of purification, in this way reducing the necessary manipulation and completely avoiding the introduction of bromine. Further-

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* Appendix to the writer's "Physics of the Earth's Crust," 2d ed., p. 34, where a table of the annual heights and lags are given, compiled from the "Results of the Harmonic Analysis of Tidal Observations," by Major Baird and Prof. Darwin, Proc. Roy. Soc., vol. xxxix, p. 135, 1886.

† Zeit. f. anorgan. Chem., ii, 36.

more the recent work done in this laboratory by Drs. Mar and Browning* on barium sulphate depends for its validity upon the practical utility of this means of gathering and weighing barium sulphate. Accordingly the following preliminary series of experiments were undertaken with a view of discovering under what conditions and how far the asbestos crucible could be depended upon in quantitative methods as applied to the estimation of barium as sulphate. In Series I the crucible with a felt was ignited to bright redness for different periods of time and weighed, then washed with hydrochloric acid, both cold and hot, ignited, and re-weighed with results as shown below. The crucible used was finely perforated and furnished with a cover and cap, and the asbestos was prepared as directed by F. A. Gooch,† in his original paper. A felt weighing 0·0258 grm. was thrown upon the crucible, washed thoroughly with distilled water, dried, ignited, and weighed in less than twenty minutes. The formation of blisters due to rapid generation of steam was easily avoided by gradually increasing the temperature from a gentle heat. A second crucible with a felt weighing twice as much (0·0441 grm.) was ignited at low redness for equal periods with similar results.

SERIES I.

Time of ignition.	Weight in grams.	Time of ignition.	Weight in grams.
2 min.	0·0258	10 min	0·0258
2 "	0·0258	10 "	0·0258
2 "	0·0258	20 "	0·0258
5 "	0·0258	20 "	0·0258
5 "	0·0258	30 "	0 0258

The same felt was washed with 20 cm³ of a twenty-five per cent solution of hydrochloric acid, then treated with 5 cm³, 25 cm³ cold, and 25 cm³ hot concentrated acid respectively, and suffered in no case the slightest diminution in weight, constant weights being secured after an ignition of two minutes. Finally as a matter of curiosity rather than because of its practical bearing the felt was digested in the crucible for fifteen hours in concentrated acid, washed with 100 cm³ distilled water, and even then lost but 0·0001 grm. The stability of the asbestos under the foregoing treatment is remarkable. An excessive ignition for nearly two hours at bright redness gave no appreciable change, while in the last experiment the trifling loss may perhaps be accounted for by mechanical disintegration.

In Series II, barium sulphate brought to a constant weight was treated with acid on the felt without difficulty—in the first two cases with a few drops of dilute hydrochloric acid followed

* This Journal, xli, 288; xliii, 314; xliv, 450.
† Amer. Chem. Jour., i, 317.

by 10 cm³ of distilled water, in the third, with 100 cm³ of a three per cent solution of the acid—though Ripper raises the further objection, that upon ignition the precipitate becomes so firmly attached to the felt that it is nearly or quite impossible to make a thorough treatment with acid. In experiments (1) and (2) no attempt was made to pulverize the precipitates, but in experiment (3), as also throughout Series III, on moistening with a few drops of water the sulphate was easily and completely disintegrated by a glass rod into finely divided particles. This difference in treatment explains, at least in part, the large difference in the results of the following table.

SERIES II.

BaCl₂·2H₂O taken. grm.	Time of ignition.	BaSO₄ found. grm.	Error. grm.	Treatment with acid.	Weight after treatment. grm.	Loss. grm.
(1) 0·5071	{ 10 min. 20 "	0·4848	0·0003 +	{ 4–5 drops HCl 4–5 " HCl	0·4845 0·4845	0·0003 0·0000
(2) 0·5022	{ 10 " 20 "	0·4799	0·0001 +	{ 4–5 " HCl 4–5 " HCl	0·4796 0·4793	0·0003 0·0003
(3) 0·5007	{ 5 " 5 "	0·4783	0·0001 −	{ 100 cm³ 3 per cent HCl	0·4751	0·0032

The filtrates in experiment (2) gave with an excess of sulphuric acid slight unweighable precipitates, but from the filtrate of experiment (3) 0·0030 grm. of the sulphate were recovered. The disintegrated residue from experiment (2), (0·4793 grm. BaSO₄), was next treated under precisely the same conditions as in the last preceding experiment except that in this solution there was present dilute sulphuric acid amounting to five percent of the entire volume, an excess sufficient to keep the barium in the form of sulphate.* In this case there was no loss in weight nor did the filtrate contain any barium.

This work completely demonstrates not only that strong hydrochloric acid has no effect upon the film of asbestos, but also that barium sulphate when thrown upon it may be brought to a constant weight either by itself or after treatment with dilute acids, and incidentally that the requisite excess of sulphuric acid must be present to counteract the solvent effect of the hydrochloric acid. That Ripper failed to secure constant weights is probably due to unfamiliarity with the proper sort of material to be used.

In view of the facts thus far ascertained the next step was to purify the sulphate, if possible, by the means already referred to in the beginning of this paper. The contaminating salts chosen were potassium chlorate and sodium chloride, as those

* Fresenius, Zeit. f. anal. Chem., xxx, 455

most likely to present a fair test of the efficacy of the process. The following precipitations were made:

No.	BaCl$_2$. 2H$_2$O taken. grm.	BaSO$_4$ found. grm.	Error. grm.	Contaminating salt. grm.
1.	0·5008	0·5009	0·0224 +	KClO$_3$, 3
2.	0·5014	0·4990	0·0198 +	KClO$_3$, 3
3.	0·5007	0·4980	0·0196 +	NaCl, 10
4.	0 5004	0·5165	0 0384 +	NaCl, 20
5.	0·5012	0·4979	0·0190 +	KClO$_3$, 3

By reference to the following table in which the records of treatment of these precipitates are given in their numerical order, it will be seen that the action of hydrochloric acid in the presence of sulphuric acid is to remove only from 70 to 90 per cent of the total impurity, and that, while it is possible by repeated treatments with dilute hydrochloric acid alone to so reduce the weight that there may be little or no apparent error on the original determination, the large percentage of sulphate dissolved at the same time condemns its use in accurate analytical work.

SERIES III.

	Acids used in total vol. of 100 cm^3. HCl cm^3	H$_2$SO$_4$ cm^3	Duration of acid treatment.	Loss on treatment. grm.	Impurity remaining. grm.	BaSO$_4$ recovered by H$_2$SO$_4$ in filtrate.
1.	3	5	30 min.	0·0175	0·0049	none
	3	5	15 "	0·0012	0·0037	"
	3	5	15 "	0·0012	0·0025	unweighable trace
	3	5	15 "	0·0000	0·0025	" "
	3	5	15 "	0·0003	0·0022	" "
	3	0	15 "	0·0031	0·0009 −	0·0020 grm.
2.	3	5	20 "	0·0135	0·0063	none
	3	5	20 "	0·0015	0·0048	"
	3	5	20 "	0·0003	0·0045	"
3.	3	5	30 "	0·0090	0·0106	none
	5	10	20 "	0·0013	0·0093	"
	10	10	20 "	0·0023	0 0070	"
	25	10	20 "	0·0002	0·0068	"
	50	10	15 "	0·0002	0·0066	"
4.	90	10	15 "	0·0260	0·0124	none
	90	10	15 "	0·0009	0·0115	"
5.	3	0	30 "	0·0146	0·0044	0·0007 grm.
	3	0	30 "	0·0040	0·0004	0·0032 "

Fresenius states[*] that barium sulphate impure from sodium or potassium chlorates may be completely purified by igniting the precipitate, moistening thoroughly with hydrochloric acid. evaporating to dryness and extracting with water, and that

[*] Zeit. f. anal. Chem., ix, 62.

chlorides of these elements bring about no contamination. However, in the above series of precipitations the inclusion by the sulphate of sodium chloride and potassium chloride (left on ignition) was very marked, and accordingly four new precipitations were made, two in the presence of 10 grm. of sodium chloride, and two with an equal amount of potassium chloride as the contaminating salt, in order to test the degree of purification reached by Fresenius' process. The evaporation was made over a steam bath and hot water was used in washing. It was found an easy matter to remove the precipitates from the felts after ignition by breaking up the caked mass with a glass rod by a rotary motion and gently tapping the crucible. After extraction the residue was thrown back upon the same felt, ignited, and re-weighed with results as below :

I.

$BaCl_2 . 2H_2O$ taken.	$BaSO_4 + NaCl$ found.	Impurity before treatment.	Loss on treatment.	Impurity remaining.
0·5000 grm.	0·4955 grm.	0·0177 grm. ·	0·0079 grm.	0·0098 grm.
0·5003 "	0·4973 "	0·0193 "	0·0100 "	0·0093 "

II.

$BaCl_2 . 2H_2O$ taken.	$BaSO_4 + KCl$ found.	Impurity before treatment.	Loss on treatment.	Impurity remaining.
0·5033 grm.	0·5024 grm.	0·0215 grm.	0·0131 grm.	0·0084 grm.
0·5017 "	0·5071 "	0·0277 "	0·0189 "	0·0088 "

Under the most favorable conditions an average of 0·0090 grm. of the total impurity in a half-gram of the impure sulphate remained untouched, and in one case a retreatment diminished this amount by only 0·0004 grm. Slight precipitates were recovered from the filtrates of II, the first weighing 0·0001 grm. and the second unweighable.

We are forced, then, to the conclusion that alkaline chlorides do contaminate barium sulphate thrown down in the presence of an excess of sulphuric acid[*] and that the process of purifying by hydrochloric acid does not purify. It would seem therefore that the only good method for purification is either to fuse, according to Fresenius, with sodium carbonate, extract and reprecipitate as sulphate, or to evaporate from solution in concentrated sulphuric acid according to Mar.[†]

In conclusion, the author desires to acknowledge the suggestions and help of Prof. F. A. Gooch freely given throughout these investigations.

[*] See also this Journal, xli, 288.   [†] Ibid.

ART. LVI.—*The Validity of the so-called Wallala Beds as a Division of the California Cretaceous ;* by HAROLD W. FAIRBANKS, F.G.S.A., Berkeley, Cal.

THE classification of the California Cretaceous, as given by Dr. C. A. White in Correlation Papers—Cretaceous, is as follows :

Lower Cretaceous.   Shasta Group.   Knoxville Beds.
                                        Shasta Beds.

Upper Cretaceous.   Wallala Beds.
                                        Chico.

The designation Wallala as applied to a supposed new division of the California Cretaceous was given by Drs. White and Becker to some beds discovered during the investigations for the monograph on the Quicksilver Deposits of the Pacific Slope. These occur on the coast of Mendocino Co. near Ft. Ross, and consist according to Dr. Becker of a series of shales, sandstones, and conglomerates, some thousands of feet in thickness, and in character closely resembling the Chico as it is known in other parts of the State. Dr. Becker states that the beds rest unconformably on the Metamorphic Series, but that the stratigraphical position with reference to the Chico is not shown. According to Dr. White the beds are older than the Chico but younger than the Shasta Group. The evidence with regard to the exact position of the strata is wholly paleontological and it is on this that he has established the division.

The fossils found were in bad condition but the following genera were made out: *Ostrea, Inoceramus, Pecten, Cylichna,*

* Since this article was prepared for publication there appeared in the American Geologist a resume of a paper read at the last meeting of the Geological Society of America in Ottawa, Canada, by J. S. Diller, entitled: The Cretaceous and Tertiary of the Pacific States ; and also of one by T. W. Stanton on the Faunas of the Shasta and Chico Formations. The authors of these papers arrived at substantially the same results as I have expressed in this article with regard to the validity of the Wallala beds. This is interesting because of the different fields studied and of the entire independence, each of the other, in the conclusions reached. I was not aware that any one else was engaged in such a study.

LITERATURE.

Mesozoic and Cenozoic Paleontology of California, Bull. U. S. Geol. Sur., No. 15. C. A. White.
Notes on the Stratigraphy of California, Bull. U. S. Geol. Sur., No. 19. G. F. Becker.
On New Cretaceous Fossils from California, Bull. U. S. Sur., No. 22. C. A. White.
Geology of the Quicksilver Deposits of the Pacific Slope, by G. F. Becker.
Geology of Baja, California, Proc. Cal. Acad. Sci., 1888, by W. Lindgren.
Correlation Papers—Cretaceous, Bull. U. S. Geol. Sur., No. 82, by C. A. White.

Turritella, Solarium, and one subsequently determined as *Coralliochama orcutti.* The Coralliochama is the type of a new genus and is the most characteristic fossil in the Wallala beds as well as in those on Todos Santos Bay.

About the same time C. A. Orcutt of San Diego sent to the National Museum a collection of fossils from the shore of Todos Santos Bay, Lower California. These were in a good state of preservation and included the following species: *Coralliochama orcutti, Nerita, Cerithium pillingi, C. totium-sanctorum,* and *Trochus euryostomus.* The Coralliochama is thus seen to be the only species common to both localities, the other species being new.

Although the two occurrences are so widely separated, Dr. White found a general resemblance of the faunas, and as they were different from any known Cretaceous in the United States and resembled the Gosau of Europe, he termed the whole the Wallala beds. Wallala being a town near the occurrence in northern California. The latter beds I have not seen, but the past year an opportunity was given me to examine those on Todos Santos Bay. The strata, consisting of shales, sandstones, and conglomerates resembling the Chico, are exposed in cliffs along the southern shore of the bay for about three miles. They form a narrow strip along the north flank of Punta Banda, a long high ridge of porphyry and diorite bounding the bay on the south. The strata dip to the northeast at an angle of 30–60 degrees and are somewhat faulted but are entirely unaltered. Fossils are not abundant through the formation but a considerable variety was collected during my hasty visit. The Coralliochama is exceedingly abundant in strata scattered through a vertical distance of several hundred feet. One bed four feet thick was formed almost wholly of a mass of shells. The following is a list of the fossils found here.

Coralliochama orcutti.	Tellina æqualis.
Axinæa veatchi.	Lunatia avellana.
Ostrea ——	Volutilithes ——
Pugnellus ——	Actæonina pupoides.
Astartate mathewsoni.	Cinulia obliqua.
Venus varians.	Nucula truncata.
Fusus ——	Baculites chicoensis.
Leda translucida.	Gyrodes expansa.
Turritella chicoensis.	Ancyloceras lineatus.
Tellina ooides.	Leda gabbi.
Mactra ashburneri.	

It will be seen that not only is this list much larger than that found by Mr. Orcutt but with the exception of the Coral-

liochama it is wholly different. The fauna very closely resembles the Chico as it is known in California.

During the course of several months spent in the vicinity of San Diego I made a careful study of the unaltered shales, sandstones and conglomerates along the coast. This resulted in a large collection of Tertiary and Cretaceous fossils, many of the latter being new species. The most important result of this study, however, was the proof of the actual relation of the supposed Wallala beds to the Chico; a relation which seemed probable from the fauna found on Todos Santos bay, but which at San Diego was shown both paleontologically and stratigraphically. These Cretaceous beds were found at two points on the coast, one at La Jolla the other on Pt. Loma. The latter is a long high peninsula partly inclosing the bay of San Diego. It is almost precipitous and good sections of the strata are exposed. They consist of shale and sandstone with an unconformable late Tertiary conglomerate overlying. The peninsula is formed by a local uplift, and though the strata are not greatly inclined the amount of faulting has been remarkable. There are probably not less than four hundred to be seen along a distance of four miles on its seaward face.

Dr. J. G. Cooper many years ago obtained three species of Chico fossils from this peninsula, one being an Ammonite, found in a shaft sunk for coal. No published notice was ever made of this discovery except the original descriptions in Gabb's Palæontology of California, Vol. I, pp. 69, 80 and 197. The strata dip generally to the northeast at a small angle except at the very southern extremity of the peninsula where they are reversed and dip southerly, thus forming an anticlinal with the lowest strata near the end. The peninsula lessens in height to the northeast in the direction of False Bay under which the strata seem to dip, reappearing again on the opposite side toward La Jolla, the bay lying in the synclinal. The *Coralliochama orcutti* and several other species occur in a sandstone at the base of the cliffs and almost covered by the water at high tide. The Tertiary conglomerate is fully three hundred feet thick at the extremity of the point, and consists partly of bowlders similar to the crystalline rocks in the mountains east, and partly of sandstone bowlders many of which contain specimens of the Coralliochama, Cephalopods, and well known Chico forms. The conglomerate completely covers the sandstones on the inner side of the extremity of the point, but since all the fossils found in place are similar to those in the bowlders and the bowlders themselves are lithologically similar to the rocks in place, there seems not the slightest doubt but that they all belong to the same formation,

the richest fossiliferous portions being covered by the conglomerate. The Coralliochama is fairly abundant in places but is poorly preserved. The following is a list of the fossils found in place and in the bowlders. These fossils as well as those in the other two lists given in this article were determined by Dr. J. G. Cooper. The original descriptions with two or three exceptions were by Gabb.

Actæonina pupoides.	Patella traski.
Actæonina —— n. s.	Pecten californicus.
Ammonites whitneyi.	Perissolax brevirostris.
Ampullina striata.	Pholadomya breweri.
Angaria ornatissima.	Puncturella —— n. s.
Arca breweriana.	Tapes quadrata.
Astarte mathewsoni.	Trapezium carinatum.
Callistoma —— n. s.	Tritonium —— n. s.
Cardium placerensis.	Ancillaria elongata.
Cerithium pillingi.	Architectonica horni.
Cerithium —— n. s.	Avicula pellucida.
Carbula —— n. s.	Bulla —— n. s.
Crassatella tuscana.	Conus horni.
Crassatella —— n. s.	Conus rémondi.
Crenella —— n. s.	Dentalium cooperi.
Haliotis —— n. s.	Dosinia —— n. s.
Lima microtis.	Meretrix horni.
Lithophagus oviformis.	Meretrix uvasana.
Heteroceros cooperi.	Margaritella globosa.
Lucina postradiata.	Baculites chicoensis.
Lunatia conradiana.	Inoceramus vancouverensis.
Meretrix arata.	Axinæa veatchi.

Although this list contains several species found in the Shasta Group the predominating character is that of the Upper Cretaceous.

At the northeastern extremity of the point, and about a mile west of Old San Diego, is a bluff consisting of sandstone and some shale carrying casts of Eocene fossils. Quite a variety was found here but specific determinations were in many cases impossible so that the list is not given. The strata dip northeasterly at a small angle and though they cannot be traced by surface outcrops the whole of the distance to the Chico beds at the southern end of the point four miles away, yet judging from the scattered exposures with the same character and similar dip, the indications are that they are conformable with the Chico. The vertical distance between the two fossiliferous beds is probably not over twelve hundred feet. It would appear that the Chico and Tejon are conformable here as in many other parts of the State, but that there is no blending of the faunas of the two divisions.

The Miocene is not positively recognized near San Diego, but the mesas along the eastern side of the bay on which the city is situated are filled with Pliocene fossils; the strata being separated from the Chico-Tejon by a small non-conformity.

As has been mentioned before, the rocks dip south on the north side of False Bay. The angle is small but quite uniform until La Jolla is reached when for a short distance it becomes much greater, then just north of the town where a shallow bay indents the land, there is quite an abrupt reversal of the dip toward the northeast, the angle being as much as 30 degrees. The northern side of this anticlinal is exposed along the shore for a half a mile. The rock is chiefly shale with some heavy bedded sandstones, and contains a fauna somewhat similar to that on Point Loma save that it is not as varied. The following species were determined.

Hamites vancouverensis.	Cinulia obliqua.
Helcion dichotoma.	Gryphæa vesicularis.
Inoceramus vancouverensis.	Pecten traski.
Megertia ?	Terebratula —— n. s.
Mytilus pauperculus.	Septifer dichotomus.
Pecten —— n. s.	Solen parallelus.
Stomatia —— n. s.	Coralliochama orcutti.
Ammonites hoffmani.	Baclites chicoensis.
Axinaea veatchi.	
Chione varians.	

At both Pt. Loma and La Jolla the fossiliferous Cretaceous strata appear only at the highest point in the anticlinal.

