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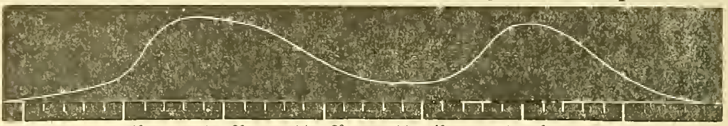
nine seconds. Mr. Allan is authority for the statement that its reading next morning was 9:51 exactly. He had received the time signal on August 31st, but as the clock was within the limit of tolerance he did not correct it. Subject to this limit he had no knowledge of the exact error of his clock and his memory on this point did not serve him The second clock was the regulator which controls the time of the North Eastern Railway. This clock was compared with the time signal on August 31st, but was not corrected, its error being within the limit of tolerance, which was eight seconds. It had been reset two days previously. Its reading was 9:51:15. It was stopped by the point of the pendulum catching behind the metallic arc in front of which it properly vibrates. The third clock was that which regulates the time of the Charleston & Savannah Railroad. It had been reset two days previously and compared with the time signal on August 31st, and was within the limit of tolerance, eight seconds. Its reading was 9:51:16 and it was stopped in the same manner as the preceding one. The fourth clock was that of the South Carolina Railroad. It had been reset by the daily time signal on the day of the earthquake. Its reading was 9:51:48.

Although these records range through an interval of 48 seconds they may be reconciled. The azimuths of the planes of oscillation of their pendulums were as follows:

James Allan & Co's	N. 85° E.
North Eastern Railroad	N. 40° E.
Charleston & Savannah Railroad	N. 66° E.
South Carolina Railroad	N. 30° W.

These azimuths may be put into relation with what is now known concerning the varying phases of the shocks, their respective durations and directions of vibratory motion. The earthquake at Charleston began as a light tremor, steadily increasing in power through an interval estimated to be from 10 to 15 seconds' duration; then suddenly or by swift degrees it swelled into the full power of the first maximum, then subsided to a minimum, then swelled suddenly to a second maximum and lastly died away gradually. The interval from the beginning of the first maximum to the close of the second maximum is estimated at from 35 to 55 seconds; the subsiding tremors are estimated at about 6 to 8 seconds: the total duration from 55 to 75 seconds. It may be expressed graphically by the following curve in which the abscissas represent time and the ordinates an arbitrary scale of intensity.

In the first maximum the waves were mainly normal and came from N. 30° W. In the second maximum the direction of vibration was about at right angles with the foregoing or about N. 60° E. It will now be seen that the planes of oscillation of the first three clocks made wide angles with the direction of motion of the first maximum, while the plane of the fourth clock was almost exactly parallel with that direction and perpendicular to the direction of motion of the second maximum. The fourth clock, then, may easily have escaped arrest



until the second maximum while the other three would have little chance of escaping the first maximum, even if they did not stop during the lighter preliminary tremors. That the second and third clocks stopped during the first maximum is rendered probable by the way in which their pendulums were caught. It would require a considerable acceleration in a direction perpendicular to their planes of oscillation and at times when the pendulums were near the extremities of their arcs of vibration in order to throw their bobs far enough backward to catch in the manner they did. These two clocks are relied upon as giving the time of the first maximum. The chances are, however, that the pendulums were not caught in this particular way during the first three or four oscillations, but went staggering along for a very few beats until finally caught. An interval of three or four seconds was probably occupied in the rapid swelling of the quake from the preliminary milder phase into the full power of the maximum. If we assume for the beginning of the first maximum an instant of time about three or four seconds earlier than that indicated by the two railroad clocks, i. e. 9:51:12, our actual error, it is believed will not exceed four seconds. The clock of James Allan & Co. probably stopped at a slightly earlier phase. If it may be assumed to have been six or eight seconds slow, its stopping would have been easily possible at that phase; for many less sensitive clocks throughout the country were arrested by tremors no more forcible than those in Charleston at the particular phase thus indicated. We shall reach the same result, 9:51:12, if we throw out the fourth clock as relating to the second maximum and (giving the weight 2 to both the second and third clocks and the weight 1 to the first) take the mean readings of the three. The whole tenor of the evidence from other clocks in Charleston points strongly to a time a few seconds later than 9:51 for the first maximum.

It is plainly necessary to select some phase of the earthquake in Charleston or at the centrum as the beginning, with which the beginning in all other places must be compared. It must plainly be a phase at which the shocks had very great power, sufficient to make themselves felt hundreds of miles away. This phase should obviously be that which has been called the beginning of the first maximum. It still remains to find the corresponding time at the centrum. As the speed of propagation is now known to have been in the neighborhood of three miles a second and as the distance of Charleston from the theoretic centrum is 20 miles, the subtraction for the time at the centrum is taken to be six seconds, making the time of beginning at that point 9:51:06 standard time of the 75th meridian.

The full catalogue was next examined in order to ascertain what reports should be finally rejected. In the final report this catalogue will be published, together with a list of the rejected observations showing the grounds of rejection. For present purposes a summary view of these reports is given, showing the number of observations corresponding to specific minutes or falling betweeen consecutive minutes.

Table showing the numbers of reports corresponding to specified minutes or falling between consecutive minutes.

9:47 and seconds	1
9:48	3
9:50	32
9:51	6
9:51 and seconds	6
9:52	25
9:52 and seconds	9
9:53	28
9:53 and seconds	16
9:54	31
9:54 and seconds	9
9:55	86
9:55 and seconds	8
9:56	21
9:56 and seconds	2
9:57	8
9:58	5
9:58 and seconds	1
9:59	3
10:00	13
10:01	2
10:02	1
Total	316

There are thus four reports giving times earlier than 9:50 and three later than 10 o'clock. The synopsis illustrates well the tendency of people to give time in terms which are multiples of five minutes. Thus we have 32 giving 9:50, but none giving 9:49, and only six giving 9:51. There are 13 giving 10 o'clock and there would have been many more of them if the catalogue had included those which stated the time as being "about" 10 o'clock or "near" 10 o'clock. There are 86, or more than one fourth the whole number, which give 9:55. Every one of the 9:50 reports is rejected. It is certain that they all involve errors greater than one minute too early, and the large number of them would introduce a large systematic error into the mean; and as there is no apparent reason for rejecting or keeping one observation rather than another, all of them are thrown out. All of the 10 o'clock observations are thrown out. For, upon further examination, all giving 9:58 and seconds, 9:59, 10:01 and 10:02 will be rejected on their merits. This would leave the 10 o'clock reports as an isolated group in an otherwise comparatively orderly series, and its effect would be to introduce an error of unknown magnitude and of anomalous character. In dealing with those giving 9:55 there is more difficulty. The following course has been adopted. Wherever a report states clearly, or raises a strong presumption, that this was really the nearest minute observed, to the exclusion of any other, it is accepted if otherwise unobjectionable. Where this evidence is wanting the report is rejected. It is quite probable that some thus rejected are very good observations; but it is clearly better to reject many possibly good observations (provided a sufficient number remain) than to admit a few bad ones with the certainty of introducing an unknown error. The number of 9:55 reports thus rejected is 43, which happens to be just one half.

Still other observations are rejected on their merits. A majority of these are thrown out for what are presumed to be large unexplained errors. There are 29 of them, of which 15 are rejected for being two minutes or more too early and 14 for being as much, or more than as much, too late, when compared with a larger number of much better observations in the same locality or in the immediately surrounding region. The rejection of these 29 observations does not greatly affect the deduced speed, but it does diminish notably the computed probable error. The total number rejected for all causes is 130 and the number accepted is 186. These have been separated into four groups, each containing data which are considered to be as nearly homogeneous as possible; that is to say, in each group the observations are presumed to have the same sources of error, whether accidental or systematic.

The first group is required to fulfill the following conditions: (1) The report must specify the beginning, or the time when the tremors first became sensible. (2) It must give not only the minutes, but also the seconds, with an uncertainty not exceeding 15 seconds. (3) It must have been obtained from a clock kept running with accuracy upon standard time or equally reliable local time, or from a clock or watch compared with such time within a few hours of the occurrence. There are five observations besides that of Charleston which meet these requirements.

The second group will consist of those which fulfill the same conditions as the first, except that they will be required to give only the minute or half minute nearest to the beginning. There are eleven which answer to these requirements.

The third group will include all that remain after taking out groups I, II, and the stopped clocks. Some of these state that the time is that of the beginning, but fail to show that any attempt was made to ascertain the error of the time-piece. Some give a satisfactory account of the time-piece, but fail to state the phase to which the reported time refers. Many do neither the one nor the other. The number of reports in this group is 125.

The fourth group consists of accepted reports of clocks stopped by the first great shock. The clocks, however, must be stated to have been regulated carefully by standard time or by local time known to be equally accurate.

In all the groups there is more or less discordance among the several observations, no two giving the same speed. As the errors of the first two groups are believed to be mainly of the accidental class, the best method seems to be to submit them to the process of least squares. The equations of condition may be formed very simply in the following manner: The computed time of the beginning at the centrum (which has already been given) must be presumed to have some error, which may be designated by x. If t_0 be the computed time at the centrum (9:51:06) and t the reported time at any other locality, then $(t-t_0)$ = the number of seconds in the observed time-interval taken by the wave to travel from the centrum to the place of observation. If D be the distance in statute miles, and y the number of seconds or fraction of a second required to travel one mile, we may form the following equation: $x+Dy=t-t_0$, in which there are only two unknown quantities, x and y. This implies that the speed is uniform. If this implication differs widely from the truth, indications of it may be expected to appear in the residuals. It is necessary to put the equations of condition into a form in which a time and not a speed shall be the unknown quantity, because the times and not the distances are the data into which the greatest uncertainty enters. If, putting v for the speed of transmission, we put our equations into the form of $v(t-t_0)=D$, they would be subject to the objection that their uncertain quantities would be the coefficients of the unknown quantities and not the absolute terms. The distances from the centrum have been taken from the Land Office map of the United States by measurement with a scale. They are subject to possible errors as great as three or four miles, but this error is so small in comparison with the best times that the distances may be regarded as sensibly exact.

The following reports constitute the first group. For the sake of brevity the full accounts of these reports are here omitted. They will appear in the final work on the earthquake.

GROUP I.—*The best Observations.*

Locality.	State.	Distance.	Time 9h+ *m.*	*s.*	Weight.	Observer.
Centrum,	S. C.	0	51	06	2	
Washington,	D. C.	452	53	20	2	Prof. Newcomb
Washington,	D. C.	452	53	23	2	Alex. McAdie.
Baltimore,	Md.	487	53	20	1	R. Randolph.
New York,	N. Y.	645	54	30	2	M. C. Whitney.
Dyersburg,	Tenn.	569	54	00	1	Louis Hughes.

From these observations the following equations of condition may be formed.

Equation	Wt.	Resid.
$x + 0y = 0$	2	$-2{\cdot}6$
$x + 452y = 135{\cdot}5$	4	$+1{\cdot}6$
$x + 487y = 134$	1	$+13{\cdot}9$
$x + 569y = 174$	1	$-0{\cdot}8$
$x + 645y = 204$	2	$-7{\cdot}3$

By the process of least squares the normal equations are:

$$10x + 4154 = 1258$$
$$4154x + 2210196 = 672408$$

The solution is, $x = -2{\cdot}6\text{s} \pm 4{\cdot}7\text{s.}$ and $y = 0{\cdot}309 \pm 0{\cdot}01$. The resulting speed is, $3{\cdot}236 \pm 0{\cdot}105$ miles or 5205 ± 168 meters per second.

GROUP II.—*Good reports, giving the time of beginning to the nearest minute or half minute.*

Locality.	State.	Distance.	Time.	Weigh	Observer.
Centrum,	S. C.	0	$51^m 06^s$	2	
Nashville,	Tenn.	438	53 30	1	J. D. Leonard.
Covington,	Ky.	488	53 41	1	Jos. Brookshaw.
Pikesville,	Md.	490	53 30	1	C. R. Goodwin.
Evansville,	Ind.	545	54	1	F. W. Norton.
Cleveland,	O.	604	54	1	Wm. Line.
Cleveland,	O.	604	54	1	G. H. Tower.
Crawfordsville,	Ind.	620	54	½	E. C. Simpson.
Belvidere,	N. J.	622	54	1	G. W. Holstein.
New York,	N. Y.	645	54 30	1	N. Y. Herald.
Stockbridge,	Mass.	765	56	½	J. O. Jacot.
Albany,	N. Y.	770	55	1	W. G. Tucker.

From these we may form the following equations.

	Weight.	Residuals.
$x + 0y = 0$	2	$-1{\cdot}6$
$x + 438y = 144$	1	$-9{\cdot}8$
$x + 488y = 155$	1	$-5{\cdot}3$
$x + 490y = 144$	1	$+6{\cdot}3$
$x + 545y = 174$	1	$-6{\cdot}6$
$x + 604y = 174$	2	$+11{\cdot}6$
$x + 620y = 174$	$\frac{1}{2}$	$+16{\cdot}6$
$x + 622y = 174$	1	$+17{\cdot}2$
$x + 645y = 204$	1	$-5{\cdot}6$
$x + 765y = 294$	$\frac{1}{2}$	$-58{\cdot}4$
$x + 770y = 234$	1	$+3{\cdot}1$

The normal equations are:

$$12\,x + 5898{\cdot}5\,y = 1811.$$
$$5898{\cdot}5x + 3577366{\cdot}5\,y = 1100677.$$

The solution gives $x = -1{\cdot}6$s. $\pm 7{\cdot}7$s. $y = 0{\cdot}31 \pm 0{\cdot}014$s. The resulting speed is, $3{\cdot}226 \pm 0{\cdot}147$ miles or 5192 ± 236 meters per second.

Group III consists of reports which fail to give either the means of judging of the comparative accuracy of clocks and watches or of determining to what phase the observation refers. Many and indeed the majority of them are defective in both of these respects. Quite probably some of them are good observations but fail to give the evidence of it. So far as errors of clocks and watches are concerned the errors may be considered as belonging to the accidental class. But all errors as to the phase must be systematic. That some of them refer to more or less advanced phases is certain, and it becomes difficult to determine how many of them do so, and how great is the average tardiness. It is obvious that the effect of all such errors is to make the time too late and the resulting speed too slow. The general indications are, however, that this systematic error is not a large one. By comparing miscellaneous reports from those cities which have also given better verified reports belonging to groups I and II there seems to be a tendency of the average value of this error to fall between one-tenth and one-twentieth of the mean value of the time-interval.

In discussing this group it seems unnecessary to go to the length of formulating a hundred equations of condition, and an equally good result or even a better one may be obtained by the following more summary process. We may take them in sets, the first of which shall comprise all times within 200 miles of the centrum, the second set all between 200 and 300 miles, the third all between 300 and 400 miles, and so on until the last, which shall comprise all beyond 800 miles. In each set we may then take the weighted arithmetic means of the times and distances as if they were single observations.

GROUP III.—*List of* 125 *miscellaneous Time Reports.*

Locality.	State.	Distance.	Time.	W't.	Remarks.
Statesburg,	S. C.	80	51m 30s	1	
Columbia,	S. C.	89	52	1	
Savannah,	Ga.	89	51 53	2	mean of 3 obs.
Augusta,	Ga.	111	51 30	2	mean of 2 obs.
Laurinburg,	N. C.	135	51	1	
Darien,	Ga.	138	52 30	1	
Brunswick,	Ga.	155	52	1	
Macon,	Ga.	203	52	1	
Jacksonville,	Fla.	211	52	2	mean of 3 obs.
Fernandina,	Fla.	225	53	1	
Olustee,	Fla.	355	53	1	
Palatka.	Fla.	255	53	1	
Thomasville,	Ga.	273	52 20	1	
Wytheville,	Va.	284	52 27	1	
Knoxville,	Tenn.	302	54	1	
Zellwood,	Fla.	306	53	1	
Chattanooga,	Tenn.	329	53	1	
Norfolk,	Va.	349	54	1	
University,	Ala.	363	52	1	
Ashland,	Va.	367	52	1	
Shelby Iron Works,	Ala.	377	54	1	
Catlettsburg,	Ky.	405	52 30	1	mean of 2 obs.
Pungoteague,	Va.	410	53	1	
Decatur,	Ala.	412	53	1	
Ironton,	O.	414	55	1	
Nashville,	Tenn.	438	54 30	1	
Washington,	D. C.	452	53 41	2	mean of 4 obs.
Louisville,	Ky.	485	54 38	1	mean of 2 obs.
Baltimore,	Md.	487	53	1	
Dayton,	Ky.	487	54 11	1	
Newport,	Ky.	488	53 21	1	
Cincinnati,	O.	491	53 41	4	mean of 6 obs.
Lancaster,	O.	491	54	1	
Wyoming,	O.	501	53 41	1	
Columbus,	O.	513	53 41	2	mean of 4 obs.
Hamilton,	O.	513	54 11	1	
Paris,	Tenn.	520	56	1	
Pittsburg,	Pa.	525	54 30	1	mean of 2 obs.
Brookville,	Ind	526	53	1	
New Philadelphia,	O.	532	54	1	
Sewickly,	Pa.	535	54	1	
Mt. Vernon,	O.	536	56	1	
Wellsville,	O.	538	55	1	
Oxford,	Miss.	548	56	1	
Paducah,	Ky.	558	52 15	1	
Philadelphia,	Pa.	566	53	1	
Burlington,	N. J.	584	53	1	
Indianapolis,	Ind.	584	55	2	mean of 3 obs.
Cairo,	Ill.	588	53	1	
Titusville,	Pa.	608	56	1	
Helena,	Ark.	609	55	1	
Toledo,	O.	637	55	1	
Newark,	N. J.	640	53	1	
Jamestown,	N. Y.	642	56	1	

Locality.	State.	Distance.	Time.	W't.	Remarks.
Brooklyn,	N. Y.	643	54^m30^s	3	mean of 4 good obs.
New York,	N. Y.	645	54 12	6	mean of 10 obs.
Hackensack,	N. J.	654	54	1	
Warwick,	N. Y.	661	56	1	
Gowanda,	N. Y.	666	55	1	
Detroit,	Mich.	675	55 12	3	mean of 5 obs.
Valparaiso,	Ind.	705	53	1	
London,	Ont.	706	55	1	
Peoria,	Ill.	710	55	1	
New Haven,	Conn.	711	55 30	2	mean of 2 obs.
Port Huron,	Mich.	712	55	1	
Hudson,	N. Y.	747	57	1	
Hartford,	Conn.	747	54 45	2	mean of 2 good obs.
Stuyvesant,	N. Y.	760	57	1	
East Saginaw,	Mich.	766	58	1	
Albany,	N. Y.	770	56 40	1	
Fonda,	N. Y.	775	55	1	
Saratoga,	N. Y.	797	53	1	
Greenfield,	Mass.	799	55	1	
Keokuk,	Iowa.	810	56	2	2 obs.
Dighton,	Mass.	812	56	1	
Davenport,	Ia.	827	55	1	
Lake Placid,	N. Y.	827	55	1	
Jamaica Plain,	Mass.	828	57	1	
Blue Mt. Lake,	N. Y.	830	56	1	
Bellows Falls,	Vt.	832	53	1	
Boston,	Mass.	832	55 30	1	2 obs.
Dubuque,	Ia.	878	57	1	
Prairie du Chien,	Wis.	924	56 30	1	

Taking these in groups in the manner just indicated we have:

		Weight.	Residuals.
Centrum	$x + 0y = 0$	2	+ 4·06
0 to 155	$x + 111y = 39$	9	+ 1·90
203 to 284	$x + 240y = 84$	8	− ·28
302 to 377	$x + 342y = 122$	7	− 4·43
405 to 491	$x + 462y = 158$	16	− ·60
501 to 588	$x + 542y = 184$	18	− ·05
608 to 675	$x + 647y = 217$	20	+ 1·80
705 to 799	$x + 744y = 255$	15	− 4·00
810 to 924	$x + 837y = 278$	11	+ 3·85

The normal equations are:

$$106x + 55768y = 18940.$$
$$55768x + 34474772y = 11668675.$$

The solution gives $x = + 4·06 \pm 1·7$ seconds, $y = 0·3319 \pm 0·0029$. The resulting speed is, $3·013 \pm 0·027$ miles or 4848 $\pm$ 43 metres per second. To this result some correction must be applied for the systematic error, which, as already stated, there is reason to believe probably lies between one-tenth and one-twentieth of the mean time-interval and therefore of the speed. Suppose it be taken at one-fifteenth of the amount, with a probable error of one third of the correction. This would make the corrected result 3·214 ± 0·072 miles or 5171 ± 116 metres per second.

Stopped Clocks.

It is natural to suppose that if a clock were stopped by an earthquake and if its error at the time were known it would give the best possible record of the time of advent of the shock. An examination of the time reports of this earthquake, however, strongly contradicts this conclusion. A clock may stop at almost any phase of the disturbance. A sensitive one may pass through an earthquake of considerable violence and not stop at all. A jeweler's clock in Charleston was found going the next morning, and when the telegraph wires were re-opened its error was found to be small, showing that its escapement had missed very few beats, if any. Clocks in Columbia, Savannah, Augusta and Wilmington, N. C., in many cases kept going. Inquiry at Wilmington elicited the reply that no jewelers' clocks had been stopped. Several reports describe clocks whose rates are satisfactorily vouched for but whose times can be accounted for only upon the theory that they were stopped by the second powerful shock, which was felt at Charleston about five minutes after the principal one, *e. g.*, Branchville, S. C., Augusta, Rome, Ga., Cape Canaveral, Camden, Ala., Memphis, Tenn. There are some cities where the time of beginning is well established by independent observation and which also report stopped clocks. In every such case the time of the stopped clock is much later. Thus at Nashville the time of beginning was noted by a clock which continued going for 42 seconds and then stopped. Similar means of comparison come from Cincinnati, Covington, Ky., Pittsburg, Newark, N. J., Brooklyn and New York. And in general wherever stopped clocks can be compared with really good personal observations they invariably show a later time and usually a much later one. The difference is plainly due to the fact that it generally takes a considerable time and an accumulation of the effects of the vibrations of the building upon the pendulum to stop a clock. An attempt has been made to evaluate this difference by taking those cases where a comparison can be made between the readings of stopped clocks and independent determinations of the times of the beginning in the same locality.

Locality.	State.	Intervals by personal obs. Seconds.	Intervals by stopped clocks. Seconds.	Ratios.	Weights.
Nashville,	Tenn.	144	186	1·29	2
Covington,	Ky.	155	235	1·52	1
Cincinnati,	O.	155	195	1·26	2
Pittsburg,	Pa.	174	234	1·34	1
Brooklyn,	N. Y.	204	234	1·15	1
New York,	N. Y.	204	249	1·22	2
		Mean ratio,		1·28	

In the above table the comparison at Cincinnati takes account only of a single clock, whose error happened to be known exactly. The time of beginning in that city is also known with exceptional certainty and accuracy. It will not differ more than eight or ten seconds from 9h. 16m. (Cincinnati local mean time or 9h. 53m. 41s.). If we consider Cincinnati and suburban towns within fifteen miles of the city which are supplied with local time from the Cincinnati observatory, we have no less than twenty-two time reports, of which nine are stopped clocks. Two personal observations giving 9:15 local have been rejected because they are multiples of five. One report giving 9:17:45 has been rejected because its author, besides indicating that it refers to an advanced phase, throws doubt on his own observation. Of the remaining ten personal observations one gives 9:15:40, eight give 9:16, and one gives 9:16:30. Of the stopped clocks, three were in the central office of the Western Union Telegraph Co. They kept standard time and were read only to the nearest minute. All three are reported to have stopped at 9:54. The clock in the fire tower is the one whose error was known. Its corrected reading was 9:16:40. The remaining clocks gave (9:15), (9:16), (9:17), (9:17:20), and (9:19). Four of the latter were from the suburban town of Lockland. Reducing to standard time and taking their mean, the ratio of the time-interval by stopped clocks to that by personal observation is 1.26, a result identical with that derived from the clock in the fire tower alone and nearly the same as that in the table. There is reason to believe, however, that this ratio is a little too great for the mean of stopped clocks throughout the entire country, and especially so for those of very distant localities; for if the ratio were uniform, the absolute differences between the two kinds of data would be very wide in remote regions and small near the centrum. This is not the case. The absolute differences at very remote localities are very little, if any, greater than those at the middle distances. This difficulty prevents us from assigning any specific value to the correction and from determining its probable error. Nevertheless the comparisons just made indicate that the systematic error is probably of such magnitude that, if due allowance were made for it, the corrected result for the stopped clocks would not differ much from those of the preceding groups. While this group furnishes evidence which strongly supports the approximate correctness of the results of the other three it cannot be a source of greater precision nor can it furnish the means of reducing the final probable error.

Group IV.—*Stopped Clocks.*

Locality.	State.	Distance.	Time.	No. of clocks.	W't.
Centrum,	S. C.	0	51^m06^s		
Charleston,	S. C.	20	51 12	4	3
Columbia,	S. C.	89	51	2	2
Savannah,	Ga.	89	51 55	2	2
Langley,	S. C.	103	53	1	1
Augusta,	Ga.	111	52	1	1
Cochran,	Ga.	192	52	2	2
Macon,	Ga.	203	51 30	1	1
Jacksonville,	Fla.	211	52	1	1
Atlanta,	Ga.	252	52 22	4	3
Catlettsburg,	Ky.	405	53	1	1
Nashville,	Tenn.	438	54 12	1	1
Columbus,	Miss.	481	56	1	1
Covington,	Ky.	488	55	1	1
Cincinnati,	O.	491	54	3	2
Cincinnati,	O.	491	54 21	1	1
Meridian,	Miss.	500	54	1	1
Lockland,	O.	505	54 26	4	3
Havre de Grace,	Md.	515	55	1	1
Pittsburg,	Pa.	525	55	1	1
Newcastle,	Del.	538	54	1	1
Atlantic City,	N. J.	552	54	1	1
Wooster,	O.	558	55 45	1	1
Newcastle,	Pa.	565	55	1	1
Indianapolis,	Ind.	581	55	1	1
Memphis,	Tenn.	587	54 50	6	4
Cairo,	Ill.	588	53	1	1
Meadville,	Pa.	608	55	1	1
Newark,	N. J.	640	55	1	1
Brooklyn,	N. Y.	643	55	1	1
New York,	N. Y.	645	55 15	2	1
Ithaca,	N. Y.	696	55	1	1
Manistee,	Mich.	855	57	1	1

We may arrange these in groups or sets according to their distances, as was done in the discussion of group III, and obtain the following equations of condition.

		Weight.	Residuals.
0 to 89	$x + 59y = 15$	7	+ 12·29
103 to 192	$x + 150y = 69$	4	− 7·21
203 to 252	$x + 234y = 110$	5	− 16·37
405 to 491	$x + 469y = 194$	7	− 11·29
500 to 588	$x + 549y = 209$	16	+ 4·04
608 to 696	$x + 642y = 237$	5	+ 12·80
855	$x + 855y = 354$	1	− 24·97

The normal equations are:

$$45x + 183335\,y = 7172.$$
$$18335x + 9567895\,y = 3717233.$$

From which $x = +5{\cdot}0$, $y = 0{\cdot}379$. The resulting speed is $2{\cdot}638 \pm 0{\cdot}105$ miles, or 4245 ± 168 meters per second. If the correction for the systematic error has a value approximately that which has been derived from the comparisons of the stopped clocks with well determined times of particular localities, or not less than one-fifth the amount, the corrected speed would be from 5100 to 5200 meters.

We may now proceed to combine the results of the first three groups and obtain from them a single mean. The probable error of the fourth group being uncertain it is necessary to omit it. Taking the weights inversely as the squares of the probable errors we have:

		W't.
Group I,	$5205^m \pm 168^m$	2
Group II,	$5192^m \pm 236^m$	1
Group III,	$5171^m \pm 116^m$	4
Mean result,	$5184^m \pm 80^m$	

It remains to inquire whether the data indicate any variation of the speed. The answer is in the negative. The data are inconsistent with any variation of a systematic character and there is no apparent means of detecting an unsystematic one. A small irregular variation, such as might be caused by varying density and elasticity of the propagating medium, would not be inconsistent with the data; but the evidence of it cannot be separated from the errors of observation.

Art. II.—*History of the changes in the Mt. Loa Craters;* by James D. Dana. Part I. Kilauea. (With Plate I).

[Continued from vol. xxxiii, p. 433 (June), vol. xxxiv, p. 81 (August), and p. 349 (November).]

4. General Summary, with Conclusions.

From the foregoing review of publications on Kilauea, it appears that we have already much real knowledge about the changes in the crater, and that this knowledge embraces facts that are fundamental to the science of volcanic action. This will be made more apparent by the Summary and Conclusions which follow. It will be convenient to consider, first, the Historical conclusions, and secondly, the Dynamical.

I. HISTORICAL.

1. *Periodicity or not in the discharges of Kilauea.*

In the sixty-three years from 1823 to 1886, there appear to have been at least eight discharges of Kilauea. Four of them were of prime magnitude—those of 1823, 1832, 1840 and 1868—distinguished by a down-plunge in the floor of the crater making in each case a lower pit several hundred feet deep. Others, as those of 1849, 1855, 1879, 1886, were minor discharges, discharges simply of the active lakes, without any appreciable or noticed sinking of the floor of the crater. The eruption of 1849 might be questioned; but it was preceded by far more activity in the crater than that of 1886. Other subterranean discharges may have occurred since 1840 of which no record exists. Even small breaks below might empty Halema'uma'u.

The mean length of interval between the first three eruptions was 8 to 9 years (xxxiv, 81). The great eruption of 1789, the only one on record before that of 1823, occurred 34 years back of 1823, or $4 \times 8\frac{1}{2}$ years; and the 1868 eruption was $3 \times 9\frac{1}{3}$ years after that of 1840.

The above approximate coincidences in interval and multiples of that interval seem to favor some law of progress. But it is not yet proved that they have any significance. The minor eruptions which have been referred to above have intervals varying from 6 to 13 years. Moreover, looking to the summit crater of Mt. Loa for its testimony, we find still greater irregularity, the successive intervals between its six great outflows from 1843 to 1887 being 9, 4, $3\frac{1}{2}$, 9, $12\frac{1}{2}$, $6\frac{1}{4}$ years.

A partial *dependence of the activity of the fires on seasons of rains* was suggested by Mr. Coan; and there is some foundation for the opinion in the times of occurrence of the Kilauea discharges mostly within the four months, March to June, as shown in the following table:

1823	March ?	1855	October.
1832	June (Jan. ?) (xxxiii, 445)	1868	April 2.
1840	May.	1879	April 21.
1849	May.	1886	March 6.

In addition, there was a brightening of the fires around the crater in October of 1863; and again in May and June of 1866; whether followed by a discharge of the Great Lake is not known. The future study of the crater should have special reference to this point.

2. *Mean rate of elevation of the floor of the crater after the great eruptions.*

After the eruption of 1823, between the spring of that year and October of 1829, an interval of $6\frac{1}{2}$ years, the bottom, if the depth was 800 feet as inferred after the measurement of the upper wall by Lieut. Malden, rose at a mean annual rate of 138 feet, or, taking the depth at 600 feet, of 93·3 feet. Lieut. Malden's 900 feet for the upper wall, sustained, after explanation (xxxiii, 440), may need reduction on the ground that the present width of the crater is greater than in 1825, owing to falls of the walls; but it is useless with present knowledge to make any definite correction. Only general results are possible.

After the 1832 eruption, the lower pit in February of 1834, was 362 feet deep, by the barometric measurement of Mr. Douglas,* and in May of 1838, about 4½ years later it was filled to within 40 feet of the top; whence the mean annual rate of 71½ feet.

After the 1840 eruption, between January, 1841, and the summer of 1846, 5½ years, the 342 feet of depth, found for the lower pit by the Wilkes Expedition, was obliterated, and the floor was raised on an average 40 or 50 feet beyond this; a rise of 400 feet in the 5½ years would give for the mean annual rate, 72¾ feet.

Subsequent to 1846 the rising of the floor was slower. Between 1846 and 1868, 22 years, the rise over the central plateau is estimated at 200 feet. It is not certain that subsidences in the plateau of greater or less amount did not take place at the eruptions of 1849 and 1855, or at other times.

3. *Levels of the floor after the eruptions of* 1823, 1832, 1840, 1868 *and* 1886.

The measurements of depth already given and the mean annual rate of progress deduced are approximate data for determining the depth of the lower pit as it existed immediately after the great eruptions.

The depth after the 1823 eruption is considered above. To arrive at the depth after the 1832 eruption, the depth obtained in 1834 by Douglas has to be increased by an allowance for change during the previous year and a half, which, at the rate arrived at above, would give 450 feet. This is so much less than the estimate of Mr. Goodrich (xxxiii, 446) that it is almost certainly below rather than above the actual fact. For the depth in June 1840, the Wilkes Expedition measurement, 342 feet, should be increased for a preceding interval of seven months, which at the rate deduced above for the next four years, would make the amount about 385 feet. In 1868, according to the two estimates for the lower pit (xxxiv, 92), the depth was about 300 feet. Mr. Severance of Hilo, informed me in August last that the pit in 1868 was as deep as in 1840. The lower estimate is adopted beyond. In 1880, the lower pit of 1868 had wholly disappeared, and, according to

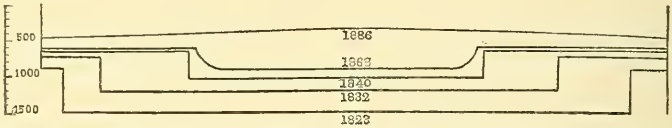
* See the first part of this paper. vol. xxxiii, p. 446, June, 1887, where the facts are definitely given, and also other evidence.

the description of Mr. Brigham (xxxiv, 95, from page 20 of the same volume) the bottom of the crater had already the form of a low eccentric cone, the surface rising from the foot of the encircling walls to the summit about Halema'uma'u. This has continued to be the form of the bottom, and the Government map gives the present depth. (See the accompanying Plate I).*

The following table contains (A) the above deduced figures for the depth of the lower pit; (B) the height of the *highest part* of the western wall; and (C) the level of the center of the pit below the top of the western wall.

	Depth of Lower Pit.		Height of W. Wall above ledge.	Height of W. Wall above center of bottom.	
After eruption of 1823	600	(800?)	900 (?) Malden	1500	(1700?)
1832	450	(600?)	715 Douglas	1165	(1315?)
1840	385		650 Wilkes †	1030	
1868	300		600 (550?)	900	(850?)
1886	0		500 Govt. Survey	380	

These numbers have much instruction in them notwithstanding all uncertainties. The following diagram, based on them, represents a transverse section of the crater at the several levels of the floor and black ledge. The minimum depths for 1823 and 1832 are here accepted, there being in them no probability of exaggeration.



The sides of the pit in this section are made vertical from 1823 onward—an error which there are no data for correcting.

* Mr. Brigham's paper gives results of his barometric measurements in 1880, that are not reconcilable with those of the Government or of earlier determinations except on the assumption of great changes of level between 1880 and 1886 and small difference of level as regards the base of the cone between 1840 and 1880. His depths are 650 feet at the northern base of the cone near the place of descent, where Wilkes made the depth 650 feet, and the Government map in 1886, 481 feet; and 300 at Halema'uma'u, where the Government survey made the depth nowhere less than 320 feet. By the reported measurements, the cone had a height of 350 feet in 1880, and of 150 in 1886; accordingly the base of the cone to the north had been raised 140 feet in the 6 years after 1880 while nothing or little in the 40 years preceding it, although large overflows during the interval, adding 50 to 100 feet to its height, are mentioned by Mr. Brigham and others; and the level about Halema'uma'u had lost 30 feet between 1880 and 1886. The latter difference of level is not impossible; but the former it is natural to question, since so great a rise of the border in 6 years could not have taken place by any method without being noticed.

† The Wilkes Expedition appears to have made the place of encampment the datum point. The exact position of the place is not precisely known. It may probably be ascertained nearly enough to give by leveling the height with reference to the Volcano House; but at this time the height has not been determined.

The diminution since 1823 in the height of the western wall above the black ledge is probably due almost wholly to the *flooding* of the black ledge. According to the numbers, this diminution was about 185 feet from 1823 to 1832; 65 from 1832 to 1840; and 160 feet since 1840. But subsequent to 1840, as Emerson's map shows, the diminution of level along the black ledge or lateral portion of the pit has been much less than over the central, the amount of diminution at center having been at least 200 feet, and about Halema'uma'u 250 to 300 feet.

The bottom of the emptied basin of Halema'uma'u after the eruption of 1886 was 900 feet below the Volcano House; and this was 50 to 100 feet above the liquid lava of the basin in 1840.

The relations between the amounts discharged in 1823, 1832, 1840 and 1868 could be approximately inferred from the size of the lower pit as determined by the mean breadth of the black ledge, if the width of the crater were the same at all periods. But in addition to other uncertainties we have that arising from sloping walls, and very sloping on the southeast side. The pit of 1823 should therefore have been narrower at the black-ledge level than that of 1840. Still, the width of the ledge in 1823, according to all the observations and maps, was so very narrow compared with that in 1840, that we may feel sure of the far larger amount of the earlier discharge. But the depth of the lower pit was also greater in 1823, and this requires an addition of one half to the amount which the area of the lower pit suggests, if not a doubling of it.

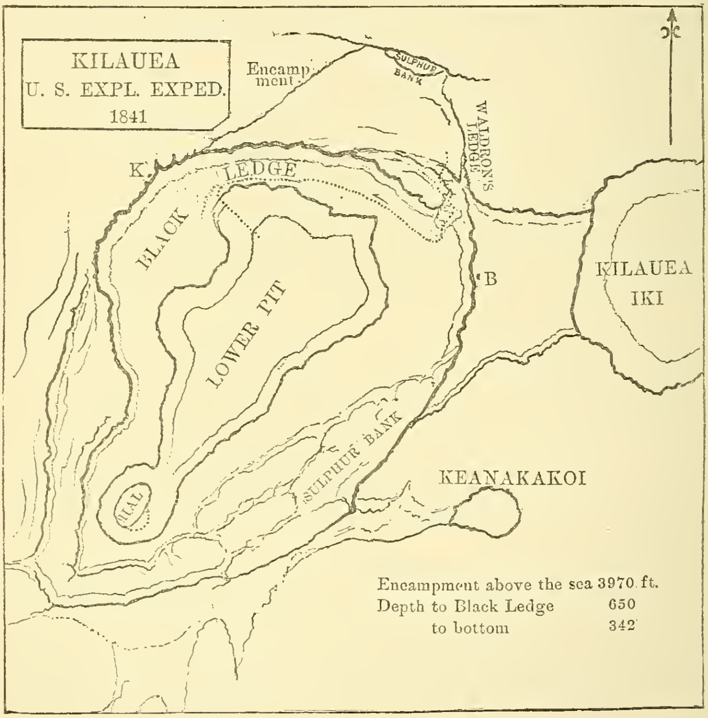
For an estimation of the discharge of 1832 we are still more uncertain as to the mean width of the ledge. But that the ledge was narrow, much like that of 1823, is most probable. In 1868 the down-plunge, according to the most reliable estimate, was a fourth less than in 1840, the depth of the pit being not over 300 feet.

There are no sufficient data for putting in figures the relative amounts of discharge at the great eruptions. But the general fact of a large diminution in the amounts since the first in 1823 is beyond question. It has to be admitted, however, that we can hardly estimate safely the discharge in 1868 from the size of the pit then made, since the thickness of the solid floor of the crater may have prevented as large a collapse in proportion to the discharge. But it did not take place until 28 years had passed after 1840, and this strengthens the evidence as to an apparent decline in the outflows, whatever be true as to the activity. The following eighteen years produced only minor eruptions.

4. *Other points in the Topographic history of the Kilauea region.*

Besides the points considered, the chief events in the topographic history since 1823 are: (1) avalanches and subsidences along the border of the crater; and (2) overflowings and changes of level over the bottom.

Down-falls of the walls and sinkings of the borders are reported as having been common during periods of eruption and earthquake; but direct testimony as to the amount at any time does not exist. In view of the great numbers of deep fissures about Kilauea (xxxiv, 358) and the many fault-planes and sunken areas, the fact cannot be doubted; and Mr. Brigham has estimated* that the crater in 1880 was five per cent larger than it was 18 years before. The increase in mean diameter on this estimate would be 300 feet. I think the estimate large.

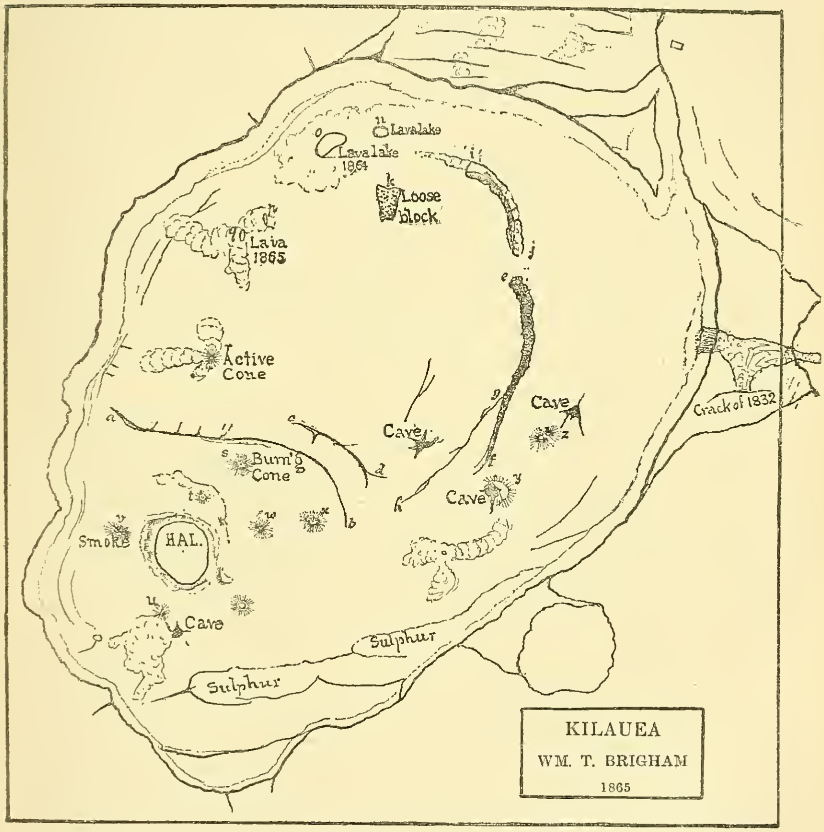


Of the gradual changes over the bottom of the crater pretty full records have been gathered from the published accounts. But we naturally look with the greatest confidence to the maps that give the results of personal surveys, especially with regard to changes in the outline of the walls. We have two such maps—that made personally by Wilkes in 1841, and that by Brigham in 1865, besides the recent map by the Hawaiian

* This Journal, III, xxxiv, 20.

government, under Professor Alexander's charge, completed in 1886. For convenient comparison the reduced copies of Wilkes's and Brigham's maps are here reprinted; that of the Government survey is reproduced in Plate 1 of this volume.

In using the maps a difficulty is encountered at the outset in consequence of a discrepancy between the first two of the maps and that of the Government survey as to the dimensions of the crater. Accepting the latter as right, the scale of each of the others should be diminished about an eighth to bring the three



maps into correspondence. The maximum diameters in Wilkes's map, using his own scale, are 16,000 and 11,000 feet; while according to the Government map they are about 14,000 and 9800 feet; and the length of the line from K to B on the former is 10,000 feet and on the latter 8500 feet. It is certain that the crater in 1840 was not *larger* at top than now. Mr. Brigham's map appears to have been carefully made, but for some reason it requires the same correction. Such a discrepancy unavoidably throws doubts over other parts of the maps. But while closer study increases confidence in Mr. Brigham's, the result is not so satisfactory with the Wilkes map. The following remarks suppose the scale of the two maps to have been corrected.

Wilkes's map of Kilauea.—The relations of the map made by Capt. Wilkes to that of the Government Survey is exhibited on Plate 1, the outline of the crater from the former being drawn over the latter where it is essentially divergent. This diverging part of the outline is lettered A B C D E, D E showing the outline of the sulphur banks of 1840. Besides this, the outline of the black ledge of 1840 is indicated by the line L L L, and its surface by cross-lining. Some important features from Brigham's map also are drawn in and indicated by italic letters. These include small lava-lakes, the outline of Hale-ma'uma'u as given by him, small cones, fissures, etc.

The plate shows, in the first place, a general conformity between the eastern wall of the Wilkes and Government maps, but a far greater width of sulphur banks in that of 1840. These sulphur banks have become submerged by the lava flows of later time, and thus the floor of the crater has in this part been extended eastward about 2500 feet. Of this I believe there is no doubt.

In the second place, there is no conformity between the maps in the southern half of the western wall. Instead, on Wilkes's map, south of the Uwekahuna station, the west wall (A B C on Plate 1) is 1200 to 1500 feet inside of the position of the existing wall as given on the Government map; showing, apparently, a very great topographical change on that side of Kilauea since January, 1841, and one of the highest interest; a change either by subsidence, or by overflowings of lava streams, adding nearly 10,000,000 square feet to the area of the crater.

Looking about for other evidence of this change, and finding no allusion to it in Mr. Coan's reports, and nothing in Mr. Lyman's paper or map of 1846 (xxxiv, 83), but, on the contrary, a general conformity in Lyman's map to that of the recent survey, I was led to question the unavoidable conclusion, although it involved a doubt of the Wilkes map. A consequence of the doubt was my sudden determination to revisit Hawaii and sustain the conclusions from Wilkes's map if possible; for they made too large a piece in the history to be left in doubt. Mr. Drayton's sketch, reproduced as Plate 12 in a former part of this paper (xxxiii, 437), suggested the method of deciding the question.

The conclusion arrived at while on the ground in August last, was that Drayton's sketch represented sufficiently well the *existing* outline of that part of the crater, that is, of the crater of to-day. It follows, consequently, that the west wall of 1841 and of 1887 are essentially alike in position, and that Wilkes's map of the southern half of its western wall is 1200 to 1500 feet out of the way.

To make this large correction on Wilkes's map involves some other large changes; namely, the widening greatly of the black ledge west of Halema'uma'u; and also a probable widening of the Halema'uma'u part of the lower pit with the entrance-way to it. Both changes are favored or required by Drayton's sketch. The entrance-way referred to is thus widened (on the ground of Drayton's sketch chiefly), from Wilkes's 800 feet at top of wall to about 1500 feet. The dotted line L′L′L′ on Plate 1 is believed to show the probable limit of the 1840 black ledge along the west border of Halema'uma'u.*

So large an error in so small a map excites an uncomfortable query as to all the rest of its details; fortunately not, however, as to the depth of the crater and its lower pit, since this was obtained by the independent measurements of two of the Expedition officers, Lieutenants Budd and Eld. Moreover the map may be used for some general conclusions.

Drayton's sketch was probably taken from the point marked *Dn* on the map, south of Wilkes's encampment, or on the higher land to the west of this point.†

The sketch has three headlands along the west wall. Of these, only the second and third exist as they then were. The first or nearest stood, as the sketch shows, between the Uwekahuna summit and the second of the deep western bays on Wilkes's map of the lower pit, a spot where great subsidence has taken place in the western wall, east or southeast of the Uwekahuna station (xxxiv, 358); and the sketch appears to be sufficient testimony for the reality of this subsidence and its amount.

Looking again at Wilkes's map (page 20), it is seen that, as already stated, the outer *eastern* wall has the same position that it has on the Government map, but that the *southeastern* wall of Wilkes is not continuous with his western, but is an independent one situated more to the eastward; and here came in the error. The error is so extraordinarily great that we sought while at the crater for some extraordinary excuse for it. We concluded (Mr.

* Another smaller change is proposed in the eastern outline of the lower pit, near *e*, suggested by Brigham's map. No attempt is made to give on the Government map Wilkes's outline of the southeast angle of the crater, as the existing features offer no available suggestions.

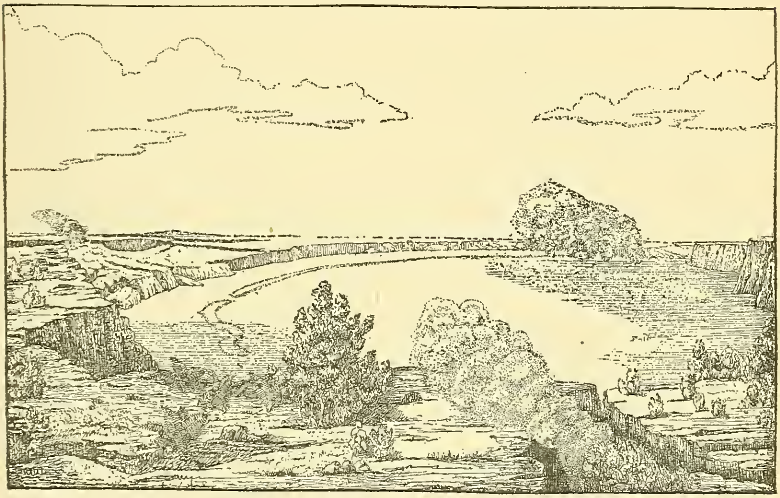
† While the sketch bears evidence of being generally faithful to the facts, the foreground appears to be modified for the artistic purpose of giving distance to the rest.

Merritt and myself) that Captain Wilkes in his visit to "all the stations around the crater in their turn" (xxxiii, 451), on reaching the high Uwekahuna summit, instead of relying on his angles, probably took the shorter way of sketching in the ridges that stood to the southeast and south; and that he was led by insufficient topographical judgment to throw the wall, together with the parallel ridge outside of it, too far to the eastward. The error, as we saw when there, is an easy one for him to have made. This cramped the map to the southward about the Great South Lakes, but the angles taken from other stations were not enough to serve for the needed correction and the sketching was allowed to control the lines. However this may be, it is lamentable that a correct map, with a careful determination of heights around the crater, was not made in 1840.

An important error also exists in Wilkes's determination of the longitude of his encampment near the crater. The Surveyor-General of the Islands, Prof. Alexander, informed me that the position Wilkes gives Kilauea is $8\frac{1}{2}$ minutes too far west; and that the error affects all the southeastern quarter of his map of Hawaii including the position of the coast line. His longitude of the summit of Mt. Loa is correct.

Mr. Brigham's map.—Mr. Brigham's map is a register of the facts of 1864–65, a period just half way between 1841 and 1887. It indicates unfinished changes in progress within the crater which were commenced in 1840, and other conditions that became pronounced only in later years.

The remnants it represents of Lyman's ridge of lava-blocks, —the talus of the lower wall uplifted upon the rising floor of the lower pit—has already been referred to (xxxiv, 89). That it may be fully appreciated, the reader is directed again to Mr. Lyman's map, here reprinted with corrections by him;* and then to Plate 1, which shows these remaining parts of the long ridge drawn, from Brigham's map, on the recent map of the Government survey (lettered *ef*, *gh*). The ridges are not put as far from the east wall of the crater as on Brigham's map, but are made to accord with the statement of each Lyman and Coan, and of Brigham also, that they followed the course of the lower-pit wall of 1840 a little inside of its position, over the site of the original talus—Wilkes's position of the wall being adopted except for a short distance near *e*. Halema'uma'u, as



the dotted line inside of the basin of the Government map shows, was small in 1864–65, it being only 1,000 feet in diameter and but little raised above the level of the liquid lavas.

The preceding additional view of the crater is introduced at this place because it contains the remains of the Lyman ridge as mapped by Mr. Brigham, and is further testimony as to its

* The copy of Prof. Lyman's map, reproduced on page 85 of the last volume of this Journal, is not from a tracing of his original map, but from a roughly drawn copy left on the islands. The original was lost by him, as he informs me, when in California on his return to New Haven. He has here placed the "canal" along side of the ridge, in accordance with the statement in his description and also in his note-book of 1846, which makes the interval between them "10 to 40 and 50 yards." Before publishing the map I endeavored to obtain corrections from him. But on account of his illness at the time I could not communicate with him.

position with reference to the walls. The view is from a photograph of a painting made by Mr. Perry, a California artist, in 1864 (?) the year of Mr. Brigham's first visit, and which I received from Mr. Brigham in March, 1865.* The sketch of the crater bears evidence throughout of great accuracy of detail. It has much interest also because it gives, with clear definition, the outlines of the depression (on the left) between Kilauea and the side crater Kilauea-iki;—in which respect it is more satisfactory than Drayton's sketch. The point of view was on the north border of Kilauea, a little to the east of Drayton's; and consequently it necessarily differs widely from Drayton's sketch as regards the headlands of the western wall, yet resembles it quite closely on the eastern side. Halema'uma'u is not defined; and this is explained by Mr. Brigham's map and description.

Mr. Brigham's map shows also the positions of active lava-lakes in 1864 or 1865, lettered *i*, *k*, *l*, *m;* and the interesting fact is to be noted that two of them, to the northwest, *i*, *k* lie *at the edge of the black ledge*, while *l*, *m* are a little back of it, but in a line with *i*, *k*.

The long curving line of deep fissures and fault-plane, already referred to as marking the outline of the Halema'uma'u region, is seen on Plate 1, at *a b*, not to be concentric with the Halema'uma'u basin of either Brigham's map (p. 21) or of the recent map; but to that of Halema'uma'u *plus* the New Lake region of 1884 to 1887. Thus in 1865, when Halema'uma'u appeared as a small basin 1,000 feet broad (not half its existing breadth), the fissure indicated the presence of deep-seated conditions as to the fires and forces, that finally ultimated in its extension over the New Lake area. And the expression of this fact in 1865 was doubled by a second concentric fissure 500 feet farther north (Plate 1, *c d*). Further, four of the cones mapped by Brigham in the vicinity of Halema'uma'u in 1865, *p*, *q*, *r*, *s*, on Plate 1, are inside of the existing Halema'uma'u basin; and one of the others, *o*, is near the north border, and another, *t*, is close by the east side of New Lake.

On Mr. Brigham's map, the position is given of a very large loose block of lava, which is shown at *w*, on Plate 1. It lies, as is seen, in the northwest part of the crater, and is over the lower edge of what in 1840 (see Wilkes's map, p. 20) was an inclined but even lava plain to the bottom that had been made in 1840 by an oblique down plunge (xxxiv, 82) carrying the inner side of the great mass down and leaving the other, that against the black ledge, on a level with the ledge, with a broad

* See Brigham's Memoir, page 419, where a wood-cut from it is introduced, but without doing the photograph justice. Mr. Brigham does not state in his memoir the date of the painting. "Perry" is mentioned as the painter on page 468.

fissure between. The block probably slid down the slope to its bottom; and, as the talus at the bottom of the lower wall was lifted on the rising floor to make Lyman's ridge, so it appears that this loose block was lifted in the northwest corner; and the lift along that part of the crater consisted in the restoring of the half engulfed mass with the lava-block on its surface, to its former horizontal position—the position it had when Mr. Brigham's map and observations were made.

It is interesting to note thus how the 1864–1865 condition of Kilauea grew out of that of 1840, and foreshadowed that of 1887. It is worthy of consideration also that just as the fault-plane *ab* is concentric with the Halema'uma'u basin *plus* New Lake, so the far greater Kilauea fault-planes, 2000 to 5000 feet north and northeast of the crater (xxxiv, 358), are concentric, not with Kilauea, but with Kilauea *plus* Kilauea-iki.

2. DYNAMICAL CONCLUSIONS.

General cycle of movement in Kilauea.—The history of Kilauea, through all its course since 1823, illustrates the fact that the cycle of movement of the volcano is simply: (1) a rising in level of the liquid lavas and of the bottom of the crater; (2) a discharge of the accumulated lavas down to some level in the conduit determined by the outbreak; (3) a down-plunge of more or less of the floor of the region undermined by the discharge. Then follows another cycle: a rising again, commencing at the level of the lavas left in the conduit by the discharge; which rising continues until the augmenting forces, from one source or another, are sufficient for another outbreak.

In 1832 the conditions were ready for a discharge when the lavas had risen until they were within 700 or 800 feet of the top; in 1840, when within 650 feet; in 1868, when within 500 or 600; in 1886, when within 350 feet. The greater height of recent time may seem to show that the mountain has become stronger, or better able to resist the augmenting forces. But it also may show a less amount of force at work. In 1823, 1832 and 1840, the down-plunge affected a large part of the whole floor of the crater, which proves not only the vastness of the discharges, but also indicates active lava through as large a part of the whole area preceding the discharge, while in 1886, the down-plunge and the active fires in view were confined to Halema'uma'u and its vicinity. It was not in earlier time, therefore, the greater weakness of the mountain, but probably the greater power of the volcanic forces.

The broad low-angled cone which the volcano tends to make, has a great breadth of stratified lavas to withstand rupturing forces. How great may easily be calculated by comparing a cone of 8° or 10° with one of 30°, the latter the average angle of the greater volcanic mountains of western America; and this suggests important differences in the results of volcanic action independent of those consequent on the possible prevalence of cinder-ejections in the latter. But somehow or other Mauna Loa breaks easily—very easily, its quiet methods say—and it seems to be because such rocks, however thick, can offer but feeble resistance to rupturing volcanic agencies.

In the discussion beyond of the operations going on and of their causes, I speak, I, of Kilauea as a Basalt-volcano, the basis of its peculiarities; II, of the size of the Kilauea conduit; III, of the ordinary work of the volcano; IV, of its eruptions; and V, of the contrast in volcanic action between Kilauea and volcanos of the Vesuvian type.

I. KILAUEA A BASALT–VOLCANO.

1. *The mobility of the lavas.*—The phenomena of Kilauea are largely due to the fact that it is a basalt-volcano in its normal state. By this I mean, first, that the rock-material is doleryte or basalt, and secondly, that the heat is sufficient for the perfect mobility of the lavas, and therefore for the fullest and freest action of such a volcano. It is essentially perfect mobility although there is not the fusion of all of its minor ingredients, that is of its chrysolite and magnetite. This is manifested by the lavas, whether they are in ebullition over the Great Lake, throwing up jets 20 to 30 feet high, throughout an area of a million square feet or more, or when only splashing about the liquid rock and dashing up spray of little lava drops from areas of a few square yards. There is in both conditions the same free movement, almost like that of water, and suggesting to the observer no thought of viscidity. Of the two conditions just mentioned, the former was that of November, 1840, the latter that of August, 1887; and that of August seemed to be the more wonderful, because we naturally look for some of the stiffening of incipient solidification where only a few square yards of lava are in sight.

2. *This mobility is dependent largely on the fusibility of the chief constituent minerals of the lava.*—Along with augite, a relatively fusible species, the rock contains, as its other chief constituent, labradorite, almost as fusible as augite, and the most fusible of the feldspars. Andesine and oligoclase are less fusible feldspars, and orthoclase is of difficult fusibility. Thus in this prominent physical character the feldspars widely differ, and accordingly there should be, and are, volcanoes of different characteristics, for example, Andesyte volcanoes, in which oligoclase or andesine is the pre-

dominant feldspar, and Trachyte and Rhyolyte volcanoes in which orthoclase is a chief constituent; and, besides these, there are also intermediate grades or kinds.

The differences in form and action among these kinds of volcanoes depend chiefly on the physical quality of *fusibility*, but partly on that of *specific gravity.*

Neither of these qualities, it is to be noted, has any relation to the *acidic* or *basic* character of the feldspar or rock, that is to the amount of silica present. The distinction of *basic* and *acidic*, of great interest mineralogically and chemically, has in fact little importance in the science of volcanoes, while that of fusibility is fundamental. The most basic of all the feldspars, anorthite, is as little fusible as the most "acidic" of feldspars, orthoclase, and more so than the equally "acidic" albite.* It is plain therefore that the quality of being *basic*, does not explain the fusibility of the lavas. Neither does it explain any other of the physical characteristics on which the peculiarities of the volcano depend.

It is also true that the chrysolite (or olivine), the ultra-basic constituent of the lavas, has little influence on their physical characters except through its high specific gravity—which is about 3·3 to 3·4. The mineral chrysolite is infusible, and cannot *increase* the mobility of the lavas; and there is commonly not enough of it in the Kilauea rocks to diminish the mobility; for a large part of the lava contains less than 5 per cent, and much of it less than ·1 per cent. Chrysolite, is *ultra-basic;* but this quality has little volcanic importance. It is not the little amount of silica in it that is influential volcanically but the much iron, the ingredient that gives it its high density or specific gravity. The presence of much chrysolite may affect the distribution of the lavas in the conduit, or of the out-flows from the conduit, on account of their high density; but it does not accomplish this through the ultra-basicity of chrysolite, but through its ultra-ferriferous character, and the conditions under which it is formed.

3. *The degree of mobility is dependent also on temperature.*—It is probable, that at the temperature of fusion, or better a little above it, all the feldspars, the least and the most fusible, are nearly alike in mobility. But the lower the degree of fusibility the less likely is the heat to be deficient, or below that required for complete fusion and mobility; and here comes in the great difference among them as regards lavas and volcanoes.

The basalt-volcano has special advantage over all others in this respect, as the copious Mount Loa lava-streams and the

* In my Manual of Mineralogy and Petrography, page 436, I point out further that the distinction of alkali-bearing and not alkali-bearing among the silicates is of much more geological importance than the much used one of acidic and basic.

immense basaltic outflows of other regions exemplify. In Hawaii the heat required for the existing mobility is no greater than the deep-seated conditions below the mountain can keep supplied, in spite of cooling agencies from the cold rocks, the subterranean waters and the air; it is no greater than it can continue to supply for half a century and more, as the records have shown; and supply freely to the top of a conduit 3000 to 3500 feet above the sea-level, and even to the top of another conduit but twenty miles off, rising to a height of 13,000 feet above the sea-level. The temperature needed for this mobility judging from published facts, is between 2000° F. and 2500° F. The fusing temperature of augite and labradorite has not yet been determined. We are certain that a white heat exists in the lava within a few inches of the surface; for the play of jets in a lava-lake makes a dazzling network of white lightning-like lines over the surface; and white heat is equivalent to about 2400° F. Considering the height of Mt. Loa and the greatness of its eruptions, and the vastness of basaltic outflows over the globe, we may reasonably assume that the temperature needed for the normal basalt-volcano has long been, and is now, easy of supply by the earth for almost any volcanic region; and that the difficulty the earth has in supplying the higher heat for equal mobility in a trachyte or rhyolyte volcano is the occasion of the common semi-lapidified pasty condition of their outflowing lavas.

Even if the higher temperature required for orthoclase-lavas, were always present quite to the surface in the volcano, the ordinary cooling influences of cold rocks and subterranean waters and air would be sure to bring out, in some degree, on a globe with existing climatal conditions, the characteristics of the several kinds of volcanoes designated.

I do not say that this higher heat required for the complete fusion of trachyte or rhyolyte is wanting at convenient depths below; for it has been manifested in the outpouring of vast floods of these rocks through opened fissures, many examples of which over the Great Basin are mentioned in King's "Systematic Geology" of the 40th Parallel. But in the volcano, whose work, after an initial outflow, is carried forward by periodical ejections and requires for long periods a continued supply of great heat, the more or less granulated or pasty condition of the outflowing orthoclase-bearing lava streams is the usual one. Consequently, when a volcano changes its lavas from the less fusible to the more fusible, as sometimes has happened, some change in the features of the volcano should be looked for, except perhaps when the change occurs directly after the initial discharge.

Here the question suggests itself whether the temperature existing at depths below may not be one of the conditions that determine whether the discharged lavas shall be of the less fusible or the more fusible kind.

But a *basalt*-volcano also may fail to have heat enough for perfect fusion, and hence have partially lapidified or pasty lavas, and thus be made to exhibit some of the characteristics of the other kinds of volcanoes. This condition may result from three causes: (1) A decline in the supply of heat of the conduit, as when the partial or complete extinction of the volcano is approaching; (2) When the lava is discharged by lateral openings or fissures, in which case the lateral duct of lava may not be large enough to resist completely the cooling agencies about it; (3) The sudden entrance of a large body of water into the conduit.

The effects from the *first* of these conditions—declining heat connected with approaching extinction—are strikingly exemplified in two great volcanic mountains of the Hawaiian Islands, Mt. Kea on Hawaii, and Haleakala on Maui. Those of the *second*, in which the ejections are from lateral openings, are abundantly illustrated in the cinder and tufa cones of the islands, and also in widespread cinder or ash deposits through the drifting of the ejected material by the winds. The *third*, a sudden incursion of waters through an opened fissure, if a possibility, should both lower the temperature and produce violent projectile results, and even Kilauea bears evidence of at least one eruption of great magnitude which was thus catastrophically produced; for the region bordering the crater on all its sides, and to a distance of ten or fifteen miles to the southwest, is covered with the ejected stones or bowlders, scoria and ashes of such an eruption.

4. *Eruptive characteristics of a Basalt-volcano.*—The obvious results of superior mobility and density in lavas, are, as in other liquids:

(1) First: greater velocity on like slopes, and thus an easier flow, with less liability to be impeded by obstructions; a lower minimum angle of flow, and consequently a less angle of slope for the lava cones.

(2) Secondly: The vapors ascending through the liquid lava encounter comparatively feeble resistance, and hence the expansive force required for escape of bubbles through the lava to the surface is feeble; and so also are the projectile effects due to the explosion of the bubbles. Hence the projected masses commonly go to a small height—it may be but a few yards—and fall back before cooling, instead of reaching to a height that involves their cooling and solidification in the fall and the making thus of cooled fragments of lava or scoria, called cinders and volcanic ashes.

The projectile process in the basalt-volcano, as long as it is in its normal stage, makes not cinder-cones, but *dribblet-cones*, 15 to 40 feet high, out of the projected masses, the falling driblets becoming plastered together about the smaller places of ejection. Such cones consist of cohering drops, clots, pancake-like patches, or abortive streamlets, and form into spires and columns on rude bases and take other fantastic shapes. They are necessarily small, and mostly of blow-hole origin, because when the vent is broad, like a lava-lake, the jettings fall back into it again; yet enough may fall on the margin of a lava-lake to gradually raise and steepen its border. Such driblet-cones are of all angles from 30° to 90°. Among the projectile results of volcanoes, driblet-cones are at one extremity of a series, and cinder or tufa cones, many hundreds of feet high, at the other. A cinder cone of 1000 feet in height has 15,000 to 20,000 times the bulk of any driblet-cone. The process is one ; but the result varies with the mobility and fusibility of the lavas.

Further: in the great lava cone of a basalt-volcano in its normal stage, cinder or tufa deposits rarely alternate with the large lava-streams, while they commonly alternate in other kinds of volcanoes.

Further: cinder cones and beds of volcanic ashes may form about a basalt-vocano, as already explained, whenever the condition of insufficient heat is in any way occasioned.

The above views as to the characteristics of a normal basalt-volcano are sustained by the facts from the volcanic mountains of all the Hawaiian Islands.

In the first place, the slopes are not only the lowest possible, usually from 1° to 10°, but continuous flows of 10° to 90° occur. I have seen many of them descending as unbroken streams vertical precipices on southern and western Hawaii.

Again the alternation of the lava-streams of the great volcanoes with deposits of volcanic sand, scoria or stones that were ejected from the great craters, is of rare occurrence, and such deposits make only thin beds of the kind whenever they occur. In such examinations as I have been able to make of the walls of Kilauea and Haleakala, and of the precipices and bluffs of Oahu, I have not succeeded in finding cinder or tufa deposits among the layers. The walls of Kilauea are stratified from top to bottom, but with lava-streams, and comparatively thin streams; I could find no evidence, in my examination of its walls, of any intervening stratum or bed of scoria, tufa or stones like that which now covers its border. This testimony is not conclusive as to the absence of such projectile eruptions in former times, for thin beds of scoria or sand like that just referred to—its thickness is only 25 to 30 feet—might be fused and annexed to the succeeding lava-flow. But the evidence against *great* tufa deposits, excepting those from lateral ejections, is, I believe, sufficient; and by great I mean 50 or 100 feet; not the 1000 feet and more common in the regions of the Rocky Mountains and the Pacific border.

On the island of Maui, I found no such beds of projectile origin in the walls of Haleakala, or in those of Wailuku valley the probable crater cavity of western Maui. On Oahu, the pitch of the layers of lava along the Manoa and Nuuanu valleys is only 1° to 3°; and in the precipices and bluffs which bound them I saw no layer of tufa. The thick tufa deposits are confined to cinder and tufa cones, and these are common.*

This point needs investigation; for the existence of even thin tufa beds in alternation with the lava beds of the great volcanoes of the islands, may still be true, and such facts would have much interest.