A little valley opens out to ocean north of the Cretaceous strata just described and no outcrops appear for nearly a mile. North of the valley there begins a long stretch of perpendicular cliffs rising nearly four hundred feet. The strata have the same dip and strike as those forming the northern side of the anticlinal at La Jolla. At the base are a few Eocene fossils which become more abundant northward along the coast, that is higher in the series. No contact of the Eocene with the Chico is shown but there is apparently a conformability.

The conclusion to be drawn from these facts warrants the assumption that the Coralliochama is a distinctly Chico fossil in the three known localities on the southern coast, namely :— Todos Santos bay, Pt. Loma and La Jolla, and though there are no stratigraphical relations shown near Wallala, yet the general character of the beds and the resemblance of the fauna to that of the localities just described, leads me to the belief that they are all approximately synchronous. It will be seen on comparison of the list of fossils that about half of those from Todos Santos were found at Pt. Loma and La Jolla, while

the strata at the two latter localities were seen to be followed upwards in a short distance by well characterized Eocene.

Richly fossiliferous beds of the Upper Cretaceous lie along the western slope of the Santa Ana Mountains, about one hundred miles north of San Diego. The fauna is, however, quite different from that of the localities just described, but few species being common. Westward toward the ocean the Cretaceous is followed by the Miocene without any apparent physical break. Eocene fossils have not yet been found in this region. Southward toward San Diego the Miocene is replaced by the Eocene but the boundaries have not been made out.

The Cretaceous bordering the Santa Ana Mountains dips away at a high angle, and shows a basal conglomerate resting unconformably on the somewhat metomorphosed Paleozoic Series.

The Lower Cretaceous has not yet been recognized in southern California, unless it be in some local beds on the summit of the Carrizo Mts., on the western border of the Colorado Desert. The locality is about seventy miles east of San Diego and on the opposite side of the Peninsula Range. Fossils are numerous but in poor condition, save for one species of the coral Astræa which is in large masses and exceedingly well preserved. The beds are unconformable with the Miocene and very much older. The region is a very interesting one and deserves careful study.

The discoveries announced in the foregoing article add emphasis to the fact that too much care cannot be exercised in classifying beds when only a scanty paleontological evidence is available. The importance of stratigraphy and lithology has been greatly undervalued in the study of California geology. In my opinion it is one of the reasons that such serious mistakes have been made in the classification of the older rocks of the Coast Ranges.

ART. LVII.—*On the Nature of Certain Solutions and on a New Means of investigating them ;* by M. CAREY LEA.

THE three strong acids with which we are best acquainted have this in common that they all form two classes of compounds, the one perfectly neutral and perfectly stable in solution, the other class instantly decomposing when it is attempted to dissolve them in water. As types of the first class may be taken the alkaline salts. Of the second, mercuric sulphate,

bismuth nitrate and stannous chloride offer examples, as also the thallic salts of all three.

Between these limiting cases are certain intermediate ones as to which our knowledge of the form which the salts take in solution is not very exact.—It need scarcely be mentioned that what has been said does not refer to dissociation into anions and kations but into separation of free acid and basic salt, an entirely different question.

In the case of sulphates—to a consideration of which this paper will be devoted—we know that the number of salts of the metals which give a purely neutral reaction with litmus is comparatively small; that all the normal sulphates of the heavy metals show an acid reaction even after any number of recrystallizations although these may be made from solutions rendered alkaline by the addition of free alkali, and that all the normal sesquisulphates have an acid reaction. The question is as to the meaning of this acid reaction and whether in any or all cases free acid is present.

The uncertainty that exists depends partly upon the imperfect nature of our indicators. Litmus, which is perhaps the best, is reddened by the contact of any substance which will deprive it of its alkali. Methyl orange, which is by some considered more sensitive than litmus, has this disadvantage that it seems to be decomposed by some metallic salts so that its color is rendered lighter by them instead of darker although free acid may be present. This tendency greatly diminishes its usefulness.

Another method has been proposed for the detection of free sulphuric acid in the presence of combined. The solution is heated to 100° and evaporated to dryness in the presence of a small quantity of organic matter which is blackened if free sulphuric acid is present. As what we want is to determine the nature of the *solution* at ordinary temperatures such a method is quite worthless.

But by means of a new reaction the conditions of such solutions can be examined and free sulphuric acid can be detected in the presence of sulphates with great accuracy and sharpness even when only a trace is present.

The method is as follows : Taking the well known polarizing salt discovered by Herapath, the sulphate of iodo-quinia, it is possible to remove the whole of the sulphuric acid without breaking up the molecule. This may be done with either barium carbonate or barium hydroxide. The mode of operation is as follows. The barium compound is placed in a beaker and covered with weak alcohol of about 70 per cent. Into this the crystallized herapathite is dropped. In cold alcohol of this strength it is but very slightly soluble but in the presence of the barium compound it dissolves with facility and in large

quantity forming a deep sherry wine-colored liquid.   This solution when allowed to dry spontaneously leaves an amber-colored varnish without a trace of crystallization.   If, however, we add to this solution a minute quantity of sulphuric acid there is left behind on evaporating a characteristic bluish black film and isolated crystals of iodo-quinia sulphate.   In forming this reagent it is more convenient to employ barium carbonate as the decomposition is effected equally well and with it we are certain that the solution contains no barium compound. Barium carbonate decomposes iodo-quinia sulphate with slow disengagement of carbonic anhydride, it seems therefore probable that the resulting solution contains a free base.

From this solution the sulphate is regenerated with great facility by free, but not by combined sulphuric acid.   And as the herapathite thus formed is a well characterized substance we obtain a most useful means of deciding as to whether sulphuric acid in certain solutions is free or combined.   It is not necessary that the combined sulphuric acid should be united to a strong base, neutral sulphates of weak bases are wholly without action.   Thus neither brucia nor quinia sulphate causes formation of herapathite, the sulphuric acid in these salts has no more tendency to bring about the reaction than for example that in sodium sulphate.   The fact that quinia sulphate does not form herapathite with the test, indicates that there is *no* free iodine present, thus confirming the view that the iodoquinia molecule is not broken up.

Space cannot be spared here to go with detail into the chemistry of iodoquinia compounds.   The whole series of acid persulphates has been most thoroughly studied by Jörgensen[*] who distinguishes seven compounds of quinia, sulphuric acid, and iodine of which four belong to the herapathite type, that is, they contain three molecules of sulphuric acid to four of quinia, and two of hydriodic acid, with increasing amounts of iodine.   Putting Ch for $C_{20}H_{24}N_2O_2$, the composition of these four salts may be taken as

$$4Ch, \ 3H_2SO_4, \ 2HI, \ I_4$$
$$4Ch, \ 3H_2SO_4, \ 2HI, \ I_5$$
$$4Ch, \ 3H_2SO_4, \ 2HI, \ I_6$$
$$4Ch, \ 3H_2SO_4, \ 2HI, \ I_7$$
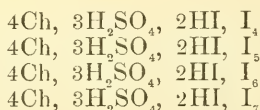
The first of which series is herapathite.   All are isomorphous (l. c. p. 253).   Jörgensen's view of the constitution of herapathite is that it is "half superiodide, half sulphate" he gives as its rational formula :

$$J_2J \cdot HChH \cdot O \cdot SO_3O \cdot HChH \cdot O \cdot So_2O \cdot HChH \cdot O \cdot$$
$$SO_2 \cdot O \cdot HChH \cdot JJ_2.$$
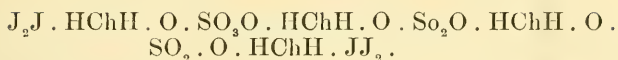
It appears, however, that the sulphuric acid may be removed not only by barium carbonate but by its hydrate, without breaking up the molecule. It is easily shown that the solution of herapathite after treatment even with barium carbonate contains no sulphuric acid. This may be proved by adding to the solution after the treatment, ammonia till it becomes pale yellow, evaporating to dryness and then warming with very dilute hydrochloric acid. An aqueous solution of barium chloride then gives no precipitate, nor even any troubling by standing. It seems perhaps doubtful if a substance having the constitution indicated by the rational formula above cited could have its molecule subsist unbroken, after the removal of the sulphuric acid.

The application of this test leads to the following conclusions :

1. *Sulphates of the type R'_2SO_4 or $R''SO_4$*

I find that these salts dissolve in water and exist in solution as such and absolutely without separation of sulphuric acid even in those cases in which the solution is acid to litmus. The substances examined were the alkaline sulphates and the sulphates of Mg, Zn, Cd, Cu, Ni, Co, Mn, Tl, also the sulphates of morphia, quinia, strychnia and brucia. To this series of reactions there is a single exception of an interesting character.

A solution of ferrous sulphate invariably contains free acid, no matter how often recrystallized or under what circumstances prepared. A small flask was filled with freshly distilled water and was well boiled, corked and set aside to cool. In this, ferrous sulphate was dissolved and potash was added in quantity sufficient to precipitate a considerable proportion of oxide. Even this solution gave the reaction indicating the presence of free acid. So too the double salts of ferrous oxide with ammonia and with magnesia, their solutions always contain free acid, no matter how often they may be recrystallized or purified by precipitation of their solutions in water by alcohol. This exceptional behavior probably results from the great tendency of ferrous solutions to rapid absorption of oxygen from the air, and as will presently appear, sesquisulphates are dissociated in solution.

With this one exception the heavy metallic sulphates above mentioned dissolve in water without decomposition although their solutions redden litmus. The alkaloids mentioned yield sulphates which after suitable purification are perfectly neutral to litmus.

To explain this contrast it is necessary to remember that a salt reddens litmus whenever the affinity of its acid for the potash in litmus is not held in check by two affinities which oppose it, that of the base for its acid and that of the litmus dye for its potash. If the base is sufficiently weak, the affinity of its acid for potash preponderates.[*] The whole question therefore reduces itself to that of the strength of the base with which the acid is united, and it consequently follows irresistibly that even very weak alkaloids are stronger bases than such metallic oxides as those of zinc, copper, cobalt, etc.

Although this deduction seems clear it may be supported by additional evidence. As bases, the alkaloids vary very greatly in strength. A few which contain no oxygen are bases approximating to ammonia in strength. Such are nicotia and conia. Among those which contain oxygen there is much difference in strength, morphia and codeia are strong bases and are known to precipitate iron, copper, cobalt and nickel salts. The weaker alkaloids do not seem to have been examined in this respect and one therefore was selected for examination.

Brucia is one of the weaker alkaloids. It is precipitated from its saline solutions by morphia, strychnia, etc. It forms a neutral and an acid sulphate both crystallizing well. The alkaloid itself is very sparingly soluble in cold water, it is therefore convenient to operate with solutions raised to a temperature of $50°$ or $60°$ C. The sulphates of zinc, cadmium, copper, manganese, nickel and cobalt, proved to be readily precipitated by brucia. The reaction is always easily obtained and well marked. It is particularly so in the case of cobalt, the rose red solution of which becomes quickly filled with blue flocks of oxide.

That weak bases such as the oxides of zinc, cadmium, and copper should be precipitated by a weak alkaloid like brucia is not surprising but the case is somewhat different with stronger bases like manganous oxide and the oxides of nickel and cobalt. These two last are classed by Mendeléef as " fairly energetic " bases. This, however, can be understood only by comparison; no base can be considered as a strong one whose neutral salts redden litmus.

When brucia is added to solution of magnesium sulphate there is no precipitation. Magnesia is a stronger base and its salts are neutral to litmus not because the acids are more fully saturated by it but because the potash of the litmus is unable to detach the acids from the base.

---

[*] It is of interest to observe that the reaction may be changed by the presence of an additional substance although the latter may be quite neutral. Thus mercuric chloride is faintly acid to litmus, but not after the addition of potassium chloride. The tendency to form a double salt changes the balance of affinities.

2. *Sesquisulphates.*

Chromic sulphate.—The violet salt was obtained free from green salt by acting on the nitrate with sulphuric acid. It was freed from excess of acid by repeated precipitation with alcohol and thorough washing. It had a pale violet color and satiny luster. In solution it always gave when examined with the test liquid, marked indications of the presence of free sulphuric acid.

Aluminum sulphate.—This was purified from excess of acid in the same manner as the preceding and gave a similar reaction.

Glucinum sulphate.—Same treatment as the preceding and similar reaction.

Ferric sulphate.—Same reaction.

In all these cases the reaction was extremely well marked. It indicates that these sulphates do not exist as such in solution but that a portion of their acid is set free.

3. *Alums.*

The alums as might be expected show reactions similar to those of the sesquisulphates with one notable exception.

Potash alumina alum is always dissociated in solution. A specimen made by combining pure aluminum sulphate with potassium sulphate was recrystallized ten times with thorough washing of the crystals. The presence of free sulphuric acid was as evident after the last recrystallization as before.

Ammonia ferric alum is also dissociated by solution.

Potash chrome alum.—This alum differs remarkably from the others. After two or three recrystallizations which of course must be made at low temperatures, the crystals may be dissolved in water without dissociation. The test liquid indicates that there is no free sulphuric acid present.

It appears therefore that this alum alone of its congeners exists as an alum in solution.

The alums consequently form a series with varying properties, according to the nature of the sesquisalt present. At the head stands chrome alum perfectly stable in solution; next alumina alum dissociated in solution but reforming itself by crystallization with the utmost facility; next ferric alum also dissociated and also reforming itself by crystallization but with less facility. And finally manganese alum whose violet octahedra are so completely dissociated by solution in pure water that they cannot be reproduced by crystallization.

4. *Acid Sulphates.*

At one time it was considered to be an established fact that the acid salts of the alkaline bases were completely decomposed by solution in water into neutral salt and free acid. In a review of this subject Berthelot quotes Andrews, and Favre and Silbermann as expressing this opinion positively and without question.[*] His own investigation led him to the conclusion that the separation was never complete, that a certain proportion of acid sulphate was always present, diminishing in proportion to the amount of water present; increasing in proportion to the amount of free acid. The formation of acid sulphate was always endothermic, was accompanied by the absorption of 1·05 cal. in the case of $NaHSO_4$.[†] He especially remarks that when a very small proportion of acid is added the tendency is to a complete combination in the form of acid salt.

This last mentioned result is contrary to that which I have been able to observe and I will therefore mention my reactions with some particularity.

I invariably found that when a trace of sulphuric acid was added to the solution of a neutral alkaline sulphate it reacted as free acid. The matter was examined especially in the following manner. To 40^{cc} of distilled water 2 drops of sulphuric acid were added, the liquid was divided into two equal parts in one of which was dissolved a gram of neutral sodium sulphate. These two liquids were then examined with the test solution and the detection of the acid was found to be fully as easy in the presence of the large excess of sodium sulphate as in the case of the acid alone.

It is true that this result is open to the following criticism. Alcohol extracts sulphuric acid from solid acid sodium sulphate showing thereby, as Mendeléef remarks, the extremely weak affinity which unites it to the neutral salt. In the present examination the test can only be used in alcoholic solution. It may be said that the alcohol first precipitates the solid acid sulphate and then abstracts free acid from it. There is force in this objection but I think it may be answered in the following manner. We first reduce sulphuric acid nearly to the limit of dilution and quantity at which it can be detected. We then find that the addition of a comparatively large quantity of neutral sulphate makes absolutely no change in the reaction. It seems therefore legitimate to conclude that no combination has taken place because otherwise it would be necessary to admit that alcohol can abstract all the acid united with the solid neutral sulphate, which is highly improbable.

* Mech. Chim., ii, 318.   † Mech. Ch., ii, 323.

The weight of the evidence seems therefore to favor complete decomposition by solution into neutral salt and free acid.

When herapathite is dehydrated either by long keeping over oil of vitriol, or by exposure to a temperature of 100° C. for several hours its color changes from green to dark brown and its luster is lost. In this condition it dissolves sparingly in boiling absolute alcohol and separates by cooling in blackish particles which show little trace of crystallization.

When the brown substance is placed in a vial with barium carbonate also dried, and absolute alcohol, scarcely a trace of action ensues. The liquid, even if kept warm, scarcely colors and the brown color of the salt is retained. The addition of a little water brings on rapid action. The dull brown color changes to bright metallic green and solution goes on steadily as the sulphuric acid is removed by the barium carbonate.

We thus have the curious result that two substances, both entirely insoluble in water, scarcely act on each other until water is present, and then a rapid decomposition results.

The question naturally presents itself whether it is necessary to first form and then decompose herapathite or whether a suitable test solution could not be obtained by simply acting on quinia with iodine. An iodine solution instantly produces in one of quinia a bulky precipitate of a light yellowish brown color, quickly redissolving if the solutions were not too strong and the liquid thus obtained if the iodine is not in excess, immediately forms herapathite on the addition of sulphuric acid.

But the reaction is not a delicate one; a trace of sulphuric acid cannot be detected as with the solution obtained from herapathite. The reason appears to be as follows : When pure herapathite is used the resulting solution contains absolutely no excess of either quinia or iodine. But, however carefully we may attempt to mix quinia and iodine we will always have a slight excess of one or the other and in either case the delicacy of its reaction is lost. If quinia is present in excess a trace of sulphuric acid is required to saturate it and it has been already mentioned that the test solution will not take sulphuric acid from quinia or from any other alkaloid. On the other hand, if iodine is present in excess the first action is to form one of the more highly iodised bases, more soluble than herapathite and crystallizing less well. So that in either case a trace of sulphuric acid is consumed before the proper reaction occurs and if only a trace is present the reaction may fail.

It is better therefore to prepare herapathite in the first place and a convenient means of obtaining it will be here given.

In a Griffin's beaker place 100^{cc} of alcohol of 95 per cent add 5 grams of quinia sulphate and 40^{cc} of acetic acid of 50 per cent. Take dilute sulphuric acid containing one-tenth by weight of acid and add of this 7^{cc}. Place the beaker in a water bath and apply heat till the alcohol begins to boil gently, then add with constant stirring 20^{cc} of a ten per cent solution of iodine. Turn off the heat, cover the beaker with a glass plate and allow it to cool slowly with the bath. Next day throw the crystals on a filter and wash with 70 per cent alcohol. Press between blotting paper and dry at ordinary temperature.

Herapathite appears to be a very permanent substance. Some that I prepared over thirty years ago has been kept in a stoppered but not sealed white glass bottle and freely exposed to light during this time. It appears to be quite unchanged and was used in part of the work just described.

In preparing the test solution time is gained by using the barium carbonate in considerable excess and by frequent shaking. The herapathite should be in fine powder. After the green particles have entirely disappeared, which will usually take a day or two, the solution must be filtered off and be placed in contact with a fresh portion of barium carbonate with frequent shaking for several days. The complete removal of the last traces of sulphuric acid cannot be judged of, as might be supposed, by allowing a portion to evaporate and examining for the crystals of herapathite. A specimen may dry up to a yellow varnish and yet may contain sulphuric acid as may be shown by evaporating to dryness with a little ammonia, exhausting the residue with very dilute hydrochloric acid and adding a drop of barium chloride solution. But there is a very much simpler and at the same time more effective means of testing. A solution is allowed to evaporate spontaneously after adding a drop or two of solution of oxalic acid. Then if there is the slightest trace of herapathite present it will show itself in extremely characteristic crystals, either small rosettes of black prisms or in thin light brown transparent plates which are black when crossed. A great many acids have this property of forcing out a crystallization, for example acetic, citric, tartaric, malic and even arsenic. On the other hand hydrochloric, hydrobromic and nitric acids have not this power.

The explanation appears to be this. Iodoquinia is a colloid and when present in large excess is able to prevent the crystallization of the relatively small proportion of herapathite present. The addition of either of the first named series of acids appears to convert the colloid base into a crystalline salt

which of course no longer interferes with the crystallization of the herapathite.

Method of applying the test.—After having ascertained in the above mentioned manner that the test solution is absolutely free from herapathite, a few drops of the liquid to be tested are to be placed in a small porcelain basin, a little alcohol added and then a few drops of test solution. When the quantity of sulphuric acid is something more than a trace an immediate black precipitate is formed. If the quantity is something less, no immediate result is visible but as the alcohol evaporates, it leaves behind a film of dark crystals which under a lens are easily recognizable. In this way a quantity of sulphuric acid amounting only to ·000015 gram, about $\frac{1}{66}$ of a milligram, can be detected with certainty provided the test solution is not used in too great excess. To detect so small a quantity however requires some familiarity with the reaction.