5. *The crater of a basalt-volcano is the same in origin, history and functions as those of volcanoes of other kinds, but differs usually in form.*—The crater of a great volcano probably has always its beginning—as I set forth in my Exploring Expedition report—in a great discharging fissure. But once open, it usually continues open until a temporary or final decline of volcanic action, whatever the kind of volcano. It continues open because (1) of the fixed position of the supply conduit; because *secondly* of the conduit-work going on through it in the discharge of vapors and lavas; and because, *thirdly*, of the down-plunges in the crater consequent on the undermining which the discharge of the conduit occasions. The open end of a deep-reaching conduct determines thus, by its discharges and the subsequent underminings, the existence of the crater; and the crater, by the work done within and about it, makes the volcanic cone. This appears to be the order of rank or importance in the phenomena—the crater begins in the opened fissure and is the indicator and future builder of the cone. In the history of the volcano, the era of summit outflows may pass, and only lateral discharges take place; and still the discharge of vapors from the lava conduit and the accompanying movements in the lavas, together with the down-plunges in the crater following the discharges, will keep the crater, or portions of it, in continued existence, and the work of eruption or outflow, if subaerial, is still adding to and shaping the cone.

This is the present stage of Kilauea and Mt. Loa; and these are the results as they exemplify them. The action, functions

* The cinder or tufa deposits of lateral cones have often great extent. This is well seen on Oahu where Diamond Hill, Punchbowl, and the region about Aliapaakai or the Salt Lake, are examples.

and processes are the same whether the lavas fill up to the summit before outflowing, or become discharged at a lower level by an opened fissure.

Examples in the Hawaiian Islands teach also that volcanoes may end with an open crater over 2,000 feet deep, like Haleakala, a cone 10,000 feet high, or with a filled crater, as in the case of Mt. Kea, 13,800 feet high.

The preceding remarks about the permanence of craters apply to other kinds of volcanoes as well as the basaltic; but in the form of the crater the basalt volcano has peculiarities, owing to the mobility of the lavas and the paucity of cinder discharges. The ordinary crater of such volcanoes is pit-like, with the walls often nearly vertical, and the floor may be a great, nearly level plain of solid lavas. The liquid material of the extremity of a conduit works outward from the hotter center, through the fusing heat and the boiling and other cauldron-like movements; and hence, where the mobility favors freedom of action in these respects, it tends to give the basin or crater a nearly circular form with steep sides—an explanation I give in my Expedition report. Besides, when the discharge takes place there is usually a fall of the walls which is still another reason for vertical sides, and the pit-like form.

The small lava-lakes of Kilauea, and the Great South Lake also after a discharge, (or an eruption as it is usually called) are literally pit-craters. Such was the condition of the Great Lake after the eruption of 1886. They all illustrate how the great pit-crater, Kilauea, was made. The lower pits of 1823, 1833, 1840 are other examples.

Such pit-craters are normally circular; but where there is a large fissure beneath the crater, they may be much elongated.

From the considerations which have been presented we see why the volcanic mountains of the Hawaiian Islands, with slopes rarely exceeding 10° in angle, differ so widely from the great andesyte cones of western North America, with their high slopes of 28 to 35 degrees. We see that the fact of being basalt-made means much in a volcano; that it affects profoundly all the movements and the results of those movements as well as the shapes of the mountains and of their craters.

[To be continued.]

ART. III.—*The Analysis and Composition of Tourmaline;* by R. B. RIGGS.*

APART from the work by Rammelsberg (Pogg., lxxx, 449, lxxxi, 1, cxxxix, 379, 547), very little has been done toward solving the question of the composition and constitution of the varieties of tourmaline. Their apparent complexity and the difficulties attending the determination of certain constituents have possibly turned many aside, possibly also the impression that with Rammelsberg's investigations the matter was settled. While Rammelsberg's work was comprehensive and was good for the times, his analyses are so seriously faulty in certain important respects, as to justify a new investigation. Though the direct estimation of both water and boric acid would seem to be of the highest importance, before any satisfactory conclusions could be reached with reference to the constitution of tourmaline, we find that, having failed in one single attempt to determine the water directly, he falls back on the loss on ignition, deducts therefrom an amount equal to the amount of silicon tetrafluoride, representing the fluorine found in the mineral, and calls the balance water. He takes it for granted that the fluorine is driven off quantitatively. But while this supposition is questionable, it is not the ground of objection. In the revision (Pogg., cxxxix, 379) of his earlier work, Rammelsberg comes to the conclusion that the iron contained in tourmaline is all there in the ferrous condition, yet wholly ignores the fact of its possible oxidation on ignition, especially an ignition such as would be necessary to expel the fluorine. In a few cases boric acid is determined directly, but by a method (Stromeyer's) which has ever been counted one of the most unsatisfactory. In the majority of the analyses it is estimated by difference. But if the results called water are incorrect and low, as they surely are, the boric acids ought to be correspondingly high or the analysis must be elsewhere at fault.

The direct estimation of water being possible, and a satisfactory method for determining boric acid having lately been devised by Dr. F. A. Gooch, (Am. Chem. Jour., Feb., 1887), new tourmaline analyses seemed desirable. Through the kindness of many, abundant and varied material has been at my disposal.

* An abstract of a paper which is to appear in a forthcoming Bulletin of the U. S. Geol. Survey.

Methods of Analysis.

A few words on the methods of analysis may not be out of place here, that the character of the work may be the better judged.

Water.—The water was directly determined by igniting a mixture of the mineral and carbonate of soda in a Gooch tubulated crucible, the sodium carbonate being used to hold back any fluorine that might otherwise be driven off. The carbonate of soda used was first fused, and then, in order to ensure perfect dryness, the mixture of mineral and reagent was again dried in an air bath at 105° C. for two or three hours. This estimation, as well as all the other more important ones, was made in duplicate.

Boric acid.—Where the tourmaline contained fluorine, the same portion was used for determining both the boric acid and the fluorine, the filtrate, from the mixed carbonate and fluoride precipitates, being used for the estimation of the boric acid. The borate of lime, which may be formed, is sufficiently soluble in hot water so that no difficulty is experienced in bringing it quantitatively into the filtrate. After evaporating this filtrate to a conveniently small volume, it is brought into a retort and acidified with nitric acid. The boric acid is then volatilized as methyl borate, according to the Gooch method, and weighed as borate of lime. It is scarcely necessary to say that throughout this treatment, nitric acid should be used as the neutralizing reagent, and that, if care be taken in its use, in no case need the amount of salt, which is to be brought into the retort, become inconveniently great. Where no fluorine is present, the soda fusion may be digested with water at once, the solution, containing the borate of soda, filtered off, neutralized and treated as above indicated. One might save himself even this filtration, but for the fact that, in using the whole fusion, a quantity of bases would thus be brought into the retort, which, even at the low heat required by the distillation, give up their nitric acid, thereby rendering the determination, in its after stages, both more difficult and possibly less exact.

Fluorine.—The fluorine was estimated by the Berzelian method. Though it is far from a good method, care and experience enable one to obtain fairly reliable results. The tendency is toward too high results, because of the difficulty of freeing the calcium fluoride from last traces of alumina and silica; and a better method will probably show even less fluorine to be present in the tourmaline than the insignificant quantity now found.

Ferrous oxide.—Tourmaline, especially the varieties containing lithia and iron, are decomposed by acids with extreme difficulty. This fact together with the fact that the iron in tourmaline, possibly for some inherent organic reason, as the high and unstable degree of oxidation of the boric acid, oxidizes with unusual ease, has rendered the determination of the condition of this constituent most troublesome On account of its refractory nature, usually not more than 0·2 grams of the finely ground mineral was taken for this determination. Several methods of decomposition were tried without any satisfactory results other than to lead to the conviction that the presence of ferrous iron in large amounts was doubtful, until the digestion of the mineral with hydrofluoric acid, in a sealed platinum crucible over the direct flame, was resorted to with fairly satisfactory and conclusive results.

1st. The mineral was digested with hydrofluoric and sulphuric acids in a sealed platinum crucible in boiling water from one to seven days, a treatment which decomposes most minerals in the course of a few hours. In a few cases complete decomposition seemed to have been effected, in the greater number however it was at the best very incomplete. In no case was more than one per cent of ferrous oxide found, though between thirty and forty experiments were made, and some of the tourmaline analyzed contain as high as eleven per cent of the metal. These attempted determinations were made in a deep heavy platinum crucible of about 60 c.c. capacity. This crucible is made with a flaring mouth into which fits a platinum head secured in place by a gallows screw clamp. Though the platinum joints are ground, a rubber washer is inserted between the cap and the lip of the crucible to ensure tightness. Before sealing the crucible a little carbonate of ammonia is thrown in to expel the air. During the period of digestion the crucible is kept completely immersed in water, so that it is hard to comprehend how the outside air can play any part in the oxidation of the iron. I am accordingly tempted to think that we have here to deal with a very slow reduction of a highly oxidized condition of the boric acid at the expense of which there is a corresponding oxidation of the iron. Either the change goes on very slowly or the explanation proves too much.

2d. From 0·2 to 0·5 grams of the mineral were treated with sulphuric acid—4 parts acid to 1 of water—in sealed glass tubes, from one to four days, at temperatures varying from 150° C. to 250° C. Although the tubes were taken out of the bath frequently and shaken, decomposition, in none of the fifteen attempts, was more than partial. As even the best acid contains organic matter, sometimes in considerable quantities, a higher heat than 200° C. is likely to be attended by a reduction of the acid, thus vitiating the results. This was the method used by Mitscherlich (Journ. prakt. Chemie, lxxxvi, 1) in establishing the fact that the iron in tourmaline is chiefly ferrous oxide. Rammelsberg, following in his steps, afterwards confirmed the results. But from what I can learn of their determinations they involved a correction which is of such a nature as to render the results worthless as quantitative results. The decomposition being invariably incomplete, the undecomposed material was removed from the glass tube, its amount determined, and a correction made accordingly.

3d. The mineral was also fused with bisulphate and with bifluoride of potash respectively in an atmosphere of carbon dioxide. Though decomposition was usually effected in a couple of hours, the iron was invariably all oxidized. A reduction of the sulphuric acid may be the cause of the result when bisulphate of potash was used. No such explanation avails in the case of the bifluoride fusion.

4th. Convinced, by the summations of some of the analyses, and by comparing the loss on ignition with the corresponding direct water determinations, that the iron in tourmaline must be there, in large part at least, in the ferrous condition, I finally heated the mineral with hydrofluoric and sulphuric acids in the closed platinum crucible over the direct flame, thus digesting at a moderately high temperature and a correspondingly high pressure, and at the same time securing a constant agitation of the powdered mineral—a condition of vital importance. In these determinations a thin lead washer replaced the rubber. A half hour, with these conditions, usually sufficed to bring about complete decomposition. The crucible was cooled in an atmosphere of carbon dioxide and the iron determined in the ordinary way with a permanganate solution. Fair results were obtained, such as to indicate that the iron in tourmaline is there chiefly in the ferrous condition.

Alkalies.—Several vain attempts were made to decompose the tourmaline with hydrofluoric and sulphuric acids. As showing the refractory nature of the mineral the following is a case in point: One gram of the pale green Auburn variety, after being ignited, was evaporated to dryness with 20 c.c. of hydrofluoric acid five times, and yet left an insoluble residue of 0·473 grams. The Lawrence Smith method was finally adopted and with highly satisfactory results. The only precautions necessary are that the mineral be finely powdered and that the mixture with ammonium chloride and calcium carbonate be intimate, which latter condition is only to be secured by grinding the several ingredients together. When these conditions are what they should be, there is no trouble in bringing about complete decomposition in the course of an hour's gentle ignition. After the alkalies have been leached out with water the residue should of course be treated with acid to test the completeness of the disintegration. In the case of the tourmalines, with their low silica percentages, the solution is usually complete if the decomposition has been complete. After the alkalies have been freed from the other bases by the usual well-known methods, though the greater part of the boric acid will have been driven off by the repeated evaporations, more or less may remain. This residual is removed by two or three evaporations with methyl alcohol. The separation of lithia from the other alkalies was made by the Gooch method, i. e., by boiling the mixed chlorides in amyl alcohol, and the further separation of the potash and soda effected after the usual manner.

Silica.—On the strength of the belief that tourmaline sometimes contained fluorine in considerable amounts, the silica was at first estimated by precipitating it with carbonate of ammonia. When the bases, thrown out by this reagent, are so in excess of the silica as they are in tourmaline, its precipitation is quite easy and quantitative. Nevertheless, when the method was used of duplicate determinations, the higher was taken in the summation of the analysis. (Save where the silica is greatly in excess of the bases thrown down by ammonium carbonate, the addition of zinc or like compounds, as is commonly recommended, is wholly unnecessary. In fact, even in dealing with such minerals as the lepidolites, which contain about fifty per cent of silica and less than thirty of alumina, the addition of zinc compounds gives no better results than can be obtained by simple evaporation with carbonate of ammonia, the evaporation being repeated several times.)

So soon as it became evident that the amount of fluorine, if present at all, was so small that its influence in carrying off silica (the amount of silica carried off by fluorine on evaporating a soda fusion with hydrochloric acid is but a small part of the tetrafluoride equivalent) could be neglected, the ordinary method of separation was employed. In all cases the silica was corrected by evaporation with hydrofluoric acid.

Alumina.—The only point worthy of mention in this connection is the necessity of testing the alumina for the silica which it frequently contains. This is usually done by fusing the ignited oxides with bisulphate of potash. But when they amount to as much as they do in the tourmaline a carbonate of soda fusion works more satisfactorily. It can be continued longer and at a higher temperature. This fusion is readily converted into a sulphate fusion and the desired silica separation thus accomplished. As regards other determinations nothing in particular need be said.

Analyses.

Analyses have been made of material from the following localities: Auburn, Rumford, and Paris, Maine; Calhao, province of Minas Geraes, Brazil; Dekalb, Gouverneur and Pierrepont, N. Y.; Hamburg, N. J.; Orford, N. H.; Monroe and Haddam, Ct.; Stony Point, N. C., and Nantic Gulf, Baffin's Land. These represent well the variations in physical properties and chemical composition which characterize the different varieties of tourmaline. The results of these analyses are grouped for the sake of compactness. The tourmalines from Maine and Brazil are thrown together according to localities. Those from other localities are roughly grouped on the basis of their composition.

Maine.—These tourmalines occur in veins of albitic granite, the chief constituents of which are quartz, albite and muscovite, with lepidolite and beryl as important accessories.

Auburn.—*A*. Colorless to pale green crystals, some of which were tinged pink and blue; infusible. G. 3·07. *B*. Light green fragile crystals, infusible. *C*. Dark green massive tourmaline, fuses with difficulty. *D*. Massive black tourmaline, easily fusible. G. 3·19.

	A		B		C		D	
	I.	II.	I.	II.	I.	II.	I.	II.
SiO_2	38·14 —	38·00	37·85 —	37·80	36·26 —	36·98	34·99 —	34·87
Al_2O_3	39·60		37·73		36·68		33·96	
Fe_2O_3	·30		·42		·15		none	
FeO	1·38	41·37-41·48	3·88	42·37-42·54	7·07	44·65-44·73	14·23	49·76–49·79
TiO_2	none		none		none		?	
P_2O_5	trace		trace		trace		trace	
MnO	1·38		·51		·72		·06	
CaO	·43		·49		·17		·15	
MgO	trace		·04		·16		1·01	
Li_2O	1·34		1·34		1·05		trace	
Na_2O	2·36		2·16		2·88		2·01	
K_2O	·27		·62		·44		·34	
H_2O	4·16	4·06-4·26	4·18	4·16-4·20	4·05	4·00-4·11	3·62	3·56-3·68
B_2O_3	10·25	10·15-10·34	10·55		9·94	9·83-10·04	9·63	9·44-9·82
F	·62 —	·72	·62 —	·72	·71 —	·80	none	
	100·23		100·39		100·28		100·00	
less oxy.	·26		·26		·30			
	99·97		100·13		99·98			

The material for the above analyses was received from Mr. N. H. Perry, of South Paris, Maine.

Rumford. A. Massive, rose-colored, infusible. G. 2·997. *B.* Massive, dark green, fuses with difficulty.

Paris, Black Mt. Massive, black, powder bluish, easily fusible.

	A		B		Paris.	
	I.	II.	I.	II.	I.	II.
SiO_2	38·07 —	38·02	36·53 —	36·42	35·03	34·99–35·06
Al_2O_3	42·24		38·10		34·44	
Fe_2O_3	—		none		1·13	
FeO	·26	42·44–42·64	6·43		12·10	
P_2O_5	none		trace		trace	
MnO	·35		·32		·08	
CaO	·56		·34		·24	
MgO	·07		none		1·81	
Li_2O	1·59		·95		·07	
Na_2O	2·18		2·86		2·03	
K_2O	·44		·38		·25	
H_2O	4·26	4·25–4·28	3·52	3·44–3·60	3·69	3·63–3·75
B_2O_3	9·99	9·85–10·13	10·22	10·03–10·41	9·02	8·92–9·12
F	·28		·16		none	
	100·29		99·81		99·89	
Less oxygen	·12		.07			
	100·17		99·74			

For the Rumford material I am indebted to Mr. E. M. Bailey, of Andover, Maine. The Paris tourmaline was kindly furnished me out of the National Museum collection.

In connection with the Maine tourmaline the following interesting alteration products were studied. *A.* An alteration from the light green Auburn (B) variety. *B.* Flesh-colored alteration from the Rumford locality. *C.* An alteration from the Hebron rubellite.

	A	B	C
SiO_2	—	53·03	43·90
Al_2O_3	—	31·67	38·71
Fe_2O_3	—	·51	·58
FeO	—	—	·25
MnO	—	trace	·04
CaO	—	trace	·41
MgO	—	trace	·05
Li_2O	2·86	·26	—
Na_2O	2·16	·54	1·05
K_2O	9·64	9·44	10·92
H_2O	—	4·80	4·25
B_2O_3	trace	trace	trace
F	—	trace ?	none
		100·25	100·16

While the light green Auburn tourmaline were mostly translucent crystals, a few were found, which, having become partially opaque, had assumed a micaceous structure. With scant material but the above partial analysis was possible. The results indicate a change in the direction of lepidolite.

The Rumford alteration product was examined microscopically by Mr. J. S. Diller, who observed as follows: "under the microscope it is seen to be composed of two minerals most thoroughly intermingled in nearly equal proportions. One of these minerals is micaceous in structure, with strong double refraction like damourite, which it closely resembles in general appearance. The other mineral is clear, colorless and apparently monoclinic, with a rather low index of refraction and moderately intense double refraction."

While the Hebron rubellite alteration product retains its crystalline form, its material is altered into a softer mineral of an opaque talcose appearance. The analysis shows the change to be toward damourite (F. W. Clarke, this Journal, Nov., 1886), and not lepidolite as has been supposed in this case.

Brazil, Calhas, Province of Minas Geraes. The association of these tourmalines I was unable to find out. From their composition however it is probable that it does not differ greatly from that of the Maine varieties. The specimens analyzed were from the hands of Mr. G. F. Kunz. *A.* The pink, almost colorless center of crystals having a green border, infusible, G. 3·028. *B.* Pale green, like the border of B, infusible. *C.* Olive green, fusible in very thin splinters. *D.* Black, in thin splinters a smoky blue green, fuses easily, G. 3·20.

	A	I.	II.	B	I.	II.	C	I.	II.	D	I.	II.
SiO_2	37·19	—	37·12	37·39	—	37·31	36·91			34·63	—	34·50
Al_2O_3	42·43			39·65			38·13			32·70		
Fe_2O_3	none			·15			·31			·31		
FeO	·52	42·94–43·08		2·29	42·30–42·38		3·19			13.69		
P_2O_5	none			trace			·11			none		
MuO	·79			1·47			2·22			·12		
CaO	·57			·49			·38			·33		
MgO	none			none			·04			2·13		
Li_2O	1·73			1·71			1·61			·08		
Na_2O	2·24			2·42			2·70			2·11		
K_2O	·23			·25			·28			·24		
H_2O	3·90	3·86–3·93		3·63	3·60–3·66		3·64			3·49	3·42–3·56	
B_2O_3	10·06	9·96–10·16		10·29	10·10–10·49		9·87	9·85–9·88		9·63	9·55–9·70	
F	trace ?			·32	—	·41	·14	—	·17	·06	—	·10
	99·66			100·06			99·53			99·52		
Less oxygen				·13			·06			·02		
				99·93			99·47			99·50		

Dekalb, St. Lawrence Co., N. Y. Colorless to light brown translucent crystals, in calcite, with quartz and titanic oxide inclusions, easily fusible, G. 3·085.

Gouverneur, St. Lawrence Co., N. Y. Brown, massive, associated with calcite. Easily fusible.

Hamburg, N. J. Large cinnamon-brown crystals, associated with quartz and colorless mica in calcite, abounding in inclusions of small black scales of titanic oxide. Easily fusible.

	Dekalb.		Gouverneur.		Hamburg.	
		I. II		I. II.		I. II.
SiO_2	36·88		37·39	37·33–37·45	35·25	
Al_2O_3	28·87		27·79		28·49	
Fe_2O_3	—		·10		none	
FeO	·52		·64		·86	
TiO_2	·12		1·19		·65	
P_2O_5	undet.		none		trace	
MnO	none		none		none	
CaO	3·70		2·78		5·09	
MgO	14·53		14·09		14·58	
SrO	trace		trace		trace	
BaO	none		none		none	
Li_2O	trace		trace		trace	
Na_2O	1·39		1·72		·94	
K_2O	·18		·16		·18	
H_2O	3·56	3·55–3·57	3·83	3·77–3·89	3·10	3·02–3·18
B_2O_3	10·58	10·46–10·70	10·73	10·63–10·83	10·45	
F	·50		trace ?		·78	
	100·83		100·42		100·37	
Less oxygen	·21				·33	
	100·62				100·04	

For the Dekalb and Hamburg tourmaline I am greatly indebted to Mr. G. F. Kunz. The Gouverneur material was from the National Museum collection.

From the large amount of titanic oxide found in the Gouverneur specimen, it was feared that it might be there as an impurity. Mr. Diller kindly examined a section microscopically and found it, on the contrary, to be quite free from inclusions of any kind. Specimens, from other Gouverneur localities, viz: from the town of Gouverneur itself and from Reese's farm, seven miles to the northward, were also found to contain the oxide in large amounts.

Orford, N. H. Dark brown crystals in chloritic schist. Easily fusible.

Monroe, Ct. Dark brown crystals in chloritic schist. Easily fusible.

	Oxford.		Monroe.	
		I. II.		
SiO_2	36·66		36·41	
Al_2O_3	32·84		31·27	
Fe_2O_3	none		none	
FeO	2·50		3·80	
TiO_2	·23		1·61	
P_2O_5	none		trace	
MnO	trace		trace	
CaO	1·35		·98	
MgO	10·35		9·47	
Sr,O	trace		trace	
BaO	none		none	
Li_2O	trace		none	
Na_2O	2·42		2·68	
K_2O	·22		·21	
H_2O	3·78	3·77–3·79	3·79	3·76–3·82
B_2O_3	10·07	9·86–10·28	9·65	9·57–9·73
F	trace		none	
	100·42		99·87	

The Orford material was received from Mr. C. H. Hitchcock, the Monroe specimen came from the National Museum Collection. The schistose gangue, in which the tourmaline from Orford and Monroe are imbedded is of particular interest, and was studied microscopically as well as chemically, in the hope that it might throw light on the genetic relations of magnesian tourmaline. The microscopic work, which was of special importance was kindly undertaken by Mr. J. S. Diller. The following are the results of partial chemical analysis:—

	Orford.	Monroe.
SiO_2	27·18	43·30
Al_2O_3	33·10	27·44
CaO	·19	1·96
MgO	28·09	19·22
Na_2O	undet.	1·47
K_2O	undet.	·60
Ign.	11·75	7·45
	100·31	101·44

While Mr. Diller found the Orford matrix to be essentially chlorite, in agreement with the results of chemical analysis, the gangue rock of the Monroe tourmaline turned out to be particularly interesting.

Of this Mr. Diller says, "this light gray glittering rock is composed chiefly of biotite, chlorite and a light colored mineral which may possibly be zoisite. The biotite is very dark and apparently uniaxial and negative, with all the other physical properties of the species. The chlorite is much paler than the biotite, and is of a greenish color. It is distinctly biaxial, with a small optic angle, and positive. The relation of the chlorite to the biotite is readily seen in the thin sections where it evidently is derived from the latter by a process of alteration. An interesting feature is that in the immediate vicinity of the imbedded tourmaline the biotite is all changed to chlorite, and is arranged with its foliae approximately perpendicular to the crystallographic planes of the tourmaline, against which it impinges. The chlorite completely envelopes the tourmaline and the other portions of the hand-specimen are made up chiefly of biotite and the zoisitic mineral, with a small proportion of chlorite. This variation in the mineralogical composition of the hand-specimen readily explains the discrepancy there at first appeared to be between the results of chemical analysis and my observations." That the analysis represents a portion of the rock rich in chlorite and poor in biotite, the high magnesia and low alkalies plainly show. The relation existing between the biotite, chlorite and tourmaline in this Monroe matrix is instructive, indicating, as suggested, the transition to be from the mica through the chlorite to the tourmaline.

Pierrepont, St. Lawrence Co., N. Y. Perfect black crystals, in calcite, fuses easily. G. 3·08.

Nantic Gulf, Cumberland, Baffin's Land. A large black crystal, easily fusible. G. 3·095.

Stony Point, Alexander Co., N. C. Perfect medium-sized black crystals, with implanted crystals of quartz; associated minerals chiefly quartz, muscovite, apatite, rutile, beryl and spodumene, fuses easily. G. 3·13.

Haddam, Ct. Black crystals in quartz and feldspar, powder blue black, easily fusible.

	Pierrepont.		Nantic Gulf.		Stony Pt.		Haddam.	
	I.	II.	I.	II.	I.	II.	I.	II.
SiO_2	35·61		35·34		35·56		34·95	
Al_2O_3	25·29		30·49		33·38		31·11	
Fe_2O_3	·44		none		none		·50	
FeO	8·19		8·22		8·49		11·87	
TiO_2	·55		·40		·55		·57	
P_2O_5	trace		none		?		trace	
MnO	trace		trace		·04		·09	
CaO	3·31		2·32		·53		·81	
MgO	11·07		7·76		5·44		4·45	
SrO	none		trace		none		none	
BaO	?		?		none		none	
Li_2O	trace		trace		trace		trace	
Na_2O	1·51		1·76		2·16		2·22	
K_2O	·20		·15		·24		·24	
H_2O	3·34	3·30–3·37	3·60	3·53–3·67	3·63	3·57–3·69	3.62	3·58–3·66
B_2O_3	10·15	10·00-10·31	10·45	10·30-10·60	10·40		9·92	9·74–10·10
F	·27		none		none		none	
	99·93		100·49		100·42		100·35	
Less oxygen,	·11							
	99·82							

Mr. W. E. Hidden very kindly furnished the Stony Point material. For the other specimens I am indebted to the National Museum collection. The gravity determinations of the Pierrepont, Stony Point and Nantic Gulf tourmaline were kindly made by Dr. William Hallock.

From the above analyses it is at once apparent that we have three types to deal with, lithia, iron and magnesia tourmaline respectively, with an indefinite number of intermediate products. As an aid to comparison I have brought these results together in the following table, arranging them so as best to show how these types graduate from one into the other, beginning with the lithia tourmaline and passing from them through the iron varieties to those of the purer magnesian type. The iron tourmaline appears to be the connecting link.

	B_2O_3	SiO_2	Al_2O_3	Fe_2O_3	FeO	TiO_2	P_2O_5	MnO	CaO	MgO	Li_2O	Na_2O	K_2O	H_2O	F	Sum	Ign.
Rumford A	9·99	38·07	42·24	----	·26	none	none	·35	·56	·07	1·59	2·18	·44	4·26	·28	100·17	4·35
Brazil A	10·06	37·19	42·43	none	·52	?	none	·79	·57	none	1·73	2·24	·23	3·90	tr. ?	99·66	4·10
Auburn A	10·25	38·14	39·60	·30	1·38	none	tr.	1.38	·43	none	1·34	2·36	·27	4·16	·62	99·97	4·09
Brazil B	10·29	37·39	39·65	·15	2·29	?	tr.	1·47	·49	none	1·71	2·42	·25	3·63	·32	99·93	----
Auburn B	10·55	37·85	37·73	·42	3·89	none	tr.	·51	·49	·04	1·34	2·16	·62	4·18	·62	100.13	----
Brazil C	9·87	36·91	38·13	·31	3·19	?	.11	2·22	·38	·04	1·61	2·70	·28	3·64	·14	99·47	3·62
Rumford B	10·22	36·53	38·10	none	6·43	?	tr.	·32	·34	none	·95	2·86	·38	3·49	·16	99·71	3·31
Auburn C	9·94	36·26	36·68	·15	7·07	none	tr.	·72	.17	·16	1·05	2·88	·44	4·05	·71	99·98	----
Paris	9·02	35·03	34·44	1·13	12·10	?	tr.	·08	.24	1·81	·07	2·03	·25	3·69	none	99·89	2·30
Auburn D	9·63	34·99	33·96	none	14·23	none	tr.	·06	.15	1·01	tr.	2·01	·34	3·62	none	100·00	2·17
Brazil D	9·63	34·63	32·70	·31	13·69	?	none	·12	.33	2·13	·08	2·11	·24	3·49	·06	99·50	2·19
Haddam	9·92	34·95	31·11	·50	11·87	·57	tr.	·09	.81	4·45	tr.	2·22	·24	3·62	none	100·35	2·41
Nantic Gulf	10·40	35·56	33·38	none	8·49	·55	?	·04	.53	5·44	tr.	2·16	·24	3·63	none	100·42	2·88
Stony Pt.	10·45	35·34	30·49	none	8·22	·40	none	tr.	2·32	7·76	tr.	1·76	·15	3·60	none	100·49	2·86
Pierrepont	10·15	35·61	25·29	·44	8·19	·55	tr.	tr.	3·31	11·07	tr.	1·51	·20	3·34	·27	99·82	2·69
Monroe	9·65	36·41	31·27	none	3·80	1·61	tr.	tr.	·98	9·47	none	2·68	·21	3·79	none	99·87	3·59
Orford	10·07	36·66	32·84	none	2·50	·23	tr.	tr.	1·35	10·35	tr.	2·42	·22	3·78	tr. ?	100·42	----
Gouverneur	10·73	37·39	27·79	·10	·64	1·19	none	none	2·78	14·09	tr.	1·72	·16	3·83	tr. ?	100·42	----
Dekalb	10·58	36·88	28·87	none	·52	·12	?	none	3·70	14·53	tr.	1·39	·18	3·56	·50	100·62	----
Hamburg	10·45	35·25	28·49	none	·86	·65	tr.	none	5·09	14·58	tr.	·94	·18	3·10	·78	100·04	----

As the outcome of his work, Rammelsberg concludes that all tourmaline may be referred to the following silicate types: R'_6SiO_5, R''_3SiO_5, and R'''_2SiO_5, in which $R'=H$, Li, Na and K, $R''=Mg$, Ca, Fe, and Mn and $R'''=Al$ and B, making boric acid and alumina equivalent. He groups them in two classes: I, iron-magnesian tourmaline, represented by the formula

$$m\left\{\begin{matrix} R'_6SiO_5 \\ 3R'''_2SiO_5 \end{matrix}\right\} + n\left\{\begin{matrix} R''_3SiO_5 \\ 3R'''_2SiO_5 \end{matrix}\right\}$$

$R'''=B:2Al$ and II, lithia tourmaline referred to the formula

$$m\left\{\begin{matrix} R'_6SiO_5 \\ 8R'''_2SiO_5 \end{matrix}\right\} + n\left\{\begin{matrix} R''_3SiO_5 \\ 8R'''_2SiO_5 \end{matrix}\right\} \text{ where } R'''=B:3Al,$$

with the following special formulæ: $R'_2R''_2Al_4B_2Si_4O_{20}$ for the more purely magnesian varieties; $R'_{10}R''_4Al_{12}B_6Si_{12}O_{60}$ for the purer iron varieties, and for the lithia tourmaline $R'_6Al_{12}B_4Si_9O_{45}$, and other complications for those lithia varieties containing iron.

Attention has been called to the weak points in Rammelsberg's analyses; but, for the sake of emphasis, I refer again to his method of determining the water and what depends on it. He assumes that the fluorine is driven off quantitatively on ignition, carrying with it silicon as the tetrafluoride. This assumption is a questionable one. A half hour's blasting would seem to be sufficient to drive off the water, but it was repeatedly observed that where the tourmaline contained fluorine. further blasting, after the water was presumably all expelled, was invariably accompanied by a small loss. This after loss was probably fluorine in some of its silicon compounds, as experiments made it clear that boric acid is driven off by no amount of blasting. While making this correction for fluorine, the oxidation of the iron is wholly ignored. If anything was noticeable in the ignition of tourmaline it was the apparent ease with which the iron oxidized. In the above table the loss on ignition is given in many cases. Comparing this loss with the direct determinations of water, at the same time noting the amounts of iron contained in the tourmaline in question, one is forced to conclude that the oxidation of the iron plays an all-important role here, in diminishing the loss by ignition by the amount required to convert it into ferric oxide. If we take Rammelsberg's ignition results* and make the more justifiable correction for the oxidation of the iron, setting aside the fluorine correction, we would have more concordant results to deal with; results, moreover, which agree closely with the direct determinations of water. But if the percentages repre-

* Pogg., lxxx, 449; lxxxi, 1.

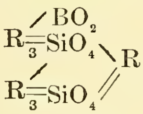
senting water be low, those of boric acid, where estimated by difference, ought to be correspondingly high, and so they are in a few cases. In the greater number of analyses, however, they are unaccountably low, unless we suppose, as I am inclined to, that the silica determinations were high, representing in some cases, besides actual silica, more than a per cent of impurities. If all this be true, in working out his ratios, Rammelsberg found in water and boric acid two variables instead of the two constants that they probably are, and one need not wonder that he found it difficult to discover unity in his analyses.

It is scarcely necessary to say that certain constituents found in tourmaline are non-essential, but have been thrust upon them by their associates. The idea that a tourmaline must have its fluorine was long since exploded.