With larger quantities of free sulphuric acid the characteristic violet-black crystalline precipitate falls immediately. In dealing with quantities too small to cause precipitation it is advantageous to gently warm the basin beforehand; in this way a crystallization is obtained within two or three minutes and the danger of secondary reactions such as might be caused by the presence of oxidizing acids is diminished.[*]

The conclusions derived from the foregoing investigations may be briefly summed up as follows :—

1. The solution of iodoquinia affords the means of detecting free sulphuric acid even in traces in presence of combined sulphuric acid.

2. The salts of heavy metallic protoxides do not owe their acid reaction to dissociation. The solutions of their sulphates contain no free sulphuric acid. To this there is one exception. Solutions of ferrous sulphate always contain free sulphuric acid.

3. Sesquisulphates as far as examined are always dissociated in solution.

4. Alums are always dissociated in solution with a single notable exception. Chrome alum exists as such in solution.

5. Acid salts are dissociated in solution. The dissociation is very great and may perhaps be complete.

Philad., April, 1893.

[*] Very faint traces of free sulphuric acid are detected as follows: If the test liquid dries up without showing indications, 1 or 2^{cc} of alcohol are poured into the basin and slowly washed round. As the yellow film dissolves it may leave behind it a violet black film of herapathite which being much less soluble resists the action of the alcohol longer. This is a test of very great delicacy and the treatment with alcohol should never be omitted.

Art. LVIII.—*Mineralogical Notes;* by Alfred J. Moses.

1. *Pyrite Crystals from Kings Bridge, N. Y.*

THE crystals described in this paper were obtained on November 19, 1892, by G. F. Sherman and E. H. Messiter, students of the Columbia College School of Mines, from material recently quarried within 300 feet of the eastern end of the cut known as "the Harlem River Improvement" at Kings Bridge, New York City. The pyrite crystals were in a narrow cavity, in a block of limestone, associated with small crystals of dolomite, very pretty crystals of pale green transparent mica and curiously modified crystals of quartz. In a few instances minute crystals of rutile were also noticed.

The pyrite crystals are rarely more than $\frac{1}{4}$ inch in their longest dimension but a few were found almost $\frac{1}{2}$ inch in length. In most of the crystals the prevailing form is the octahedron always however modified by three or more other forms. The curious fact was noticed that in all the specimens showing quartz the general shape of the pyrite crystals was cubic and the crystals were relatively small. No large crystals of the cubic type were observed.

The angles were measured with a Mallard-Wollaston goniometer reading to half minutes. The angles obtained were:

	Measured.	Calculated.
$1 \wedge i-2$	$39°\ 13\frac{1}{2}'$	$39°\ 16'$
$1 \wedge 3-\frac{3}{2}$	$22°\ 14\frac{1}{2}'$	$22°\ 15'$
$1 \wedge 2-2$	$19°\ 25\frac{1}{2}'$	$19°\ 28'$
$H \wedge 2-2$	$35°\ 19'$	$35°\ 16'$
$i-2 \wedge 3-\frac{3}{2}$	$16°\ 59'$	$17°\ 1\frac{1}{2}'$

Closer results might have been obtained by readjustment but these were sufficiently exact to determine the symbols beyond question.

The occurring faces (see fig. 1) are therefore the common faces of pyrite: cube (100, $i-i$); octahedron (111, 1); and pentagonal dodecahedron (120, $i-2$); and the rarer forms: diploid (321, $3-\frac{3}{2}$) and tetragonal trisoctahedron (211, $2-2$).

In pyrite crystals striations are frequently found upon the faces of the cube and pyritohedron ($i-2$) parallel to the intersections of the faces of these forms and this is attributed to oscillations between the two forms. In the crystals from Kings Bridge all faces *except* those of the cube are more or less striated sometimes with only one or two very prominent lines, at other times in several directions and with many lines.

The accompanying figure (2) copies striations observed upon two crystals; the upper left hand octahedral face in particular is a fairly accurate reproduction. The striations on octahedral faces rarely if ever cross and in each face are parallel always

1.   2.
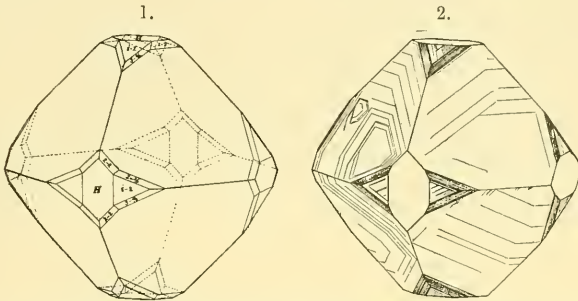
either to its intersections with the cube or with the pyritohedron *i*–2. The striations on the diploid and the pyritohedron were not parallel to intersections with the cube but to intersections with each other (or with the octahedron). No striations were observed on any cube face.

2. *Ettringite from Tombstone, Arizona, and a formula for Ettringite.*

The first specimen of this mineral I received over a year ago and proved it to be a hydrated sulphate of alumina and lime, but was prevented from making a complete examination by the small amount of material available. Since that time I have received and examined several other specimens.

The mineral was found by Mr. W. F. Staunton in an ore shoot in the white crystalline limestone of the Lucky-Cuss Mine, Tombstone, Arizona; just at the water level. It occurs incrusting a massive silicate of lime and alumina from which it has apparently been produced by the action of sulphuric acid, as it frequently fills little veins and hollows in the silicate and the latter is usually in these portions loosely coherent as if corroded.

In appearance the sulphate resembles a fibrous pectolite as it is made up of white somewhat translucent radiating fibers of a length up to one inch, or sometimes in little bunches of silky parallel fibers. No crystals have been found but the fibers are doubly refracting and appear to extinguish parallel to their length; cross fractures (or cleavage) approximately at right angles to the length are frequent. The hardness is a little over 2 and the specific gravity determined on 200^{mg} was 1·55.*

---

* If the silicate in the sample is assumed to be of the specific gravity of the silicate gangue (2·66) the gravity of the sulphate is reduced to 1·27, but the silicate near the sulphate is very much altered and probably nearer the gravity of the sulphate.

Before the blowpipe the mineral fuses readily coloring the flame red and forming a white enamel. On grinding it is damp and adhesive. Dissolves partially in water to an alkaline solution and is rapidly and completely decomposed by hydrochloric or even acetic acid.

It differs from the ettringite of Prof. Lehmann in that the latter occurs in needle-like hexagonal crystals, has a recorded specific gravity of 1·75 and is said to be infusible.

From the tendency of the portions of the silicate nearest the sulphate to crumble the material for analysis had to be picked almost fiber by fiber. Upon the purest sample thus obtained a complete analysis yielded :

	No. I. On ·2235 grms.
CaO	25·615
Al_2O_3	10·157
SO_3	17·675
H_2O (at 115°)	33·109
Loss (at red heat)	10·872
SiO_2	1·901
	99·329

The SiO_2 is present as a silicate more or less impregnated with metallic ores but which two analyses show to contain proportionately SiO_2 100 pts., CaO 27·89 pts., Al_2O_3 47·02 pts., H_2O (at 115°) 9·70 pts., H_2O (at red heat) 25·97 pts. Deducting in this proportion and recalculating to 100 we have :

	No. I (recalculated).
CaO	26·31
Al_2O_3	9·72
SO_3	18·54
H_2O (115°)	34·53
H_2O (red heat)	10·88

To prove that there had been no volatilization of SO_3 or reduction to sulphide during ignition ·2088 gms. of the mineral was dissolved in acid without ignition and the SO_3 and SiO_2 determined.

SO_3	15·066
SiO_2	9·909

Recalculated as in previous analysis this corresponded to SO_3 19·03.

An attempt was made to obtain another complete analysis on a sample of material not quite so pure as the first but in the ignition there was a loss of SO_3 due partly to reduction to

sulphide as evidenced by effervescence and odor in the subsequent solution, and also made evident by the very low result for SO_3. The comparison therefore fails for SO_3 and ignition. The other results were:

$$
\begin{array}{ll}
CaO & 24{\cdot}174 \\
Al_2O_3 & 8{\cdot}298 \\
H_2O\ (110°) & 30{\cdot}613 \\
H_2O\ (ignit.) & 15{\cdot}514 \\
SiO_2 & 3{\cdot}497 \\
\end{array}
$$

Recalculated as in No. 1 these correspond to

$$
\begin{array}{ll}
CaO & 25{\cdot}04 \\
Al_2O_3 & 7{\cdot}18 \\
H_2O\ (115°) & 32{\cdot}68 \\
H_2O\ (red\ heat) & 15{\cdot}76 \\
\end{array}
$$

Another determination yielded CaO 23·445, SiO_2 3·920. Recalculating as before we find CaO 25·55.

The comparison therefore is

| | Arizona mineral | | | | Ettringite of |
	No. I.	No. II.	No. III.	No. IV.	Ettringen.
CaO	26·31	25·04		25·55	27·27
Al_2O_3	9·72	7·18			7·76
SO_3	18·54		19·03		16·64
H_2O (115°)	34·53	32 68			} 45·82
H_2O (red heat)	10·88	15·76			
				Loss	2·51

If the loss in Prof. Lehmann's analysis is taken as SO_3 the comparison is still more striking and my own results in No. II proved the probability of such a loss.

Analysis No. I of the Arizona mineral was very satisfactory in all respects, needed very slight deductions and recalculations and I prefer to regard the other determinations as confirmatory but not worthy to be averaged with this of No. I. The formula suggested for ettringite was $6CaO$, Al_2O_3, $3SO_3$, $33H_2O$; but the analysis of No. I suggests a more simple formula very closely fitting the analysis.

	No. I.		Approximate ratio.
CaO	26·31 ÷ 56	·470	10
Al_2O_3	9·72 ÷ 102	·095	2
SO_3	18·54 ÷ 80	·232	5
H_2O (115°)	34·53 ÷ 18	1·918	40
H_2O (red heat)	10·88 ÷ 18	·605	14

This means a mineral of closely the type of felsöbányite $(2Al_2O_3 . SO_3 + 10H_2O)$, for the ratio yields $(H_{28}Ca_{10}Al_4)O_{30}(SO_3)_5 + 40H_2O$ or $2R_2O_3 . SO_3 + 8H_2O$. This formula not only suits the analysis of the Arizona mineral almost exactly but that of the Ettringen variety at least as well as the formula assumed as may be seen.

	Ettringite of Ettringen.	Ettringite of Arizona.	Percentages required by $(H_{28}Ca_{10}Al_4)O_{30}$ $(SO_3)_5 + 40H_2O$.	Percentages required by $6CaO, Al_2O_3, 3SO_3$ $32H_2O$.
CaO	27·27	26·31	26·21	26·4
Al_2O_3	7·76	9·72	9·55	8·0
SO_3	19·15	18·54	18·72	18·9
H_2O	45·82	45·41	45·50	46·7

We may therefore conclude that this mineral is to be placed in a group of hydrous basic sulphates of the general formula $2R_2O_3 . SO_3 + nH_2O$ and that the definite and close division between the loss at 115° and at red heat in my analysis supports the supposition that 14 pts. of H_2O may be considered as basic in the Arizona variety while the almost perfect agreement in total H_2O in the Arizona and Ettringen analyses makes a similar assertion for the latter not improbable.

The calculated ratio would yield the formula for the Arizona variety

$$H_{28}Ca_{10}Al_4O_{30} . 5SO_3 + 40H_2O$$
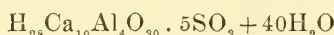
While the assumed formula for the Ettringen variety might be written

$$H_{18}Ca_6Al_2O_{18} . 3SO_3 + 24H_2O$$
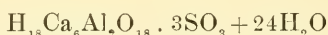
Both of these are of the type $2R_2O_3 . SO_3 + nH_2O$ and closely agree when reduced

Arizona variety $\quad 2[H_{1\frac{4}{5}}CaAl_{\frac{2}{5}}O_3] . SO_3 + 8H_2O$

Ettringen variety $\quad 2[H_3CaAl_{\frac{1}{3}}O_3] . SO_3 + 8H_2O$
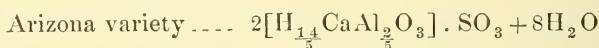
The group therefore of hydrous basic sulphates of the general formula $2R_2O_3 . SO_3 + nH_2O$ is composed of

Glockerite	$2Fe_2O_3 . SO_3 + 6H_2O$	Earthy or massive.
Felsöbányite	$2Al_2O_3 . SO_3 + 10H_2O$	Orthorhombic six sided scales.
Paraluminite	$2Al_2O_3 . SO_3 + 15H_2O$	Massive.

Ettringite
  Arizona $2[H_{1\frac{4}{5}}CaAl_{\frac{2}{5}}O_3].SO_3 + 8H_2O$ Silky double refracting fibers.
  Ettringen $2[H_3CaAl_{\frac{1}{3}}O_3].SO_3 + 8H_2O$ Hexagonal needle crystals.

Mineralogical Laboratory, Columbia College.

Art. LVIX.—*On Pentlandite from Sudbury, Ontario, Canada, with Remarks upon three supposed new species from the same Region ;* by S. L. Penfield.

Pentlandite.

Up to the present time the occurrence of pentlandite at the Sudbury nickel and copper mines has never, to the author's knowledge, been definitely proved. Some years ago Mr. F. L. Sperry, then chemist of the Canadian Copper Company, sent a suite of Sudbury ores to the Sheffield Scientific School and several of these were carefully analyzed by Mr. J. F. McKenzie, a student at the time in the Sheffield Laboratory. His results have been published only as a private contribution in the sixth edition of Dana's Mineralogy. Analysis 17, page 74, is of a nickeliferous pyrrhotite, with Fe = 56·39 and Ni = 4·66 per cent. Analysis 3, page 65, is of a normal sulphide of iron and nickel, with Fe = 25·81 and Ni = 39·85 per cent, the latter including a trace of cobalt. The specimen from which the material for the latter analysis was taken was a piece of massive ore, apparently very pure. The writer examined it carefully for indications of isometric crystallization or octahedral cleavage, but none could be found ; it seemed to break everywhere with irregular fracture. The specimen was referred, however, to the isometric pentlandite because it agreed better in its chemical composition with that species than with pyrrhotite.

Later, among the same lot of specimens sent by Mr. Sperry, a piece was found composed mostly of massive pyrrhotite but showing in places a mineral lighter in color and which broke with flat surfaces. On separating some of the latter it was found to differ from pyrrhotite in being non-magnetic and giving a strong reaction for nickel before the blowpipe. Moreover on a number of pieces the angle between the flat surfaces was measured twelve different times on the reflecting goniometer within the limits 70° 23′ and 70° 46′, giving as a mean 70° 33′, which agrees well with the angle of the isometric octahedron 70° 32′. Three of the above angles were measured in different zones on a single fragment. There is no doubt, therefore, but that the mineral in question is isometric. The flat surfaces are apparently not the result of an octahedral cleavage but rather planes of parting, of secondary origin, similar to the octahedral parting observed on some varieties of magnetite.* The fracture of the mineral is irregular and the

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* A. Cathrein, Zeitschr. Kryst., xii, p. 47, 1886. O. Müggs, Jahrb. Min., i, p. 244, 1889. J. F. Kemp. This Journal, xl, p. 62, 1890.

distinct parting was observed only at certain intervals. The attempt to cleave from a given piece an octahedron was not successful and among a great many fragments which were examined only one was found with a distinct octahedral shape. This octahedral parting, rather than cleavage, is perhaps characteristic of the pentlandite from the original locality in Lillehammer, southern Norway. Scheerer in his original article* describes it as follows: " Molecular structure : Foliated parallel to the faces of a regular octahedron. Fracture : in places which show no foliation, fine-grained to conchoidal."†

As the associated pyrrhotite was strongly magnetic the separation of the two minerals could readily be made. The ore was crushed and sifted to a grain of from $1 - 2^{mm}$ in diameter and the pyrrhotite was extracted by means of an ordinary magnet. The pentlandite for analysis was further carefully selected by hand picking. The specific gravity of this portion was found to be 5·006. This was so much higher than that given by Scheerer, 4·60, that a second sample was separated which gave 4·946. The pure mineral had a pale yellowish bronze color, between that of pyrite and pyrrhotite. The analysis is as follows :

		Ratio.	
S	33·42	1·044	
Fe	30·25	·451 ⎫	
Ni	34·23	·582 ⎬ 1·047	
Co	·85	·014 ⎭	
Gangue	·67		
	99·42		

The gangue was silica which had undoubtedly separated from some decomposable silicate, but no attempt was made to determine the small amount of bases in combination with it. The ratio of S : (Fe + Ni) is 1·044 : 1·047, almost exactly 1 : 1 or that of a normal sulphide. The ratio of Fe : Ni is 1 : 1·32 while in pentlandite from Lillehammer it is about 2 : 1.

On three supposed new Sulphides of Iron and Nickel from the Sudbury Region.

Folgerite.

In a recent number of the Journal of the American Chemical Society,‡ Dr. S. H. Emmens has described as a new species

* Pogg. Ann , lviii, p. 315, 1843.
† "Innere Form : Blätterdurch gänge parallel den Flächen eines regulären Octaëders. Bruch : auf Stellen wo sich keine Blätterdurehgänge zeigen, fein-körnig in's Muschlige."
‡ Vol. xiv, No. 7.

a sulphide from the Worthington Mine, on the Algoma Branch of the Canadian Pacific Railroad, about 30 miles southwest of Sudbury. To this mineral he has given the name folgerite. From his description and the analyses it is evident that folgerite is identical with the pentlandite just described. His discription of the physical properties agrees fairly well. "A fragment associated with adhering pyrrhotite showed a sp. gr. of 4·73" while that of pentlandite is 5·00. "Form, massive, with a platy structure. No crystals have as yet been observed." This description of the platy structure corresponds to some specimens of pentlandite which were seen at the laboratory of the late Prof. F. A. Genth, only a few weeks before his death. He was about to examine the mineral and had obtained specimens of the Sudbury ores from the Canadian Geological Survey. His material was much better than that examined by the author, in that it showed larger patches of the pentlandite in the pyrrhotite. The octahedral parting, developed especially in one direction, gave the platy structure noted by Dr. Emmens. A most remarkable statement by Dr. Emmens can not be readily understood. "Magnetism—In large fragments the mineral is non-magnetic. In minute grains it is magnetic. The finely triturated powder is non-magnetic." The formula proposed for this mineral is $NiFeS_2$ deduced from the following analyses by Mr. C. T. Mixer, in all of which the sulphur was determined by difference. One direct determination of sulphur in a fourth sample gave 34 per cent.

	A	B	C	Calculated for $NiFeS_2$
Ni	35·20	31·45	29·78	32·87
Fe	33·70	31·01	26·89	31·30
S	31·10	37·54	43·33	35·83
	100·00	100·00	100·00	100·00

It is evident that the above are all analyses of pentlandite or of some mixture in which it predominates. They differ from the analyses of the pentlandite from Lillehammer chiefly in the relative proportion of iron and nickel, which, being isomorphous, may replace one another through a wide range. The agreement between the separate analyses and theory is far from satisfactory and certainly for the establishment of a new mineral species a direct determination of the important constituent, sulphur, should have been made. There is, therefore, no sufficient ground for making a new species of this mineral and it is to be hoped that folgerite will never find a place in mineralogical literature.

Blueite.

Under this name Dr. Emmens has described a massive sulphide ore, which is found in several mines of the Sudbury district, notably at the workings of the Emmens Metal Company, where it is found associated with niccolite, gersdorffite, pyrrhotite and chalcopyrite." The following are some of its properties. "Luster,—Metallic, somewhat silky. Color,— pale olive-gray, inclining to bronze. Specific gravity, 4·2. Form, Massive,—No crystals have as yet been observed. Solubility.—The mineral dissolves readily in nitric acid without separation of sulphur and yields a yellow solution.—Magnetism. —The mineral is non-magnetic."

The chemical analysis is given under A. B, is the same after deducting the insoluble and recalculating to 100 per cent. The theoretical composition, calculated for the proposed formula $Fe_{12}NiS_{26}$ is given under C.