If we study the essential constituents in the light of their molecular or atomic ratios, we will find some very interesting relations. The ratios of certain elements are constants in all varieties of tourmaline. $Si : B : H : O = 1 : \frac{1}{2} : \frac{2}{3} : 5{\cdot}2$. All the other constituents are variable and within rather indefinite limits. Considered individually they are enigmas. If, however, the bases, including hydrogen, be reduced to a common univalent basis and be consolidated, the results fall into line with the above ratios. This reduction may be made in either one of two ways, and with almost equally good results. In the table of the ratios of constants given below it will be noticed that the oxygen ratio is invariably slightly in excess of the amount necessary to the silicon and boron even though we assume both the SiO_4 group as we certainly must, and the group BO_2 as is also necessary if we would give account for the oxygen. This small residual is to be disposed of. It can be done by postulating either an $Al{=}O$ or the $O{-}H$ group. Both hypotheses have been used in constructing the following table. $R(^1)$ is the univalent equivalent of the bases with the oxygen excess incorporated in an $Al{=}O$ group, $R(^2)$ the univalent equivalent of the bases on the basis of an assumed $O{-}H$ group. The table is given in full that the extent of the variations, from what seem to be simple ratios, may in no wise be concealed, as is often the case, when averages are given. The hydrogen ratio, though already included in R, is given by itself, being one of the constants. For much the same reason the alkali ratios are also given, although here the constancy would seem to be limited to a type. This at least appears to be true for the iron and lithia varieties.

	Si	: B	: R (1)	: R (2)	: O	: H	: Alk.
Rumford A.	1	·46	4·48	5·01	5·18	·74	·28
Brazil A.	1	·47	4·45	5·12	5·26	·70	·31
Auburn A.	1	·46	4·43	4·83	5·10	·72	·28
Brazil B.	1	·47	4·50	4·92	5·17	·66	·31
Auburn B.	1	·48	4·48	4·80	5·11	·71	·30
Brazil C.	1	·45	4·42	4·93	5·15	·66	·32
Rumford B.	1	·48	4·44	4·95	5·20	·64	·30
Auburn C.	1	·46	4·50	4·99	5·20	·74	·28
Paris.	1	·45	4·47	5·09	5·21	·70	·12
Auburn D.	1	·48	4·50	5·01	5·21	·70	·12
Brazil D.	1	·48	4·50	5·02	5·21	·68	·13
Haddam.	1	·50	4·51	5·00	5·24	·69	·12
Nantic Gulf.	1	·51	4·52	5·00	5·25	·68	·12
Stony Pt.	1	·51	4·19	5·01	5·41	·68	·10
Pierrepont.	1	·51	4·52	4·77	5·13	·63	·09
Monroe.	1	·46	4·43	4·89	5·12	·69	·15
Orford.	1	·48	4·48	4·99	5·20	·68	·13
Gouverneur.	1	·50	4·51	4·73	5·10	·68	·10
Hamburg.	1	·51	4·50	5·08	5·30	·59	·06
Dekalb.	1	·50	4·51	5·08	5·29	·66	·08
	1 :	·48 :	4·47 :	4·96 :	5·20 :	·67 :	

Except in two or three cases the ratios of Si : B : R(1) : O approximate closely $1 : \frac{1}{2} : \frac{9}{2} : 5$. The oxygen, in excess of the amount exactly represented by the ratio (5), having been absorbed in an Al=O group. These ratios give as a general tourmaline formula the simple boro-orthosilicate $R_9BO_2 2SiO_4$, which resolves itself into the graphic formula



The R_9 includes the constant $H=R_{\frac{4}{3}}$ (Li, Na, K), varying between the limits $R_{\frac{1}{6}}$ and $R_{\frac{2}{3}}$, (Ca . Mg) varying from R_0 to R_3, Fe varying from R_0 to $R_{\frac{4}{3}}$ and (Al, Al=O) varying from R_4 to R_7. On the other hand the ratios Si : B . R(2) : O are about as $1 : \frac{1}{2} : 10 : 5·20$, which would give the equally simple general formula $R_{10}BO_2 2SiO_4$, where R_{10} includes the above constant and variables excepting that OH replaces the Al=O group and Al accordingly varies between the limits R_5 and R_8. If we expand, in order to bring out the hydroxyl ratio, we have $12SiO_4$, $6BO_2$, $R_{52}H_5(OH)_3$=Si : B : R : O=$1 : \frac{1}{2} : 5 : 5·25$.

Between these two views there are at present no means at hand of deciding. Could we find out that the water is not all driven off at the same temperature or something of the kind, the knowledge would favor the latter assumption.

Experiments to this end are desirable. But whichever postulate we make, the following special formula may be taken as representing typical compounds of the three varieties:

I. Lithia tourmaline $12SiO_2$, $3B_2O_3$, $4H_2O$, $8Al_2O_3$, $2(NaLi)_2O$.
II. Iron tourmaline $12SiO_2$, $3B_2O_3$, $4H_2O$, $7Al_2O_3$, $4FeO$, Na_2O.
III. Magnesian tourmaline $12SiO_2$, $3B_2O_3$, $4H_2O$, $5Al_2O_3$, $\frac{28}{3}MgO$, $\frac{2}{3}Na_2O$.

Calculated.	I.	II.	III.
B_2O_3	11·00	10·18	10·90
SiO_2	37·70	34·89	37·38
Al_2O_3	42·75	34·59	26·49
FeO	——	13·95	——
MgO	——	——	19·31
Li_2O	1·57	——	——
Na_2O	3·21	2·90	2·18
H_2O	3·77	3·49	3·74
	100·00	100·00	100·00

On comparing the theoretical composition of the above types with the results of analysis, they will be found to agree as closely as could be expected, at least in values of the constants. The boric acid found invariably falls short of the theory. This is to be expected. The analyses do not represent ideal compounds, but are made of material more or less impure and the case would be very exceptional where the impurity tended to raise and not lower the percentage of boric acid.

In some of the above formulas the group BO_2 has been assumed because the oxygen ratio demanded it. As has already been suggested the ease with which the iron oxidizes and the mysterious manner in which this change takes place, under conditions when we would suppose it to be impossible, possibly point toward a higher degree of oxidation than the more common B_2O_3. As the result of a slow molecular rearrangement the one is oxidized at the expense of the other. Such a change is, I believe, not without its analogies. Certain borates, where the assumption of an even higher oxide is thought necessary, on being heated give borates of a lower order.

Notes.—The question of color is an interesting one, particularly when the varying colors of the lithia tourmaline are concerned. For, while the color of the iron and magnesian varieties depends on the amount of iron present and ranges from the colorless Dekalb through all the shades of brown to the Pierrepont black, the lithia tourmaline, containing more or less manganese, give us the red, green and blue, as well as the colorless varieties, the shades of color not depending on the absolute amount of manganese present but rather on the ratios existing between that element and the iron. When the ratios of Mn : Fe approximate =1 : 1 we have the colorless, pink or very pale green tourmaline. An excess of manganese produces the red varieties. On the other hand if the iron be in excess the result is the various shades of green and blue.

As regards fusibility, the lithia tourmalines which are free from both iron and magnesia are infusible. The presence of either or both of these elements brings with it a degree of fusibility increasing with their increase till we find in those tourmalines containing much of either or both constituents easily fusible minerals.

The titanic oxide associated with the Hamburg and Dekalb tourmaline attracted special attention because of its form. Having been examined chemically it was studied microscopically by Mr. J. S. Diller, who observed as follows: "The small iron black scales with a rather brilliant metallic luster are cleavable into very thin folia, the thinnest of which, under the microscope, are perfectly opaque. In reflected light these lamellæ show three systems of cleavage planes, traces of which, upon the plane of foliation, intersect at an angle of 60°. The cleavage planes make a large angle with the plane of foliation and it is evident that this mineral is rhombohedral in crystallization. It is infusible on very thin edges and does not become magnetic when heated. By this means it is distinguished from hematite and ilmenite. From its physical properties alone I should conclude that it is a member of the ilmenite series rich in oxide of titanium. As analysis shows it to be essentially titanic oxide, it becomes of special interest. In the first place it is the extreme member of the ilmenite series and in the second place it is a new form of titanic oxide, which is thus shown to be tetramorphic."

Laboratory U. S. Geol. Survey, Washington, August 31, 1887.

ART. IV.—*On the different types of the Devonian System in North America*; by HENRY S. WILLIAMS.*

THE sections of the Devonian rocks in North America present at least four distinct types of stratigraphy in their outcrops in different parts of the continent. The four areas blend somewhat at their borders, but in their central sections are very distinct.

The four areas may be called the

(1) *Eastern Border Area*, including the outcrops of Gaspé, New Brunswick, Maine, and other places in Northern New England;

* Read at the New York meeting of the American Association for the Advancement of Science, August, 1887, and constituting a part of a preliminary report on the Devonian to the American Committee of the International Congress of Geologists.

(2) The *Eastern Continental Area*, including the New York and Appalachian tracts as far south as West Virginia, and extending northwestward into Canada West and Michigan;

(3) The *Interior Continental Area*, typically seen in Iowa and Missouri, extending into Illinois and Indiana, and probably northward toward the valley of the Mackenzie River; and

(4) The *Western Continental Area*, best known through Hague and Walcott's studies of the Eureka, Nevada, sections.

Each of these four areas presents sections of the Devonian, which in all the details of their stratigraphical, lithological and paleontological composition are different from each other.

The Eastern Border Area.

The typical eastern border section, as seen at Gaspé, is a heavy series of arenaceous shales, sandstones and conglomerates, gray, drab and red in color, of some 7,000 feet thickness. It lies upon 2,000 feet of limestone, which holds in the upper part fossils of upper Silurian age. These are regarded by Billings as of Helderberg types. The first thousand feet of the sandstone shows a rich flora, and, by some traces of invertebrate fossils, is known to date back as early as the age of the Oriskany sandstone. The first 5,000 feet of the sandstone represents the interval from the top of the Silurian to the top of the Chemung series of the New York section, and the terminal 2,000 feet may represent the Catskill series of New York. (See Logan's Report upon the Gaspé section in "Geology of Canada," 1863, p. 390, etc.) The greater part of this section contains very few fossils, and these are mainly plant remains. In the continuation of the Gaspé sandstones on the Bay de Chaleur the lower and upper beds, as I am informed by Sir William Dawson, are not only distinguished by characteristic plants but also by a rich fish fauna resembling that of Scotland, and divisible into a lower zone with Cephalaspis, Coccosteus, etc., and an upper with Pterichthys. On tracing the outcrops westward across Maine and Northern New England, the coral-bearing limestones of the lower Devonian appear, indicating a changed condition of the seas on approaching the old Archæan axis on the westward, but the outcrops, as well as the identity of the fossils, are too indefinite to give a clear idea of the relation of this border region to the better known sections south of the Adirondacks and farther west in New York State.

The Eastern Continental Area.

The second area, the eastern continental, is represented typically in New York State. From there it has been traced downward along the Appalachians as far as to West Virginia (the Tennessee section assuming a closer relation to the interior area), and northwestward in Ohio, Canada West and Michigan. On the western side of the Cincinnati axis the section is intermediate, but presents closer relations with those of the interior than with the typical New York section.

In New York there is a full series of temporary stages of deposition each having its characteristic lithological composition and each holding its distinctive fauna. The lower Helderberg limestones were followed, in this area, by a deposit of coarse sand which is thicker and more prominent in the eastern and southeastern part of the region, there attaining several hundred feet in thickness, but thins out toward the northwest, and fails altogether, both in the extreme southwestern and in the extreme northwestern extension of the area. This is the Oriskany sandstone, marked by a few large and well-defined Brachiopods. The Oriskany stage is generally more or less calcareous, and runs up into calcareous shales and grits along the northeastern border of the area. These latter are the Cauda-galli and Schoharie grits of the New York section. They are followed above by the Onondaga and Corniferous limestones, averaging less than a hundred feet in thickness, but reaching three hundred feet thickness, or more, in some parts of New York and in Michigan.

In this eastern continental area there was evidently some relationship between the sandy deposits beginning in the Oriskany and the calcareous deposits typically represented in the Onondaga and Corniferous limestones; for we find in the northwestern part of the area the sandstones thinning out to almost nothing, while the limestones reach their greatest thickness, and in the eastern and more southern parts of the area the sandstones reach their greatest thickness, while the limestone dwindles and in some parts has not been distinguished at all. The limestone is rich in corals, and in some layers, has abundant Brachiopods; the latter are types of wide geographical distribution, and, in the more common forms, such as *Strophomena rhomboidalis* and *Atrypa reticularis*, are species of long geological range. Some of the corals, too, have a long range in the western continental section, appearing in the upper part of the Nevada limestone, according to Mr. Walcott.

In New York the next lithological stage of the Devonian is a series of shales, often beginning and terminating in black and sometimes partly calcareous shales; but in the central part of the section, gray, soft argillaceous shales, temporarily calcareous in places, and holding a rich and abundant fauna, constitute the Hamilton stage. The Hamilton also shows tendency to be more calcareous westward and more arenaceous in the eastern outcrops, and the sandstones and arenaceous shales are thicker and predominate in the Pennsylvania, Maryland and Virginia sections, while the argillaceous and calcareous shales are more conspicuous in New York, Ohio, Canada West and Michigan. A thousand feet may be taken as an average for the thickness, including the two terminal black shales, though some of the Appalachian sections double this thickness. In our accepted classification the upper, Genesee black shale is grouped with the Hamilton, but, as I have shown elsewhere, there are good reasons for drawing the distinctive line, separating middle and upper Devonian, below rather than above the Genesee shale.

Above the Hamilton stage a period of deposition of arenaceous shales and sandstones prevailed all over this eastern area, called the "Chemung Period" by Dana, and divided into the Portage and Chemung stages. The deposits attain a thickness of two or three thousand feet in New York and Northern Pennsylvania, and farther south are represented by 5,000 feet of sandy deposits, coarser toward the top, and with occasional gravel conglomerates. This series of deposits is characteristic of the eastern area, and is not recognized in the central or western areas. It is linked by its flora with the eastern border sections, and by its fauna is recognized as intimately associated with the upper Devonian deposits of North Devonshire in England.

The faunas of the upper Devonian change rapidly in composition on passing westward from the Appalachian ridges, and the pure Chemung type is scarcely recognized west of western New York and Pennsylvania, although some of its species are seen in the Iowa and Nevada sections. Passing into Ohio, Canada West and Michigan, the upper part of the Devonian assumes a distinct type, which is more closely allied with that of the Indiana and Illinois sections. It appears to be a prevalence of the conditions expressed in the Genesee shales and associated Portage shales and sandstones of New York, with the failure of the Chemung rocks and fauna, running up into shales and sandstones of the Waverly and closing with conglomerates. The more eastern sections, after the Hamilton, run up into sandstones, red and gray shales, sandstones of considerable thickness, and conglomerates, and present no trace of any marine fauna intermediate between the Chemung and the Carboniferous. As we approach the Ohio border going westward the Chemung fauna also fails, and the Waverly follows the Hamilton with only the fauna of the black shales intervening.

In the eastern part of New York, Pennsylvania and southward, the coarse sands and conglomerates with red and green shales, prevail after the Hamilton stage, reaching a thickness of 6,000 or 7,000 feet, and then the Chemung fauna is sparse and confined to the lower strata. This red shale and sandstone type is called the "Catskill group" in New York, the "Cadent series" of the Pennsylvania nomenclature. In the eastern Appalachian area this same lithological type of rocks continues all the way upward to the coal measures; green and red shales, sandstones and conglomerates, and occasionally thin beds of limestone, but with no trace of the marine faunas which characterize the interval in Ohio, Indiana, and, particularly, in the interior continental area. In Pennsylvania these rocks have been called "Vespertine Series," "Umbral Series," and "Seral Conglomerates" by the first survey, and "Pocono Sandstone and Conglomerate," "Mauch Chunck Red shale," and "Pottsville Conglomerate," by the second survey, and in central and eastern Pennsylvania they together reach a maximum thickness of nearly 5,000 feet. These peculiarities, however, do not extend westward of Pennsylvania and New York. Before reaching that line, in fact, the red shales have nearly disappeared from the total section, and as the Chemung fauna disappears upward, the new Waverly fauna comes in, but only in the border regions between the two areas, are found sections in which both the Chemung and the higher Waverly faunas appear. This Waverly fauna is a transitional fauna and is, in the east, generally associated with the higher Sub-carboniferous marine faunas, and in sections in which the next lower fauna is that of the Hamilton or Middle Devonian. In the Eureka faunas described by Mr. Walcott, representatives of it are found in the upper Devonian shales ("White Pine Shales") associated with traces of the upper Devonian faunas of the east.

The Central Continental Area.

The central continental area is typically represented in Iowa, Illinois and Missouri, and reaches into Indiana, Kentucky and Tennessee, and possibly far north into British America.

Its prevailing characteristics are calcareous shales and limestones, with some arenaceous admixture at the eastern and southern extremities, terminating in black shales, and rarely exceeding two or three hundred feet in thickness. On the north, east and south-east borders of the area the black shale termination is a conspicuous feature, but in the more central portion, in Iowa and Missouri, the black shale is either entirely wanting or but slightly represented.

In Illinois and Indiana the black shale reaches a thickness of one hundred feet or more, and is immediately followed by the shales and limestone of the Kinderhook, or Knobstone group holding a fauna closely allied with that of the Waverly group of Ohio. East of the Cincinnati axis the black shales are first thin; they thicken on going eastward, and distinctly represent the upper Devonian of Western New York. Including all that is now rated as above the Hamilton shales and below the Bedford shales this upper Devonian of Eastern Ohio is from 400 to 2,000 feet in thickness, thinning westward (See Professor Orton's Preliminary Report on Petroleum and Gas, 1887, p. 26).

When we reach the central part of the interior area we find the Devonian represented by limestones running up into fine argillaceous shales, resting on upper Silurian limestones which in numerous places are of Niagara age and, in the southern border of the region, are more or less siliceous, and hold fossils of the later Silurian time, as in the *Delthyris shales* of Missouri which are, doubtless, as late as Lower Helderberg time. This central area lacks the black shale and runs up immediately into Sub-carboniferous limestones, calcareous shales and sandstones, and the total representatives of the Devonian are scarcely 200 feet thick.

The Western Devonian Area.

I take the Nevada section of the Eureka district as typical, since this has been carefully developed by the labors of Hague and Walcott. (See Walcott's Monograph, Paleontology of the Eureka district, U. S. Geol. Survey, 1884).

The peculiarities of this section are as follows:

Lying unconformably upon a thick series of limestone beds, representing the Trenton and, at the top, the Niagara of eastern sections, comes the *Nevada Limestone*, 6,000 feet thick, indistinctly bedded and siliceous below, and becoming massive toward the top with intercalated beds of shale and quartzite. The same fauna runs from bottom to top, but with some change in part of the species. In the lower 500 feet the fauna is distinctly lower Devonian, and in the terminal 500 feet it is as distinctly allied with the upper Devonian of the east. Throughout there are found species which in the typical eastern sections are restricted to particular zones. In its species it shows closer relationship with the Iowa Devonian than with the more eastern faunas, containing two species (see p. 265) that have been found far to the north in the Mackenzie River Basin, i. e. *Orthis McFarlini* and *Rhynchonella castanea*, (N. 67° 15′ long. 126° W.) Overlying this limestone is the White Pine Shale, a black shale, estimated at 2,000 feet in thickness, running into red and brownish sandstones and arenaceous shales, with some plant remains and a sparse fragmentary fauna which closely resembles in general character the fauna of the similar upper Devonian black shales of the eastern continental area.

In these western sections there is a remarkable difference in the range and habit of species. "Some species," as Mr. C. D. Walcott has shown, "have reversed their relative position in the group as they have been known heretofore, and others have a greater vertical range." (Pal. of the Eureka District p. 4). Some cases mentioned by Mr. Walcott are *Orthis Tulliensis* at the top, *Orthis impressa* at the base, and several Corniferous corals at the upper horizon (see pp. 4 and 5, etc).

It is also noticed that the faunas in the higher shales show combinations of Devonian and Carboniferous types (White Pine Shales), but a careful study of the species reveals the characteristic changes of the general fauna that are seen in the eastern sections.

For instance, the new type of Brachiopods belonging to the genus *Productus* (called *Productella* in the New York Reports) begins in this western section with certain small forms typical of the lower and middle Devonian of the east, and it is only in the upper horizons that the larger Chemung types of *Productus* appear. The same thing is seen in the changes in the types of *Spirifera;* the characteristic upper Devonian *Sp. disjuncta* appears only in the upper part of the section as in the east. The peculiarities of this western section in its Paleontology, are most readily explained by the assumption, supported also by other facts, that throughout the whole age the deposits of this area were made in a wide, open ocean, with islands, perhaps, but with no great masses of land to disturb the general uniformity of the conditions of life.

The central area was, doubtless, at considerable distance from land but in no great depth of depression. The eastern continental area from Michigan around through Canada, New York and down the Appalachians, must have been during the Devonian age, near enough to shores for the faunas, as well as the nature of the deposits, to be affected by the ocean currents, and to feel strongly the effects of relatively small amounts of change of level between land and water. Here the faunas are both more local and more limited in geologic range, changing more suddenly and fully in their combinations and species. The conditions of the eastern border were those of rough and tempestuous coasts.

Conclusions.

There are thus, 1st, a northeastern border area, mainly composed of coarse, arenaceous deposits, thick, and with little to distinguish it into subordinate zones.

2d. An eastern continental area, with sandstones, limestones, shales and conglomerates alternating with each other, and presenting a rich and varied series of faunas, marking a considerable number of distinct zones which follow in a constant order.

3d. A central continental area, mainly limestone and soft argillo-calcareous shales, and, compared with the more eastern sections, very thin, and presenting a fauna which represents the whole eastern Devonian and is plainly a sequent to an underlying upper Silurian fauna. It is followed by a Carboniferous fauna to which it is generically closely related, and about its border is terminated by a black shale.

4th. A western area represented by a massive thick series of limestones followed by black shales, not separated into distinct faunas, but carrying a common fauna showing but slight change from bottom to top.

With all these great contrasts in lithological, stratigraphical and paleontological characters the evidence is satisfactory that the several sections are representatives of the same geological age; that, taken as wholes, they do not represent parts, the one taking the place of an interval in the other, but they cover approximately the same interval, and probably represent approximately the depositions of the same length of geological time.

They are bound together, and their relationship certified to by the fossils they contain. The relationship is recognized in the combination of species to form faunas and in the varietal modification of species, as well as in the identity of the species themselves. We cannot find stronger contrasts across the Atlantic eastward than are found across the continent westward. The principles which the American geologist is required to apply in discussing the geology of his own domain are no less broad than those which the International Congress meets with when it attempts to unify nomenclature for all the world. Wherever unification is practicable in America it is practicable for all the world, and where America finds unification a cumberance it is useless for an International Congress to attempt it.

What is there in the Devonian system, as represented in North America, which demands uniformity of nomenclature, and wherein will attempts at uniformity in nomenclature either strain or misrepresent the facts?

1st. It is perfectly clear to a paleontologist studying the faunas and floras, that the system under consideration, in each of the so dissimilar types, is the representative of the Devonian system of Great Britain, Belgium, Germany and Russia, in all the central features of its marine and brackish invertebrate, and vertebrate faunas, and in its floras. That the name Devonian, as the first name used, should be applied to this system of rocks, we see no reason for dispute.

2d. In all the sections, in so far as they exhibit it, the order of sequence in the modification of faunas is the same, and this sequence as presented in foreign sections is found to follow the same order, wherever species are identical, or are closely allied varieties of the same type; their place of dominance in the series is the same for each section, but the range may vary; in one area species may be restricted in range; in another, species may range through a long series of deposits. In other words, species which are found to have a world-wide distribution, although in one area they may be restricted to a particular stage of the Devonian, are likely to have a long geological range in other areas, not less than from bottom to top of some complete Devonian sections. But a particular combination of species, forming a characteristic fauna of a special stage in one area, occurs at the same relative position in any other area in which it appears. Such faunas are, however, actually more or less local, and, as far as the Devonian is concerned, it is not practicable to form more than three subdivisions of the Devonian to which to apply universally a uniform name. These three, in their general typical faunas, can be recognized (so far as they are present) in the different areas of America and Europe, the lower, typically seen in the Corniferous limestone of New York; the middle, represented in the Hamilton of New York; the upper, represented in the Chemung fauna of New York.

Any attempt to unify in the finer details is useless for America, and, of course, would be useless if attempted for all countries.

3d. In the sections of America alone there is found nothing in lithological composition or sequence which is uniform for the several areas.

In seeking uniformity of nomenclature the study of the American Devonian leads to the following conclusions:

(1) That uniformity is desirable in the names and prominent distinctive biological characters of the so-called systems.

(2) That valuable results may be reached by a discussion, on the part of those acquainted with the same system in the different parts of the world, as to the best biological criteria for marking the boundaries of the systems.

(3) That while uniformity is possible in subdividing a system into parts, the number of such parts, and the characters distinguishing them, must be determined after a wide, comprehensive and minute study of their biological characters.

(4) That preliminary work in classifying rocks should not seek uniformity, but should adopt local nomenclature, and that nomenclature based upon an exhaustive comparison of representative sections can alone reach a uniformity that will be of permanent value.

Art. V.—*On the law of Double Refraction in Iceland Spar*; by Charles S. Hastings.

The law of double refraction in uniaxial crystals, first discovered by Huyghens, was supposed for a time to be definitively established by Fresnel's deriving it from principles of molecular mechanics. It was soon recognized, however, that a fundamental hypothesis in his reasoning does not bear critical inspection; namely, that the elastic forces brought into play by distortions due to the passage of waves are the same in kind as those produced by the displacement of a single particle. In short, Fresnel assumed that the velocity of a light wave is independent of the direction of propagation and depends only upon the direction of vibration. There have been many notable efforts to get rid of this difficulty in the theory of double refraction by a general treatment. Cauchy, Mac Cullagh, Neumann and Green are those whose names are most closely connected with the interesting history of investigation in this field of mathematical physics. All of these investigations have the feature in common, that the natural interpretation of the equations makes the direction of vibration in plane polarized light lie in the plane of polarization. To adapt the solutions to the contrary assumption, which is almost certainly the only one which can be reconciled to the known phenomena of optics, requires the most artificial restrictions in the relations of the constants involved. By such forced interpretations of formulas having a large number of constants, it is possible to derive a law for double refraction, even in Iceland spar, which does not differ from Huyghens's construction by an amount discoverable by observation; but an agreement between observation and theory extorted in this way cannot be regarded as satisfactory.

Intimately bound up with this question of double refraction is the question as to whether the differing velocities of light in vacuum and in a dense medium are due to differing densities or differing rigidities. Of these two views, equally probable *à priori*, only the first can possibly be brought into agreement with the observed phenomena of reflection. But in the case of a velocity of propagation dependent on the direction of wave-motion, which is the case of double refracting media, the difficulty is to conceive of a *density* as dependent upon direction. Rankine made the ingenious suggestion that this difficulty might be avoided by assuming that the molecules of a crystalline solid move in a frictionless fluid, and thus that their effective masses might depend upon the direction of motion. The special interest of this view from our standpoint is that it led Stokes to the first careful investigation of the accuracy of Huyghens's construction.*

In these investigations Professor Stokes found that the error in the construction could hardly exceed a unit in the fourth place of decimals, which was quite sufficient to disprove Rankine's hypothesis. This study, the details of which have not been published, remains unexcelled to the present time; for the investigations since made by Abria, Glazebrook and Kohlrausch, whether by the prism method or by total reflection, do not present a closer accordance between theory and observation. The results of earlier observers, cited in most treatises on double refraction, are all of quite inferior accuracy.

Of all these investigations, Glazebrook's, given in the Trans. Roy. Soc., vol. clxxi, 1880, is the most extensive. His method was to measure the deviations produced by four different prisms, so cut from the same piece of Iceland spar that the directions of the propagation of the light varied from an angle of $-3°$ to $+94°$ to the crystalline axis, the relation of this axis for each prism to its faces being determined by reference to planes of cleavage. The observations were made with considerable accuracy, indicating a probable error in the deduced indices of refraction considerably less than fifty units in the sixth place of decimals. The reductions, however, show a systematic deviation from Huyghens's construction, varying from 100 to 200 in the sixth decimal in the three hydrogen lines observed—the wave-surface for the more refrangible ray deviating most widely. This result would be of great theoretical interest if the values derived from observation were not vitiated by an important oversight in the details of the experiment, which the author himself points out. In view of this source of error the conclusion from the investigation is, that Huyghens's construction is true within the limit of error of these observations.

Briefly, then, the state of the case is this. The law of double refraction in Iceland spar as given by Huyghens is known to be true to within about one part in ten thousand, but no reason, dependent on the theories of elasticity, can be assigned why it should be as accurate as this, or how much more accurate we may expect to find it. The labor of testing the law to the last degree of refinement possible with modern instrumental means seems well worth while; for, except its simplicity, there is no reason in the world why it should not break down just at the limit assigned by Stokes's observations. I am quite willing to admit, also, that the systematic deviations of Glazebrook's observations, so near the limit of magnitude set

* Proceedings of the Royal Society, June, 1872; quoted by Sir Wm. Thomson in his Baltimore Lectures, p. 273.

by Stokes, and so difficult to explain by any plausible hypothesis as to their cause, suggested a not too remote probability that they indicated a physical reality.

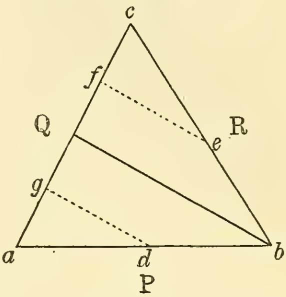
With these ends in view, all methods except those based upon prismatic refraction were practically excluded. Again, since it is impossible to get cleavage faces which admit of very accurate determinations of their angles of inclination, e. g., to within a second of arc, it seemed necessary to arrange the experiment so as to be independent of such accurate determinations. The method chosen, then, was to measure the various angles involved in an equilateral prism of Iceland spar in which one face was normal to the crystalline axis, the other two as nearly equally inclined to the axis as possible, and all three refracting edges as perfectly at right angles to the axis as practicable. Such a prism restricts the range of wave velocities which can be observed, but on the other hand, it enables us to find the direction of the crystalline axis from the observations themselves by mere considerations of symmetry, wholly independently of all assumptions of the law of double refraction.

(2) *Description of Prism.*

Since the accuracy of a determination of a refractive index depends largely on the character of the prism used, and especially in this case of extraordinary refraction, it may be worth while to describe the method employed to secure satisfactory results.

After selecting a good block of spar, a wooden model of the largest prism of desired orientation which could be obtained from the block was made. As this model represented the cleavage faces as well as the prism faces, it served as a guide as to how far any process of grinding should be carried. One of the obtuse trihedral angles was ground down, so that when the block rested upon this ground surface under a fixed telescope nearly perpendicular to it, the images of a distant object reflected by the three opposite cleavage faces could be brought to the crosswires of the telescope by merely rotating the block on the ground surface. This admitted of securing a face, P in the accompanying figure, very nearly perpendicular to the crystalline axis. The limit of accuracy was restricted only by the character of the reflection from the cleavage faces. The size of the face was determined by reference to the model. The next step was the formation of the surface, $dbefg$ of the figure, to serve as a base for the prism and a rough guide for the other two faces of the prism. It was ground perpendicular to P, and, by a process similar to that used in fixing the direction of P, equally inclined to the cleavage planes abQ

and *b c Q*. Then *R* was ground so that it made equal angles with the cleavage surfaces *a b Q* and *a d g*, and an angle of 60° with *P*. As it was desirable to make this last angle tolerably accurate in order to eliminate all errors of the circle in a determination of the refracting angle, or, in other words, so that a repetition of the angle three times would bring the circle back to the same position within the range of the reading microscopes, the surface *P* was polished sufficiently to yield a good reflection, and then the angle at *b* was adjusted until it was equal to that of a glass prism known to be accurately 60°. *Q* was determined in a precisely similar way. The three surfaces were then polished to as close approximations to planes as possible. In this process most interesting differences in the physical properties of the surfaces were found, as might have been expected. *R* worked almost as readily as glass, except that its departure from flatness tended toward cylindrical surfaces instead of spherical. It was not difficult to make *P* flat, but the slightest carelessness in handling would produce tetrahedral pits in it. The surface *Q*, being inclined only 15° to the direction of cleavage, gave by far the most trouble, because it did not seem possible to get it very smooth by grinding. After carrying this process to its limit of accuracy, determined more, perhaps, by the extraordinary thermal properties of the material, than by purely technical difficulties in working, the faces were cut away until only circular areas were left on the three prism faces. These round faces were then modified, by methods which would only have an interest for the practical optician, until they were optically flat; that is, until their departures from their average planes was not more than a tenth of a wave-length of light. The test of flatness was the colors produced when white light was reflected nearly normally from the surface brought closely in contact with a surface of glass known to be plane. The diameters of the surfaces, in order of lettering, were:



2·8 cm., 2·8 cm. and 2.6 cm.

(3) *Spectrometer.*

The instrument with which the measures of the various angles were made has some features peculiar to it. The circle is of glass, 8 inches in diameter, and divided to single degrees, except in the case of the first degree, and three others separated from it and each other by quadrants, which are subdivided to tenths of a degree. The observing telescope may be moved independently or clamped to the circle; it is checked in its rotation only by the collimating telescope. It is obvious that by this construction it is always possible to measure an angle so that one end of the arc shall be at a degree mark and the other end fall within a subdivided degree; hence both ends of the arc are within the range of the reading microscopes. The great and manifest advantage of this construction is that every angle can be accurately measured after determining the absolute place of only 396 lines or 198 diameters.

The reading microscopes have micrometer screws of 80 threads to the inch, with heads divided into 100 parts, one revolution of the screw being equal to one minute of arc. The magnifying power is 220 diameters, doubtless unnecessarily high, but not found inconvenient, and a much lower power would have necessitated a notable change in the design, either finer micrometer screws or longer microscopes with correspondingly higher table and telescope carrier. The probable error of a single setting of the microscope was found to be less than $0''\cdot3$, or less than half a division of the micrometer head.

The errors of the circle were determined by means of two auxiliary microscopes clamped to the base-plate of the instrument at opposite sides. By bisections and trisections the absolute position was determined of each diameter at multiples of $5°$ from the initial diameter, to within a probable error of less than $1''$. As practically every such interval was involved in the observations several times, equations of condition were formed as checks upon the results; if a discrepancy as great as $1''$ was found the intervals were re-measured. A determination of any angle was thus reduced to a maximum of five repetitions, whence the true angle could be found, and, incidentally, the corrections of four other arcs. As an illustration of the precision of the method, I may state that in the only case where a suspicion of the accepted value led to a complete redetermination of all the constants involved, the correction deduced differed only $0''\cdot1$ from the former one. The origin of the suspicion was afterwards found to be a false temperature correction. This determination of the errors of the circle was the most laborious part of the whole investigation.

(4) *Angles of prism.*

The angles measured were those between the normals to the faces P and Q, Q and R, R and P, which were made with all attainable accuracy; those between the normal to P, and the normals to its three adjacent cleavage faces; the normal angle between *R* and the narrow cleavage face at *b*; and finally, the normal angles between the cleavage faces *a b Q* and *b c Q* respectively. The precision of all the measures involving reflection from a surface of cleavage is of course much inferior to those made upon the polished surfaces. The first group gives the refracting angles, and the others only serve to determine the direction of the crystalline axis, a datum not used in the final reduction but useful as a check on the work.

The general method of determining these angles was as follows: The telescope replaced the fixed collimator which was removed. By means of a plate of plane parallel glass and a *quasi* collimating eyepiece* the axis of the telescope was rendered strictly perpendicular to the axis of rotation of the instrument. The focal adjustment of the telescope could be made at the same time with great precision: magnifying power used, twenty diameters. Following this adjustment the glass plate was replaced by the prism, which was so adjusted that the line of collimation fell close to the center of each face when in position for observation. That this condition, a most important one, was fulfilled, was determined by removing the ocular and looking at the prism through the telescope tube.

TABLE I.—*Angles of prism* = α = 60.

PQ			PR			QR		
Obs.	*t*	Red.	Obs.	*t*	Red.	Obs.	*t*	Red.
+1′·205	17·2	+1′·285	−2′·516	17·0	−2′·519	+1′·330	16·5	+1′·303
·242	17·1	·280	·492	17·0	·519	·298	16·5	·303
·273	17·0	·276	·521	17·0	·519	·254	16·6	·293
·407	19·8	·421	·521	19·55	·394	·067	19·2	·046
·421	20·0	·412	[·652]	19·65	----	1·141	19·25	·041
·432	20·0	·412	·418	19·75	·384	0·908	19·55	1·013
·391	20·0	·412	·350	20·7	·338	·895	21·0	0·875
·469	20·1	·417	·315	21·0	·323	·883	21·0	·875
·453	20·0	·412	·225	21·5	·299	·858	21·5	·828
·390	20·0	·412	·235	21·3	·308	·836	21·1	·866
475	20·1	·417	·350	21·1	·318	·842	21·1	·866
·514	20·1	·417	·354	21·1	·318	·873	21·2	·856
·470	21·0	·457	·306	21·2	·313	741	22·5	·732
·484	21·2	·466	·231	20·8	·333	·703	22·6	·723
·481	21·1	·462	·242	22·9	·230	+0·695	22·8	+0·704
·453	21·7	·489	·247	23·0	·225			
·427	21·7	·489	−2 ·247	23·0	−2 ·225			
·478	21·6	·485						
·519	21·6	·485						
·445	21·6	·485						
·435	21·8	·494						
·511	23·0	·548						
·511	23·0	·548						
+1 ·528	23·0	+1 ·548						

* This is described in the paper "On the influence of temperature on the optical constants of glass." This Jour., III, vol. xv, p. 271.

In the case of the prism angles each was repeated three times, whence, since they were all quite close to 60°, not only were all errors of graduation eliminated, but the absolute values of the instrumental arcs 120° and 240° determined with great accuracy. The influence of temperature on the magnitudes of the angles becomes evident even in comparatively rude observations. Table I gives *all* the measures of these angles. Of course the angles given are the supplements of those directly observed; they are also corrected for circle errors. Following the column containing the observed angle is given the temperature of the prism, and then the value reduced to a temperature of 20° C. The method by which the last column was calculated will be given farther on.

The observation of PR enclosed in brackets is rejected. Two or three others might have been rejected without changing the results except to give them smaller probable errors.

In order to find the values of the angles a standard temperature (20° C.) was chosen as the standard, observation equations of the form

$$M = m + n\ (t-20),$$

whence normal equations of the form

$$\Sigma\alpha^2.\ m + \Sigma\alpha\beta.\ n - \Sigma\alpha.\ M = 0,$$
$$\Sigma\alpha\beta.\ m + \Sigma\beta^2.\ n - \Sigma\beta.\ M = 0,$$

gave the means of finding m and n. The values of the coefficients of the normal equations are as follows:

	$\Sigma\alpha^2$	$\Sigma\alpha\beta$	$\Sigma\beta^2$	$\Sigma\alpha M$	$\Sigma\beta.\ M$
PQ	24	13·7	72·67	34·514	22·647
PR	16	7·9	64·6	—37·570	−15·588
QR	15	2·4	66·42	14·324	— 3·980

The observed values of a from these equations are:

For PQ	60°	$1'.412 \pm 0'\cdot006 + 0'\cdot0454\ (t-20°)$
PR	59	$57'.628 \pm 0'\cdot009 + 0'\cdot0489\ (t-20°)$
QR	60	$0'.970 \pm 0'\cdot008 - 0'\cdot0950\ (t-20°)$

The probable errors of a single observation of an angle were found to be 0′·028, 0′·035 and 0′·032, respectively, and the probable errors of the coefficients of the terms containing the temperature 0′·0035, 0′·0045 and 0′·0039, respectively. The probable error of 2″ for a single observation seems large, considering the refinement of the method used, and indeed it would be for a glass prism; but regarding the enormous change from temperature and the extreme difficulty of determining that of the prism, it must, I think, be regarded as satisfactory.

These constants derived directly from observation are subject to certain geometrical conditions which will modify them very slightly and reduce the probable errors. As it was found, in the course of the observations, that the normal to any one face is inclined only 12″ to the plane fixed by the other two normals, we have—

$$\Sigma\alpha = 180^\circ$$
$$n_1 + n_2 = -n_3.$$

But as observed,

$$\Sigma\alpha = 180^\circ\ 0'{\cdot}010 \pm 0'{\cdot}013.$$
$$n_1 + n_2 = -n_3 + 0'{\cdot}0007 \pm 0'{\cdot}006.$$

Adjusting the observed values in accordance with the equations of condition we have finally:

$$\alpha_{PQ} = 60^\circ\ \ 1'\ 24''{\cdot}59 \pm 0''{\cdot}29.$$
$$\alpha_{PR} = 59^\circ\ 57'\ 37''{\cdot}42 \pm 0''{\cdot}43.$$
$$\alpha_{QR} = 60^\circ\ \ 0'\ 57''{\cdot}98 \pm 0''{\cdot}39.$$

$$n_3 = -5''{\cdot}68 \pm 0''{\cdot}19.$$

The value of n_3 enables us to find at once the difference in the principal coefficients of thermal expansion, as well as the variations of the angles of the rhombohedron. By an obvious relation, if a_1 and a_2 are the coefficients in the axial direction and at right angles to it respectively, we deduce

$$a_1 - a_2 = 10^{-6}(31{\cdot} \pm 1{\cdot}).$$

The best value known is that of Fizeau, which is

$$10^{-6}(31{\cdot}6).$$

But the relations of immediate value to us are those of the temperature variations of the angles between the normals of *P* and an adjacent cleavage face, of *R* and the cleavage face *b*, and of the two faces *a b Q* and *b c Q*. They are, in the order named, if ϑ is the measured angle

$$\frac{\Delta\vartheta}{\Delta t} = +0'{\cdot}056.$$
$$= -0'{\cdot}103.$$
$$= -0'{\cdot}085.$$

(5) *Position of crystalline axis.*

The measures upon which this constant depends are subject to large errors on account of the imperfect reflections from the cleavage faces, especially from the edge *b*, which is only 1^{mm} wide and gives two images. The values given below are reduced to a temperature of 20° C.

Angle.	
P*b*	= 44° 39′·12 ± 0·50.
P(*ab*Q)	= 44° 36′·57 ± 0·045.
P(*ady*)	= 44° 37′·05 ± 0·120.
R*b*	= 75° 25′·00 ± 0·160.
(*ab*Q) (*bc*Q)	= 105° 4′·88.

Of these the first and fourth, giving them equal weights, yield

$$Pb = 44° \; 38'{\cdot}26$$

which, with the second and third, give

$$44° \; 37'{\cdot}29$$

as the angle between the crystalline axis and the normal to a cleavage plane. The last of the measured angles implies

$$44° \; 36'{\cdot}70$$

for the angle between the axis and the normal to a cleavage face. This value, however, rests upon two observations only and cannot therefore be regarded as of great weight. We may, perhaps, attribute to it a weight $\frac{1}{5}$ that of the value derived from the other measures, whence the accepted value becomes

$$44° \; 37'{\cdot}19.$$

This value gives, for the direction of the axis drawn from *P inward*, an inclination

$$\xi = 1' \; 4''{\cdot}1$$

from the normal to P towards Q, and

$$\eta = 0' \; 12'',$$

i. e., 12″ below the refracting plane of the prism QR; they can hardly be in error as much as 15″.

It is perhaps worth noting that the accepted value 44° 37′·19 gives 105° 5′·07 for the dihedral obtuse angle of the rhombohedron at 20° C., which is practically the value accepted by mineralogists.

(6) *Angles of deviation.*

Minimum angles of deviation were determined in each case; there are thus two angles for each prism-angle. The line pointed upon was the more refrangible component of the D line of the solar spectrum, except in the case of the extraordinary image by the faces QR, of which the dispersion was too small to admit of easy separation, and, by mistake, in four pointings on the double deviations for the ordinary image by the same refracting angle when D_1 was observed on one side. Care was taken to adjust the collimator, telescope and prism, so that the axial ray passed through the center of the prism in both positions for minimum deviation, i. e., right and left. The lines of collimation were made at right angles to the axis of the circle and to the refracting faces by means of the plane glass plate and the collimating eyepiece. For observing the spectrum a magnifying power of 31 was employed. Table

II contains all the measures for the ordinary ray, then the temperature (t), the barometric height (Bar.), and the angle corrected to 30 inches barometric height. In the table, the mistakes mentioned, and which were confined to the four preceding the last, are corrected by adding 0′·285, the measured distance between D_1 and D_2.

TABLE II.—*Double angles of deviation for ordinary ray D_2.*

$2\Delta_0 = 104°$

PQ				PR				QR			
Obs.	t	Bar.	Cor.	Obs.	t	Bar.	Cor.	Obs.	t	Bar.	Cor.
+8′·454	20·3	29·85	+8′·423	−3′·772	19·4	30·1	−3′·752	+7 ·658	16·7	30·1	+7′·678
·472	20·4	29·85	·441	·701	19·8	30·1	·681	·546	17·1	30·1	·566
·497	20·7	29·85	·466	·661	19·9	30·1	·641	·531	17·2	30·1	·551
				·559	20·3	30·1	·539	·336	17·9	30·1	·356
				·560	20·2	30·1	·540	·134	18·8	30·1	·154
				·552	20·6	30·1	·532	+7′·085	19·0	30·1	·105
				·618	19·8	29·75	·669	+6′·983	19·1	30·1	+7′·003
				·479	20·3	29·75	·530	·921	19·7	30·1	+6′·941
				−3′·455	20·4	29·75	−3′·506	·914	20·1	30·1	·934
								·799	20·1	30·1	·819
								·839	20·2	30·1	·859
								·743	20·6	30·1	·700
								+6′·680	20·6	30·1	+6′·762

The observations for PR and QR were reduced by forming observation equations of the type

$$M = m + n(t-20).$$

and, the temperature correction for PQ being assumed as the same as that for PR, the reduced values for Δ are, for

PQ	52°	4′	$10''\cdot20 \pm 0''\cdot54 + 6''\cdot72(t-20)$
PR	51°	58′	$11''\cdot52 \pm 0''\cdot18 + 6\ \cdot72(t-20)$
QR	52°	3′	$26''\cdot10 \pm 0''\cdot30 - 7''\cdot17(t-20)$

TABLE III.

$2\Delta_\varepsilon =$

PQ 94°				PR 94°				QR 72°			
Obs.	t	Bar.	Cor.	Obs.	t	Bar.	Cor.	Obs.	t	Bar.	Cor.
+7′·983	20·7	29·85	+7′·955	−2′·518	19·6	30·1	−2′·537	+3′·474	16·8	30·1	+3′·489
8′·045	20·7	29·85	8′·017	·555	19·7	30·1	·574	·454	16·9	30·1	·469
·101	20·8	29·85	·073	·454	19·9	30·1	·472	·456	17·4	30·1	·471
·110	20·9	29·85	·082	·430	19·9	30·1	·448	·360	17·7	30·1	·375
+8′·088	21·0	29·85	+8′·060	·436	20·5	30·1	·454	·356	18·9	30·1	·371
				·391	20·6	30·1	·409	·307	19·0	30·1	·322
				·429	20·0	29·75	·475	·331	19·2	30·1	·346
				−2′·361	20·1	29·75	−2′·407	·309	19·4	30·1	·324
								[3′·495]	20·1	30·1	----
								·294	20·4	30·1	·309
								·277	20·5	30·1	·392
								·251	20·6	30·1	+3′·266
								[3′·634]	20·6	30·1	----

Table III gives the double angles of deviation as measured for the extraordinary ray for each refracting angle. As has already been stated, the deviation is that belonging to D_2, except in the case of the edge QR, where, on account of the small dispersion, the sodium line was set upon as a single line. As before, the observations enclosed in brackets are rejected. These were reduced in quite the same way as were the deviations for the ordinary ray, with the following resulting values for Δ_ε:

PQ	47°	3′	$58''\cdot23 \pm 0''\cdot39 + 3''\cdot60(t-20°)$
PR	46°	58′	$45''\cdot69 \pm 0''\cdot24 + 3''\cdot60(t-20°)$
QR	36°	1′	$39''\cdot21 \pm 0''\cdot21 - 1''\cdot58(t-20°)$

In order to reduce the angle of deviation for QR to what it should be for D_2, the angular distance between D_1 and D_2 for the ordinary ray was determined, and half its product by $\frac{d\Delta_\varepsilon}{d\Delta_0}$ for this region of the spectrum, was taken as an additive correction. The value of the correction was found to be $3''\cdot85$, whence the deviation for the extraordinary ray D_2 for QR becomes

$$36° \quad 1' \quad 43''\cdot06 \pm 0''\cdot21$$

(7) *Principal indices of refraction.*

The crystalline axis has been found to make an angle of less than 1′ with the plane bisecting the refracting angle QR; hence we may apply the ordinary formula connecting the index of refraction with the angles of minimum deviation and refraction, namely,

$$\mu = \frac{\sin \frac{\Delta + \alpha}{2}}{\sin \frac{\alpha}{2}}$$

The resulting indices will be the principal indices for calcite at a temperature of 20° C.

	$\mu_0 =$
for PQ	$1\cdot658393 \pm 2$
PR	$1\cdot658387 \pm 2$
QR	$1\cdot658387 \pm 2$
	$1\cdot658389 \pm 1\cdot2$

The single value of μ_ε is

$$1\cdot486450 \pm 1\cdot4$$

(8) *Test of Huyghens's Law.*

We are now in a position to test the law of extraordinary refraction from the principal indices of refraction and the observed extraordinary deviations by the refracting angles PQ and PR. First, we have the well known law,

$$\left[\frac{1}{\mu'_\varepsilon}\right]^2=\frac{\cos^2\vartheta}{\mu^2_o}+\frac{\sin^2\vartheta}{\mu^2_\varepsilon},$$

where μ_o and μ_ε are the reciprocals of the principal wave velocities as before, and μ'_ε is the reciprocal of the velocity of the extraordinary wave whose normal makes an angle ϑ with the crystalline axis. This enables us to compute μ'_ε, knowing ϑ. Second, we have the series of relations given by Professor Stokes (British Association Report, 1862),

$$\mu'_\varepsilon=\frac{\sin\varphi}{\sin\varphi'}=\frac{\sin\psi}{\sin\psi'}$$
$$\varphi+\psi=\Delta+\alpha$$
$$\varphi'+\psi'=\alpha$$
$$\operatorname{tg}\frac{\varphi'-\psi'}{2}=\operatorname{tg}\frac{\alpha}{2}.\operatorname{tg}\frac{\varphi-\psi}{2}.\cot\frac{\Delta+\alpha}{2},$$

where φ ψ are the angles of incidence and emergence respectively, and φ' ψ' the angles which the wave normal makes with the faces of the prism within it. These relations enable us to derive a value for μ'_ε from the observations, perfectly independently of any assumption as to the law of double refraction if we know either φ or ψ. They afford a much readier test than that of calculating the deviations for an assumed law.

We do not, it is true, know the values of φ for the extraordinary refractions by PQ and PR, but as the prism was always set for minimum deviation it is easy to find these values, either by taking advantage of the fact that Huyghens's law is already known to be nearly true, whence the angle of incidence for minimum deviation can be calculated, or, more simply, from the relation

$$\frac{\sin\varphi}{\sin\varphi'}=\frac{\sin\psi}{\sin\psi''}$$

and the two purely geometrical equations which follow this equation above.

It is found by trial that for PQ, the light being incident on Q the value of φ which satisfies the condition is 50° 25′, and for PR and incidence on R, the value of φ is 50° 21′. A small change in these angles does not alter the difference between the observed and calculated values of μ'_ε, which affords the test of the law.

The substitution of these values in the equation of Stokes gives—

	μ'_ε
PQ	1·606114±1·6
PR	1·606103±1·6

It remains to calculate the values of μ'_ε from Huyghens's theory from the known values of φ' or ψ' and the assumed direction of the crystalline axis defined by ξ above, since η is so small that it can be regarded as zero. The measured value of ξ is 1′ 4″ with a considerable uncertainty, but I find that a value of 1′ 6″ will make the differences between observation and theory symmetrical. With this value we have

	ϑ	μ'_ε [calc.]
PQ	31° 19′ 45″·68	1·606109±1·8
PR	31 19 58 ·34	1·606099±1·8

where the probable errors are calculated without disregarding the fact that we have imposed the arbitrary condition that the differences shall be symmetrical.

The difference between a measured index of refraction in Iceland spar at an angle of 30° with the crystalline axis, and the index calculated from Huyghens's law and the measured principal indices of refraction, thus appears to be 4·5 units in the sixth place decimals, while, assuming the truth of the law we ought to expect, from the probable errors of the quantities involved, a difference of ±2·4, only about half as great. There is, however, one source of constant error in the observations which has not been alluded to, namely, the fact that the temperatures of the prism were measured by a different thermometer in the case of the angles of the prism and the angles of deviation. In the former a rather insensitive thermometer divided to single degrees and estimated to tenths was used, and in the latter a very sensitive thermometer divided to half-degrees. By reference to my notes I find that the two systems of temperatures are connected only by an eye comparison on a single day, so, although I believe that the error of comparison cannot be much over one tenth of a degree, it is by no means certain, or even improbable, that an error of this magnitude may enter. It was not thought in that stage of the investigation that such an error was of any significance. Unfortunately one of the thermometers has since been broken so that a direct comparison is out of the question. The observations of the ordinary indices contain implicitly, however, the desired correction as appears from the following reasoning:—

Let dt be the excess of the reading of the first thermometer, used in the prism-angle measures, over that of the second; then its most probable value is that which renders the probable error of the mean value of μ_o a minimum, when the three observed values are regarded as independently determined magnitudes.

Thus $$\frac{d\mu_o}{dt}=\frac{d\mu_o}{d\alpha}\cdot\frac{d\alpha}{dt}=4{\cdot}2\times5{\cdot}68 \text{ for QR}$$
$$=-4{\cdot}2\times2{\cdot}84 \text{ for PQ and PR},$$

the first differential coefficient being derived from the formula from which μ_o is calculated, and the second is given on p. 66. From these and the values of μ_o on p. 70 treated as independent determinations, we have

$$23{\cdot}9\ dt=-2$$
$$11{\cdot}9\ dt=\ \ 2$$
$$11{\cdot}9\ dt=-4,$$

whence

$$dt=-0^\circ{\cdot}084\pm0{\cdot}032.$$

From this it is obvious that such a correction is required. Supposing, then, that the angles of the prism given above correspond to a temperature of 19°·916 C. instead of 20° C. we have the following definitive values for the quantities involved:

	α	Δ_o	Δ_ε	μ_o
PQ	60° 1′ 24″·83	52° 4′ 10″·20	47° 3′ 58″·26	1·658392
PR	59 57 37·66	51 58 11·52	46 58 45·69	1·658387
QR	60 0 57·60	52 3 26·10	36 1 43·06	1·658389

whence $\mu_o=1{\cdot}658389$ μ_ε 1·486452

	μ'_ε	μ'_ε [calc.]
PQ	1·606113	1·606110
PR	1·606102	1·606100.

The conclusion is, that Huyghens's law is probably true to less than one part in five hundred thousand, and, consequently, that there is no known method by which we can hope to discover an error in it by observation alone.

New Haven, Nov., 1887.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Decomposition of the Hydrides of the Halogens by Light in presence of Oxygen.*—Some time ago it was observed by Backelandt and by McLeod that hydrogen chloride gas, when exposed to the combined action of atmospheric oxygen and sunlight, was partially decomposed, chlorine being evolved. In order to determine the conditions under which this change is effected, Richardson has made a series of experiments on hydrogen chloride, bromide and iodide gases, (1) when the gaseous mixture exposed to the sunlight is moist; and (2) when it is dry.

In the former case, oxygen was present (a) in only sufficient quantity to oxidize the hydrogen, or (b) in large excess. Bulbs of about 300 c. c. capacity were filled with the gaseous mixture and sealed. The hydrogen chloride gas was prepared from sodium chloride by the action of pure sulphuric acid. The oxygen was freed from any chlorine it might contain by passing it through sodium hydrate. After exposure to the light, the bulbs were opened under water and the chlorine compounds thus absorbed. The resulting solution, made up to known volume, was divided into two equal parts. In the first the total chlorine was determined and in the second the free chlorine. In the first experiment the moist gases were mixed in the ratio of 4 vols. hydrogen chloride and 1 vol. oxygen, and the bulb was exposed to sunlight for 24 days. The free chlorine formed amounted to 0·34 per cent. In the second experiment, in which the oxygen was 8 vols. to four of hydrogen chloride and in which the exposure was 21 days, 73·81 per cent of chlorine was evolved, the mixture in the bulb being distinctly greenish after five days. In the third and fourth experiments, the gases were mixed in the same proportion and exposed to sunlight for 57 days. Notable quantities of hypochlorous oxide or other oxide of chlorine were produced. In the fifth experiment the gases were both carefully dried over phosphoric oxide. After 27 days exposure in one case and 63 days in another, not a trace of free chlorine could be detected. The hydrogen chloride was then saturated with moisture and mixed with dry oxygen. But an exposure to sunlight of 60 days failed to produce any free chlorine. Hence, a mixture of hydrogen chloride and oxygen is perfectly stable in sunlight not only when dry, but even in presence of aqueous vapor, provided liquid water be absent. Similar experiments were then made with hydrogen bromide. When the gases were moist and the oxygen was that required to oxidize the hydrogen, an exposure of 46 days produced 0·64 per cent of free bromine. When, however, the oxygen was in large excess, 7·73 per cent of bromine was set free in the same time. In case the gases were dry, no bromine was evolved. In the experiments with hydrogen iodide, 94·31 per cent of free iodine was produced in 20 days when the oxygen was not in excess and 96·08 per cent when an excess of oxygen was used. Even dry mixtures of these gases were found to be decomposed by sunlight. Hence, the author concludes: 1st, The stability of the moist hydrides of chlorine, bromine and iodine is dependent on the mass of oxygen present, in excess of that required for their complete decomposition. 2d, Dry or partially dry hydrogen chloride and bromide are completely stable, even when mixed with a large excess of oxygen. 3d, Dry hydrogen iodide is decomposed in presence of oxygen.—*J. Chem. Soc.*, li, 801–806, November, 1887. G. F. B.

2. *On the Influence of Liquid water in promoting the Decomposition of Hydrogen chloride by Sunlight in presence of Oxygen.*—In a paper immediately following the one above mentioned,

ARMSTRONG discusses the apparently anomalous result that water in the liquid state is necessary to the reaction just described. He regards the interaction in this case as only another instance showing the general fact that interactions which are commonly assumed to occur between *two* substances, are possible more frequently than not, only in presence of a third substance (which he calls a *catalyst*). The case in question is parallel to that of the oxidation of sulphur dioxide investigated by Dixon. "In gaseous mixtures chemical change appears so take place only when a comparatively high electro-motive force, or its equivalent, is employed; one sufficient to produce disruptive discharge being usually required. Regarding the interaction as a case of electrolysis, a gaseous mixture of HCl, O, and OH_2 therefore might be expected to prove insensitive to light. But an aqueous solution of hydrogen chloride is one of the best of liquid conductors and it is easy, therefore, to understand that a relatively small electromotive force should suffice to electrolyze a *liquid* system of the same three elements."—*J. Chem. Soc.*, li, 806–807. G. F. B.

3. *On the Concentration of Solutions by Gravity.*—Experiment teaches that a homogeneous solution left to itself at constant temperature, preserves sensibly its homogeneity. GOUY and CHAPERON have examined this question mathematically in order to see how far this result, taking gravity into the account, is in accordance with thermodynamic principles. And they find that under these conditions, the permanent state of a solution is not one of absolute homogeneity but that the density of the liquid increases from the surface downward according to a determinate law; so that in time the primitive homogeneity of a solution will be destroyed by gravity, and a new state of equilibrium will be established within it. To show that the principle of Carnot is in contradiction with the hypothesis of absolute homogeneity in the case of a heavy solution in the permanent state, the authors suppose a perfectly homogeneous solution placed in a vessel of height H. Let a very small portion of this liquid of volume V, at its upper surface, be supposed temporarily isolated from the remainder of the solution. If the weight $d\omega$ of the solvent pass by distillation from this isolated portion to the rest of the liquid at constant temperature, evidently no work will be expended. Suppose now that, since the weight of the solvent $d\omega$ has gone from this isolated portion to the rest of the liquid, the density of this portion increases in consequence by an amount dD, its volume will diminish by dV; and now if by reason of this increased density, this portion sinks to the bottom of the vessel, it will do a positive amount of work equal to $H\ (V-dV)\ dD$. If after this we suppose the homogeneity of the solution to be re-established by diffusion the cycle will be closed, the total work done in the cycle will be zero and hence dD must be zero. It is not possible therefore for a solution to be perfectly homogeneous in the permanent state unless its density does not vary for an infinitely small variation of the concentration. But if, on the contrary, the solution is not homogeneous,

its density increasing gradually downward, the isolated portion above mentioned will be in equilibrium in the liquid when it has fallen through a distance dH; so that the positive work done in this case will be an infinitesimal of the second order and therefore negligible. From a formula deduced in the paper, the authors have calculated the amount of substance at the top and at the bottom of a column 100 meters high, for four different solutions. For cadmium iodide at top 0·166, at bottom 0·153; a difference of 0·013. For sodium nitrate 0·20 and 0·196; a difference of 0·004. For common salt 0·11 and 0·1095; a difference of 0·0005. And for sugar 0·55 and 0·546; a difference of 0·004. These differences, though apparently too small to have any practical value, have a very considerable theoretical importance.—*Ann. Chim. Phys.*, VI, xii, 384, Nov., 1887. G. F. B.

4. *On the Percentage of Oxygen in the Air.*—HEMPEL has published the results of analyses of the air of Dresden, made for the most part by his assistants Oettel and Schumann, in comparison with analyses of air collected simultaneously at Poppelsdorf, near Bonn, by Kreusler, at Cleveland by Morley, at Para, Brazil (lat. 1½° S.) by Pusinelli, and at Tromsöe, Norway (lat. 69½° N.) by Schneider. The samples analysed were taken daily between April 1 and May 16, 1886, the hour being 2:12 P. M. at Bonn, and the corresponding time at the other stations. The results are given in detail in tabulated form. They show that the mean percentage of oxygen in the air was for Para 20·92, Bonn 20·92, Cleveland 20·93, Dresden 20·93, and Tromsöe 20·95. The highest observed percentage was 21·00 at Tromsöe on April 22d; and the lowest 20·86 at Para on April 26th. The mean percentage as deduced from all the experiments is 20·93.—*Ber. Berl. Chem. Ges.*, xx, 1864, June, 1887; *J. Chem. Soc.*, lii, 885, Oct., 1887.

G. F. B.

5. *On the Constitution of Selenous Acid.*—MICHAELIS and LANDMANN have continued their researches on the constitution of selenous acid and have offered new proof that this is a di-hydroxyl-acid $SeO \cdot (HO)_2$. They have produced the chloride of ethoxyselenyl, $C_2H_5O \cdot SeO \cdot Cl$, by distilling selenyl chloride with absolute alcohol for a long time with an inverted condenser. They have also formed di-ethyl selenite $(C_2H_5O)_2SeO$, either by the action of selenyl chloride upon sodium ethylate or by that of silver selenite on ethyl iodide. This ether has a density of 1·49 at 16·5° and boils between 183° and 185°.—*Ber. Berl. Chem. Ges.*, xx, (Ref.) 625, Nov., 1887. G. F. B.

6. *Indexing of Chemical Literature.*—The fifth annual report of the Committee of the American Association for the Advancement of Science on Indexing Chemical Literature has recently been received. The report mentions the publication of Professor C. E. Munroe's Index to the Literature of Explosives, Part I, in which no less than 442 volumes of serials have been indexed. After noticing reports of progress from eight persons, the report considers the suggestion of the chairman made at the Buffalo meeting as to the

formation of a Standard List of Abbreviations of titles of Chemical Periodicals. The committee give the nine principles by which they were governed in compiling the Provisional List of Abbreviations which accompanies the report. This list gives proposed standard abbreviations of 206 chemical periodicals (including some of general science) for adoption by chemists with a view to securing uniformity. Those desiring copies of this list can obtain them by addressing the chairman of the committee, care of the Smithsonian Institution.

The report also gives a list of the Indexes to chemical literature published to date, twenty in number. The committee is now constituted as follows: H. Carrington Bolton, Chairman, F. W. Clarke, Albert R. Leeds, Alexis A. Julien, John W. Langley, Samuel H. Scudder, and C. K. Wead.

7. *Mechanical Equivalent of Heat.*—Dr. DIETERICI employing the electrical method for the determination of the mechanical equivalent of heat, obtains as the results of his series of measurements, 424·4 and 424·2. The highest and lowest values differ very little from the mean of the determinations. The value of the specific heat of water taken was the mean of the determinations between 0° C. and 100° C. The author believes that the specific heat of water can best be determined by the electrical measurement of the mechanical equivalent of heat.—*Nature*, Nov. 10, 1887, p. 48. J. T.

8. *Radiation in absolute measure.*—Mr. J. T. BOTTOMLEY placed a wire in a blackened copper cylinder which was exhausted of air. The wire was heated by an electric current and the amount of energy measured which was necessary to maintain the wire at a constant temperature. The constant temperature was shown by the constancy of the resistance of the wire. The energy was measured by obtaining the value of the current and the difference of potential. The measurements were obtained at such a low pressure that a further reduction of this pressure did not appreciably affect the energy given off. By means of an asymptotic curve the energy given off by radiation was then calculated.

The energy radiated, expressed in gram-water Centigrade units, was at 408°, $378·8 \times 10^{-4}$; at 505°, $726·1 \times 10^{-4}$. Two equal wires of platinum were enclosed by melting in two equal cylinders. One of these wires was covered with lamp black. By a suitable arrangement both wires were raised from a red to a white heat by known electrical currents and known differences of potential. It was seen that the temperature of a dull body must be much higher than that of a polished one in order to exhibit the same brightness.—*Proc. Roy. Soc. Lond.*, xlii, pp. 357–359, 1887; ibid., pp. 433-437. J. T.

9. *Maximum of Light Intensity in the Solar Spectrum.*—G. MENGARINI after a careful study concludes that the relative brightness of different colors of the spectrum changes, and the maximum of the intensity of light is not in any fixed position. It varies between tolerably wide limits.—*Rend. della R. Acc. dei Lincei* (4) iii, pp. 482–489, 1887. J. T.

10. *Relation of the wave-length of light to its intensity.*—One of the most important questions in optics is the question whether the velocity of light depends upon its intensity. EBERT has undertaken an elaborate study of this point. Interference fringes were employed, the writer showing that changes in wave-lengths amounting to only $\frac{1}{200,000}$ of their values, or changes in velocity of light amounting to $\pm 1 \cdot 5$ kilometers can be detected by this method. Different sources of light were employed. It was found that the wave-lengths and the velocity of light did not change a millionth in value when the intensity of light varied from 1 to 250.—*Ann. der Physik und Chemie*, No. 11, 1887, pp. 337–383.

J. T.

11. *Brief notice of a paper by Mr. Hallock* entitled: The Flow of solids, etc.;* by W. SPRING. (Communicated by the author.)—I have shown, it will be remembered, by numerous experiments, that solid bodies possess, to different degrees, the property of being welded together, while cold, under a sufficiently strong pressure. In compressing bodies of a different chemical nature I have been able to obtain, at a low temperature, a number of combinations of bodies in a solid state, combinations which are, generally, produced only with the aid of a temperature more or less high. These researches were undertaken with the view of deciding whether it is possible to find in bodies in a solid state, any trace of the peculiarities which especially characterize the liquid state.

I have also been led to state, as the result of my experiments, since 1880, that "*matter assumes, under pressure, a condition relative to the volume it is obliged to occupy;*" but this condensation is permanent only when the matter admits of different allotropic states. Since then, new experiments,† still in part unpublished, have made me recognize the importance of the part that a certain degree of temperature plays in these phenomena, so that for the solid state, as well as for the gaseous one, *a critical temperature* would be remarked, above or below which, the changes by simple pressure would be no longer possible.

The consequences of all this is, for instance, that liquid bodies must pass under pressure into a solid state, taking of course the critical temperature, into account, if their specific volume is smaller in a solid state than in a liquid one, and conversely. This *converse* has been demonstrated first by Mouzon, since then by myself in coöperation with my friend J. H. van't Hoff. I had intended verifying also the first proposition, but I have been anticipated, to my great satisfaction, by M. Amagat‡ who has just produced the solidification of several liquids by the action of pressure. The verification of the general result of my experiments has given me great pleasure; its value will escape no one.