	A	B	C
Ni	3·5	3·70	3·76
Fe	38 8	41·01	42·96
S (by difference)	52·3	55·29	53·28
Insoluble	5·4	----	----
	100·00	100·00	100·00

The reasons given for making a new species of this mineral are "the considerable percentage of nickel (a very rare element in pyrite) and the easy solubility in nitric acid without separation of sulphur." Although it must be admitted that nickel is a rare constituent in pyrite, yet nickeliferous pyrites are known, and at Sudbury in particular, where iron and nickel are so abundant, we might expect to find a mutual replacement of these elements. Moreover the analysis was made on massive material; there is no guarantee of the purity of the mineral and the sulphur was determined by difference. The character of the gangue is not stated and certainly no proof has been given that the nickel has not been derived from some impurity. That the mineral dissolves in nitric acid without the separation of sulphur can not be made a ground for separating it from pyrite, for it is an easy matter to oxidize and dissolve the latter completely, if the nitric acid is strong and relatively in large quantity compared with the amount of mineral to be dissolved.

Whartonite.

Under this name Dr. Emmens describes a sulphide from the Blezard Mine, about seven miles northeast of Sudbury. The

following are some of its properties.   " Color,—Bronze-yellow. Luster,—Metallic.   Form,—Cellular; the cavities being lined with minute cubic crystals and the intermediate substance being finely granular.   Solubility,—The mineral is soluble in HNO_3 with separation of sulphur and a greenish yellow solution. Magnetism,—On comminution about 10 per cent of the mineral is found to be magnetic."   The analyses are as follows.

A, of the mixture ; B, Magnetic portion ; C, non-magnetic portion ; D, after deducting insoluble and ten per cent of magnetite from A and calculating to 100 per cent ; E, theory for the proposed formula Fe_7NiS_{16}.

	A	B	C	D	E
Ni _____	5·40			6·27	6·10
Fe _____	42·90	66·55	40·4	41·44	40·68
S _____	45·00	7·00	52·6	52·29	53·22
Insoluble__	4·80			- - - -	- - - -
	98·10			100·00	100·00

Here it is known that the analyzed material is a mixture and even if it were proved that the Sudbury pyrite is nickeliferous, to the extent indicated by analysis D, it would not be best to make a new species, for certainly the replacement of a part of the iron by nickel is nothing but an illustration of the common law of isomorphism.

Blueite and whartonite, therefore, like folgerite cannot be recognized as distinct species.   It is clear that little dependance can be placed upon chemical formulas deduced from analyses of material of such doubtful purity, especially where a chief constituent is determined by difference.

Mineralogical Laboratory,
Sheffield Scientific School, March, 1893.

Art. LX.—*Notes on the Geology of Florida : Two of the lesser but typical Phosphate Fields ;* by Lawrence C. Johnson, U. S. Geological Survey.

[Presented, with the permission of the Director.]

A.   The Geology of the Gainesville Sheet—or the " Land-pebble" phosphates of Eastern Alachua County.

Commencing with Lake Santa Fe, in the north, we find it, and Nunan Lake, to the southwest of it, both surrounded by a flat sandy country destitute of " sinks " and of rock exposures

* Before the Geological Society of America, Rochester, N. Y., Aug., 1892.

of any kind. Some distance off, however, to the westward of the former and about four miles west of Waldo, is a small exposure known as the Preston Marl, near old Fort Harlee; and seven or eight miles still farther northwestward in Bradford County, is another large sink. Both these exhibit formations of Miocene age. The small streams also, which traverse these flat woods, including Santa Fè river and several of its affluents, and Lockloosa creek rising by several small branches from the eastern end of Lake Santa Fè, have in them or in their immediate valleys, driftlike sediments, containing casts of fossils similar to those of Waldo. These flatwoods are said to have a general elevation of about 150 feet above tide water.

It is well to acknowledge here in advance, the assistance derived from the topograpical sheets of the Geological Survey.

Between Nunan Lake, and the great Alachua Sink or Lake, to the westward, are a number of exposures of clays, and phosphatic sandstones,—the latter being known as the Gainesville "Paving-rock." These may be regarded as alteration products of older Miocene beds. Fossils are rare; but traces exist of a *Venus*, a *Pecten*, and there is no scarcity of reptilian bones. Teeth of sharks and rays are quite numerous. In other parts of the region having this structure, and the *tufa*-like Gainesville Paving-rock, there are ferruginous marly sands with chalcedonized oyster shells not distinguishable from *O. Virginiana*, and there are also abundant patches of the large coral *Astrea Floridana* (or *bella*.) The contour lines of the Survey give the elevations of these deposits of the coral, and oysters and Gainesville rock at 70–100 feet.

At the great Alachua Sink, twenty feet lower than the lowest Gainesville rock of the adjoining hills, the formation is Eocene of the Vicksburg type.

For ten or twelve miles westward of this sink, and of Lake Nunan, the same relative position of the strata continues, with a constant gain to the Eocene rocks; until they reach the elevation of near 100 feet, and the Gainesville rock disappears, or becomes very thin and represented by its alternate clay. This probably signifies a small dip of the Eocene to the eastward; in which direction, it sinks under Miocene clays and marls.

The region south of Gainesville, a distance of ten miles, is one of apparent depression. Within it are contained Payne's Prairie—lately Lake Alachua[*]—the Kanapaha Prairie, and the Hogtown and Sugarfoot Prairies and Sinks. To the southeast of Payne's Prairie lie series of ponds and small cypress

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[*] Alachua Lake was a *prairie*, from the oldest record, till 1878, when after great rains it became a lake of 40 sq. miles. Again in June, 1891, after a series of four dry years, it suddenly dried off. Immense numbers of fish were taken or destroyed. And now, July, 1892, after a month of heavy rains, the water is reclaiming possession of the flats

swamps by which it is connected with Orange Lake. The elevated ridges of this section are, like the Flatwoods region of Lake Nunan, Miocene. The depressions usually expose Vicksburg rocks, silicified. These outcrop in many old sinks upon Payne's Prairie and about the various ponds. None however on the hills, and none at the northern end of Orange Lake and Lockloosa Lake, its northeastern extension. The southern end of Orange Lake, and Tuscawilla Lake—separated from it by hammock ridges 100 feet high—expose Eocene rocks.

Orange Lake—like so many others which have an Eocene bottom—has a subterranean outlet. And less than a mile north of this " sink," it has within its basin, a " rise "—one of the great springs, so common in the Vicksburg formation of Florida. The lake has its overland outlet also in time of high water, through Orange Creek into Oklawaha River. Over all the foregoing region it is evident that great denudations have taken place, and that from 40 to 100 feet of Miocene marls and later sands have been removed : a history only to be understood upon the Hilgard hypothesis of an elevation of 600 feet and over, in Post-Tertiary times.

It is in the elevated region about Gainesville, the " Land-pebble " phosphates of Alachua occur. The derivation of these pebbles can hardly have been from beds of compact stone, whatever theory may obtain for other parts of the State. For several reasons :

First. The elevation assigned the pebble beds of this region is 150 feet above tide water. No known beds of compact hard rock occur above 75–100 feet.

Secondly. The pebbles are largely fossil casts or fragments of such casts ; and it may well be assumed they had their origin in a fossiliferous marl, which by disintegration and removal of the calcium carbonates, left behind the less soluble phosphates. The aggregation of phosphatic matter in fossil forms contained in marls is well known. According to Dr. Eugene A. Smith, all the shell casts in Cretaceous rocks, as well as in those of Tertiary age, of Alabama and Mississippi, are phosphatic.

Third. Compact phosphate is not composed of fossils ; nor are its beds especially fossiliferous ; though phosphatic rock containing fossils may locally occur by metamorphosis of the original limestones upon which phosphate beds were deposited.

B. The " Plate-rock" Deposits of Eastern Marion County.

The term " plate-rock " is the mining term applied to fragmentary thin flat pieces of " Hard-rock " phosphates. It analyzes as high as any, namely : about 80 to 85 per cent tribasic calcium phosphate.

The area embracing these deposits lies some twenty miles
eastward of the main belt of "hard-rock" phosphates, and
extends from Citra on the southeastward bay of Orange Lake
to the southwestern extension of Lake Wier, and to Wildwood
in Sumter County, a distance of 40 miles, with an average
width of 1½ to 3 miles.

Within this region the first mining was done by the "Penin-
sula Phosphate Company," near Anthony, 10 miles north of
Ocala, in 1890. Other works and mines have been since under-
taken at Citra, Sparr, Montagne, Welshton, Belleview and
Summerfield—stations on the line of the "Florida Central
and Peninsular," and "Florida Southern" Railroads. In only
a few of these places, however, have excavations been suffi-
ciently extensive to afford a complete insight into the nature
extent and value of the deposits, yet in the smallest *prospect*
hole, some facts of value are found.

The following figure may give a fair notion of the general
mode of occurrence of this class of phosphates.

1.
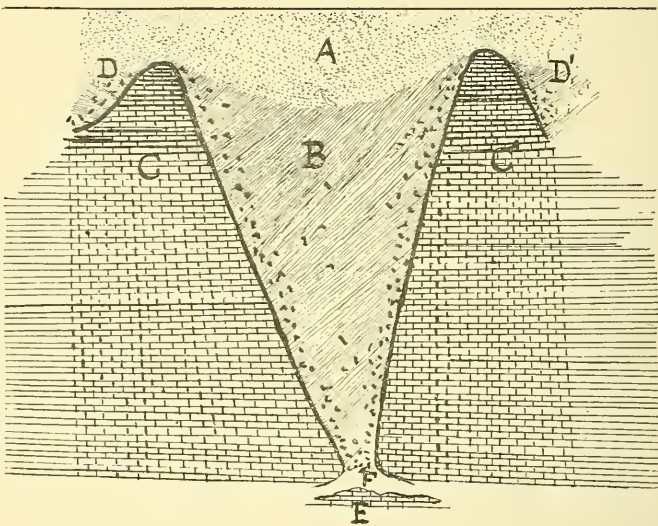
Excavation in progress at "The Ohio Mining Co's" works, Sparr, Fla. This
mine is selected from scores examined, on account of its exceeding regularity.

A, "Overburthen"—soil and sand—8 ft. in its greatest thickness.

B. Great mass of "Soft-phosphate," and matrix of the fragments of "Plate-
rock," narrowing to 2 ft. at bottom—30 feet deep.

C, C′, The two buttresses or pinnacles of Vicksburg limestone—by the miners
called "Lime-horses."

C is 33 feet high, C′ 34 ft.

D, D′, Trial excavations just begun.

E, Calcite rock beneath ; F, The drainage cavity.

This pit is 38 feet deep, from the top of sandy soil, to the cavity at the base. It is 28 feet across between the tops of the pinnacles, which are 2 feet apart at the base, where the cavity opens. The " plate-rock " is the thin layer next the limestone shoulder imbedded in the interior matrix of " soft-phosphate " —a little argillaceous. This

" Plate-rock "   carries 79½ per cent tribasic phosphate of lime.
The soft phos. matrix   "   69   "   "   "   "   "

Attention is called in this section :

(1) To the " overburthen " of surface sand which, on the tops of the pinnacles of limestone, is approximately 4 feet, while in the center it is sunken and grades to 8 feet in depth.

(2) To the filling between the pinnacles, which is chiefly " soft-phosphate," a substance of clay-like appearance and consistency, of a creamy color. It is very variable in its phosphate of lime—often high in alumina and iron. In this instance it is a 69 per cent phosphate.

(3) To the comparatively small portions, 1–3 feet thick next the limestone sloping walls, containing the angular fragments of " plate-rock." This portion of the deposit alone is considered of commercial importance. In working the mine, the matrix, however rich in phosphoric acid, is washed away.

(4) To the opening at the bottom, between the base of the pinnacles, connected with a subterranean drainage. This is not universal in all the pits, but so general, as in those at Anthony, that it may be considered as a phenomenon of all the deposits in this elevated region. When the elevation is small, as at Welshton, no opening to take off the leachings has, as yet, been observed. However, mining there has progressed but little.

(5) The " pinnacles " are evidently upward projections of the bed-rock Eocene limestone of the country. They are seen in these excavations (and in all of them except one great pit of the Pen. Phos. Co. northward of Sparr) without definite order or arrangement and of all sizes and shapes. The walls are often sloping as in the figure, often vertical and eroded into hollows and into deep round wells or pot-holes, washed out by the waves of a restless sea.

It would be tedious to enumerate all the mines in this region, and comment on the peculiarities of each, and it would serve no general purpose. Suffice it to say, the variations are principally in the phenomena of erosion, both before and subsequent to the deposition of the phosphates. Of these the general facts are about the same.

Reference has been made to the occurrence of fossils within the workable deposits. There are none, with only one excep-

tion as yet observed—at Belleview on the Florida Central and
Peninsula railroad, 12 miles south of Ocala. The remains are
chalcedonized oyster shells. As related by the manager of the
mine they are associated with the "plate-rock" next the
shoulders of Eocene limestone. As observed by the writer in
an abandoned pit, where it was said they had been numerous,
the shells of *Ostrea Virginiana* were still adhering to the
rock, evidently undisturbed since the day they attached them-
selves, and grew there.

B. Genesis of the Plate-Rock Deposits.

The problems presented by the foregoing facts are : (*a*) To
account for compact phosphate ; (*b*) To account for the "soft-
phosphate" phase ; (*c*) To account for the presence therein of
"*plate-rock.*"

Peninsular Florida first appeared above water in early Mio-
cene times, in the form of numerous small islands of Eocene
limestone, stretched along what would later be the Gulf coast
—corresponding in position to parts of the present counties—
Suwanee, Columbia, Lafayette, Levy, Hernando, Citrus, Pasco,
Sumter, and the western parts of Marion and Alachua.
Twenty miles eastward of this main line facing the Gulf, was
this smaller cluster of islets we have under consideration, then
braving the Atlantic. Denudation of these islands by the sea
imparted to them at many points the water-worn low bluffs
with pinnacles, such as are visible on any part of the present
coast composed of rocks like these. Notably may be instanced,
St. Mark's Bay, and Deadman's Bay, of the Gulf side. Upon
shores of this nature were laid down the deposits described in
the foregoing pages.

The varieties of this class of phosphates in Marion County
alone, comprise in mining language "hard rock," "laminated-
rock," "plate-rock" and "soft-phosphate."

The explanation offered herewith of the *genesis* of these
phosphates, is based upon the hypothesis of the original depo-
sition of *guano*.

In a rainless region the deposits would have remained in
form similar to those of the Chincha islands. In the present
case in a region of much rain and great moisture, the guano
beds became converted into the phosphates here encountered.
The arrangement of land and sea in the Miocene age rendered
the deposition of immense deposits of *guano* quite possible.
Only upon such secure island homes, away from the predatory
animals of the continent, could the sea-birds have successfully
maintained their breeding grounds. The waters of such an
archipelago at that age teemed with life, which with the rich
vegetation of warm shallow seas afforded ample food.

Having the material deposited, adequate to furnishing a supply of phosphoric acid, the process of change to the present forms followed as a natural consequence, from the attendant circumstances in due course of *law*. The guano beds after the leaching out of their carbonates and other soluble materials, became very compact, yet not entirely impervious to water. It is probable that some waste of material by solution is continued in degree to the present day.

Cavities are found in the most compact beds of the "hardest rock." Small cavities in close contiguity became finally separated by mere plates, and in this condition are called "*laminated-rock*."

By further disintegration such laminated rock is broken up into fragments greater or less, and is then "plate-rock"—such as is found mixed up with more finely comminuted material in the deposits of Anthony and Sparr and Fairview clinging to the walls of the pinnacles of Eocene limestone.

Still further progress of the disintegrating process results in the masses of "soft-phosphate"—the impurity of the final material depending in part upon the amount of clay originally contained in the immense deposits of the original rock, and partly upon the amount of extraneous matter washed in.

That the fragments of "plate-rock" should cling to the walls of the pits is the natural result of drainage being more energetic in the center of the hopper than at the sides; at the same time the middle portions become dissolved or reduced more quickly and more completely than the exterior.

Art. LXI.—*On Electrical Oscillations of Low Frequency and their Resonance;* by M. I. Pupin, Ph.D., Columbia College.

Part II.

V. *Electrical Resonance in mutually inductive circuits.*

a. The impressed Electromotive force is a simple harmonic. —The primary circuit consists of a coil which is in series with a condenser and an alternating current machine which generates the impressed e. m. f. $E \sin pt$. The secondary circuit consists of a coil joined in series to a condenser. The secondary coil consists of several parts, some or all of which are under the inductive action of the primary circuit. The

electrostatic capacity of the coils is small in comparison to the capacity of the terminal condensers. *Foucault currents and hysteresis losses are supposed to be negligibly small.* The symbolical expressions of the generalized form of Ohm's law will be, in the well-known notation of Maxwell :—

$$\left. \begin{array}{l} \text{L}\dfrac{dx}{dt} \ + \ \text{M}\dfrac{dy}{dt} \ + \ \text{R}x + \text{P}_1 = \text{E}\sin pt \\[2mm] \text{N}\dfrac{dy}{dt} \ + \ \text{M}\dfrac{dx}{dt} \ + \ \text{S}y + \text{P}_2 = 0 \ . \ . \ . \end{array} \right\} \quad (9)$$

Remembering that a circuit consisting of coils whose coefficient of self-induction is L and a condenser of capacity C in series with these coils may be treated analytically like a closed circuit with no capacity but having a coefficient of self-induction equal to $\dfrac{1}{p^2 C}-\text{L}$,[*] where p is the pulsation of the impressed e. m. f., it is clear that the integrals of (9) are obtained from the well-known integrals of the ideal transformer [†] by the following substitutions :—

$$\text{L}_1 = \frac{1}{p^2\text{C}_1} - \text{L} \qquad\qquad \text{L}' = \text{L}_1 - \frac{p^2\text{M}^2\text{N}_1}{p^2\text{N}_1{}^2 + \text{S}^2}$$

$$\text{N}_1 = \frac{1}{p^2\text{C}_2} - \text{N} \qquad\qquad \text{R}' = \text{R} + \frac{p^2\text{M}^2\text{S}}{p^2\text{N}_1{}^2 + \text{S}^2}.$$

When the circuits are in resonance to the impressed e. m. f. then both L_1 and N_1 are zero. Hence

$$\left. \begin{array}{l} x = \dfrac{\text{SE}}{p^2\text{M}^2 + \text{RS}} \ \sin \ pt \ . \ . \ . \ . \\[3mm] y = \dfrac{p\text{ME}}{p^2\text{M}^2 + \text{RS}} \ \cos \ pt \ . \ . \ . \ . \end{array} \right\} \quad (10)$$

The corresponding amplitudes of the condenser potential differences are given by

$$\left. \begin{array}{l} \text{P}_1{}' = p\text{L} \ \dfrac{\text{SE}}{p^2\text{M}^2 + \text{RS}} \ . \ . \ . \ . \\[3mm] \text{P}_2{}' = p\text{N} \ \dfrac{p\text{ME}}{p^2\text{M}^2 + \text{RS}} \ . \ . \ . \ . \end{array} \right\} \quad (11)$$

Let $\text{W}_1 =$ work done in the primary circuit.
$\text{W}_2 =$ heat developed in primary circuit.

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[*] See this Journal, May 1893, p. 425, footnote.
[†] Fleming: Alternate Current Transformer, vol. 1, p. 154.
Pupin: Practical Aspects of the Alternating Current Theory, Transactions of the American Institute of Electrical Engineers, Vol. vii, May 1890.

Hence $W_1 - W_2 =$ work transferred from the primary to the secondary circuit.

$$\frac{W_1 - W_2}{W_1} = \varepsilon = \text{ratio of transference.}$$

A simple calculation gives

$$\varepsilon = \frac{p^2 M^2}{p^2 M^2 + RS}.$$

The higher the frequency the higher will be the ratio of transference other things being equal. The curves expressing
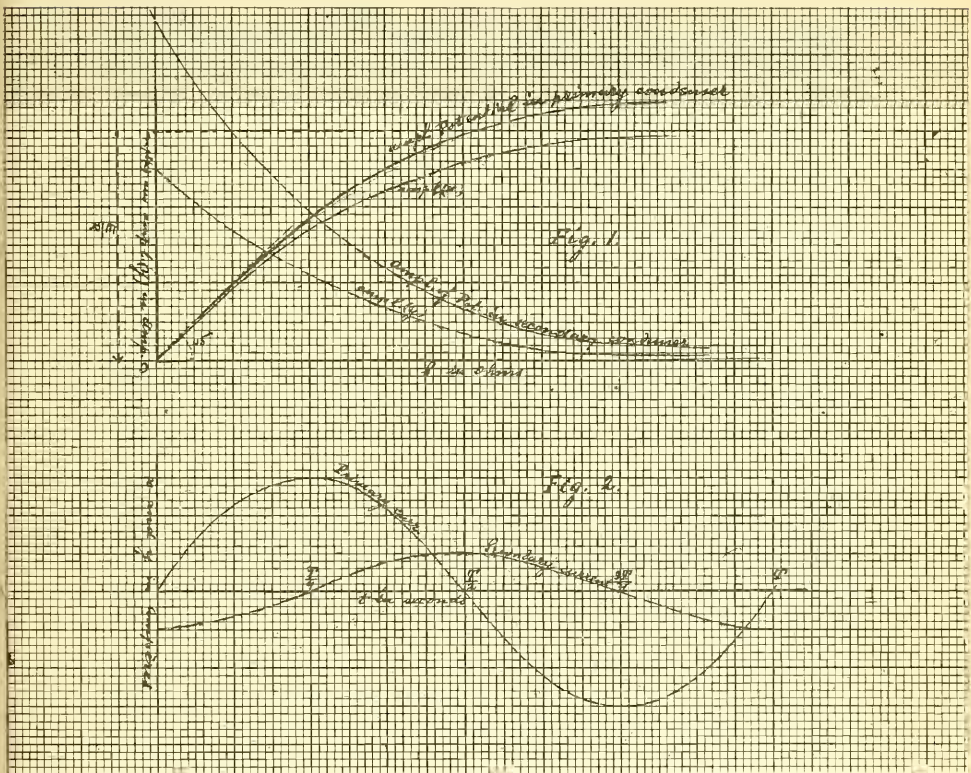
the relation between the resistance in the secondary circuit as abscissæ and the amplitudes of primary and secondary currents and potential differences in primary and secondary condenser

as ordinates are given in Fig. 1. The current curves are given in Fig. 2. (I am very sorry that these diagrams have come out very indistinct in the reproduction.)

With small resistance in the secondary the efficiency is high but the output is very low, and vice versa, when the resistance in the secondary is large then the primary current is large but the efficiency is low.

With ordinary transformers we have just the opposite relations, namely, the lower the resistance in the secondary the larger is the current in the primary. Here, however, owing to the fact that the counter electromotive force in the primary produced by the variation of the secondary current differs by half a period in phase from the primary impressed e. m. f., it is evident that the larger the secondary current the smaller is the effective e. m. f. in the primary circuit and hence the smaller is the current.

Let E_c = counter electromotive force in the primary due to variation of the secondary current.

Then
$$E_c = M \frac{dy}{dt} = -\frac{p^2 M^2 E}{p^2 M^2 + RS} \sin pt.$$

Hence effective e. m. f. in the primary

$$= E \sin pt - E_c$$
$$= \frac{RSE}{p^2 M^2 + RS} \sin pt.$$

When $S = 0$ then the primary current would be equal to zero but the secondary would have its highest value

$$= \frac{E}{pM}.$$

These few remarks seem sufficient to clear up the rather surprising relations which the curves in fig. 1 illustrate.

When the frequency is very high, say 10^4 periods per second, then as long as S does not increase beyond the value at which RS is comparable to $p^2 M^2$ so long will

$$\left.\begin{array}{l} x = \dfrac{SE}{p^2 M^2} \sin pt \ . \ . \ . \ . \\[2ex] y = \dfrac{E}{pM} \cos pt \ . \ . \ . \ . \\[2ex] P_1' = pL \dfrac{SE}{p^2 M^2} \ . \ . \ . \ . \ . \\[2ex] P_2' = pN \dfrac{E}{pM} \ . \ . \ . \ . \ . \ . \end{array}\right\} \quad (10^a)$$

Denoting the limiting values of these quantities (for $S = \infty$) by brackets we shall have

$$(x) \;=\; \frac{\mathrm{E}}{\mathrm{R}} \, \sin\, pt$$
$$(y) \;=\; 0$$
$$(\mathrm{P_1}') \;=\; \frac{p\mathrm{L}}{\mathrm{R}} \; \mathrm{E} \qquad (11^a)$$
$$(\mathrm{P_2}') \;=\; 0$$

as it should be.

The curves given in fig. 1, fig. 2 hold true in this case also but with this characteristic difference that for all variations of S between 0 and a considerably large limit (especially if R is very small, as in the case of Tesla's high frequency circuits) the secondary current and secondary potential are practically constant. The higher the frequency the larger is this limit.

More than ordinary interest is attached to the relations given in (10^a), because they give an approximately correct account of the electrical flow in the secondary circuit of an induction coil when the primary is excited by a Tesla high frequency alternator, the primary coil of the induction transformer, a condenser of suitable capacity and the alternator being connected in series. It must be observed, however, that since in general the induction coil which Mr. Tesla employs in his experiments does not differ essentially from the ordinary induction coil except that practically no iron is used—it is evident that the secondary coil has distributed capacity which if not necessarily as large as the capacity which would bring this circuit in resonance to the impressed e. m. f. at Mr. Tesla's high frequencies is certainly far from being negligibly small in comparison to it. For this reason equations (10^a) do not give the exact mathematical relations of Mr. Tesla's circuits. It is evident, however, that the values which these equations assign to the secondary current and secondary potential are the largest values which Mr. Tesla's circuits can possibly yield.

I do not find a single discrepancy between the theory just given and Mr. Tesla's experimental results. A full discussion of these results from the standpoint of this theory would lead me far beyond the limits of this paper. A few brief observations relative to the agreement between theory and Mr. Tesla's experiments[*] seem desirable :

a. On account of the considerable internal capacity of Mr. Tesla's induction coils there is a critical speed of the generator at which a large secondary coil by its own internal capacity will be in resonance to the impressed e. m. f. If it is desira-

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[*] See Mr. Nikola Tesla's lecture in the N. Y. Electrical World, vol. xviii, July 11, 1891, p. 20.

ble to add capacity to the terminals of the secondary coil then the speed of the alternator must be below this critical point.

b. By diminishing the speed it is possible to increase the terminal capacity without diminishing perceptibly the secondary voltage. Hence the secondary current will be thereby increased and therefore the physiological effect of a lower frequency Tesla current may be considerably more powerful than that of the higher frequency.

c. At very high frequencies, say 10^4 periods per second the Tesla current will in general be exceedingly small, considering that the impressed e. m. f. of his generator is about 140 volts only. Hence the physiological effect of these currents will also be small. (But I do not wish to be understood as denying that the rapidity of reversals in itself diminishes the physiological effect.)

d. Since the rise of potential will be the higher the smaller the dissipation of the work which the impressed e. m. f. does it is evident that dielectric hysteresis, in consequence of which the dielectrics are heated, will pull down considerably the secondary voltage. It is therefore desirable to employ liquid or solid dielectrics of small specific inductive capacity, since in these the heating due to dielectric hysteresis is smaller than in dielectrics of high inductive capacity.

e. It is evident that by a suitable diminution of the coefficient of mutual induction M within the limits within which $p^2 M^2$ is considerably larger than RS for the highest value of S at which the high frequency system is expected to run both the secondary current and the secondary e. m. f. can be increased very considerably. This•could be done by dividing the secondary coil into two parts and allowing one part only (and that too probably the smaller part) to surround the primary coil, in which case the remaining part would be employed as additional inertia coil in the secondary circuit, this inertia coil performing the function of assisting the impressed e. m. f. to produce a high rise of potential in the secondary circuit. In one of his papers* Mr. Tesla mentions that, by removing partly the primary coil from the secondary, higher potentials can sometimes be produced, and the output of the secondary circuit very much increased. "*St. Elmo's Hot Fire*" is the name which Mr. Tesla gives to the powerful flame discharge obtained, by this arrangement of the two coils, from one of the secondary poles, when the other pole (the terminal of the secondary turns which are nearest to the primary coil) is connected either to the primary or to a body having considerable capacity. Mr. Tesla states that his object in arranging the

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* See Mr. Tesla's article cited above, p. 23.

Chas. D. Walcott.

coils in the manner just described was for the purpose of avoiding the brush discharges between the primary and the secondary coils. He does not seem to have been aware at that time of the fact that by this method of arranging the two coils it is possible to obtain another and probably quite as important advantage, namely : to diminish the number of turns in the secondary coil very much and thus diminish its resistance, capacity and self-induction and all the evils connected therewith and therefore to increase the secondary terminal capacity and potential. In such an arrangement the relations of (10^a) are very nearly true and the nearer they are to the truth the higher will be the output and the efficiency of the high frequency system.

These few observations will suffice to point out that on the one hand the high frequency currents as developed by Mr. Tesla are resonant electrical oscillations, whose period is very long in comparison to the period of Herzian oscillations, and that on the other hand their mathematical theory is simply the theory of the ordinary low frequency resonance given in this and the preceding paper.

It is my pleasant duty to thank Mr. Tesla on this occasion for the favor which he conferred upon me by lending me his remarkable apparatus for a few days. My short experience with it has taught me many an instructive lesson for which I feel very grateful to Mr. Tesla.

Before describing some of my experiments on resonance in mutually inductive circuits with low frequency impressed e. m. f. it seems desirable to point out the relations in mutually inductive circuits when the primary circuit contains no condenser.

When an alternator containing iron in the armature is employed to generate the impressed e. m. f. then this method of arranging the circuits must be adopted in experiments on resonance, especially when the frequency is over 100 periods per second. The reason for this will be apparent further below. For this arrangement of the circuits we shall have when resonance is established in the secondary circuit

$$x = \frac{ES}{\sqrt{p^2L^2S^2 + (p^2M^2 + RS)^2}} \sin(pt - \varphi) \qquad (13)$$

$$y = \frac{pME}{\sqrt{p^2L^2S^2 + (p^2M^2 + RS)^2}} \sin(pt - \psi) \qquad (14)$$

$$\tan \varphi = - \cot \psi = \frac{pLS}{p^2M^2 + RS}.$$

Hence
$$\varphi = \frac{\pi}{2} + \psi.$$

Let P_2 = amplitude of the potential difference in the secondary condenser, then

$$P_2 = pN \frac{pME}{\sqrt{p^2L^2S^2 + (p^2M^2 + RS)^2}}.$$ (15)

When R^2 is small in comparison to p^2L^2 and p^4M^4 is small in comparison to $p^2L^2S^2$ then

$$P_2 = pN \frac{M}{L} \frac{E}{S}$$ (16)

which is the same in form as relation (8) in the preceding paper [*]

These relations differ very little from those in (10) and (11); hence curves fig. 1 and fig. 2 will apply to this case also.

The theory of low frequency resonance in mutually inductive circuits when the impressed e. m. f. is a complex harmonic is of no importance in connection with experiments in which the impressed electromotive force is generated by an ordinary alternating current machine, because the upper harmonics, as will be seen presently, are almost entirely absent then. When the alternating current is produced by transforming an interrupted current, then, since in this case the currents employed are small and therefore the iron cores but slightly magnetized, the harmonics are incomparably more persistent.

I prefer to discuss first those experiments in which circuits with iron cores subject to considerable magnetizations are employed, and where a marked difference exists between theory and experiment because the behavior of iron is so peculiar then and so strongly brought out by resonant circuits that these experiments appeared to me of much greater importance than the experiments with circuits without iron which circuits, having no hysteresis losses, bear more directly upon the theory of what may be called Ideal Low Frequency Resonance.

Description of Experiments.

The alternator was a 1 H-P machine consisting of a Gramme ring armature with 16 poles, such as is used in the Crocker-Wheeler motors. Its field magnet consisted of a cast iron ring with sixteen pole-projections. The field was separately excited. The armature rotated at the rate of about 2810 revolutions per minute, the e. m. f. had therefore about 375 periods per second. The amplitude of the impressed e. m. f. was about 600 Volts. The primary poles *cd* (fig. 3) of an induction coil were connected to the poles of the alternator. The primary of this coil consisted of 3000 turns of No. 20 B. & S. W. G. wire having a

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[*] See this Journal, May, 1893, p. 426.

resistance of nearly 40 ohms. The secondary consisted of 120 turns No. 14 B. & S. W. G. wire. The iron core *e* was a cylinder of well packed fine iron wire. The diameter of this cylinder was 5^{cm} and its length 40^{cm}. High voltage was measured by a Thomson electrostatic voltmeter, small voltage by a Thomson multicellular voltmeter or a Weston alternating current voltmeter. It is, however, not advisable to use this last instrument in resonance work when the voltage exceeds 50 volts. An *inertia coil a' b'*, fig. 3 was connected in series with the secondary of the induction coil and also with an adjustable Marshall condenser of 1·9 microfarads, the smallest subdivision being 0·05 M.F. The inertia coil consisted of about 1000 turns of coarse copper wire, about No. 16, so that its resistance was only a few ohms. A removable iron wire bundle could be inserted into this coil, so as to study the effect of iron upon resonance.

The first series of experiments was done without iron in the inertia coil. The speed of the alternator was maintained at 2810 revolutions per minute or nearly 375 complete periods per second. The capacity was gradually varied from 0 to 1·6 microfarads when the maximum point of the voltage of the condenser was reached. The values are tabulated in table 1, curve fig. 4 (unfortunately very indistinct in the reproduction), was plotted from this table, by taking the capacities in 10^{-7} Farads for abscissæ and the corresponding difference of potential in volts in the condenser for ordinates.

TABLE I.

Condenser capacity in 10^{-7} Farads.	Corresponding value of the difference of potential of the condenser in volts.
·0	40·5
0·5	43·
1·0	46·
1·5	51·
2·0	56·5
2·5	53·
3·0	51·5
3·5	52·
4·0	53·
5·0	57·5
6·0	63·5
7·0	70·5
8·0	77·
9·0	89·
10·0	103·
11·0	118·
12·0	140·
15·0	750·
16·0	1090·

A simple consideration will show that the curve in fig. 4 is exactly the curve which theory demands; but, as I stated
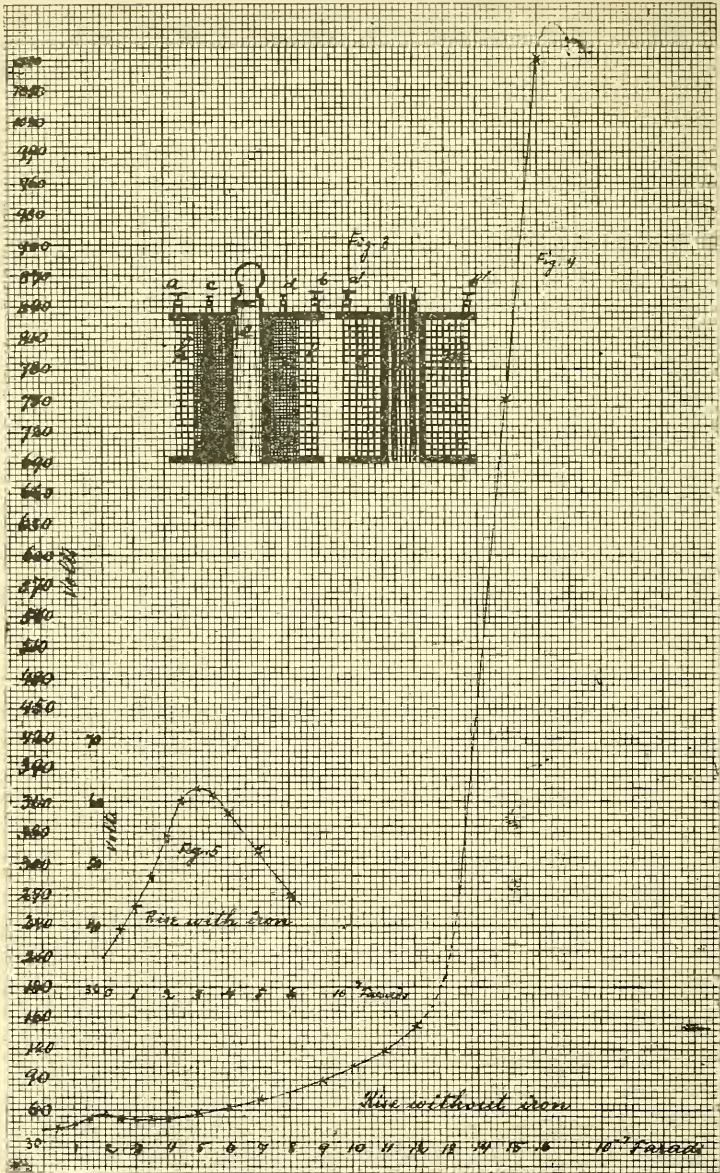
before, *I prefer for the present to discuss those cases in which there is an apparently striking disagreement between theory and experiment.*

When the maximum point is reached then the slightest variation of the capacity one way or the other causes a very large variation in the potentials. The curve of potentials looks and behaves just like a sensitive flame. The maximum potential is at about 1·66 microfarads. There is however another maximum at about 0·18 microfarads which would correspond to the first upper harmonic. This second maximum has been determined with exceedingly great care, so that there is not the slightest doubt about its existence. From the shape of the curve one is led to infer that the form of the impressed e. m. f. is given by

$$\text{E} = a_1 \sin pt + a_3 \sin 3 pt.$$

where the amplitude a_3 is exceedingly small. This was rather surprising, since, owing to the peculiar shape of the armature one would have expected a much stronger development of the upper harmonics.

Before I obtained the alternator just described my experiments on the rise of potential by resonance were all performed by means of alternating currents obtained from the interrupter described in my first paper.* In these experiments, an account of which will be given at some future time, the upper harmonics appear very strongly in curves corresponding to the curve in fig. 4. In fact, the crest corresponding to an upper harmonic can be made considerably higher than that corresponding to the fundamental. In the experiment with our large alternator giving about 100 periods per second, which experiment I described in my last paper † the upper harmonics seemed to be present in strong force although the armature of this alternator has no iron projections nor is the machine in any other respect as apt to generate a complex e. m. f. as the small machine described above. The consideration of the circumstance that since the small machine generated an e. m. f. of nearly four times the frequency of that generated by the large machine and that therefore in the case of the small machine the self-induction is much more effective in destroying upper harmonics did not seem to explain matters quite satisfactorily. There was evidently something going on in my circuits during those experiments† that I did not understand clearly.

* This Journal, April, 1893.
† This Journal. May, 1893, pp. 426, 427 and 429.

IV. *On the Effect of Iron upon Resonance and the Relation
between this Effect and the Frequency.*

Experiment 1.—A few iron wires were then introduced into
the inertia coil and the secondary circuit was tuned   To
my great surprise, I found that now the upper harmonic
maximum had disappeared and the maximum rise had dimin-
ished quite perceptibly, although the self-induction of the inertia
coil and therefore of the whole resonant circuit had been
considerably increased.   But I must mention here that the
iron got so hot in a few seconds as to cause the fibre spool of the
inertia coil to smoke where the wire touched it.   There was a
serious discrepancy between experiment and formula (15).
To bring out this discrepancy very strongly I placed all the
iron wire into the inertia coil (about 500 wires, each 40^{cm} long
and 1^{mm} in diameter).   On tuning the circuit it was found that
the maximum potential was reached at considerably smaller
capacity and that the rise of potential was incomparably smaller
than in the previous case.   Table II gives the experimental
data, the curve in fig. 5 was plotted from this table.   The
frequency was maintained nearly the same as in the previous
experiment, namely 375 complete periods per second.

TABLE II.

Capacity in 10^{-7} Farads.	Difference of potential in the condenser in Volts.
·0	35·5
0·5	39·5
1·0	43·
1·5	48·
2·0	54·
2·5	60·
3·0	62·
3·5	61·
4·0	58·
5·0	52·
6·0	45·

In the experiment (described in my last paper) with our
large alternator giving 100 periods per second I obtained with
similar inertia coil and the same iron wire a rise from 60 to
900 volts.   In this experiment with four times the frequency
I expected to get nearly four times the rise and instead of that
there was hardly any rise at all.   I inferred, therefore, that
the presence of iron in all probability diminishes at higher
frequency the rise of potential due to resonance.