This taken for granted, I come to Mr. Hallock's article. The author imputes to me the absurd idea that solid bodies

* See this Journal, xxxiv, No. 202, October, 1887, p. 277.

† Zeitschrift f. phys. Chemie, i, p. 227. ‡ Comptes Rendus, cv, p. 165, 1887.

would all *liquefy* under the action of pressure. He even imagines that I have drawn this conclusion from my own experiments! To second his statement he alters some passages of my works, substituting for the word "*welding*" (*souder*) while I have used that of "*fusion*," or even in misconstruing the text. The reader may judge: Mr. Hallock makes me state, for instance (p. 281), "Sulphur prismatic—5000 atm.-fusion to the octahedral form . ." he adds, of his own invention: "and so on through a long and varied list." But I said, on page 391 of my memoir of 1880: "*Du soufre prismatique transparent, fraichement préparé, a été sousmis à une pression de* 5000 *atm. à la temperature de* 13°; *il s'est* MOULÉ *en un bloc opaque beaucoup plus dur que ceux qu'on obtient par fusion.*"*!* . . . . . After having thus prepared the ground, he gives an account of some new experiments which have shown him, naturally, that solid bodies do not fuse under pressure! Finally, he closes by showing my absurdity, referring to Amagat's experiments which prove, as I have just called to mind, *the solidification of certain liquids by pressure*, that *which excludes the contrary.* It is quite evident that there is no reason for arguing with Mr. Hallock, since his study, which rests on a chimera, is, in my opinion, null and void. But I think I have a right to protest against the carelessness which has led him thus to misstate my views.

Liége, 6 Nov. 1887.

12. *Lessons in Elementary Practical Physics:* vol. ii, *Electricity and Magnetism;* by BALFOUR STEWART and W. W. HALDANE GEE. 497 pp. 12mo. London and New York, 1887 (Macmillan & Co.).—Those who are already familiar with the preceding part of this excellent work on Practical Physics will not need any special introduction to this second volume. It covers the subjects of electricity and magnetism, the first three chapters giving the elementary phenomena and principles to be worked through by the student experimentally; after this he is fitted to take up the more advanced portion dealing in successive chapters with the measurement of resistance, the tangent galvanometer, the determination of the magnetic elements, electro-magnetism, the condenser, electrometer and so on.

II. GEOLOGY AND NATURAL HISTORY.

1. *Communication by Raphael Pumpelly, of the U. S. Geological Survey, on the fossils of Littleton, New Hampshire.*—In the course of a reconnaissance of some of the limestone areas of New England made under my direction by Mr. T. Nelson Dale in August and September, 1885, the following fossils were found in the limestone and interbedded slates at Fitch Hill, the north end of Blueberry or Parker Mountain, near Littleton, N. H.

The determinations of the trilobites and mollusks were made by Mr. Chas. D. Walcott, those of the corals by Mr. C. Rominger. *Dalmanites limulurus* (Green), abundant; *Strophomena rhom-*

boidalis (Wahl.), *Pleurotomaria*, fragment, *Strophodonta*, a species allied to *Trematospira multistriata* (Hall), *Stromatopora*, *Syringopora* similar to Niagara forms, *Favosites* most likely *favosa* (Goldf.), *Favosites* with the special character of Niagara forms *Favosites*, a ramose species, Niagara group.

The following fossils were also found at the same locality, thus corroborating the discoveries made there in 1870 by Professor Ch. H. Hitchcock, and the determinations by the late Mr. Billings, (this Journal, III, vol. vii, 1874, pp. 468, 557; also Geology of New Hampshire, vol. i, p. 48, 1874, vol. ii, p. 339–340, 1877, *Pentamerus Knightii* (Low.), *Halysites*, differing but slightly from *H. catenulata* (Lin. sp.), *Zaphrentis*, crinoid columns, fragments of another gasteropod. The following species also given by Professor Ch. H. Hitchcock from the same locality were not found: *Favosites basaltica* (Goldf.), *Favosites Gothlandica* (Lam.) and a Lichas.

The fossils found by Professor Hitchcock seemed to indicate the age of the Upper or Lower Helderberg for these deposits, with a preponderance in favor of the latter. Mr. Walcott's and Mr. Rominger's determinations agree however in assigning the beds to the Niagara period.

2. *The Geological history of the Swiss Alps.*—Prof. RENEVIER, one of the ablest and most active of Swiss geologists, has an important paper on the Alps, in the "Archives des Sciences," of Geneva, for October 15, 1887 (xviii, 367). He first discusses the age of the crystalline rocks, and opposes the hypothesis of their universal Archæan age and igneous origin. He observes that the crystalline rocks are so varied, so frequently stratiform, not to say stratified, so similar, so indisputable sedimentary rocks, that their general igneous origin cannot, in his view, be sustained. Some may be of this nature, but the micaceous and other schists appear to be ancient argillaceous rocks, foliated by pressure; some gneisses, old sandstones more or less metamorphosed. Further, instead of uniform unconformability between the fossiliferous beds of the Coal formation and these alleged Archæan schists, in many places there is perfect concordance, and the beds of the Coal formation also are often semi-crystalline.

It appears, moreover, to be more and more incontestable that some of the crystalline rocks of the Alps contain organic remains. Some time since Sismonda reported the discovery of an impression of an Equisetum in a crystalline rock of the Val Pellina. Recently, M. A. Muller announced the discovery of Crinoids and other fossils, apparently Devonian, in a kind of Graywacke, from the Etzlithal; and M. Stapff has found, in schists from the interior of the St. Gothard tunnel, joints of Crinoids in calcareous mica schists, impressions of fucoids in shining slates, and in a calcareous bed intercalated with mica schists, a microscopic network (figured by him), which probably pertained to a sponge. The past year the discovery has been made known of two trunks which are certainly vegetable, in the sericitic (hydromica) schist of Guttanen. Such facts may leave some doubts still, but they afford, at least, a strong presumption that there is not the long unrepresented interval between the Archæan and Carboniferous which has been claimed by some; on the contrary, that the Silurian and Devonian may be represented in different parts of the Swiss as well as in the Austrian Alps.

Mr. Renevier continues with an account of the extensive distribution of the Carboniferous beds in the Swiss Alps; of the Triassic, but mostly the upper Trias, and, unlike the Austrian, without marine fossils; and of the Triassic and Jurassic, which in the Rhetian beds—here referred to the Lias rather than the Trias—include the first of the marine beds in this series. These marine beds are stated to indicate, apparently, that the sea encroached on the region of the Alps in a direction to the southeastward, the Rhetian beds not extending to the High Alps, the upper Lias reaching farther in that direction than the Rhetian, and the Upper Jura, or Malm, constituting the calcareous backbone of the mountains, being found between the different crystalline centers of the Alps, on both flanks of Mt. Blanc, in the valley of Chamouni on the north and that of Entrèves on the south; and also at Zermatt at the foot of Mt. Rosa. The fossils in the limestones of these high regions are not determinable, but the beds can be followed even along the metamorphic regions, to places where, as at Mœveran, the fauna is determinable. It hence appears that, at this Jurassic period, the sea had its largest extension, and the Alps were an archipelago, consisting of more or less oblong islands. After this there is evidence of a gradual retreat of the waters.

As the geological chart shows, the Cretaceous beds occupy only the outer zone of the northern Alps. The Lower Cretaceous beds have the greatest extension. Passing to the later epochs of the Cretaceous, the distribution shows a gradual retreat of the sea. The Lower Cenomanian beds of the Upper Cretaceous are the last and are only circumferential in distribution; after this the emergence of the Alps was carried on through the Cretaceous until it was complete.

The upward movement of the Cretaceous era probably continued through the era of the oldest Eocene (Paleocene, anterior to the Nummulitic beds), so that at this time the Swiss Alpine region was continental. After this a return of the sea commenced at each extremity of the Alps, producing the Nummutic deposits of Kressenberg, Bavaria, and of Appenzell and Schwytz which is prolonged even to Lake Thun; and also other beds in the southern part of Savoy; the intermediate region being still "terra firma," as proved by terrestrial and lacustrine deposits. The Nummulitic beds were followed by the Flysch—a marine deposit of the later Eocene; and after it, came a new retreat of the waters.

The Miocene beds occur in the Rigi, the Pèlerin and the Speer, but are not known to occur in the synclinal valleys of the Alps; they may yet be traced into some of them, but it appears certain that the Alps had become mainly emerged by the commencement of this era.

The Flysch, the last of the Eocene marine deposits, is much folded up with the beds below, entering into the remarkable double folds; and it is probable that the great flexures of the Swiss Alpine chain had hardly commenced before the era of its deposition had closed. The era of folding may have covered the whole of the Miocene period.

By the beginning of the Pliocene period, the folding was completed, and the Alps had acquired their present altitude or may have exceeded it.

The Glacial era probably began with the close of the Pliocene. Then followed an interglacial period, represented by immense accumulations of rounded, stratified gravel, which are situated between two systems of angular erratics; and during this epoch the plains of Switzerland became free of the glacier. Later, owing to new elevations or new meteorological conditions, the ice spread itself anew over the plains; but whether to a greater or less extent than in the first glacial epoch is uncertain. Then followed the era of the formation of the great accumulations of gravel in the Alpine valleys, and the terraced materials along the lake valleys, and river borders, and the final retreat of the ice to its present limits.

3. *Gradual variation in intensity of metamorphism.*—A paper on Crystalline and Metamorphic rocks of the lower Himalaya, Garhwal and Kumaum, by C. S. MIDDLEMISS, B.A. (Records Geol. Surv. India, xx, part 3), gives some facts on this subject which show that the metamorphic phenomena of India are much like those of New England. The author emphasizes two points; that "the schist near the gneissose granite is entirely a thorough crystalline schist, a fact needing no miscroscope to demonstrate; and, secondly, along a line of country where rock is exposed at every step, it is seen that this culminating intense form *graduates* into a widespread less intense form, and this in turn, *graduates* into ordinary slates and quartzites." "About a mile from any outcrop of gneissose granite, as we approach the Dudatoli massif, in no matter what direction, there is a rapid, but gradual change in the metamorphism of the schistose beds. The faint films of micaceous material assume by degrees the aspect of distinct layers of mica-plates of considerable thickness." "Garnets gradually assemble in the schist; first showing as minute pin-heads under a coating of what one may call mica-leaf, and gradually increasing in size and definiteness concomitantly with the mica until they reach an average size of peas and rarely as large as filberts."

An exact counterpart as to the change in the mica and garnets with increasing intensity of metamorphism, connected with a graduation from hydromica schist into gneiss occurs within 10 miles west of New Haven, Connecticut, and in a less restricted area, in the Taconic range of Massachusetts. At the India locality the gneiss graduates into porphyritic gneiss and granite; so, west of New Haven, the gneiss becomes a coarse porphyritic gneiss with crystals of orthoclase as large as the thumb; and at the junction of the mica schist and gneiss several alterations of the two occur, becoming coarser and coarser, before the passage is complete into the porphyritic gneiss. In the gneiss a mile west of the junction, large masses of porphyritic granite occur with the layers of the micaceous gneiss broken and involved in it; which has appeared to indicate that part of the rock material of the porphyritic gneiss had been reduced by the heat to a pasty condition, and in that state had been forced up through the fractured schist. J. D. D.

4. *Mission Scientifique du Cap Horn*, 1882–1883; par le Dr. HYADES. Published under the auspices of the "Ministères de la Marine et de l'Instruction Publique." Tome iv, *Geologie.* 242 pp., 4to, with 30 plates and 3 maps. Paris, 1887. (Gauthier-Villars.)—In this volume on the geology of the region about Cape Horn, after a brief notice of other explorations, the author describes the various rocks about Orange Bay and other lands in its vicinity, and gives fine figures of many microscopic sections on ten of the plates. The rocks are mainly crystalline, and include diorytes, andesytes, diabase, trachyte, hornblende schist, granulyte, quartzyte, quartz-syenyte, and others. Several of the plates give excellent views of columnar rocks and of the scenery of the rugged region, and the maps show well the wonderful Fuegian archipelago. An appendix contains descriptions of other specimens collected in 1882 by Professor Lovisato of the University at Cagliari, and among them, in the vicinity of Cape Conway, a limestone in schist and a marly slate each containing fossils, that of the limestone a coral near *Coscinocyathus calathus* Bornemann, a Silurian fossil.

Among the interesting facts cited from Darwin, in the introductory historical notes, is his discovery of Cretaceous fossils in an argillaceous schist or slate on the summit of Mount Tarn *Ancyloceras simplex* and a *Natica* and *Pentacrinus*, and near Port Famine specimens referred to *Hamites elatior*, *Lucina eccentrica*, and a Venus and Turbinolia.

The author refers also to Wilkes's "Narrative," and cites a few sentences. He makes no mention of the writer's report on the vicinity of Orange Harbor, in which is mentioned, besides other facts, the discovery on the shores to the north of the harbor, in a slate, where passing into argillaceous sandstone, of a species of *Belemnite.* It was February, 1839; an opportunity for only one day's excursion over the region was allowed. Accompanied by one of the sailors of the vessel, the walk was continued for some hours over the bleak hills, and then along the sea-shore with the intention of returning by the shore to the harbor where the vessels of the expedition were at anchor; and on this coast part of the excursion, about half way between the harbor and the head of the bay (the latter probably Point St. Bernard on the map of the work here noticed) the fossils were found "quite thickly distributed" in one of the layers, "15 to 20 occurring in a slab a foot square" (p. 604). The coast had many deep coves and long points, so that the one excursion was prolonged unintentionally, and somewhat imprudently considering the savage climate and people of the region, to twenty-four hours, the best place under some bushes being selected for the night. But no more fossils were found.

The other volumes of the series are: I, History of the Voyage; II, Meteorology; III, Terrestrial Magnetism, and Constitution of the Atmosphere; V, Botany; VI, Zoology; VII, Anthropology and Ethnography. Only II, III and IV are published. J. D. D.

5. *The American Geologist.*—The prospectus of an American geological monthly has been recently issued, announcing the appearance of the first number on the first of January. Its aim will be to cover all branches of the science in its publication of papers and notices of discoveries, and also to afford special aid, by suggestion and information, to the teacher in geology. The editors and publishers for the coming year are as follows: Professor S. Calvin of Iowa, Professor E. W. Claypole, of Ohio, Dr. Persifor Frazer of Philadelphia, Professor L. E. Hicks of Nebraska, Mr. E. O. Ulrich of Kentucky, Dr. A. Winchell of Michigan and Professor N. H. Winchell of Minneapolis. The Journal will be published at Minneapolis, in monthly numbers of at least fifty-six octavo pages each, at three dollars a year. There is no lack of good material from home investigation for the American Geologist. It promises to be of great service to the science and the country.

6. *Geology and Mining Industry of Leadville, Colorado;* by S. F. Emmons. 750 pp. 4to, with a folio Atlas and numerous plates.—United States Geological Survey, Clarence King, Director. Washington, 1886.—This report of Mr. Emmons gives a full account of the Leadville region, as regards its geology, its mineral veins and their products, its mines and its mining industry, and discusses ably the origin or genesis of the veins of ore. The illustrations accompanying the text represent scenery, the microscopic structure of the rocks, furnaces, implements for assaying and smelting, and various other matters connected with the mining operations. The Atlas contains maps with contour lines of Central Colorado and of the Leadville mining region, and others giving in color the topographical geology, besides numerous geological sections. The work is grandly prepared in all respects and is a very important contribution to geology and the science of mines and mining.

7. *Fifteenth Annual Report on the Geological and Natural History Survey of Minnesota for the year*, 1886. N. H. Winchell, State geologist. 496 pp. 8vo. St. Paul, 1887.—This volume consists chiefly of Reports by Dr. Alexander Winchell on observations in northeastern Minnesota, which is accompanied

by a map and fifty-seven structural illustrations; Prof. N. H. Winchell, on the iron ore of Minnesota; and by Aug. E. Foerste, notes on four species of Illæni. Besides the valuable notes and discussions connected with the iron ores, there is a large amount of facts bearing on the relations of granite and the associated schistose rocks, (gneiss and mica and hydromica schist), which go far in the way of elucidating the conditions of origin of granite and the associated schists. The accompanying figures are highly instructive. There is much in the report which geologists will find it profitable to study.

8. *New York Paleontology: Vol. VI, Corals and Bryozoa, containing descriptions and figures of species from the Lower Helderberg, Upper Helderberg and Hamilton Groups;* by James Hall, State Geologist and Paleontologist, assisted by George B. Simpson. 298 pp. 8vo, with sixty-seven lithographic plates. Prof. Hall has here added another to the long series of volumes on the Paleontology of New York. The number of species described is 371, and of these 328 are figured on the plates. Prof. Hall states, in his prefatory remarks, that about 100 additional species he has studied and had drawn, which he could not add to the present volume on account of the restriction limiting its extent. The illustrations of the species are beautiful, and the volume a great contribution to paleozoic paleontology and especially to the department of Bryozoans.

9. *Annual Report of the Geological Survey of Pennsylvania, for* 1886, *by the State Geologist.* 574 pp. 8vo.—This volume, Part 1 of the report, treats of the Pittsburgh Coal Region, and has been prepared as regards the geological structure, by E. V. d'Invilliers; the general mining methods of the Pittsburgh Coal Region, by Selwyn Taylor; the mining methods practised by Westmoreland Coal Co., Irwin, Pa., by A. N. Humphreys, Engineer; and the character and distribution of Pennsylvania plants, by L. Lesquereux. The subjects of the other parts yet to be issued, are: II, Oil and Gas region; III, Anthracite Coal region; IV, Miscellaneous Reports. A large colored geological map of Southwest Pennsylvania, with special reference to the Pittsburgh Coal bed, accompanies the report.

10. *Fossil Mammals from the White River formation contained in the Museum of Comparative Zoology.* Bull. Mus. Comp. Zool., xiii, No. 5, 1887.—Messrs. W. B. Scott and H. F. Osborn here present an abstract of a detailed memoir in course of preparation. Besides a number of species first described by Dr. Leidy, there are here included notices of the new species *Hyænodon leptocephalus* Scott, *Hyotherium americanum*, *Menodus tichoceras*, *M. dolichoceras*, *M. platyceras*, and a restoration of *M. Proutii* (*Titanotherium*) on plate II; *Metamynodon planifrons*, *Hyracodon major*, *H. planiceps.* Plate I gives a restoration of *Hoplophoneus* (*Drepanodon*) *primævus* Leidy, one-fourth the natural size. Many wood-cuts also illustrate the paper.

11. *Diatomaceous Earth in Nebraska.*—In a soft, chalky rock of Tertiary age near Scotia, Greeley County, Nebraska, there are numerous diatoms. I have seen entire specimens, or well characterized fragments, of the following species: *Navicula cuspidata, Cocconema lanceolatum, Amphipleura sigmoidea, Pinnularia radiosa, Nitzschia longissima, Nitzschia sigmoidea.* Mr. F. W. Russell, who kindly furnished me a specimen of the rock, reports that the stratum is twenty feet in thickness near the base of a cliff seventy-five feet high on the North Loup river. The diatoms form but a small proportion of the whole mass of rock. L. E. H.

University of Nebraska, Oct. 6th, 1887.

12. *The Upper Beaches and Deltas of the Glacial Lake Agassiz;* by WARREN UPHAM. 8vo. 1887. Bull. U. S. Geol. Survey, No. 39.—An important paper by Mr. Upham, who has studied more than any other geologist the Winnipeg Lake region with reference to its ancient drainage. The memoir is accompanied by a map of part of Dakota, Minnesota and Manitoba.

13. *Supposed diamonds in a Meteorite.*—It is stated (*Nature* of Dec. 1) that a meteoric stone, which fell at Krasnoslobodsk, in Russia, on September 4, 1886, has yielded a number of small granules having the hardness, density and other characters of the diamond and believed to be that mineral. It is interesting to note in this connection, the cubic form of graphitic carbon called cliftonite, from the meteoric iron of Youngdegin, by Fletcher, and which he suggested might perhaps be pseudomorphous after diamond (this Journal, Sept., 1887).

14. *Cryptolite.*—Mallard has shown recently that the rare cerium phosphate, cryptolite, occurring in minute crystals embedded in apatite from Norway, has the form of monazite and is doubtless to be referred to that species.

15. *Grundriss der Edelsteinkunde von* DR. P. GROTH. 165 pp. 8vo, with a colored plate. Leipzig, 1887 (Wm. Engelmann).—Professor Groth has found time, among his more serious duties, to prepare this attractive little volume on the properties of the gems. His experience as a writer and teacher has enabled him to present the subject more systematically and intelligibly, than has hitherto been done.

16. *Rivista di Mineralogia e Cristallografia Italiana, diretta* da R. PANEBIANCO, vol. i, 81 pp., with 3 plates. Padua, 1887.—The latest addition to mineralogical publications is this Italian review which, judging from the first volume is of much more than local interest. Among its contents may be mentioned well illustrated papers on celestite, zircon, and datolite.

17. *Catalogue of all recorded Meteorites*, with a description of the specimens in the Harvard College collection including the cabinet of the late J. Lawrence Smith, by OLIVER WHIPPLE HUNTINGTON, Ph.D. From the Proceedings of the American Academy of Arts and Sciences, vol. xxiii, pp. 37–110, with five plates.—Since the acquisition of the cabinet of Dr. Smith, the Harvard collection of meteorites has taken a prominent place

among the great collections of the world, and this fact makes the catalogue, carefully prepared and annotated by Dr. Huntington, of great and general interest.

18. *A Chapter in the History of Meteorites*, by the late WALTER FLIGHT. 223 pp. 8vo, with seven plates. London, 1887 (Dulau & Co.).—This volume is for the most part a republication of papers by Dr. Flight, giving a digest of a large number of memoirs on meteorites since 1868. It is thus a continuation of the works of Buchner and Rammelsberg, and to the student of the subject and to the collector it is of high value. It is to be hoped that it may be widely distributed not only for the sake of making its author better known who was so early arrested in his active scientific life, but also because the proceeds are to go to increase the amount of the *Flight Fund*, which is being raised for the benefit of his family.

19. *Das pflanzenphysiologische Praktikum;* by Professor DETMER of Jena. Jena, 1888, 8vo, pp. 352.—Vegetable Physiology takes its appliances for research from Chemistry and Physics. Many of the special methods of using these appliances with the least expenditure of time and labor, and with the greatest certainty of securing trustworthy results, were brought together in a useful handbook long since out of print, namely Sachs' Experimental-Physiologie der Pflanzen. Since the date of that work, 1865, many new methods have been introduced, and new fields of investigation have been opened. It seems, therefore, quite time that some compendious and yet convenient treatise should be available to teachers and students, in which modern methods of experimental research in this interesting department should be clearly described.

By the lectures by Sachs and by Pfeffer, and by the small treatise by Bretfeld, a student is placed in possession of references to the memoirs giving details of researches in the different parts of the subject, but there does not appear to be any single handbook for laboratory practice which covers the ground of the present work. The subject is divided into the two parts, (1) Nutrition, (2) Growth and Movements. As might be naturally expected the author has given some description of what he regards the most desirable single method for investigating each minor point, but in many instances the methods are merely described without critical examination of their merits or faults. Perhaps this, on the whole, is all the better for any student who might be led thereby to distrust a method until he had for himself examined rival methods not here referred to, but it would be all the worse for any student who should confine himself to the single methods here detailed. The latter course would inevitably lead to superficiality. But in the hands of a judicious teacher the treatise can be made of great assistance.

One of the charms of Strasburger's "Practicum," consists in the almost colloquial minuteness with which all possible difficulties are explained, to the student of histology; the present treatise lacks that charm. Many a student who uses it will be likely to lose his interest in experimenting, when he finds that some trifling direction has been omitted by which success could have been secured. No handbook dealing with manipulation should fail to give even fussy details, rather than leave the student to find out all such minor points of practice for himself.

Although we miss a good many excellent methods which should find place in a work of this sort, it is nevertheless a valuable aid in the laboratory. The illustrations are numerous and excellent. It is to be regretted that the work has no index. G. L. G.

III. Miscellaneous Scientific Intelligence.

1. *Proceedings of the Colorado Scientific Society*, vol. ii, part 2, 1886, 153 pp. 8vo. Denver, Col. (published by the Society).—The Colorado Society, though somewhat removed from the chief scientific centers has shown an admirable spirit in the amount and excellence of the scientific work it has called out. This closing part of volume ii contains a series of papers chiefly geological and mineralogical. Mr. P. H. Van Diest describes the telluride veins of Bowlder county, with an excellent map. A paper by Charles G. Slack follows on the artesian wells of Denver; these wells number about 200, furnishing about 3,000,000 gallons daily, they draw their water from sandstone or shale layers, from a few inches to 80 feet in thickness, at varying depths down to 900 feet. Mr. S. F. Emmons furnishes notes on some Colorado ore deposits. Mr. W. Cross on the Cimarron land-slide of July, 1886; Mr. R. C. Hills on the circulation of water through the strata of the Upper Cretaceous Coal-measures of Gunnison county. There are also a number of mineralogical articles, several of which have been printed in this Journal.

2. *Relative Proportions of the Steam Engine*, being a rational and practical discussion of the dimensions of every detail of the steam engine, by W. D. Marks, 3d edition, revised and enlarged. 295 pp. 8vo. Philadelphia, 1887 (J. B. Lippincott Company).—A new and considerably enlarged edition of this excellent manual will be acceptable to all interested in the steam engine. The chief additions are in an important line, being an attempt on the part of the author, approaching the subject both from the mathematical and practical side, to develop the laws of the condensation of steam within the steam cylinder.

3. *Modern American Methods of Copper Smelting;* by Edw. D. Peters. 342 pp., large 8vo. New York, 1887. (Scientific Publishing Company.)—The author gives here a practical and detailed description of the methods employed in this country for smelting copper, adding more than usual of minute directions and with many useful data as to the actual cost. The volume will be valuable to the student and still more to the practical worker.

Obituary.

Ferdinand Vandeveer Hayden.—Dr. Hayden, for many years at the head of Government Exploring Expeditions in the Rocky Mountain region, and the author of various geological papers, died on the 22d of December, in his 59th year. A notice of his special scientific work is necessarily deferred.

APPENDIX.

Art. VI.—*Notice of a New Genus of Sauropoda and other new Dinosaurs from the Potomac Formation*; by O. C. Marsh.

The variegated red and gray clays which form so conspicuous a feature in their outcroppings between Baltimore and Washington have long been a puzzle to geologists. They have been supposed to be Mesozoic, but as no characteristic fossils had been found at the typical localities, or in the known extensions of the deposits, their true age was uncertain. They are evidently above the red Triassic sandstones, and are supposed to pass into clays which extend beneath the Cretaceous marls of New Jersey.

The United States Geological Survey has named these problematic deposits the Potomac formation, and the Director recently requested the writer to institute a special search for vertebrate fossils, to solve, if possible, the question of its age. The field work was intrusted by the writer to Mr. J. B. Hatcher, whose experience in the West has especially fitted him for it. The results of two months' investigation prove that these deposits, so long supposed to be nearly or quite destitute of fossils, contain a rich vertebrate fauna, apparently of Upper Jurassic age, but quite distinct from any hitherto discovered in this country.

The most abundant fossils obtained are remains of Dinosaurian reptiles, three orders of which are represented, and in the present article, some of the new forms are described. Associated with these are remains of crocodiles and tortoises, also of Jurassic types, some fishes, and a few mollusks. A number of plants have been found, mainly conifers and cycads. The strata containing these fossils are evidently of lacustrine origin.

Pleurocœlus nanus, gen. et sp. nov.

The most common fossils secured thus far from the Potomac formation are the remains of a small Dinosaur which clearly belongs to the *Sauropoda*, but is by far the most diminutive member of this group yet discovered. Portions of the skull, vertebræ, and limb bones of several individuals have been obtained, and these agree so nearly that they may be referred to one species. They differ somewhat in size, owing apparently to a difference in age.

In comparing these remains with the *Sauropoda* now known, they appear to resemble most nearly those of the genus *Morosaurus*, so well represented in the upper Jurassic of the Rocky Mountain region. A careful comparison, however, shows that they belong to a distinct genus. The teeth are of the same general type as those of *Morosaurus*, but their crowns are mainly compressed cones, and not spoon-shaped. The dentary bone is slender, and rounded at the symphysis, instead of having the massive, deep extremity seen in *Morosaurus*. The maxillary is also lighter, and less robust. The supra-occipital agrees closely in shape with that of *Morosaurus*, and forms the upper border of the foramen magnum, as in that genus.

Fig. 1.

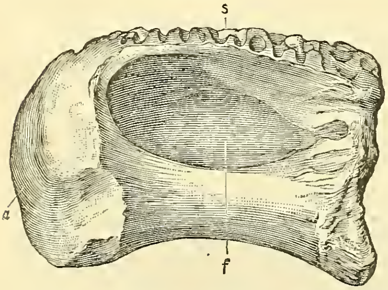


Fig. 2.

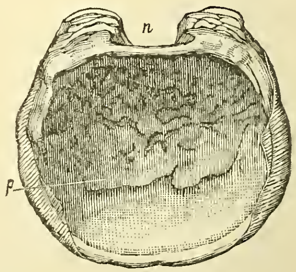


Figure 1. Dorsal vertebra of *Pleurocœlus nanus*, Marsh; side view.
Figure 2. The same vertebra; posterior view.
Both figures are one-half natural size.

The cervical and dorsal vertebræ are elongate, and strongly opisthocœlous. The latter are much longer than the corresponding vertebræ of *Morosaurus*, and have a very long, deep cavity in each side of the centrum, to which the proposed generic name refers. All the trunk vertebræ hitherto found are proportionately nearly double the length of the corresponding centra of *Morosaurus*, and the lateral cavity is still more elongate. These points are shown in the posterior dorsal vertebra represented in figures 1 and 2. The neural arch in this region is lightened by cavities, and is connected with that of the adjoining vertebræ by the diplosphenal articulation.

The sacral vertebræ in *Pleurocœlus* are solid, as in *Morosaurus*, but much more elongate. The surface for the rib, or process which abuts against the ilium, is well in front, more so than in any of the known *Sauropoda*. Behind this articular surface, is a deep pit, which somewhat lightens the centrum. These characters are seen in the sacral vertebra represented in figures 3 and 4.

FIG. 3. FIG. 4.

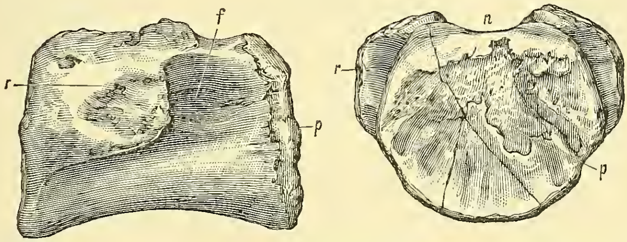


FIGURE 3. Sacral vertebra of *Pleurocœlus nanus*, Marsh; side view.
FIGURE 4. The same vertebra; posterior view.
Both figures are one-half natural size.

The first caudal vertebra has the centrum very short, and its two articular faces nearly flat, instead of having the anterior surface deeply concave, as in the other known *Sauropoda*. The neural spines in this region are compressed transversely. The middle and distal caudals are comparatively short, and the former have the neural arch on the front half of the centrum, as shown in figures 5 and 6.

FIG. 5. FIG. 6.

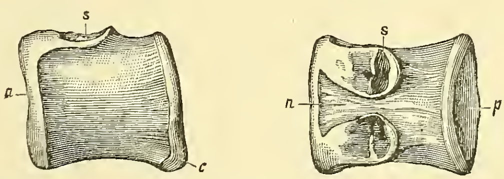


FIGURE 5. Caudal vertebra of *Pleurocœlus nanus*, Marsh; side view.
FIGURE 6. The same vertebra; superior view.
Both figures are one-half natural size.

The bones of the limbs and feet preserved, agree in general with those of the smaller species of *Morosaurus*, but indicate an animal of slighter and more graceful build. The metapodials are much more slender, and the phalanges are less robust than in the other members of the order.

The known remains of the present species, representing several individuals, indicate an animal not more than twelve or fifteen feet in length, and, hence, the smallest of the *Sauropoda*. They were found at several localities of the Potomac formation in Prince George Co., Maryland.

Regarding the present species as typical, some of the more special characters distinguishing these remains from the known *Sauropoda* are as follows:

(1) Teeth with compressed, or flattened crowns.

(2) Dorsal vertebræ with low neural sutures, and elongate excavation in each side of centrum.

(3) Sacral vertebræ solid, with cavity in each side, and with face for rib in front.

(4) Anterior caudals with flat articular faces, and transversely compressed neural spines.

(5) Middle caudal vertebræ with neural arch on front half of centrum.

These characters appear to indicate a distinct family, that may be called the *Pleurocœlidæ*.

Pleurocœlus altus, sp. nov.

A larger species apparently of the above genus is represented by various remains from the same localities as the specimens just described. A tibia and other limb bones show the animal to have had elongated posterior extremities, at least a third longer, proportionately, than in *Morosaurus*, which these remains, in some respects, clearly resemble.

The tibia has the proximal end compressed transversely, with its outline sub-rhomboidal. The cnemial crest is well developed. The shaft is solid throughout, with the exception of a very small cavity near the middle, and here it is sub-ovate in transverse section. The distal end is much flattened antero-posteriorly, and the notch in the articular face, characteristic of the *Sauropoda*, is well marked. This tibia is twenty-five inches (M. ·635) in length, with its proximal end seven inches (M. ·177) in fore and aft diameter, and the distal end six inches (M. ·152) in transverse diameter. Both extremities are rugose, indicating a heavy covering of cartilage. The fibula is massive, and its distal end somewhat expanded. The astragalus was free, and is wanting in the present specimen.

Priconodon crassus, gen. et sp. nov.

The existence of another herbivorous Dinosaur in the same horizon of the Potomac formation is indicated by a number of fragmentary remains, the most characteristic of which is the tooth figured below. This may be regarded as the type specimen. Although resembling somewhat the teeth of *Diracondon* from the Jurassic of the West, it is quite distinct. It has the narrow neck, swollen base, and flattened crown of that genus, but the serrated edges meet above at a sharp angle, instead of forming a wide curve at the apex.

FIG. 7.

FIG. 8.

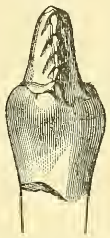


FIG. 9.

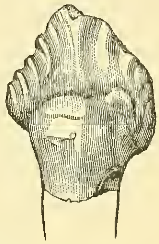


FIGURE 7. Tooth of *Priconodon crassus*, Marsh; side view.
FIGURE 8. The same tooth; end view.
FIGURE 9. The same; inside view.
All the figures are twice natural size.

The surface shown in figure 7 is much worn by the opposing tooth. In figure 9, the pit formed by the succeeding tooth is seen near the top of the fang.

The other remains at present referred to this species were not found with this tooth, and hence, their relations to it are uncertain. They will be described more fully elsewhere.

All the remains supposed to pertain to this animal are from the Potomac formation, Prince George Co., Maryland.

Allosaurus medius, sp. nov.

Besides the herbivorous Dinosaurs described above, remains of two carnivorous forms were secured from the same horizon. The larger of these, which may be provisionally referred to the genus *Allosaurus*, is represented by various specimens, the most characteristic of which are teeth, and bones of the limbs and feet. The teeth are remarkably flat and trenchant, with the edges finely serrated, and the surfaces very smooth. The limb bones, and even the phalanges, are unusually hollow, and the latter have the articulations finely finished. The principal dimensions of some of the parts preserved are as follows:

One tooth has the crown 30^{mm} in height; its antero-posterior diameter at base 15^{mm}; and its transverse diameter 7^{mm}.

The astragalus is 55mm in width; and 50mm in fore and aft diameter.

A first phalanx of the hind foot is 90mm in length.

These specimens would indicate an animal ten or twelve feet in length.

These remains are from the same horizon and localities as those above described.

Cœlurus gracilis, sp. nov.

The smallest Dinosaur found in these deposits is a very diminitive carnivore, apparently belonging to the genus *Cœlurus.* It was not more than one-half the size of the western species, and its proportions were extremely slender. The bones are very light and hollow, the metapodials being much elongated, and their walls extremely thin. An ungual phalanx of the manus measures about 25mm in length; and 14mm in vertical diameter at the base.

This animal could not have been more than five or six feet in length. The known remains are from the same horizon as those above described.

All the specimens described in the present article were found by Mr. J. B. Hatcher, of the U. S. Geological Survey, and the writer's able field assistant in paleontology.

The fossils here described, and others from the same horizon, seem to prove conclusively that the Potomac formation in its typical localities in Maryland is of Jurassic age, and lacustrine origin. There is evidence that some of the supposed northern extensions of this formation, even if of the same age, are of marine, or estuary origin.

Yale College, New Haven, Conn., Dec. 23, 1887.

ART. VII.—*Notice of a New Fossil Sirenian, from California;* by O. C. MARSH.

IN exploring a Tertiary deposit in California a few years since, the writer obtained several teeth of a large mammal, very distinct from anything hitherto discovered in this country. Other specimens were subsequently secured, and with them, a number of vertebræ, apparently pertaining to the same animal which is described below. The associated vertebrate fossils were a large edentate (*Morotherium*), a mastodon, a camel, and one or more extinct species of the horse, all indicating the Pliocene age of the strata in which they were entombed.

Desmostylus hesperus, gen. et sp. nov.

The remains known of the present species indicate an animal about fifteen feet (M. 4·5) in length, and of robust proportions. The most characteristic parts preserved are the molar teeth, which are composed of a number of vertical columns, closely pressed together, and in adult animals, firmly united at their bases. These columns are thickly invested with enamel, which is rugose externally. Inside the enamel, is a body of dentine, in which there is a central cavity.

In immature teeth, the columns are nearly round, and loosely united, but as they increase in size, they press together, and become more or less polygonal in cross section. Before being worn, they have their summits smooth and convex, but after some use, the center of each column presents a rounded elevation, well shown in the figures below. This is due to the harder material forming the walls of the central cavity. As this apex is removed by further wear, the cavity is reached, and this central opening increases in size as the tooth is shortened by attrition.

FIG. 1.

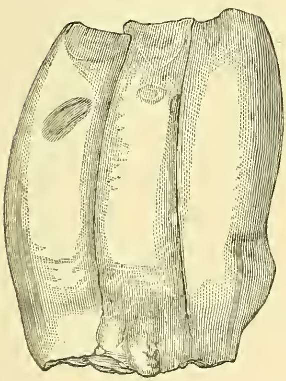


FIG. 2.

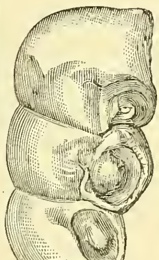


FIG. 3.

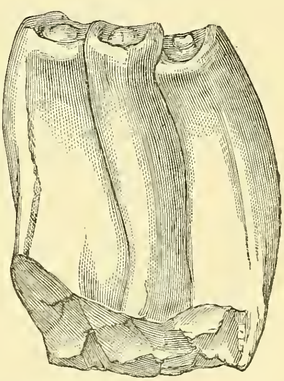


FIGURE 1. Part of tooth of *Desmostylus hesperus*, Marsh; end view.
FIGURE 2. The same specimen; seen from above.
FIGURE 3. The same specimen; inner surface.
All the figures are natural size.

The specimen figured is apparently the posterior portion of a molar tooth. The three columns shown are much smaller than the average, not half as large as some others found with them, and probably belonging to the same individual. The number of columns in a single tooth is uncertain, but there are indications of at least twelve or fifteen, and perhaps more. There were both upper and lower molar teeth of similar structure, but the rest of the dentition is unknown.

One of the best preserved specimens found with these teeth is a lumbar vertebra, which is noticeable for the extreme flatness of its articular surfaces. The sides of the centrum meet below, forming an obtuse median keel. The centrum of this vertebra has a length of 89^{mm}; the vertical diameter of the anterior face is 90^{mm}, and its transverse diameter 107^{mm}.

The known remains of this animal are from Alameda Co., California, and are preserved in the museum of Yale College. The type specimen was found by Dr. L. G. Yates.

The nearest affinities of this peculiar Sirenian are probably with *Metataxytherium* of Christol, from the Tertiary of Europe, and its nearest living allies may, perhaps, be found in the genus *Halicore.*

Yale College, New Haven, Conn., Dec. 23, 1887.

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THE

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THIRD SERIES.

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[THIRD SERIES.]

Art. VIII.—*Seismoscopes and Seismological Investigations*; by T. C. Mendenhall.*

Seismology as a science, or at least as an observational and experimental science, may be said to be the product of the past three or four decades. It is true that before as well as during this period some important applications of the statistical method of investigation were made and the distribution of earthquakes in time and space was thoroughly studied. These investigations are of really high value, although they have generally resulted in the overthrow of certain hypotheses which were constantly appearing as to the correlation of these displays of seismic energy with other natural phenomena; so that while it may be said that little is yet known concerning the real nature and origin of earthquakes, much useful work has been done in the way of elimination and possibly a reduction of the number of unknown quantities involved.

The new phase which the science has assumed may perhaps be fitly described by saying that the modern seismologist studies an earthquake, rather than earthquakes. In fact this is one of a considerable group of problems primarily geological in their nature to which, in recent years dynamical principles and physical methods have been applied. The knowledge of first im-

* Read at the meeting of the National Academy of Sciences at New York Nov. 8th, 1887.

portance in regard to an earthquake is the knowledge of the nature and location of its origin and it is generally admitted that this can be obtained only through the study of individual instances. The natural method is to proceed from the known effect to the unknown cause, and for a time progress in seismology consisted largely in painstaking and laborious investigations of the destructive effects of earthquakes from which it was believed a knowledge of their ultimate origin might be deduced. Little in the way of experiment had been attempted and nothing was known of the really complex motion of the earth-particle when subjected to the influence of an earthquake wave. False assumptions were made with regard to this motion and erroneous and perplexing conclusions resulted. The great work of Mallet on the Neapolitan Earthquake, although of much importance in its day, and always a monument to his industry and devotion to the science, can not now be considered as of any great value as a solution of the problems involved.

The importance of earthquake measurements by means of specially constructed instruments was recognized by Mallet, however, and he undertook the design and construction of such instruments at an early date. The problem seemed at first easy, but investigation proved it to be of considerable difficulty. In a general review of the state of the science in his report to the British Association in 1858 Mallet says,* "twelve years ago the construction of seismometric instruments appeared a comparatively easy matter. It is only at a very recent period that experiments and observations as to the actual phenomena, the velocity and direction of the shock, etc., have begun to show the real difficulties of the subject." But even at this time Mallet failed to recognize the true nature of the disturbance produced by an earthquake, and the several seismometers which he devised, and which will be found described in the report already referred to, are practically of no value. One of them, which was extremely elaborate in its construction, he considered competent to furnish, from a single station, all of the elements necessary for the determination of the seismic focus. Another, the arrangement of two rows of cylinders of varying diameters in lines at right angles to each other, is probably the most widely known of all earthquake machines as it is described in many encyclopædic articles and treatises on Geology in which the subject is discussed. It may be said, however, that a more useless device has never been proposed.

A notable advance in our knowledge of the subject and particularly of instrumental Seismology has been made during the last half dozen years and it must be largely attributed to the

* On the Facts and Theory of Earthquake Phenomena—Report of the British Association, 1858.

organization and active operations of the Seismological Society of Japan. Earthquakes are there so frequent that a rare opportunity for their study is offered. A few foreigners temporarily residing in the country, together with a number of native scholars, joined in the prosecution of seismic investigations and in the establishment of the Society. Its published transactions, already filling ten volumes, contain nearly all of seismology that is in advance of the old methods. Progress has been made mostly in the direction of improvement in seismographs, and is, in a great degree, due to better methods for securing the very desirable "steady point" and to a recognition of correct dynamical principles in the construction of the instruments.

The well known horizontal pendulum or "bracket" seismographs of Ewing,* Gray,† Milne and others, have greatly increased our facilities for research and, in fact, have afforded about the only fairly reliable information concerning the real movement of the earth-particle.

Notwithstanding the comparative infrequency of earthquakes in the United States, many advantages for their study are offered here. Among others may be mentioned the following: the great extent of country which could be brought under one system of observations;—a generally intelligent population, furnishing a corps of willing and reliable observers;—the extensive system of telegraph lines; and, perhaps superior to every other, the wide distribution and almost universal use of "standard time" throughout the country. In consideration of these advantages and of the fact that certain portions of the country appear to be subject to occasional seismic disturbances, it has seemed desirable that an extended and well planned series of observations should be undertaken, and that seismology should not be in the future, as it has been in the past, a somewhat neglected science.

Among American geologists especially, there has always been great interest in the subject, and a good deal has been written concerning geological theories of earthquakes. Rockwood‡ has done excellent service in his publication of frequent catalogues of earthquakes in America, together with such information regarding them as could be incidentally gathered. But the first important step towards an elaborate and systematic study of earthquakes was taken a few years ago by the Director of the U. S. Geological Survey in establishing what has been known as the "Earthquake Commission." The work of this body, during its existence, consisted mainly in the discussion of methods of observation, together with the preliminary arrange-

* Trans. Seis. Society of Japan, vol. ii.
† Trans. Seis. Society of Japan, vol. iii.
‡ This Journal, from 1872 to the present time.

ment of a plan of attack and the selection of the most desirable regions for the inauguration of the work. A scale of intensities was adopted and a series of questions formulated which were printed in the form of circulars for distribution among the intelligent observers of any disturbance. These circulars were subsequently made use of by Captain Dutton, who had the general direction of the work, and considerable information concerning several earthquakes has been obtained. The Charleston earthquake of 1886, renewed and greatly increased the interest in the problem. It was thoroughly investigated by Dutton and Hayden and their report* upon it, presented to the National Academy of Sciences in April, 1887, is of great value. As complete, perhaps, as was possible under the circumstances, it serves to emphasize the necessity for the use of seismic apparatus, and causes extreme regret that instruments had not been previously perfected and put in operation.

I think it can be said that America has made at least one really valuable contribution to the Science of Seismology. I refer to the approximate determination of the velocity with which earthquake waves are transmitted through the crust of the earth. The unexampled opportunities offered in the explosions at Hell Gate and Flood Rock† were utilized for this purpose, with the unexpected and surprising result of a rate of transmission vastly greater than that previously obtained by European and Oriental Seismologists, and generally accepted as fairly accurate. The reduction of fairly accurate time observations made on the occasion of the Charleston Earthquake,‡ served to confirm this conclusion and a speed of several thousands instead of a few hundreds of meters per second must now be admitted. Although these results are more nearly in accord with the theory of wave transmission, future determinations of velocity will be awaited with great interest, and all processes employed must be carefully scrutinized.

Before considering a plan for the inauguration and maintenance of an extensive series of seisomological observations, it will be well to inquire what knowledge is most desirable in the interests of geological investigation. This is a question for geologists to answer; but I venture the assertion that in the present state of our knowledge of seismology, it is most desirable, in the case of any given earthquake, to be able to fix the seismic vertical, or the epicentrum; to ascertain the depth at which the initial disturbance occurred; and to measure the velocity with which the resulting waves are transmitted. If these can be accurately determined for different earthquakes, under varying conditions, some light may be

* Science, May 20th, 1887. † Science, Jan. 8th, 1886.

‡ Science, May 20th, 1887; see also this Journal, Jan., 1888, pp. 1–15.

thrown upon their ultimate origin and the magnitude of the energy involved, while the study of velocities of transmission, co-seismal and iso-seismal lines, may afford valuable information concerning the nature and condition of the rocks within the disturbed area. Admitting the greater importance of a knowledge of these facts it follows that time measurements should first receive attention, and that the seismic chronograph is the instrument to be used.

The seismograph or seismometer is designed primarily for the purpose of recording or measuring the actual motion of that part of the earth to which the instrument is attached during the transit of one or many waves. In reality this motion is extremely complex. Undoubtedly the emerging wave is modified very greatly in its character by the lack of homogeneity in the material through which it last travels, as well as by the fact that this material differs immensely in elasticity and density from that in which it has in the main existed. For this reason it is believed that however accurately the motion may be resolved into three components at right angles to each other by a perfectly operating seismograph, but little information would be afforded as to the position of the origin, or the amplitude of vibration and amount of acceleration of any point in the earth, other than that at which the instrument is located. It is clear, however, that while these considerations may seriously affect the integrity of the record of a seismograph, they will have little influence upon the actual transmissive time, that is to say, while the character of a wave may be greatly altered upon emergence into a non-compacted, non-homogeneous material, the time of its arrival at a given point cannot be greatly altered, even if its velocity in this material is much less or greater than the mean, for the reason that it is subjected to this modifying influence for a comparatively brief period. It is true that the seismograph, in addition to registering the motion of the earth particle, may and generally does record the epoch of the passage of a wave, and it affords the advantage of distinguishing one wave from another. If only very short distances are used for the determination of velocities this would be of decided value, were it not that experience* seems to prove that what is the maximum wave at one point may not be the maximum at other points very near, so that it is by no means certain that a particular wave can be identified at different stations, even if they are not widely separated. These considerations, together with the very great expense of seismographic equipment and the greater difficulty of maintaining them in constant working order in a country where earthquakes are infrequent, compel the admission that

* Milne, in Trans. Seis. Soc. of Japan, vol. x.

the simple seismoscope, with a time-taking attachment, is far more likely to furnish valuable information.

Seismoscopes.

A good seismoscope should possess some if not all of the following characteristics:—

It should be simple, inexpensive and not liable to become inoperative through long periods of rest;

It should be capable of adjustment to varying degrees of sensitiveness;

The adjustment of different instruments to nearly the same degree of sensitiveness should be possible;

Its equilibrium should be unstable; that is, when once disturbed it should not "reset" itself;

It should not be liable to register phenomena other than actual movements of the earth upon which it rests.

While much has been done and notable advances have been made in the construction of seismographs with a view to the determination of the character of the motion of the earth particle, it does not appear that a seismoscope satisfying these conditions has yet been described or extensively used, although an infinite variety of instruments bearing the name have been devised. If whatever is done in the near future is likely to be done through the use of the time-registering apparatus, and this, I believe, is the opinion of the majority of the members of the earthquake Commission assembled upon the invitation of the Director of the Geological Survey, the subject becomes one of considerable importance, and a recognition of this fact has resulted in the suggestion of several new forms of seismoscopes within the last two or three years, a few of which have been actually constructed and tested. The first of them, and the only one as far as I know which has been used to register the occurrence of an earthquake in this country, was designed in the Physical Laboratory of the Signal Office at Washington. While others contributed suggestions as to certain details, the general form of the instrument is due to Junior Professor C. F. Marvin, of the office of the Chief Signal Officer.*

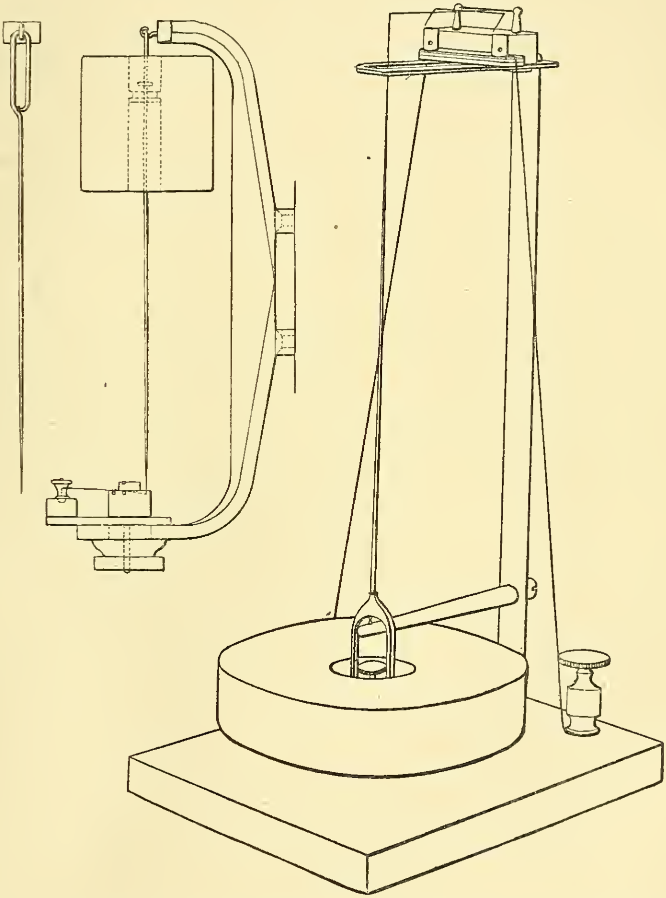
It is shown in figure 1 and a little explanation will make its operation clear.

An iron cylinder weighing three or four pounds has a cylindrical hole of about 2^{cm} in diameter, bored through concentric with its axis. At a point a little distant from the

* The first practical use of an instrument of this type was at the Flood Rock Explosion in October, 1885. It was placed by direction of the writer at the nearest point of observation, on Ward's Island. Its performance was entirely satisfactory. See Science, Oct. 16, 1885. An instrument somewhat similar in design with a very imperfect contact-making device was suggested by Milne. See Trans. Seis. Soc. Japan, vol. iii.

center of gravity this hole is suddenly diminished in diameter by a small amount, affording a shoulder against which rests a cross piece filling symmetrically only a part of the opening and carrying at its center, which is on the axis of the cylinder, a fine steel point. This point rests in a small depression on the inner side of a link, to which is attached a long steel needle as

1. 2.



shown in the cut. The upper end of the link hangs upon a hook made of wire of the same diameter and rigidly attached to the supporting frame of the instrument which is of iron. By this arrangement for the suspension of the heavy mass, the link with its needle projecting downwards, has considerable freedom of motion in all azimuths, with little frictional resistance, and for slight movements the pivotal point within the cylinder may be regarded as fixed. Rotation takes place about this point and the motion of the earth, which is that of the hook upon which the link is suspended, is magnified at the point of the needle as many times as the ratio of the length of the needle to that of the link. A small and very light lever has its short arm bent upward, and is so adjusted that when the instrument is "set," the upper end, ground to a fine point, rests against the pointed end of the long needle. The longer and heavier arm of this lever terminates in a platinum fork, the prongs of which are vertically above two small mercury cups forming terminals of the electric circuit.

The operation of the instrument is simple. A very slight movement of the point of suspension is magnified at the needle point; the short arm of the lever is released and the fork drops, closing the circuit. Different degrees of sensitiveness are obtained by grinding the abutting points to greater or less dimensions.

A seismoscope of great simplicity of design, and offering many advantages, is one originally due to Milne,* and more recently with slight modifications, experimented with by Hayden and Hallock, of the U. S. Geological Survey, by whom it was also, I believe, independently invented. It belongs to the family of liquid seismoscopes, of which many varieties have appeared, notably several devised and used by Palmieri. In all previous forms, however, the action utilized was the movement of the whole mass of liquid in relation to the containing vessel, while in this, advantage is taken of the well known fact that waves are, in general, produced upon the surface of a mass of liquid when it is subjected to a sudden disturbance. In a cylindrical vessel these waves run from circumference to center, at which point the liquid is sensibly elevated for an instant, and through this elevation an electric circuit may be momentarily closed. Mercury is the liquid used, and it is placed in a small cylindrical iron box, through the cover of which a pointed screw with a large divided head runs. The point of the screw, which is of platinum, may be brought extremely near the surface of the mercury, its position and distance being known by means of the divisions on the head. A slight jar generates a series of waves, the elevation at the center completes the circuit through the properly insulated screw. The tendency of the mercury to become oxidized or dirty upon the surface so as to become inoperative was overcome by the use of a small platinum float, a device previously employed for measuring the height of the mercury in the cistern of a barometer by electrical contact. A

* Trans. Seis. Soc. Japan, vol. iii.

simple arrangement for keeping this float in position is employed and the real contact is between two platinum surfaces, being thus much more desirable and lasting.

Several other forms of seismoscopes have been suggested and tried with more or less success. One of these is a modification of the well known Zöllner's horizontal pendulum, the extreme sensitiveness to change in level of which has been so well shown by Professor Rood.* It is easy to arrange this so that an electric circuit is closed when a disturbance occurs; and, although its greatest sensitiveness is for disturbance in one plane it is generally sufficiently delicate to respond to very feeble motions in all azimuths.

I have recently modified the instrument first described, reducing its dimensions and cost, and greatly increasing the ease with which it is adjusted and "set." The alteration consists principally in extending the multiplying needle upward instead of downward. This brings the circuit-closing part of the apparatus above, where it is open to inspection and convenient for adjustment. The supporting frame rests upon a square or triangular base, and can be placed upon any convenient pier or table, instead of necessarily being screwed to a vertical support as in the earlier form. The latter plan was adopted with a view to fastening the instrument to a post driven in the earth, but it has been found inconvenient in practice, and it will generally be better to rest it upon the top of the post, if one is used, or upon a stone imbedded in the earth, or upon a bracket shelf attached to a foundation wall.

The new form of the instrument is conveniently covered by an ordinary glass shade to protect it from dust and disturbance by air currents. An improvement is made in the arrangement for adjusting the position of the circuit closer, which is held to the table upon which it rests by means of a spiral spring, so that while it moves freely upon the application of a slight pressure it is sufficiently firm to resist accidental disturbances. The new form will be readily understood by examination of fig. 2 (p. 103.)

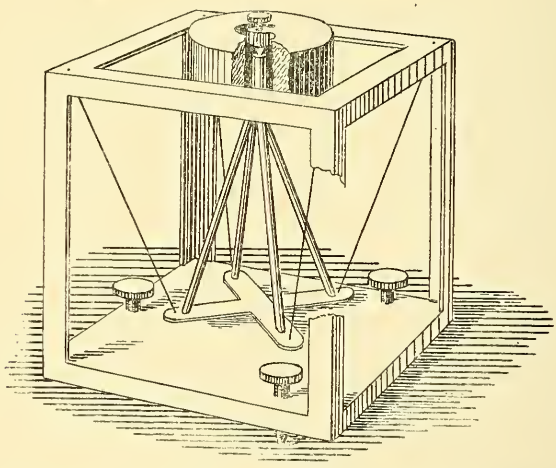
Any mechanical device by means of which a temporarily "steady point" is provided may be utilized as a seismoscope. The horizontal pendulum, first suggested by Chaplin and utilized by Ewing in his seismograph, satisfies the requirements, except that its sensitiveness exists in only one plane. The use of some form of link motion for an astatic suspension was suggested by Professor West a few years ago, at a meeting of the Seismological Society of Japan.† It is clear that an ideal arrangement would be the Peaucellier linkage for straight line motion in a horizontal plane. But it is difficult if not impossible to avoid

* This Journal, III, June, 1875.

† Trans. Seis. Soc. Japan, vol. vi.

an amount of friction which would be fatal. Ewing * has suggested the use of some form of linkage in which only ties should be used, so that flexible cords could be substituted for rigid bars. No rigorously straight-line motion is susceptible of this construction, but several close approximations may be utilized. An approximation is all that is required in a seismoscope, but it must possess freedom of motion in all azimuths. Professor Ames, of the Rose Polytechnic Institute, has devised a form consisting of a combination of two linkages of the form invented by Roberts. By arranging these in planes at right angles to each other, freedom of motion in any azimuth is secured. A heavy mass is pivoted at the tracing point and friction may be reduced to a minimum by the use of flexible cords, fine wires, or by pivoting light rigid links. The suspension is approximately astatic, but sufficiently so for seismoscopic uses, and perhaps for seismographs—It is shown in figure 3.

3.



A number of trials with several of these seismoscopes under different varieties of disturbance show that all are not equally sensitive to the same disturbance, however delicately they may be adjusted. The mercury seismoscope is peculiarly sensitive to disturbances produced by a slight jar of the table or support upon which it rests. In this case the vibrations are generally very rapid, probably from ten to fifty or more per second. It may readily be adjusted to respond to extremely slight tremors and besides it apparently affords the advantage of being set at any time to a definite degree of sensitiveness. With the two

* Memoirs of the Science Dept., Tokyo Daigaku, No. 9.

or three instruments of this class upon which I have experimented, this theoretical advantage is not realized in practice. The distance between the two platinum surfaces is so extremely small, when the instrument is sensitively adjusted, that very trifling and generally unknown causes will considerably modify the position of the divided head when contact occurs. The setting of the instrument is therefore a matter of great uncertainty.

This instrument possesses what at first appears to be an advantage, in that it is "self-setting;" but a reference to what has gone before will show that this is not considered a desirable feature of a seismoscope. In fact, it is very undesirable in my judgment, except where devices of a special character are made use of for securing time records. If the epoch is established by stopping or starting a clock or by Milne's printing device, a self-setting instrument would be objectionable. If the record is made upon the revolving drum of a chronograph, or on a continuously moving strip of paper, this form of seismoscope might fix the time of all sensible movements during the disturbance, and might, indeed, play the part of a seismometer in some degree by distinguishing the more violent motions. But it would be likely to fail in this respect, as well as in its general performance as a seismoscope, owing to the peculiarity already referred to. To vibrations of moderately long period it does not promptly respond. Earthquakes seldom, if ever, begin with a sharp and sudden movement. The maximum vibration is nearly always preceded by several of less amplitude and nearly the same period, which are themselves preceded by oscillations of extremely small amplitude but of great frequency. The intensity of these preliminary tremors is not, in general, sufficient to cause a mercury seismoscope to act, and to the succeeding movements of greater amplitude but longer period, (often as long as one second) it is not sensitive. Further experiment and investigation is needed, however, to determine the relative merits of these and other instruments.

Time Apparatus.

Various methods of time-registration have been made use of, and most of them are generally well known. A choice among them must depend largely on the probable frequency of earthquake phenomena. In Japan and some other parts of the world rarely more than a few days pass without a sensible disturbance.

A continuously operating chronograph would be desirable and profitable under such circumstances and various modifications of the ordinary astronomical chronograph will at once suggest themselves as suitable for this work. When an earthquake is a rare phenomenon, years instead of days elapsing between two successive disturbances, all appliances for their observation must be of the utmost simplicity of construction consistent with certainty and accuracy of performance. A fairly good clock is a necessity and that being provided it remains to determine how it may be used in recording the instant of disturbance. One of three different schemes may be adopted: a running clock may be stopped; a clock at rest with hands set in a known position may be started, or the position of the hands may be registered without interfering with the going of the clock. Either of these can be easily accomplished through the instrumentality of the electric circuit closed by the effect of the disturbance on the seismoscope. The simplest method is that of stopping or starting the clock, and considerable difference of opinion has existed as to the relative merits of these two processes. It will be seen at once that the plan of starting a clock from rest in a known position would have many advantages, and one of them is certainly of great importance. It is that after the happening of the earthquake the started clock can be allowed to run until a comparison with some standard time is possible and if necessary its rate may be determined, so that the exact epoch of the disturbance can be ascertained with considerable accuracy. On the other hand, if a clock be stopped our knowledge of the exact time of the occurrence will depend on our knowledge of its error at the time of stopping, which can only be known through previous observations of error and clock rate. Thus it will appear that if the method of clock stopping is to be resorted to, the clock must be under constant surveillance and frequent comparisons must be made with some standard time. The clock-starting method is also open to some rather serious objections. A clock which has been at rest for months or even years is hardly likely to be constant in its rate during the first few hours after starting. This objection can be in a great degree removed, however, by carrying out suggestions to be given later. Another, and more important, is that the record is liable to be lost entirely through the subsequent stopping of the clock by the violence of the earthquake. The clock-stopping method is not open to this objection as it is difficult to imagine the starting of a clock by an earthquake, particularly if the pendulum is held somewhat firmly by the stopping apparatus. The third plan, that of registering the position of the hands of the clock at the moment of closing the circuit without interfering in any way with the movement of the clock combines many of the advantages of both the others, but has the disadvantage of being more complicated and difficult to accomplish. It is easy to expose for an instant a quick photographic plate, upon which an image of the clock face is projected, but we at once meet with the difficulty of properly illuminating the face at night.

Among other methods which have been proposed, probably the most simple is that of Milne,* which consists in placing small pieces of cork, coated with an oily ink, upon the extremities of the hands of the clock against which a paper or card board ring is pressed by electro-mechanical devices, put in operation by the closing of the circuit at the seismoscope. After an instant of pressure the ring is withdrawn, bearing a printed record of the position of the hands of the clock. This allows the determination of the error and rate of the clock either before or after the earthquake or both, and should the clock be stopped by a violent shock, the time record is not lost. These advantages will undoubtedly lead to the invention of simple and sure methods by means of which this printed record may be obtained. For stopping a clock, Milne† has used a thin piece of board in which notches are cut in one of which the pendulum is caught at the moment of the disturbance. This method is likely to allow and sometimes to cause considerable subsequent swaying of the pendulum and I have preferred to use simply a strip of brass, curved to an arc of the circle whose radius is the pendulum. This lies always nearly touching the pendulum and is slightly lifted when the circuit is closed so as to arrest the pendulum. The brass strip is attached to the movable armature of a common telegraph sounder secured to the side of the clock case. The circuit remaining closed after the action of the seismoscope the pendulum is held in its place.

Application.

Two seismic stations with time-taking apparatus have been in operation in this country for nearly a year. The first was established in the Physical Laboratory of the Signal Office in Washington shortly after the occurrence of the Charleston Earthquake, and the second, at the Rose Polytechnic Institute, Terre Haute, Ind., was put in operation in January, 1887. Both are equipped with seismoscopes similar to that described and shown in fig. 1 and with clocks known as "Regulator No. 2," made by the Seth Thomas Co. These clocks were selected on account of their cheapness and their really excellent performance as time keepers. The stopping apparatus is of the simple form already described, and an ordinary vibrating electric bell with battery is connected with it so that a continuous alarm is maintained from the time of the disturbance of the seismoscope.

* Trans. Seis. Soc. Japan, vol. iv.

† Trans. Seis. Soc. Japan, vol. iii.

Since their installation these instruments have recorded as follows:—

At Washington.—From Oct. 6th, 1886, to Nov. 4th, 1887.

Date.	Time, (75th Mer.) h. m. sec.	Remarks.
October 22, 1886	2 46 14 p. m.	Felt generally in the vicinity.
November 5, 1886	12 27 14 p. m.	
February 23, 1887	7 33 0 a. m.	Possibly related to the great Italian earthquake of that time. From the condition of the instrument before and after the time of the record it was thought to be reasonably certain that it was due to a true seismic disturbance.

At Terre Haute.—From Jan. 18th, to Oct. 26th, 1887.

Date.	Time, 90th Mer. h. m. sec.	Remarks.
February 3d	10 27 35 a. m.	Shocks in Italy, Feb. 3.
February 6th	4 15 6 a. m.	Shocks in Ind., Ill., Ky., and Mo.
February 10th	11 22 27 a. m.	Papers reported shock at Jasper, Ind., but not verified.
May 6th	7 45 22 a. m.	May 3d and 4th, general in Mexico and from Texas to Cal. 150 lives lost at Bahispe in Sonora, Mex., also many topographical changes.
May 10th	6 1 34 p. m.	Shocks in mountains daily, May 12 and 13, shocks in S. C., Cal. and Arizona, May 19 and 20 in Europe. May 30 and 31, in Mexico.
May 24th	10 3 33 a. m.	Shocks felt in Ind., Ill., Ky., and Tenn., and in Equador, S. A.
August 2d	12 35 43 a. m.	
October 22d	6 6 35 a. m.	

Plan of Campaign.

In determining upon a systematic plan for the instrumental study of earthquake phenomena, some consideration of the foregoing remarks seems to be demanded, and some useful conclusions may be drawn from the brief experience already had.

In the first place, it is claimed that time observations are of the first importance and that under the circumstances such only should be undertaken. It is believed that the reasons briefly, and in some degree imperfectly, presented in the foregoing discussion, are sufficient to establish the claim. Seismoscopes, with the accompanying clocks, should be the only instrument used, and these should be, as far as possible, of the same type. Before the adoption of any one of several different species available, a careful study of them should be made, all being tested under similar conditions and these conditions should resemble as closely as possible those under which the instrument is expected to work. As seismic phenomena are here too infrequent to admit of such preliminary test or calibration, means must be provided for imitating at will the motion of a point upon the surface of the earth. Such an arrangement would also be useful in testing seismographs and the validity of their records.