To investigate the relation between this damping of the iron
and the frequency I substituted for the small alternator our

large alternator. The impressed e. m. f. was maintained constant and equal to about 1000 volts. The frequency was also maintained constant and equal to nearly 125 periods per second, hence just about ⅛ of the frequency obtained by the small machine. The secondary was now tuned first when there was no iron wire core in the inertia coil. The condenser potential rose steadily until the maximum point was reached. There was no sign of an upper harmonic. This distressed me very much in view of the statement which I made in my last article concerning the presence of upper harmonics in the e. m. f. generated by this alternator. I had evidently blundered somewhere in my previous experiment with the large alternator. In my endeavors *to locate the blunder I discovered a very peculiar behavior of the iron when it is under the inductive action of a resonant circuit,* which behavior explained to me perfectly why in the experiment, which I described in my last paper,* there was a much higher rise of potential when the capacity was considerably increased without apparently increasing perceptibly the coefficient of self-induction.

Experiment 2.—I next placed the iron wire bundle into the inertia coil and found that the maximum rise was one half of the rise which was obtained without the iron, which showed that with the diminution of the frequency the damping effect of the iron upon resonance was much less. *If a high impressed e. m. f. is employed in the resonant circuit just described then the rise of potential can be made even higher with iron than without it at this frequency.* Increasing the capacity considerably and then raising the wire bundle until the maximum deflection in the Thomson voltmeter was obtained I found that only a slight displacement of the bundle was necessary to reach the point of resonance. The maximum voltage, or *the resonant rise,* was considerably higher. (It will be seen presently that under certain conditions the bundle can be lowered again without destroying resonance or diminishing the resonant rise and it was owing to this circumstance that in the experiment described in my last paper I believed that I was tuning the circuit to respond to an upper harmonic of the impressed e. m. f.)

Increasing the capacity again and then raising the iron wire bundle a little more the maximum potential was again increased until a point was reached at which the maximum rise of potential began to diminish when the capacity was increased and the iron wire bundle raised in order to establish resonance again. From this point on, which I shall call the

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* This Journal, May, 1893, pp. 426, 427, 429.

critical point, the rise of potential due to resonance fell off gradually until the iron wire bundle was entirely removed. *It is very instructive to observe that the position of the critical point changes perceptibly with the amplitude of the impressed e. m. force.*

It is evident, of course, that on account of hysteresis losses the rise of potential produced by resonance will be less than the theoretical value given by (15). And the first explanation which one will naturally offer for the above discrepancy between the theoretical and the actual value will be that as the quantity of iron wire in the interia coil is increased the increase of the coefficient of self-induction tends to increase the resonant rise but that on the other hand the increase of hysteresis losses due to the increased mass of iron tends to pull this rise down and that it is then simply a question of adjustment which one of the two tendencies will predominate. This explanation does not, however, cover the ground completely as will be found by the following experiments:

Experiment 3.—In order to experiment with lower frequencies, as they seemed to bring out this peculiar behavior of the iron more clearly, I substituted a one H. P. four-pole alternator for the large alternator. The speed was such as to give the impressed e. m. f. a frequency of 50 periods per second.

TABLE III.

Part A.		Part B.		Part C.	
Capacity in 10−6 Farads.	Voltage of the condenser.	Capacity in 10−6 Farads.	Voltage of the condenser.	Capacity in 10−6 Farads.	Voltage of the condenser.
0·0	32·	0·0	32·	0·0	32·
0·5	32·5	0·5	33·5	1·9	32·5
1·0	34·	1·0	34·5	4·9	35·
1·9	36·	1·9	37·	6·1	36·
4·1	39·	4·1	42·	7·9	37·
4·9	47·	4·9	52·	11·0	38·
6·1	51·	6·1	62·5	12·9	39·5
7·0	62·5	7·0	77·	15·9	42·
7·9	77·5	7·9	97·	18·9	44·
8·2	79·	8·2	100·	21·1	46·
9·1	97·	11·0	130·		
11·0	120·	11·5	122·5		
12·4	111·	11·9	112·		
12·9	103·	13·9	94·		
15·9	65·	14·1	77·		
18·9	45·	15·9	57·		
		18·9	41·		
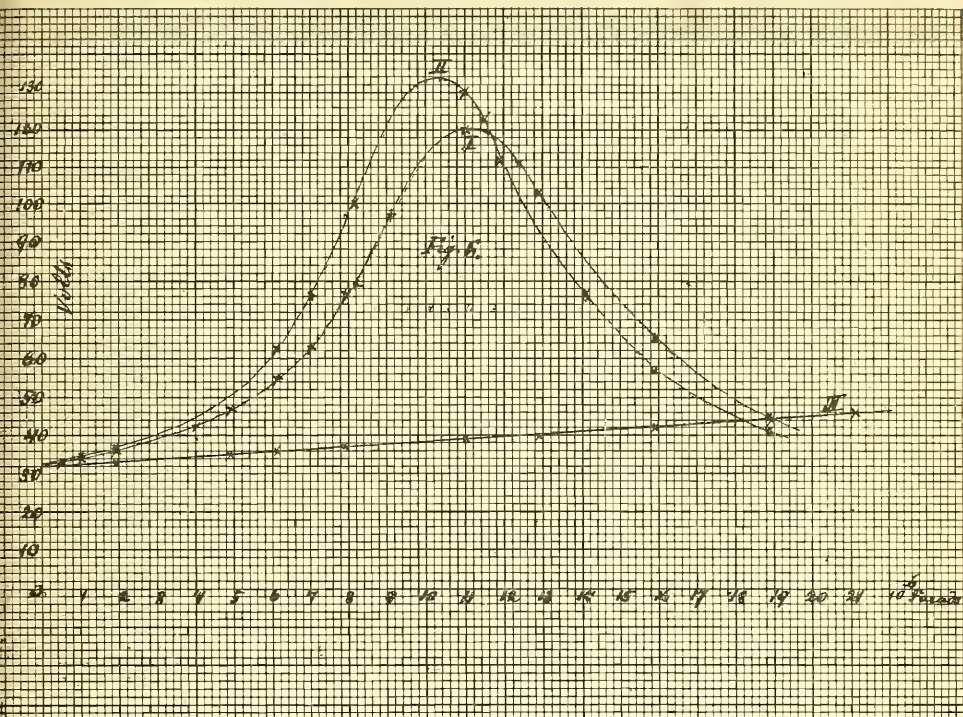
Fig. 6.

One-half of the bundle of the iron wire was placed into the inertia coil and the circuit tuned. Table III, Part A, gives the data from which curve I, fig. 6, was plotted. Next all the wire was placed into the inertia coil and the circuit tuned. Table III, Part B, gives the data from which curve II, fig. 6, was plotted. Finally the circuit was tuned without any iron and from the data of Part C, Table III, curve III, fig. 6 was plotted.

From the curves I and II it is evident that the doubling of the mass of iron produced very little change in the values of the capacity and self-induction which established resonance between the circuit and the impressed e. m. f., and yet although the losses due to magnetic hysteresis were more than doubled (since the magnetizing current was a little larger with double the mass of iron in the inertia coil), yet the rise of potential due to resonance was increased. This experiment seemed to me to indicate that hysteresis and Foucault current losses do not explain quite fully the discrepancy between the theoretical and the experimental values of the rise of potential

due to resonance.   Thinking that perhaps the development of
Foucault currents in the rather coarse iron wire or that the
mechanical vibrations of the wire may in some way or another
modify the period of the circuit and the self-induction of the
coil, I endeavored to devise some simple experiments which
would test the hypothesis just mentioned.

Experiment 4.—About 19 microfarads were plugged in the
condenser and then the iron wire was gradually introduced into
the inertia coil and the rise of potential was observed closely.
The potential went up continually until a maximum of about
100 volts was reached.   From this point on the electrometer
needle remained stationary although I kept on adding more and
more iron wire, one wire at a time.   Suddenly the addition of
another wire caused the electrometer needle to drop down con-
siderably below the midway point between zero and the maxi-
mum point.   I tried then to bring it back by removing the
iron wires slowly one at a time from the inertia coil and found
that I had to remove a considerable number of wires (about
one fourth of the total number which was about 300 wires)
before the electrometer index began to move up rapidly toward
the maximum point previously obtained.   The wires were now
gradually replaced into the coil and the same phenomenon ob-
served as before.   The experiment was repeated over and over
with invariably the same result.

Experiment 5.—After the collapse of resonance (as described
in the last experiment) by the addition of the last fatal wire,
as it were the last straw that broke the camel's back, resonance,
indicated by the large rise of potential and the singing of the
iron wire, was established again by gradually lifting the whole
bundle until the electrometer indicated the highest point.
Then the bundle was lowered again very gently until it was
entirely in the coil again.   The electrometer needle would then
remain stationary, apparently for an indefinite time.   But the
mere approach of an iron wire toward the bundle would upset
the resonance suddenly and cause the electrometer needle to
drop way down.   That this approach of the single iron wire
did not disturb resonance by the increase of the coefficient of
self-induction was proved by the circumstance that if this iron
wire was introduced into the coil and then the whole bundle
raised until resonance was established and then slowly lowered
again the maximum potential previously obtained was reached
again and maintained apparently indefinitely although the iron
wire bundle contained now that wire also by whose mere
approach resonance was upset before.   In fact it is possible to
increase in this way, the number of iron wires in the bundle
by four or five wires without changing perceptibly anything
in the resonant effect, whereas the mere approach of a single

wire from outside was sufficient to upset it entirely. In the course of these experiments it was observed that a gentle handling of the iron wire produced much more sensitive instability in the resonance. I suspected therefore, that mechanical vibrations of the wire might have something to do with the phenomena observed, and although I have been unable as yet to determine exactly to what extent these vibrations do influence the effect of iron on the resonance yet I feel that this effect is to a considerable extent due to molecular action of the iron. The following two experiments will, I venture to suggest, throw some light upon this point.

Experiment 6.—A sensitive resonance was obtained by placing a sufficiently large number of iron wires into the inertia coil until the addition of another wire caused a collapse. After the collapse the wire bundle was gently raised and then lowered again, 19 microfarads being plugged in the condenser. Now the capacity was varied by removing carefully one plug after another from the condenser. The capacity could thus be diminished fully 6 per cent without anything like a corresponding change in the resonant rise of potential. But a critical point in the variation of the capacity is then reached, after which the slightest change in the capacity will cause the resonant rise of potential to collapse suddenly, after which collapse the plugging in of the condenser plugs did not restore resonance. To bring resonance back again it was necessary to raise and lower again the wire bundle in the manner described above. *If however the capacity was varied by even less than 1 per cent, but in such a way as to allow a bright, snapping spark to take place when the condenser plug was removed, then the spark had almost invariably the effect of causing a collapse of resonance.*

Experiment 7.—All the preceding experiments were now repeated with the iron wire tied very tightly together and when the whole bundle was introduced into the inertia coil it was pressed tightly against the table so as to prevent mechanical vibrations as much as possible, but the phenomena described above appeared again. I observed however that the sensitiveness of the instability of the resonant flow was not quite as great as when the iron wires in the inertia were standing loosely.

All these phenomena are observable at high frequencies also but they are not marked as strongly as at low frequencies.

While working with weak alternating currents obtained by my electrodynamic interruptor, this peculiar behavior of iron was never observed by me, probably because in these circuits the magnetizations are so weak that iron is capable to follow every impulse of the magnetomotive force. Hence the persist-

ance of the upper harmonics in resonant circuits through which weak currents flow, and their entire absence from resonant circuits traversed by strong currents.

I expect to follow up this subject more closely and I do not know of any method by which it could be studied with greater ease and accuracy than by the method of resonant rise of potential. *The circumstance that low frequency resonance offers so delicate a method for the study of electromagnetic phenomena such as I just described seems to me to make the subject of slow frequency resonance even more important than the fact that by it rise of potential and weeding out of harmonics can be produced.*

Before closing this paper I must thank my pupil Mr. M. C. Canfield, postgraduate student in Electrical Engineering, for the very efficient way in which he has aided me in these experiments.

Electrical Engineering Laboratory, School of Mines,
　　Columbia College, New York, May 8th, 1893.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Loss of Energy due to Chemical Union.*—In order to measure the loss of energy due to a given chemical action, Gore has proposed to determine the electromotive force between a plate of platinum and a plate of some other metal (usually aluminum, tin, cadmium, zinc or magnesium) immersed first in the two given solutions separately and then in the two mixed together. Thus for example he takes a known quantity of an acid dissolved in a known mass of water and measures the electromotive force A developed by a small platinum-aluminum couple immersed in the solution. He then takes a quantity of a base chemically equivalent to this, dissolved in the same mass of water, and measures the electromotive force B developed by the same couple. Finally he determines in the same way the electromotive force C in a solution containing the equivalent quantity of the salt resulting from the combination of the acid and base already used. Multiplying then the equivalent mass of the acid into its electromotive force A, and that of the base into its electromotive force B, adding these together and dividing the sum of the products by the sums of the equivalents, he obtains a value D. Subtracting C from D and multiplying by 100 / D, the product represents the loss or gain of electromotive force in percentages ; and this the author regards as expressing the relative loss or gain of molecular energy which has taken place upon the union of the acid and the base. In the paper the results of numerous experi-

ments made with substances of various classes, are given in the form of tables. They show that when an acid and a base neutralize each other an increase of electromotive force occurs in almost all cases; a similar increase taking place in eighty per cent of the cases even when the acid is neutralized by a carbonate. When saline solutions or acid solutions are mixed with each other very little change of electromotive force is noticed; though considerable changes are produced when saline solutions are mixed with acids. The above experiments were made with dilute solutions, one gram-equivalent of the substance being dissolved in 100 gram-molecules of water.—*Phil. Mag.*, V, xxxiii, 28, 1892.   G. F. B.

2. *On the Preparation of Acetylene.*—A convenient method for the preparation of acetylene from inorganic materials has been described by MAQUONNE. Barium carbide is first prepared by mixing 20 grams of precipitated barium carbonate with 10·5 grams of powdered magnesium and 4 grams of retort carbon, previously heated in a platinum crucible; this mixture being placed in an iron bottle of about 700 c. c. capacity, to the neck of which is attached an iron tube 2 cm. in diameter and 30 cm. long. On heating the bottle to redness, an energetic reaction ensues, sparks being projected from the tube. When this ceases the tube is closed and the bottle is rapidly cooled. The product is a mixture of magnesium oxide containing about 38 per cent of barium carbide, with a trace of cyanide and some carbon. It is a light, porous, friable, amorphous mass, gray in color, permanent in dry air and not attacked in the cold by chlorine or hydrogen chloride. Acid oxides or chlorides, even phosphoric chloride do not act on it at 100°; but at a red heat it burns in air with vivid incandescence; as it also does in chlorine, vapor of sulphur and hydrogen chloride. When treated with water, or alcohol, or as a rule with any compound containing hydroxyl, at the ordinary temperature, barium carbide yields acetylene. If water be allowed to fall upon the carbide drop by drop, a regular current of acetylene is obtained containing two or three per cent of hydrogen and no appreciable trace of any other hydrocarbon, the yield being about two thirds of that calculated from the mass of magnesium employed. On passing the acetylene through a long glass tube heated to a dull redness, the author has obtained several grams of synthetic benzone in one day.—*C. R.*, cxv, 558; *J. Chem. Soc.*, lxiv, ii, 62, Feb. 1893.   G. F. B.

3. *On a New Alcohol of the Fatty Series.*—The trunks of the tree *Alnus nicana*, growing in Finland, were observed to be covered in the summer time, with a white powder. This powder, which was found to be a secretion from certain glands on the back of the plant louse *Pyslla alni* living upon the tree, has been examined by SUNDWIK. The dry insect was collected in quantity, exhausted first with hot ether and then repeatedly with hot chloroform. The latter solution on cooling deposited silky needles having the properties of an alcohol and the composition $C_{33}H_{65}(OH)$. From its origin the author calls it psyllostearyl alcohol. It fuses

at 95°–96°, is easily soluble in chloroform and acetic oxide, sparingly in absolute alcohol, insoluble in ether. It gives no reaction for cholesterin and is not altered by acetic oxide or caustic alkali even on fusion. By heating with 45 per cent hydrogen bromide to 210° or 220°, it gives a bromide melting at 85°–87°, containing 14·5 per cent bromine. On treatment with potassium hydroxide all the bromine is removed.—*Zeitschr. physiol. Chem.*, xvii, 425; *Ber. Berl. Chem. Ges.* (Ref.), xxvi, 100, Feb. 1893. G. F. B.

4. *On the Identity of Caffeine and Theine.*—Although caffeine was first isolated from coffee in 1821 and theine from tea in 1827, their chemical identity has only now been established by the researches of DUNSTAN and SHEPHEARD. Although this identity seems never to have been questioned on chemical grounds, yet the physiological action of the two seemed to indicate an isomerism between caffeine and theine. The caffeine used in the investigation was prepared from the unroasted coffee berries, by extracting with boiling water, evaporating to a small bulk, mixing with lime, drying on the water bath, and treating with boiling alcohol. After removing the alcohol, the residue was dissolved in one per cent sulphuric acid, filtered, treated with ammonia, and the caffeine extracted with chloroform. Repeated recrystallization from water gave silky needles fusing constantly at 234·5°. The theine was prepared similarly from tea. It crystallized also in silky needles fusing at 234·5°. To confirm this supposition of their identity, both bases were converted into aurochlorides and into mercurochlorides. When caffeine hydrochloride and auric chloride are mixed together the aurochloride separates on cooling in orange needles. The two aurochlorides appeared identical, fused at 242·5° and 243°, lost at 100° 6·3 per cent of water, and the anhydrous salt fused at 248·5°. The mercuro-chlorides also appeared identical, the pure salt made from theine as well as that made from caffeine fusing at 246°. The authors conclude therefore that there is no chemical ground for supposing caffeine and theine to be structurally isomeric. Several new gold compounds of caffeine are described in the paper.—*J. Chem. Soc.*, lxiii, 195, February, 1893. G. F. B.

5. *Lehrbuch der allgemeinen Chemie;* von W. OSTWALD. IIte Auflage. Band I, 1163 pp.; Band II, erster Teil, 1104 pp. Leipzig, 1891–93. (W. Engelmann). The appearance at this time of the first two volumes of the new edition of Ostwald's famous *Lehrbuch* will no little enhance the rapidly growing interest which has been aroused by the wonderful development of all phases of the theory of chemical processes during the past decade. Ostwald's style is historical and his treatment exhaustive. The first volume takes up *Stoechiometrie* and includes the modern Theory of Solutions.

An unusual measure of interest is excited by the succeeding volume, on Chemical Energy, for the reason that here for the first time in the history of chemical theory the General Doctrine of Energy is exhaustively developed and applied. Thermochemistry, Electro-

chemistry and Photochemistry are regarded as treating the transformations between chemical energy on the one hand, and heat, electricity and radiant energy on the other. The substantiality of energy, its forms, its capacity and intensity factors and the laws of its transformations are brought out and emphasized, the significance of the intensity factor of chemical energy, the chemical potential, in the theory of chemical equilibrium is made apparent, the history of the energy doctrine is outlined.

The "Thermochemistry" is very complete, both in theory and data. The "Electrochemistry" is a brilliant piece of work. The historical development, from Grotthus to the free-ion theory, from Hittorf and Kohlrausch to Arrhenius and Ostwald, is most interesting, and it is followed by a complete discussion of the magnificent results in the theory of concentration currents and of the galvanic cell, the whole treated from one point of view, as necessary deductions from the energy laws. Many new conclusions are drawn and confirmed by experiment; the whole reads like an original paper and is inspiring in the extreme. The volume is concluded by a similar presentation of the facts and theories of Photochemistry. J. E. T.

6. *Simplification of Tesla's Experiments.*—The glowing of a vacuum tube with or without electrodes can be shown by bringing it in contact with one pole of a Ruhmkorff coil or in the neighborhood of an insulated metallic plate which is connected with one pole of the Ruhmkorff. If one pole of a small Ruhmkorff is touched by the hand and a vacuum tube held in the other hand, it can be made to glow.—*Beiblätter zu den Annalen der Physik und Chemie,* p. 237. J. T.

7. *Loss of Electric Charges in diffuse light and in darkness.*— Edouard Branly finds that a disc of polished aluminum, experimented on a few days after being polished, slowly loses its charge. If the disc has been freshly polished the loss is rapid, even in diffuse light, and is only slightly diminished by surrounding it with orange light, thus showing that the loss is not due to any great extent to the refrangible rays of the spectrum.—*Comptes Rendus,* April, 1893. J. T.

8. *Influence of the character of metallic points on alternating discharges of Electricity between them.*—Wurtz states that iron terminals give small sparks. Copper and copper alloys give strong ones. An arc cannot be established between iron electrodes with a difference of potential of 1,000 volts. Steel, copper, phosphorus, bronze, aluminum bronze, tin and nickel also give no result. Zinc and also antimony resist a difference of potential of 1,000 volts. It is apparent that certain metals give off a metallic vapor in the electric arc which lessens the resistance of the arc. While other metals form an oxide which diminishes the arc by reason of its great resistance. The shorter this distance between electrodes of zinc and antimony up to one millimeter, the less permanent is the arc from an alternating current of 1,000 volts. If the air gap is increased to 5^{cm} the arc is more permanent.— *Lumière Electrique* 45, p. 79, 83, 1892. J. T.

9. *Registration of Magnetic variations.*—ESCHENHAGEN, at the magnetic observatory of Potsdam, employs a length of abscissæ equal to 20^{mm} per hour and obtains a fine curve by diaphragming the lens, determining exactly its chemical focus and by employing a very small mirror. The slit employed is 0·25^{mm}. The magnetic mirror is made in three parts or facets inclined to each other at an angle of 3°. It is enclosed in a bell jar in which the air is kept dry and free from sulphur vapor. The mirror gives three beams. During a strong disturbance just before the beam from the middle mirror leaves the drum, another point appears on the opposite side, which continues the record.—*Met. Zeitschr.; Nature,* April 6, 1893.　　　　　J. T.

10. *Discussion of the Precision of Measurements with examples taken mainly from Physics and Electrical Engineering;* by SILAS W. HOLMAN. 176 pp. 8vo. New York, 1892. (John Wiley & Sons).—Professor Holman's work is of somewhat novel character, and will be of much service to students and workers in experimental physics, pure and applied. It discusses with thoroughness, and with numerous practical examples, the general subject of precision of measurements, first, direct, and second, indirect measurements. The author's wide experience has enabled him to select wisely the special kinds of measurements discussed, and it would be difficult to find in so convenient a form elsewhere the variety of material here brought together.

11. *Practical Physics: An Introductory Handbook for the Physical Laboratory ;* by W. F. BARRETT and W. BROWN. Part I, Physical Processes and Measurements, the Properties of Matter. 284 pp. 12mo. London, 1892. (Percival & Co.).—This little volume presents in simple form, and with numerous examples worked out numerically, the introductory part of practical physics as needed by rather elementary students.

II.　GEOLOGY AND NATURAL HISTORY.

1. *A new Geological Society.*—A Geological Society has recently been organized in Washington, D. C., for the presentation and discussion of topics of interest to geologists. The Constitution and standing rules were subscribed to by 109 founders at the first public meeting, March 8th, 1893. Its members are of two classes, active and corresponding. The annual dues of the first are $2, and of the second, $1. Meetings will be held on the second and generally also on the fourth Wednesday of each month from October to May, inclusive.

The journals and bulletins of the various societies appear to furnish sufficient opportunity for the publication of papers read before the Society, so that for the present the Society will not undertake to publish the papers presented. It will probably issue one bulletin each year containing the address of the retiring President and such other matter as the Council directs. All

publications, and if desired notices of the meetings also will be sent to corresponding as well as to active members.

The above circular has been issued by the Secretary, J. S. Diller.

2. *Zeitschrift für praktische Geologie: herausgegeben von* M. KRAHMANN.—This journal, the first number of which appeared with the beginning of the present year, is devoted to the practically useful and technical side of geology, and particularly to all in this line that relates to ores and ore deposits. It aims to give the latest information concerning new discoveries of deposits of the useful and precious metals, ores, coals, etc., of deep borings, mineral springs, concerning geological surveys, etc. It is to be issued monthly in large octavo form of 48 pp., is well printed and illustrated with maps, cuts, etc. The assistant editorial staff is a large one containing the names of many well known specialists both German and foreign. It is an excellent undertaking and will no doubt meet a well merited success. The publisher's address is Julius Springer, Monbijou-Platz 3, Berlin N.

L. V. P.

3. *Annals of British Geology*, 1891. A Digest of the books and papers published during the year, with occasional notes; by J. F. BLAKE. With six plates. pp. 402. London, 1892. (Dulau & Co.).—The second volume of the Annals of British Geology, for 1891, appears with admirable promptness. It gives abstracts, in some cases running to several pages, of upwards of six hundred papers upon British Geology, Paleontology, Mineralogy, Petrology and related subjects, with also papers on foreign geology published in Great Britain. It is a work which must be most useful to all engaged in labor in these fields, and there ought to be no question in regard to its present and future pecuniary support. Unfortunately it is suggested in the preface that the financial success of the series is not yet assured.

4. *Materialien zur Mineralogie Russlands*, von NIKOLAI VON KOKSCHAROW. pp. 97–137. Elfter Band. St. Petersburg, 1893. —This final part of the eleventh volume of the great Russian Mineralogy possesses a particular interest because issued so soon after the death of its distinguished and lamented author. The closing pages are devoted to an obituary notice giving a brief statement of his life and labors. Pages i to xi contain an index to the eleven volumes of this monumental work.

5. *Reports of the Missouri Botanical Garden.*—The princely endowment by which the late Henry Shaw of St. Louis established in the city of his adoption, a park, a botanic garden, and a school of botany, has already justified itself by its fruits. Under the administration of Professor William Trelease, the institution has accomplished much in the direction of improvement, and has encouraged research of a high order.

The fourth annual report of the Director is a worthy companion to those of previous years. It contains a list of plants collected by Mr. Albert S. Hitchcock, in a voyage to the Bahamas, together

with critical remarks on the subject of nomenclature. 953 species are enumerated, together with many varieties and some cultivated plants. The table of comparison shows that the Bahaman plants are of southern rather than of United States origin.

The following figures are taken from page 171 of the report.

Total in the Bahamas				380
Of which are found also in		Cuba		321
"	"	"	Mexico or Central Am.	197
"	"	"	South America	117
"	"	"	Virgin Islands	207
"	"	"	South Florida	129
"	"	"	Southern United States	68

Professor Trelease's contribution is entitled "Further studies of Yuccas and their pollination." The admirable work done by the late Dr. Engelmann and by Professor Riley on the cultivated specimens of *Yucca filamentosa* and *Yucca glauca* is now supplemented by field studies of these and other species, and the fascinating life-history of these plants and unconscious allies is approaching completion. Professor Trelease's accomplishments as an entomologist have stood him in good stead in the experimental investigation of Pronuba, so that his results taken in connection with those obtained by Professor Riley, and published in the third report of the Missouri Garden, have given a large number of the more essential facts connected with the plant and its dependent visitant. But the mystery of the coördinate evolution of the plant and the moth seems as deep as ever. It is to be hoped that this study which preserves so thoroughly the traditions of its founder's scientific adviser, George Engelmann, will not be abandoned until a satisfactory answer is given. The conjectures before us are fertile. The patient work on which they are based gives promise that before long, even more plausible conjectures may take their place. G. L. G.

HENRY ELIASON SEATON, A. M., Assistant Curator of the Gray Herbarium, Harvard University, died in Cambridge, after a short illness, on Sunday evening, April 30th. He entered the service of the University during the present academic year and by his courtesy and assiduity commended himself, at once, to all with whom he came in contact. His original investigations in regard to Mexican plants are of a high order and gave promise of great usefulness in systematic botany.

Mr. Seaton was born in Indianapolis, 15th April, 1869. He graduated in 1890 from Wabash College and became immediately the assistant of his botanical teacher, Professor John M. Coulter. In 1891, he accompanied his teacher, who had assumed the presidency of Indiana State University, to Bloomington, where he became instructor in Botany and Curator of the Herbarium. During that summer he visited southern Mexico and made large collections of plants. The elaboration of these and other Mexican species drew him to Cambridge, where his excel-

lent work attracted the attention of all connected with the Gray Herbarium. His untimely death is sincerely deplored by the botanical department of the University. G. L. G.

6. *Discoliths in clay beds;* by ARTHUR M. EDWARDS, M.D. (Communicated.)—Last winter the railroad officials were constructing a branch of the Pennsylvania Railroad across the meadows in Newark, N. J., to the north before crossing the Passaic River. They have been making the embankments of the sandy parts of the Amboy clays from near Woodbridge, N. J. I have examined the clay which came in the sand, which itself was light cream colored, almost white. There were five colored clays from white to dark gray. In the lighter colored kinds I find *Discoliths* and perhaps *Cyatholiths*. This is of importance for it makes the clay marine and also confirms the Cretaceous character of the deposit. The *Coccoliths* (which include *Discoliths* and *Cyatholiths*) exist now at the bottom of the ocean and occur in the chalk of the Cretaceous. They existed in the clays of Perth Amboy, N. J., and perhaps they will be found elsewhere.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The following is a list of papers presented at the meeting held at Washington, April 18 to 20.

E. D. COPE: On the systematic relations of the Ophidia.

H. L. ABBOTT: Biographical memoir of General Montgomery C. Meigs.

M. C. LEA: On the nature of certain solutions, and on a new means of investigating them.

A. HYATT: The relations of allied branches of biological research to the study of the development of the individual, and the evolution of groups. The Endosiphonoidea (Endoceras, etc.), considered as a new order of Cephalopods. A new type of Fossil Cephalopod. Results of recent researches upon Fossil Cephalopods of the Carboniferous.

E. W. HILGARD: Biographical memoir of Julius Erasmus Hilgard.

A. S. PACKARD: Monograph of the Bombycine Moths of America, north of Mexico Part I.—Notodontidæ.

G. W. HILL: Intermediary orbits.

RICHMOND MAYO-SMITH: The relations between the statistics of immigration and the census returns of the foreign-born population of the United States. Statistical data for the study of the assimilation of races and nationalities in the United States.

T. C. MENDENHALL: Telegraphic gravity determinations. Fundamental standards of length and mass.

H. S. CARHART: Comparison of latitude determinations at Waikiki. A one-volt standard cell.

R. H. CHITTENDEN: Peptonization in gastric digestion.

ALEXANDER GRAHAM BELL: Helen Kellar.

S. P. LANGLEY: On a potentiality of internal work in the wind. On a bolograph of the infra-red solar spectrum.

THEO. GILL: The classification of the gastropodous mollusks.

The Draper medal was presented to Professor H. C. Vogel.

2. *American Philosophical Society.*—The American Philosophical Society celebrated its 150th anniversary at Philadelphia during the week beginning Monday, May 22d. A reception, with

address of welcome by President Fraley was held on Monday evening, and morning sessions on the four following days with addresses and the reading of papers on various subjects. Many distinguished representatives of Foreign Societies announced their intention to be present.

3. *Hydrostatics and Elementary Hydrokinetics;* by GEORGE M. MINCHIN. 424 pp. Oxford, 1892. (*The Clarendon Press,* Macmillan & Co.).—The author professes to develop the mechanics of fluids only far enough to introduce a beginner to such writers as Besant, Lamb and Lord Rayleigh. Most students, however, will find all that they need in this volume. The work shows the same happy union of rigid analysis and clearness of statement found in *Uniplanar Kinematics.* We find in the preface two statements which seem to express the secret of Minchin's success as a writer of text books. "I am convinced that more than one-half of the efficiency of the teaching of any subject consists in the anticipation . . . . . of those difficulties which are certain to occur to the student, and which if left unnoticed [are] like uncaptured fortresses in the rear of an advancing army." Again— "The view that the fundamental notions of the differential calculus are a mystery . . . . which cannot be unveiled until great experience in mathematics has been attained has long seemed to be a most unfortunate fallacy." w. b.

4. *Elementary Mechanics of Solids and Fluids;* by A. L. SELBY. 299 pp. Oxford, 1893. (*The Clarendon Press,* Macmillan & Co.).—Mr. Selby is an excellent representative of the English Scientific Reformers. He shows an Euclidian regard for continuity of reasoning and his analysis follows the lines of the Calculus; though without using its symbols. Such a text book is elementary in form rather than spirit, and the student who undertakes it with the equipment of a little Geometry and Algebra, must read slowly enough to develop that mathematical insight which is the gift of nature to only the favored few. w. b.

5. *Poole Brothers' Celestial Planisphere and The Celestial Handbook.* [Compiled and edited by Jules A. Colas. pp. xiv, 110. Chicago, 1892 (Poole Bros., 316 Dearborn St.)—A popular work which will be found attractive by the class of readers for which it has been prepared and will tend to increase the general interest in the heavens and celestial phenomena. The planisphere is well constructed and convenient for use. A full commentary is given on each constellation comprising 140 figures, many of them original. Much of the material is collected from recent astronomical periodicals. Precise statement has sometimes been sacrificed to an effort to avoid technicality.

6. *Practical Astronomy;* by MICHIE and HARLOW. 218 pp. New York, 1893.—(John Wiley & Sons).—A full and well arranged guide for the observer and computer, which does not fill the place of Chauvenet's Astronomy, but will save its owner much turning of leaves in that book and the Nautical Almanac. The rules and forms for numerical computation are especially helpful.

INDEX TO VOLUME XLV.*

A

Abbe. C., Mechanics of the Earth's Atmosphere, 442.

Absorption spectra, Julius, 254.

Academy of Sciences, National, Washington meeting, 527.

    Texas, Transactions, 78.

Agassiz, A., observations in the West Indies, 78, 358.

Age of the earth, King. 1; Fisher, 464.

Alternating Currents, Bedell and Crehore, 435.

American Philosophical Society, 527.

Astronomical Journal prizes, 168.

    Observatory, Yale University, Transactions, 357.

Astronomy, Practical, Miche and Harlow, 528.

Atkinson. E., 14th edition of Ganot's Physics, 436.

Australia, Barrier reef of, Saville-Kent, 362.

B

Baltimore. geol. map, Williams, 73.

Barker, G. F., chemical abstracts, 65, 155, 251, 346. 430, 520.

Barrett, S. T., Oriskany fauna, Columbia Co., N. Y.. 72.

Barrett. W. F., Practical Physics. 524.

Barus. C., isothermals, isopiestics and isometrics relative to viscosity, 87; colors of cloudy condensation, 150.

Base apparatus, iced-bar, Woodward, 33.

Becker, G. F., "potential" a Bernoullian term, 97.

Bedell, F., Alternating Currents. 435.

Bergen, J. Y., Jr., Text-book of Physics, 255.

Berzelius and Liebig, Letters from 1831–1845, 433.

Blake, J. F., Annals of British Geology, 525.

Blowpipe Analysis, Endlich, 76.

Botanical Garden, Missouri, reports, 526.

BOTANY—

    Blanched seedlings, how they may be saved, Cornu, 356.

    Perfumes of flowers, localization of Mesnard, 355.

BOTANY—

    Vegetation, influence of moisture on, Gain, 356.

        See also under GEOLOGY.

Branner, J. C., geol. survey of Arkansas. 1891, 73.

Brazil, nepheline rocks in. Derby, 74.

British Geology, Annals, 1891, Blake, 525.

Brown, W., Practical Physics, 524.

Browning, P. E., determination of iodine in haloid salts by arsenic acid. 334; influence of free nitric acid and aqua regia on the precipitation of barium as sulphate, 399.

C

California Cretaceous, so-called Wallala beds as a division of, Fairbanks, 473.

Celestial Handbook, Poole. 528.

Chamberlin, T. C., diversity of the glacial period. 171.

Chemical Lecture Experiments, Newth, 68.

Chemie. Lehrbuch der allgemeinen, Ostwald, 522.

CHEMISTRY—

    Acetylene, preparation of, Maquonne, 521.

    Acids. affinity-coefficients of, Lellmann and Schliemann, 348.

    Alcohol of the fatty series, new, Sundwik, 521.

    Ammonia, specific heat of liquid, Ludeking and Starr, 200.

    Barium sulphate in analysis, Phinney, 468.

        precipitation influenced by nitric acid and aqua regia, Browning, 399.

    Boiling-point apparatus for determining molecular masses, Sakurai, 346.

    Boron, the trisulphide and pentasulphide of, Moissan, 430.

    C æ s i u m - l e a d and potassium-lead halides, Wells. 121.

    Caffeine and theine. identity of, Dunstan and Shepheard. 522.

    Carbon, the oxidation of different forms, Wiesner. 431.

        di-iodide, Moissan. 253.

* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ROCKS, and under each the titles of Articles referring thereto are mentioned.

F

Fairbanks, H. W., so-called Wallala beds as a division of the California Cretaceous, 473.

Fisher. O., rigidity not to be relied upon in estimating the earth's age, 464.

Flammarion, La Planète Mars, 77.

Fletcher, Optical Indicatrix, 255.

Florida, Neocene of, Dall and Harris, 353. phosphate fields, Johnson, 497.

Foote. A. E., meteoric stone of Bath, South Dakota, 64.

Fossil, see GEOLOGY.

French Academy, Botanical prizes, 355.

G

Gain, E., influence of moisture on vegetation, 356.

Galvanometer, sensitive, DuBois and Rubens. 350.

Ganot's Physics, 14th English edition, 436.

Geikie, A., geol. map of Scotland. 74.

Gelatine slides for lantern projections, Waggener. 78.

Genth, F. A., "Anglesite" associated with boléite, 32.

Geological map of Baltimore, Williams, 73 ; Scotland, Geikie, 74 ; Chattanooga, Tenn., 163.

Society, new, 524.

GEOLOGICAL REPORTS AND SURVEYS—
Alabama, Smith, 163.
Arkansas, 1891, Branner, 73.
Michigan, 1891 and 1892. 354.
Minnesota. 1890, Winchell, 73.
Missouri, 1892, Winslow, 354.
Pennsylvania, Lesley, 73.
Texas, 1892, Dumble. 354.

GEOLOGY—
Anchisaurus, restoration of, Marsh, 169.

Archæan in northern Michigan, Wadsworth, 72.

Basic dike near Hamburg. N. J., Kemp, 298.

Bryozoa of the Lower Silurian in Minnesota, Ulrich. 440.

Cambrian fossils of New Brunswick, Matthew, 164.
in Missouri, Winslow, 221.
North American Continent during, Walcott, 163.

Ceratops beds of Wyoming, Hatcher, 135.

Claosaurus, brain and skull of, Marsh, 83.

Cretaceous bird allied to Hesperornis, Marsh, 81.

GEOLOGY—
Cretaceous floras in Canada and the U. S., correlation of early, Dawson, 439. formation of Mexico, Hill, 307.

Devonian fishes of Canada, Woodward, 73.

Earth's age, King, 1 ; Fisher, 464.

Eureka District, geology, Hague, 161.

Flora tertiaria Italica, Meschinelli and Squinabol, 438.

Folds and faults, underthrust, Smith, 305.

Fossil mammals, North American, 159.
Plants as tests of Climate, Seward, 438.
of the Coal measures, Williamson, 437.

Geologic time, discussed, King 1 ; Upham, 209 ; Fisher. 464.

Glacial period, unity of, Upham, 70 ; diversity of, Chamberlin, 171 ; in Iowa, McGee, 71 ; in Russia, Nikitin, 459.

Hematite and martite iron ores in Mexico, Hill, 111.

Ice age as one glacial epoch, Upham, 70.

Lafayette formation, McGee, 163.

Neocene, Dall and Harris, 351.

Nikitin on the Quaternary deposits of Russia, Wright, 459.

Oneonta and Chemung formations in Eastern Central New York, Darton, 203.

Oriskany fauna, Columbia Co., N. Y., note on, Barrett, 72.

Palæobotany of the Cretaceous formation of Staten Island, Hollick. 437.

Phosphate fields of Florida, Johnson, 497.

Pleistocene history of N. E Iowa, McGee, 71.

Quaternary carnivores of the Island of Malta, 74.
deposits of Russia, Nikitin on the, A. A. Wright, 459.

Soils, origin and nature, Shaler, 163.

Tæniopterid fern and its allies, new, White, 439.

Tertiary geology of Calvert Cliffs, Md., Harris, 74.
Mollusks of Florida, Dall. 441.

Time, geologic, discussed, King, 1 ; Upham. 209 ; Fisher, 464.

Wallala beds, so-called, as a division of the California Cretaceous, Fairbanks, 473.

Geology, Annals of British, 1891. Blake, 525.
experiments in, Reyer, 164.

V

Viscosity, investigation of, Barus, 87.
Voltaic arc, mercury, Avon, 159.

W

Wadsworth, M. E., subdivisions of Archæan in Northern Michigan, 72.
Waggener, gelatine slides for lantern projection, 78.
Walcott, C. D., North American continent during the Cambrian, 163.
Ward, H. A., meteorite from Japan, 153.
Weather, a short cycle in, Hall, 227.
Wells, H. L., cæsium-lead and potassium-lead halides, 121.
West Indies, observations in, Agassiz, 78, 358.
Wheeler, H. L., double halides of tellurium with potassium, rubidium and cæsium, 267.
White, D., a new tæniopterid fern and its allies, 439.

Whitney, A. W., refraction of light upon the snow, 389.
Williams, G. H., geological map of Baltimore, 73 ; rock-cutting and grinding machine, 102.
Williamson, W. C., fossil plants of the Coal measures, 437.
Wilson, H. M., Manual of Irrigation Engineering, 442.
Winchell, N. H., geol. survey of Minnesota, 1890, 73.
Winslow, A., Cambrian in Missouri, 221 ; geol. survey of Missouri, 354.
Woodward, A. S., Devonian fishes of Canada, 73.
Woodward, R. S., iced-bar base apparatus of the U. S. Coast and Geodetic Survey, 33
Wright, A. A., Nikitin on the Quaternary deposits of Russia, 459.

Z

Zahm, J. A., Sound and Music, 69.

DIAGRAM

OF

EARTH PRESSURES

AND

TEMPERATURE

FOR RADIUS

3×10^6 Atm.

2×10^6 Atm.

1×10^6 Atm

E 3900°C A 100×10⁶ Years.

E 1741°C A 20×10⁶ Years.

4000°C.

3000°C.

2000°C.

1000°C.

.9   .8   .7   .6   .5   .4   .3   .2   .1   O

Plate II.

c — E 3900°   A 600×10⁶

b —

g —

E 3900°   A 100×10⁶

E 3900°   A 237×10⁶

DIABASE MELTING POINT AND DEPTH

E 2800°   A 400×10⁶

4000°C.

3000°C.

h — E 2560°   A 100×10⁶
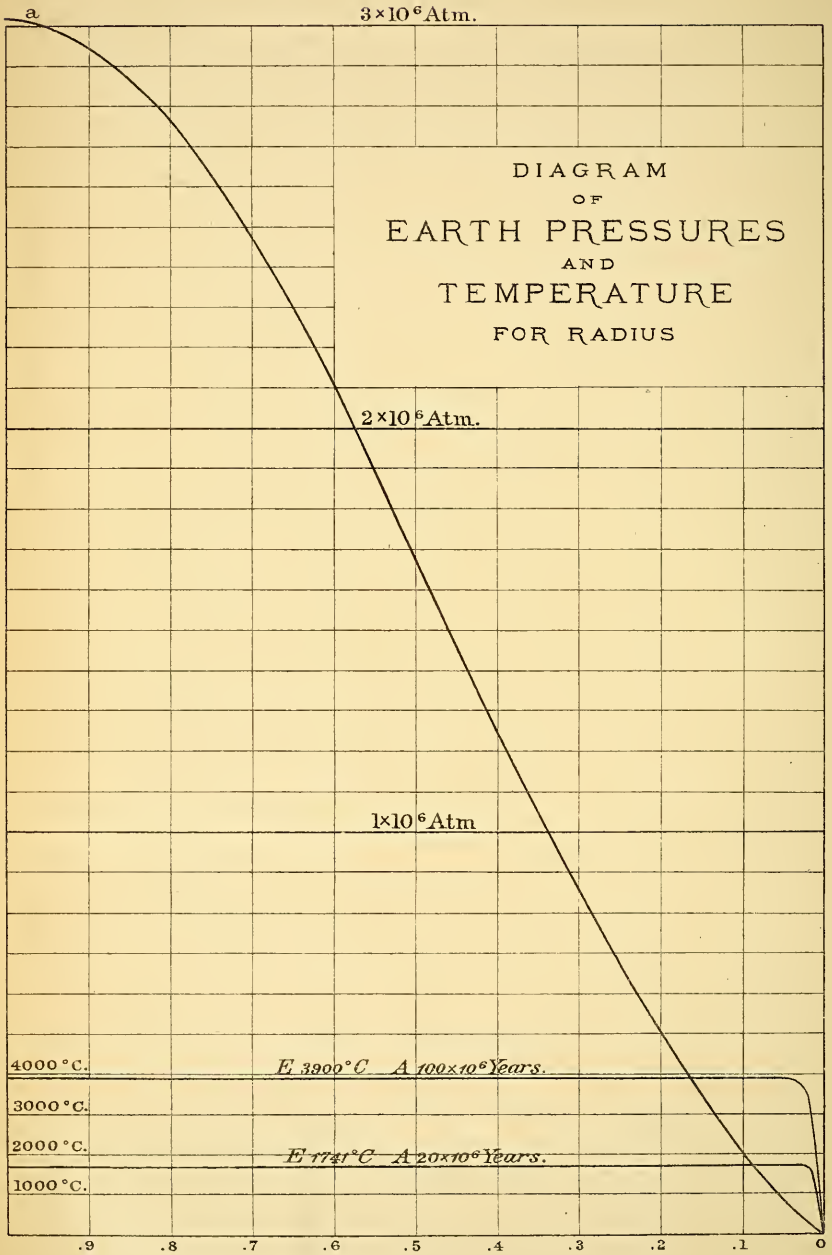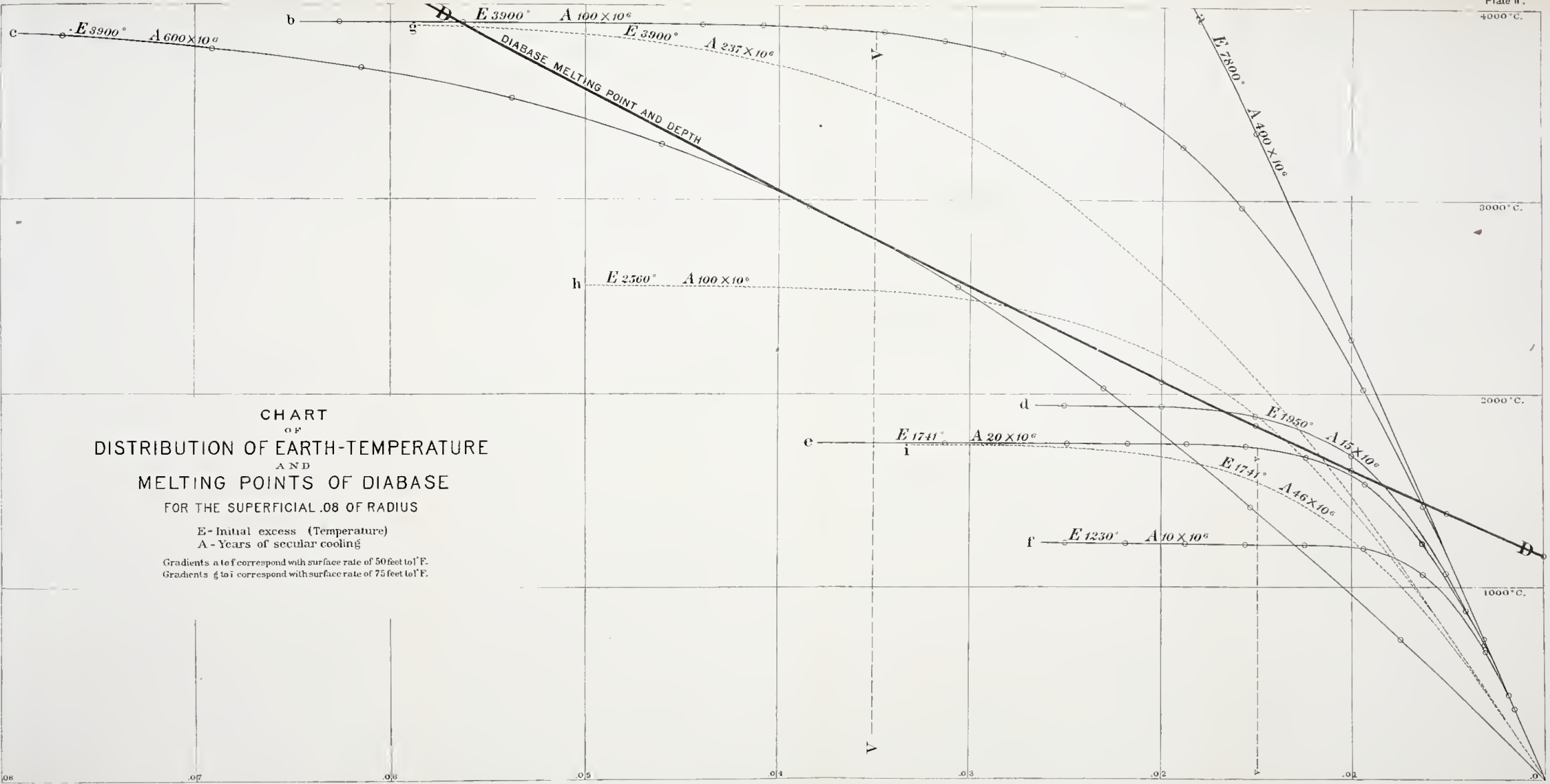
CHART
OF
DISTRIBUTION OF EARTH-TEMPERATURE
AND
MELTING POINTS OF DIABASE

FOR THE SUPERFICIAL .08 OF RADIUS

E - Initial excess (Temperature)
A - Years of secular cooling

Gradients a to f correspond with surface rate of 50 feet to 1°F.
Gradients g to i correspond with surface rate of 75 feet to 1°F.

d —

e —
i

E 1741°   A 20×10⁶

E 1950°   A 15×10⁶

E 1741°   A 46×10⁶

2000°C.

f — E 1230°   A 10×10⁶

1000°C.

.08   .07   .06   .05   .04   .03   .02   .01   .0
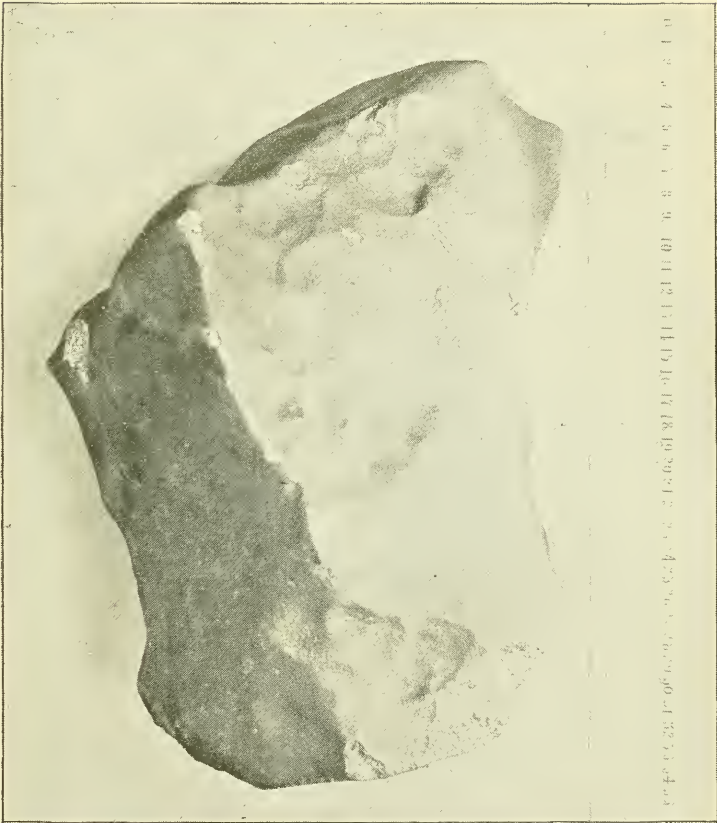
A Meteoric Stone which fell at Bath, South Dakota, Aug. 29th, 1892.
Weight, 46¾ pounds.   Photographed with metric scale.

1.
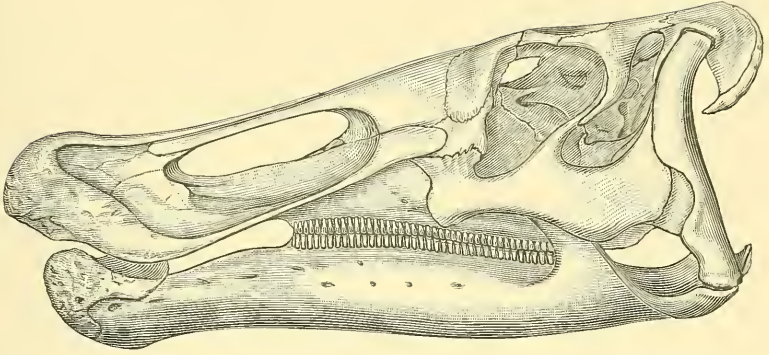
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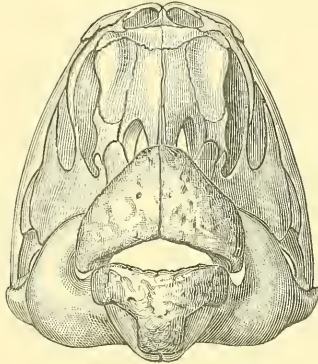
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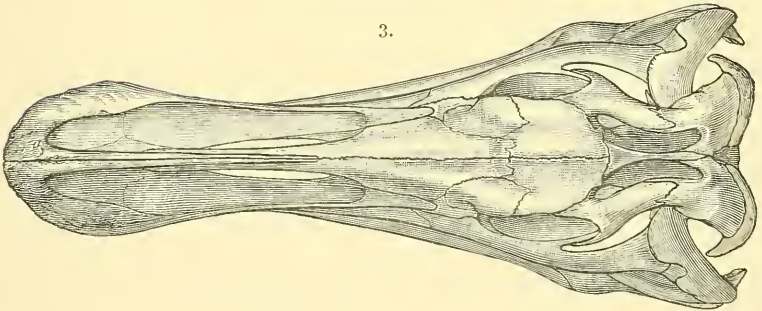
CLAOSAURUS ANNECTENS, Marsh.
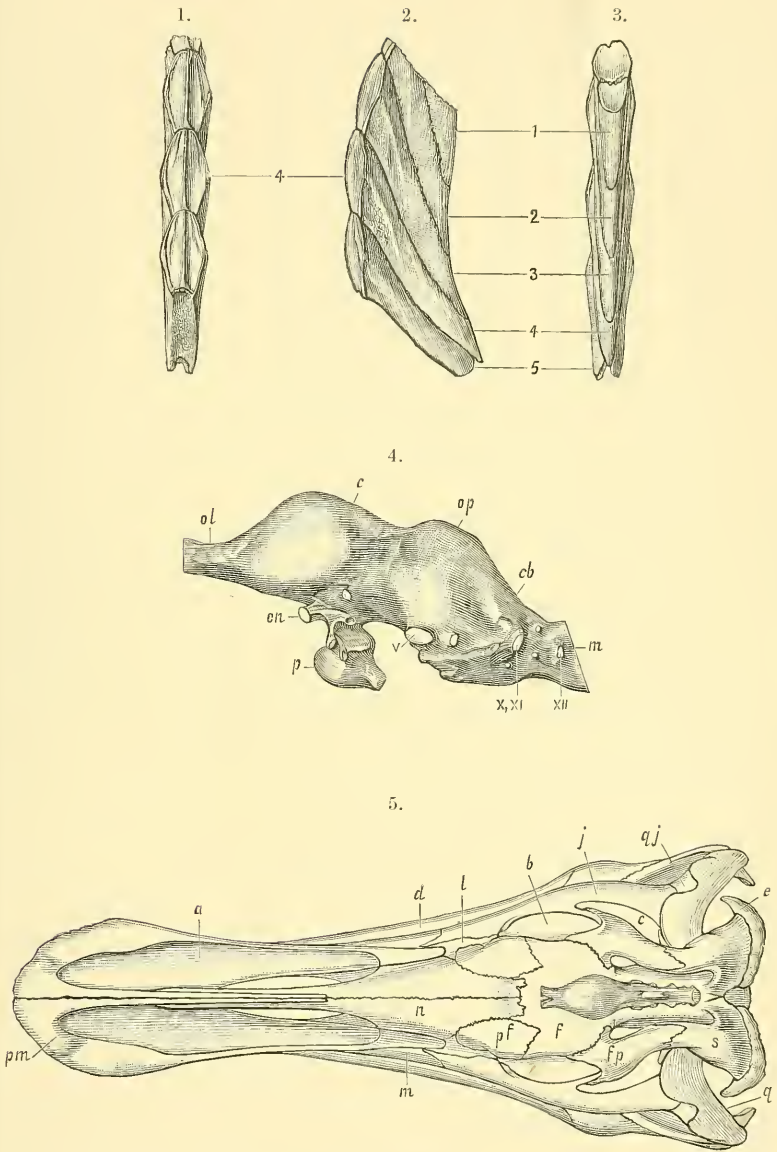
CLAOSAURUS ANNECTENS, Marsh.
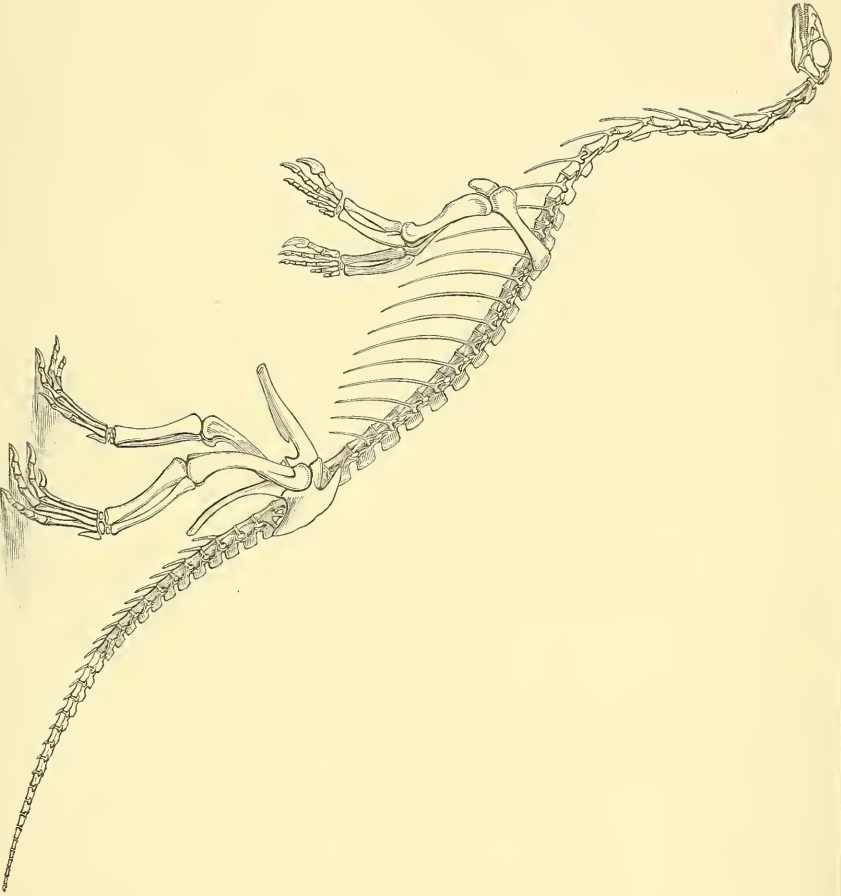
Restoration of ANCHISAURUS COLURUS, Marsh. One-twelfth natural size.

CONTENTS.

SCIENTIFIC INTELLIGENCE.