For this purpose what may be called a "seismic table" has been designed. It consists essentially of a horizontal surface, large enough to furnish room for two or three seismoscopes or seismographs, and which by suitable mechanism may be given a vibratory motion in either one or all of three directions at right angles to each other, two of these motions being in a horizontal plane. The vibrations are all derived from a single piece rotating with a uniform angular velocity, and all are on a close approximation to simple harmonic motion. By a simple device their amplitude may be varied at will and without arresting the movement, from zero to a prescribed limit. Another mechanism enables the operator to vary the frequency of vibration from zero to any desired number per second. The machine is to rest upon a solid foundation and power is to be drawn from a steam or gas engine. At any moment, the amplitude and frequency of vibrations along any of the three components will be shown by suitably arranged indices. The disturbance to which a seismoscope is subjected can generally be resolved into approximately simple harmonic motions along these axes, and as the period and amplitude of vibration for earthquakes of moderate intensity are now tolerably well-known, through the investigations of Japanese earthquakes by Ewing, Milne, Gray and Sekiya, it will be possible to reproduce their movements with considerable accuracy and with such variations as to intensity as to satisfy every demand in testing seismic instruments. In this way it can be determined to what particular species of vibration a seismoscope is sensitive; whether the same seismoscope can be repeatedly set to the same degree of sensitiveness, and whether several different instruments can be made to agree in this respect. In addition to its great value as affording a means of testing and comparing instruments, it is believed that such an apparatus may be useful in studying certain observed effects of earthquakes upon simple structures. By submitting small but dynamically similar models of such structures to differently compounded vibrations and studying the results, some light may be thrown upon the confusing and often contradictory phenomena of actual earthquakes.

Assuming that a satisfactory form of seismoscope has been selected by subjecting all proposed or submitted to the test of the seismic table, it is important to consider next their distribution and use. As it is very desirable that they should be as numerous as possible, and as the cost of the equipment of a station is of great practical moment, it may be stated that the whole outfit for a single station, including clock, seismoscope, battery and all, need not cost more than twenty-five dollars, and it is hoped that a sum considerably less than that amount may be found sufficient. In selecting stations it is of the utmost importance that the question of accurate time should be first considered. Standard time signals from one observatory or another are now distributed so generally over the whole country, that in any considerable town no difficulty will be found in determining the clock error and rate, provided that the apparatus is in the hands of a suitable person. It is likely that in many instances jewelers or watch makers, who receive time signals daily will be willing to undertake the care of a seismic station. The seismoscope may be mounted upon a bracket secured to the stone or brick foundation of a building, in the cellar or basement, while the clock should be placed where it will be often seen, or where it may be of real service as a time-keeper to the observer. The use of an electric alarm, while not a necessity, is very desirable, as through its action attention is immediately called to the disturbance, and even a second or two of warning might enable many interesting observations of phenomena which would otherwise escape the observer.

I have found it very useful to provide for regular tests of the apparatus on the first of each month. An artificial disturbance near the seismoscope takes the place of a real earthquake and the operation of the bell-ringing, clock-stopping apparatus is observed, the clock error and rate applied, and in fact everything is done as if a real earthquake had occurred. This will enable the observer to detect any fault in his arrangements and will serve in a great degree to maintain his interest and sustain his patience through months or years of waiting for an actual record. Blanks should be furnished on which the results of these tests may be recorded and forwarded to the person in charge of the whole system of observations. Many other details might be referred to, but they belong rather to a code of instructions for observers. There is one matter connected with the establishment of stations, however, which experience has shown to be important.

The records of a seismic station, even when equipped in the best possible manner, will be unquestionably affected by what may be called "accidental errors." That is to say, it is believed that the best of seismoscopes will fail to satisfy entirely the conditions given above and will occasionally "go off" when there has been no real seismic disturbance. This may be due to a variety of causes, among which may be mentioned: changes in the position, level, etc., of the support of the instrument, through a slow movement of the wall or pier to which it may be attached; occasional movement of heavy bodies in close proximity to the instrument; very violent winds which may disturb the foundation of the building in which it is placed, etc. It is often difficult to distinguish a false alarm thus given from a true seismic disturbance and in the records of the seismoscopes at Washington and Terre Haute already given, two or three doubtful instances occur.

When the earthquake is sufficiently violent to be detected without instrumental aid, confirmatory evidence is furnished; but one of the principal objects in making use of instruments is to detect movements which would otherwise pass unnoticed and to extend the range of observation of the more violent far beyond what it can be at present. As an illustration of the great importance of being able to know a genuine record I may invite attention to one of the records made at Washington a few hours later than the Italian earthquake of last year. The epoch of the disturbance is such that there is nothing unreasonable in supposing that it was really a wave which had been transmitted across the sea or through the crust of the earth. Interesting as this fact would be, it would be rash to make such an assumption in view of the possibility of a purely accidental disturbance of the instrument.

A very similar state of affairs exists in connection with one of the records of the Terre Haute seismoscope. Had there been several instruments along the Atlantic coast they might have confirmed or confuted the record made at Washington. It is highly probable, however, that disturbances frequently occur which do not affect large areas. In arranging for the systematic observation of phenomena so rare and so uncertain as to time and place as earthquakes, it will hardly be possible to place stations sufficiently near each other to insure the detection of these minor movements, although they are for many reasons of prime importance. With the possibility of accidental disturbance and with seismoscopes somewhat widely separated, it would seem impossible ever to certainly detect such minor movements in the surface of the earth. There is a remedy, however, and it lies in the precaution, the truth of which experience has forced upon me, that *wherever there is one seismoscope there must be two.* That is to say, when any locality is selected as a suitable place for a seismic station two complete stations must be established, separated sufficiently so as not to be liable to the same accidental disturbances but near enough to render it reasonably certain that a real seismic disturbance which affects one will also affect the other. If separated by a distance of from a few hundred feet to a quarter or half a mile, the necessary conditions would be satisfied. Two such stations ought to sensibly agree as to the exact time of any disturbance and not only would they enable the observers to distinguish accidental or false alarms, but they would afford excellent checks upon each other on the occasion of a genuine record.

It is hardly necessary to refer to the interesting and important results which would almost certainly come from the organization of one hundred or even fifty such stations wisely distributed, at first over those sections of the country known to be most subjected to earthquakes. On the hypothesis of transmission through a homogeneous, elastic medium, records at less than a half dozen stations will suffice to determine the velocity of transmission, and the coördinates of the origin of the disturbance. Although in the case of the earth this hypothesis is not tenable, it is an approximation to the truth, and there can be no doubt that the mean of a number of such determinations, based upon different groups of observations would have considerable weight in the discussion of the dynamics of the problem.

I think it will be generally admitted that the management and direction of an investigation so extensive as the territory involved could only be successfully carried out by the government; and that the Director of the Geological Survey, of whose disposition in the matter there can be no doubt, should be furnished by Congress with the authority and material for its accomplishment.

ART. IX.—*On a new Petrographical Microscope of American Manufacture;* by GEORGE H. WILLIAMS.

THE importance of the microscope in geological investigations—particularly in the domain of the crystalline rocks—is now universally recognized, even by those geologists who do not themselves employ it. The light already shed upon some of the darkest and most intricate problems by recent petrographical methods, uncertain though it sometimes be, is full of promise for the future. Geology is reaping almost as great benefits from the application of the microscope as her sister sciences, biology and medicine; and there seems to be no good reason why this instrument should not be made of as much educational value in her field as in theirs.

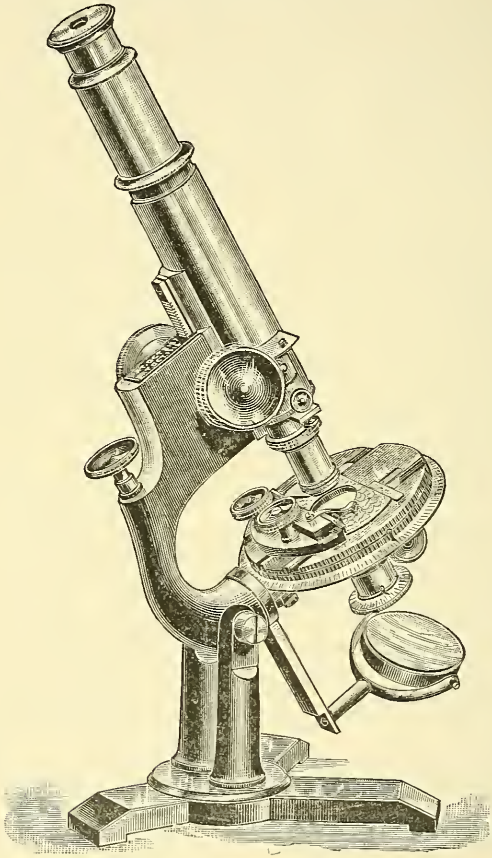
Not all who study the natural sciences are able or care to become original investigators. The scientific training, however, possesses for every one certain peculiar advantages, and the organic sciences have not been slow to appreciate how valuable a factor in such a training the microscope may be made. Five years of practical experience have convinced the writer that the microscope in geology may, with as great success, be employed for purely educational purposes.

If then the microscope be of such use in geology, both as a means of research and as an educational discipline, the production of instruments especially designed for rock-study becomes a matter of importance. Such a demand has for some time past been met, with varying success, by several Continental manufacturers; but, owing to the limited interest in micro-geology on this side of the Atlantic, the attempts of American makers to supply petrographical microscopes have hitherto been wholly inadequate.

The advantages to the constantly increasing number of petrographical students in America, of a suitable instrument of home manufacture, are too apparent to need enumeration. Indeed, the actual demand for such an instrument has been so often and so urgently forced upon the writer's attention, that, at his request, the well-known Bausch and Lomb Optical Company of Rochester, N. Y., undertook the construction of a purely petrographical stand which should satisfy all the demands for mineral and rock study and at the same time come within the means of geological students. Each essential point was designated by the writer and has been elaborated by the manufacturer in the simplest and most inexpensive manner consistent with satisfactory results. The instrument in its present shape, though it may be subject to further improvements, offers at a reasonable price ($135.00) a complete petrographical and mineralogical microscope of excellent workmanship, possessing all essential features, and several advantages (such as a sliding analyzer and mechanical stage) to be secured only on the more expensive European stands.

It has been thought that a figure and description of this microscope would prove of interest to all whose attention is devoted to geology, whether as teachers or as investigators.

The accompanying cut shows the instrument constructed upon what is known as the Bausch and Lomb "*Model Stand.*" (See Bausch and Lomb Illustrated Catalogue for 1887, pp. 15.) This has a frame of japanned iron, with brass tube, stage and mirror-bar. It was selected in order to reduce the total expense as much as possible, but all the petrographical appliances may be adapted to any of the brass stands of this firm, if desired, with a proportionate increase in expense.



(One-third natural size.)

The screw supporting the arm between the pillars allows the instrument to be inclined at any angle. The main tube is provided with a cloth lining into which the draw-tube carrying the ocular, is fitted. There is a coarse adjustment by rack and pinion and a fine adjustment by a micrometer screw. The mirror is both flat and concave and the mirror-bar adjustable.

Coming now to the peculiarly petrographical features, we have the lower nicol-prism or polarizer enclosed in a cylindrical metal box, both ends of which are protected by glass. This box is capable of a complete revolution and is provided with a graduated silvered circle and index. It is held by a cylindrical frame in which it may be raised or depressed at will by a rack and pinion movement. This frame is attached to the under side of the stage by a swinging arm, so that the whole polarizing apparatus may be thrown to one side if desired. A strong compound lens may be screwed upon the upper end of the polarizer whenever strong illumination or converged polarized light are needed.

The circular stage (9·5 cm. in diameter) is provided with a beveled silvered edge, graduated to degrees. Upon this is mounted for smooth and concentric revolution the admirable mechanical stage, known in the manufacturer's catalogue as No. 1052. This carries an index for reading the graduated circle, and is also provided with silvered graduations for its two rectangular movements, whereby any point in a section can be readily located. The upper sliding bar which carries the object has been shortened so as to be only flush with the revolving stage when pushed to its extreme limit on either side. With this, square or short rectangular glasses must be used for mounting which will avoid any interference with the revolution of the stage.

Into the nose-piece, just above the objective, is an opening intended to receive the four following accessories, each mounted in a separate brass frame: (1) a Bertrand lens for magnifying the interference figures; (2) a quarter-undulation mica-plate; (3) a quartz wedge; (4) a Klein quartz-plate or a gypsum plate with red of the first order.

The centering of the various objectives is secured by two screws having motions at right angles to each other.

The upper Nicol-prism or analyzer is inserted in the tube in order to avoid the diminishing of the size of the field which is unavoidable when the prism is placed over the ocular as a cap. To accomplish this, and at the same time to keep the tube dust-tight, the nicol is enclosed in one side of a double chambered box. The other side is left vacant and the box may be slid to and fro according as ordinary or polarized light is desired. A metal sheath protects this box from above.

The microscope as here described in a case with a single eye-piece, but without objectives, may be obtained for $108.00. With two eye-pieces (one with cross-hairs and the other with micrometer) and two objectives ($\frac{3}{4}$ and $\frac{1}{5}$ inch) its cost is $135.00. The cost of a solid brass stand is about $25.00 more.

The instrument as here figured is less expensive than the importation of the lower grades of European petrographical stands; and considerable practical experience with it has shown that it renders decidedly better service.

Petrographical Laboratory, Johns Hopkins University, November, 1887.

Art. X.—*A new Ammonite which throws additional light upon the geological position of the Alpine Rhætic;* by William B. Clark.

In a paper* upon the geology of a part of the northern Tyrol, published in Munich in February, 1887, I described among several new forms a species of ammonite of the genus *Arcestes*, which is of some considerable importance, as pointing to the probable position of the Rhætic beds.

In the region above mentioned this much debated formation consists of the three typical divisions of *Haupt Dolomit*, *Kössener Schichten* and *Dachstein Kalk*, the lower or Haupt Dolomit being plainly subdivided into a zone of dolomite of somewhat over 1,000 feet in thickness, overlaid by a thinner zone of limestone, the so-called Platten Kalk of Gümbel. The lower zone is probably unfossiliferous, with the exception of some interstratified beds of asphalt which contain ganoid scales; while the upper, although containing numerous ill-defined gasteropods, doubtless of the genus *Rissoa*, affords no distinctive forms that would of themselves demand a close union either with the underlying Trias or overlying Jura. The Kössener Schichten, in contradistinction to the lower division, are very fossiliferous and present the chief ground of discussion. The rock is a dark limestone, often of a marly, schistose character, with frequent interstratified beds of marl, that grades down insensibly into the Platten Kalk. The fossils show numerous affinities both with Triassic and Jurassic forms, but for the most part appear to be of the former character. They are largely corals, brachiopods and lamellibranchs, and the example here cited is the first case of a well-defined ammonite. The genus *Choristoceras*, so commonly encountered, is a degenerate form placed with the *Ceratitidæ*, and has small value in this connection. The third division, the Dachstein Kalk, is of white limestone, and contains almost exclusively lithodendron-like corals, though the large *Megalodon triqueter*, the characteristic bivalve of this zone, is frequently encountered. It is without doubt of coral-reef origin, as many physical facts along its contact with the Lias give proof.

Facts seem to indicate that these different divisions, certainly so far as the Kössener Schichten and Dachstein Kalk are concerned, are only facies, and may under suitable conditions be interchangeable.

* Ueber die geologischen Verhältnisse der Gegend nordwestlich von Aachensee mit besonderer Berücksichtigung der Bivalven und Gasteropoden des unteren Lias. 8°. 45s., 2 taf., 1 Karte. München, 1887. (Inaugural Dissertation).

When we examine the stratigraphical relation of these beds to the underlying Trias we find that no unconformity exists, but that an insensible gradation often takes place from one to the other; while toward the Lias, on the other hand, although unconformity does not exist, yet the break is so marked and clearly defined that we are unprepared to admit an intimate connection between the Rhætic and Lias.

Stratigraphical and paleontological evidence in the Eastern Alps is, then, strongly indicative of a close affinity of the Rhætic to Trias; and the Arcestes species, which we will now describe more in detail, adds another important proof to this more or less generally accepted fact.

Arcestes rhaeticus, n. sp.*

The ammonite in question, to which, from its important occurrence, I have given the name of *Arcestes rhæticus*, has the following dimensions:

Diameter	70mm
Height of last whorl	40
Thickness	50
Umbilicus	14

The shell is involute, with rounded dorsal surface, and the cast shows upon the last whorl two depressions, which run in a straight line over the convex back, and which were occasioned by successive contractions or interior thickenings of earlier mouth-edges. The sutures form regularly decreasing series of lobes and saddles from the dorsal siphuncle toward the interior. These lobes and saddles are finely branched, the latter containing upon the outside 4–5, upon the inside 3 obliquely diverging divisions. Beyond the dorsal and the two lateral saddles there are only two auxiliary saddles present. The dorsal lobe is divided by a median saddle into two points, which are very considerably deeper than the lateral lobes. The latter are by means of small branches two- or three-pointed.

This species belongs to the group of the *Galeati*, and shows close affinities to *Arcestes giganto-galeatus* Mojs., from the Hallstädter Kalk.

We have thus a form which belongs to a family and genus most characteristic for the Trias and until now never found above that formation. The Lias has not a single representative. The interest in this particular species is greatly heightened from the very close similarity in outward form and minute division of the lobes to *Arcestes giganto-galeatus*. This fact, if we were to consider the Rhætic beds as belonging to the Lias, would be without a parallel, for on account of the ex-

* Figured in the paper before mentioned, Plate I, fig. 3, *a*, *b*, *c*.

treme variability of the ammonites, the most marked changes are shown from stratum to stratum. Hence it is scarcely possible that a well-marked form could be preserved through any considerable extent of time or any marked change in the conditions of life. In other classes of animals many cases can be cited where forms have continued unchanged for long periods of time, but when such is observed among the ammonites it is certainly a proof of the faunal affinity of the formations considered and a strong reason for uniting them most closely in the geological system.

Before closing this brief contribution it will not perhaps be irrelevant to refer in a word to the general positions held by geologists of different countries upon this question, as shown in their reports to the Committee for the Unity of Nomenclature at the Geological Congress at Berlin. In this report the opinion of French and English geologists was decidedly in favor of according a closer relationship of the Rhætic beds to Lias than to Trias, while the weight of evidence obtained from German sources plainly pointed to the opposite conclusion. The inability and folly of endeavoring to correlate the strata of widely separated regions is thus most forcibly shown, since facts which in certain localities warrant the close association of conformable beds, in others preclude the union of apparently synchronous horizons.

Geological Laboratory, Johns Hopkins University, Oct. 1887.

ART. XI.—*Three Formations of the Middle Atlantic Slope;* by W. J. McGEE. With Plate II.

INTRODUCTION.

THE Middle Atlantic Slope may be described as that portion of Eastern United States which sheds its waters directly into the Atlantic Ocean and in which the principal rivers rise within the Appalachian mountain system. Thus defined, it extends from near the Mohawk and Hudson on the north to the Roanoke (called the Staunton in the middle part of its course) on the south, or from southern New York to northern North Carolina. Its principal rivers, in addition to those mentioned, are the Delaware, the Susquehanna (including its continuation, Chesapeake Bay), the Potomac, and the James; and its smaller but yet notable streams extending to tide water are the Raritan, the Schuylkill, the Brandywine, the Patapsco, the Patuxent, the Occoquan, the Mattaponi, the North Anna and South Anna (which unite to form the Pamunkey), the Appomattox, the Nottoway, and the Meherrin.

By geologic structure, by topographic configuration, by behavior of streams, and by the various cultural conditions resulting from these natural conditions, the Middle Atlantic Slope is separable into three distinct zones:—viz, the Appalachian zone, the Piedmont region, and the Coastal plain.

In the Appalachian zone the rocks are Paleozoic, and are characteristically corrugated by greatly elongated flexures; the predominant topographic characteristic of the region is long, parallel ridges separated by flat-bottomed valleys, the whole —save the sharpest ridges—diversified by a plexus of narrow stream-cut valleys and intervening minor hills; the great rivers wander meanderingly through the mountain ranges while the smaller streams and secondaries generally gather in elongated basins bounded by the ranges, and both large and small streams flow rapidly over the rocky bottoms of narrow, steep-sided ravines or gorges; and the civil boundaries and the routes of travel and traffic are generally determined by the parallel ridges and greater waterways, while the industries are determined largely by the resources of the rocks—anthracite and other coals, iron, building-stone, etc.,—the thin-soiled mountain slopes being unsuited for agriculture and allied pursuits.

The Piedmont region comprises an area of highly inclined crystalline rocks, abundantly diked, veined and faulted; its surface is a rather strongly undulating plain without conspicuous eminences, inclined seaward, and everywhere graven deeply by the larger and to proportionately less depths by the smaller waterways, which thus give origin to endless mazes of minor hills; its hydrography comprises the great rivers which meander irregularly through it, and a widely-branching dendritic system of secondary and tertiary drainage in which the individual members have no uniformity in direction, in which the basins are irregularly rounded or pyriform, and in which the divides are low and inconspicuous and constantly curving and recurving in labyrinthine convolutions; while, as in the Appalachian region, both the larger and smaller streams are unnavigable and rush rapidly over the rocky bottoms of sharply cut valleys, the declivity of the streams culminating at the seaward side of the zone, where all, river and rivulet alike, descend to tide level in cataracts and rapids. The civil boundaries of the region follow the waterways and transect the divides, the lines of traffic are either confined to the greater valleys or distributed over the surface, and the pursuits of the people are largely determined by the soil and its products.

In the southern part of the area, the Appalachian and Piedmont zones are sharply separated by the Blue Ridge—the easternmost member of the parallel Appalachian series; but in

Pennsylvania this mountain ridge looses its integrity and continuity and the boundary between the two zones is indefinite, while in northern New Jersey and southern New York the natural boundary fails and only an arbitrary demarkation can be drawn between the zones so sharply distinguished in Virginia and Maryland.

The Coastal plain extends from the line of cataracts and crystalline rocks to the ocean. Structurally, it consists of generally incoherent deposits of later Mesozoic and Cenozoic age, slightly inclined seaward but otherwise undisturbed; topographically, it is a plain, trenched by broad but shallow tidal estuaries and thus separable into smaller plains which sometimes undulate gently but irregularly, and again take the form of steeply-scarped terraces miles in extent, cut by steep-sided ravines and deeply scalloped along the greater waterways; the hydrography comprises the broad flat-bottomed estuaries into which the principal rivers are transformed on entering the plain, and local drainage systems of widely branching dendritic type in which the principals are also generally estuarine toward their mouths; the divides are but labyrinthine and crenulated remnants of an imperfectly drained plain only partially invaded by erosion; and throughout the region the water is slack except toward the heads of the adolescent drainage ways. The political boundaries and principal lines of traffic are determined by the great water avenues, while the civil boundaries and lesser lines of traffic are independent of the physiography, and the industries grow out of the products alike of sea and soil and out of the natural facilities for traffic and transportation.

The common boundary of the Piedmont region and the Coastal plain is one of the most strongly marked physiographic and cultural lines on the land surface of the globe: On the one hand there is a great series of crystalline rocks giving origin to a characteristic soil in which all streams, from the greatest rivers to the smallest brooks, flow through constricted gorges in a succession of cataracts or rapids; while on the other hand there is a series of incoherent and undisturbed deposits of clay, sand, and gravel through which the waters, gathering in the more elevated zones, move sluggishly in broad tidal estuaries. The boundary has long been known among students of manufacturing industries as the *fall-line;* yet it is even more noteworthy as a line of deflection in the rivers than as one of declivity. The great waterways of the Middle Atlantic Slope maintain their courses through Appalachian ranges and Piedmont highlands alike; but on reaching the low-lying Coastal plain they are turned aside, literally by a sandbank little higher than their depth, and thence hug the hard rock margin for scores of miles before finally finding their way into the open ocean. By this deflection of the rivers the northern half of the Coastal plain is nearly insulated; the isthmuses between the Raritan and the Delaware, between Claybank creek and Elk river, between the Patapsco and the Anacostia, and between Potomac creek and the Rappahannock, from tide-water to tide-water, are low, and but 20, 15, 25, and 5 miles in width respectively; measured directly along the fall-line, so that, the Hudson is barred from the Rappahannock by only about 60 miles of land and unnavigable water. The deflected portions of the rivers indeed occupy a great trough skirting and accentuating the Piedmont escarpment.* This remarkable physiography has materially affected the culture of the region: The pioneer settlers of the country ascended the tidal canals to the falls of the rivers where they found, sometimes within a mile, clear fresh water, the game of the hills and woodlands and the fish and fowl of the estuaries, and, as the population increased, abundant water-power and excellent mill sites, easy ferriage and practicable bridge sites; here the pioneer settlements and towns were located; and across the necks of the inter-estuarine peninsulas the pioneer routes of travel were extended from settlement to settlement until the entire Atlantic Slope was traversed by a grand social and commercial artery stretching from New England to the Gulf States. As the population grew and spread, the settlements, villages, and towns along this line of Nature's selection waxed, and many of them yet retain their early prestige—for Trenton, Philadelphia, Wilmington, Baltimore, Washington, Fredericksburg, Richmond, and Petersburg are among the survivors of the pioneer settlements; and the early stage route has become a great railway and telegraph line connecting North and South as they were connected of old in a more primitive fashion. The influence of natural conditions upon man and his institutions is nowhere else more strikingly exemplified.

No discussion of the phenomena of the Atlantic slope is intelligible without clear comprehension of the great physiographic divisions into which it is naturally separated. These divisions are represented graphically in the accompanying stereogram, which also exhibits the essential continuity of the Coastal plain to the great submarine escarpment off the Atlantic coast; the submarine profiles being based on soundings by the Coast Survey, the Fish Commission, etc., while the indicated sub-marine structure is hypothetic.

* It is shown elsewhere (7th Annual Report, U. S. Geol. Survey) that this trough is due to a post-Tertiary displacement along which movement is now in progress, probably at a rate as high as in the well-known recent faults of the Wasatch or the Sierras.

Four years ago the writer undertook to ascertain the origin and relations of certain conspicuous deposits in the District of Columbia, under the direction and auspices of the U. S. Geological Survey. It was soon found that while certain formations of the region—especially those containing fossils,—had received more or less study, while the various formations had been classified by means of the fossils contained in a few of them, and while the entire region had even been repeatedly mapped geologically, nothing was accurately known of the exact relations of the different fossiliferous and unfossiliferous deposits forming the portion of the Coastal Plain within and contiguous to the District of Columbia; it was soon found, moreover, that the formations in question are not only generally unfossiliferous in the district, but that the deposits themselves are destitute of constant and definite petrographic and structural characters whereby the stratigraphy might be ascertained; and thus it was early found difficult, if not impossible, either to correlate the different local exposures and deposits among themselves, or to establish their relations to formations already classified elsewhere by commonly employed methods. Accordingly, the investigation was commenced *de novo;* and in default of fossils or definite structural characters, locally applicable methods, standards, and criteria were developed as the work progressed: Conditions of deposition were inferred from deposits, and continent-movement was in turn inferred from evident conditions of deposition superinduced thereby; conditions of degradation in unsubmerged areas were inferred from the topographic forms thereby developed, and, since degradation is preëminently dependent on base-level, another means of inferring continent-movement was thus evolved; the record of events interpreted from earth-forms fashioned in accordance with determinate principles on the one hand was compared with the record interpreted from correlative deposits on the other hand, and history was thus deduced from independent but consistent and cumulative testimony; and final correlations were made through deposits regarded not only as rocks but also as indices of continent movement, and at the same time through the correlative topographic forms. In short, the methods, standards, and criteria have been of necessity physiographic rather than paleontologic or petrographic.

Certain preliminary results of the work appear of sufficient moment to merit a place in the standard medium of American students of science. They are summarized in the following pages.

In the present sensitive if not revolutionary condition of geologic terminology, it may be wise to define, without specially defending, the term "formation" as employed in this article. It is applied to a naturally defined series of deposits, evidently formed by a definite set of agencies within a determinate area during a definitely limited period—an easily recognizable structural, chronologic, and taxonomic unit.

The formations described are: (1) the *Potomac*, consisting of irregularly bedded and heterogeneous sand, clay, arkose, gravel, etc., of Mesozoic age and forming the base of the series of unaltered deposits of the Coastal plain, named from the river on which it is best developed; (2) the *Appomattox*, a series of predominently orange-colored sands and clays of later Tertiary age, also named from the river on which it is typically exposed; and (3) the *Columbia*, a series of delta and associated littoral deposits formed during a brief period of submergence in early Quaternary time, named from the district in which it is typically developed and in which it is first systematically studied. Certain deposits of each of the formations have already been investigated by different geologists, but they have not hitherto been correlated and systematically combined. The Potomac formation has already found place in geologic literature and taxonomy; the Columbia has been defined and briefly described in print;* but the Appomattox is here defined and named for the first time.

Professor William M. Fontaine began his elaborate investigations of the later Mesozoic formation and its flora in Virginia some time before the study of the contemporaneous deposits of the District of Columbia was taken up by the writer; but a meeting was soon arranged, notes were compared and exchanged, and a detailed examination of the principal exposures in Virginia, in the District, and in Maryland south of Baltimore, in which Mr. Lester F. Ward participated, was undertaken in the summer of 1885; during this joint study the characters of the Potomac formation were worked out and its name (previously proposed by the writer) adopted, the Appomattox formation was discriminated, and many features of the Columbia formation were brought to light; and it is a pleasure not only to acknowledge indebtedness to these gentlemen, and especially the former, for the greater share of our knowledge of the Potomac and Appomattox formations, but to record their substantial concurrence in the following statements and inferences concerning them. It is an equal pleasure to add that the phenomena of the Columbia formation have been more or less carefully examined in the vicinity of Washington by the same gentlemen and several other geolo-

* Rep. Health Officer of the District of Columbia, 1884–85 (1886), 20; this Journal, III, xxxi, 1886, 473; Proc. A. A. A. S., xxxvi, 1888, 221; etc.

gists, that acknowledgments are due to them for pertinent and valuable suggestions, and that all coincide in the essential conclusions as to its genesis and age set forth in subsequent pages.

The Potomac Formation.

Character and Distribution.—The southernmost observed occurrence of the formation is at Weldon, N. C., where a bed of obscurely stratified arkose, interspersed with well rounded quartzite pebbles, appears in the north bank of the Roanoke beneath the railway bridge. The deposit rests on an unequally eroded surface of gneiss, is not over a foot thick, and is unfossiliferous; but its composition and structure are characteristic, and there is little doubt as to its identity.

Better exposures occur on the Nottoway river just below Bolling's bridge. An irregularly and obscurely stratified arkose, unquestionably belonging to this formation, here rises four or five feet above low water, and is unconformably overlain by three or four feet of stratified greenish-blue clay containing Eocene fossils; and exposures of similar character occasionally occur in the river channel within the next five miles up stream. In all of these outcrops the deposit exhibits a typical and easily recognizable aspect: it is a nearly homogeneous, granular, loosely aggregated, almost mealy mass of quartz grains (generally angular but sometimes rounded), flakes and grains of kaolin (sometimes so little decomposed as to retain the form of the parent crystals of feldspar), and scales of mica, with an unimportant admixture of loamy particles, and now and then a rounded or irregular pellet of white plastic clay. The fresh surface is commonly light gray in color, but is frequently flecked with white and stained with brown in curiously curved lines. In structure it is either massive or obscurely stratified and cross-laminated; but even where the bedding is most distinct it is rarely consistent and continuous for more than a few feet vertically or a few yards horizontally. Except for its obscure structure planes, its pellets and lenticular pockets of clay, and the slight admixture of loamy matter, the mass could hardly be distinguished from decomposed granite or gneiss *in situ*. Some of these deposits on the Nottoway river were observed and referred to the "secondary class of rocks" by W. B. Rogers in 1839;* but *a propos* to the interesting question of geographic changes during the historic period, it is significant that Rogers failed to find the formation where it is now best exposed but found it "nearly on a level with the water" at a point "about 4 miles above Bolling's bridge" where it now rises fully 8 feet above the river; the

* Geology of the Virginias, 1884, 261.

indications being that the river has here deepened its channel several feet since 1839.

The next exposures of the formation occur on the Appomattox between Petersburg and its mouth at City Point; the most conspicuous being Point of Rocks (some four miles above the mouth) where the larger part of the material is an arkose similar to that on Nottoway river, interspersed with well rounded quartz and quartzite pebbles and rounded or irregular masses of plastic clay, interstratified with laminated clay beds, and the whole so firmly lithified that the solid quartzite pebbles fracture as readily as the matrix. The deposit here forms a prominent bluff 50 or 60 feet high, the material of which has been largely quarried as a building stone.

On James river the formation is notably exposed between Richmond and Deep Bottom, a few miles above the mouth of the Appomattox. Perhaps the most abundant constituent is arkose, such as occurs on the Nottoway, generally friable but sometimes lithified; but the arkose beds are frequently intercalated with beds of massive or laminated clay and heterogeneous sand or gravel, sometimes forming the greater part of the mass. Where laminated, and especially in the lenticular bands intercalated between beds of arkose, the clay frequently contains well preserved impressions of leaves; and silicified wood is common in the sandy and gravelly portions, as are lignitized trunks and branches of trees in the beds of clay. One of the most conspicuous elements in the deposits exposed on James river is its large pebbles and bowlders, reaching three or four feet in diameter, sometimes of Piedmont gneiss (which crops out in the river channel within a few miles of Dutch Gap), but more frequently of quartzite sometimes containing *Scolithus* borings and casts of brachiopods identifying it with the axial quartzites of the Blue Ridge. It is noteworthy that W. B. Rogers recognized the materials of this formation in borings from an artesian well at Fort Monroe at a depth of 835–907 feet.*

Interesting exposures of the formation occur on the South Anna river (where, as at Point of Rocks, it is in part a firmly lithified arkose containing well rounded pebbles of quartz and flakes and pellets of plastic clay) as well as on the Little river, the North Anna, the Mat, the Taponi and its tributaries, on Massaponax creek, and indeed in nearly every considerable valley or deep ravine, and occasionally on the surface, between the South Anna and the Rappahannock. It is generally overlain by the orange sands and clays of the Appomattox formation; and in the neighborhood of Hanover Junction it reposes unconformably upon the petrographically similar, but disturbed

* Ibid., 733–5.

and diked, Rhætic beds. Here too, the quartzite pebbles, so abundant on the James and Appomattox, disappear.

About Fredericksburg the formation is well exposed and exhibits some noteworthy characters: it consists predominantly of locally lithified arkose with abundant pebbles either irregularly disseminated or arranged in bands and beds, and numerous bowlders of gneiss and vein-quartz (quartzite being altogether absent) up to two feet or more in diameter, together with heterogeneous sand containing a considerable element of finely divided diffused clay; while lenticular beds of clay are frequently intercalated in both arkose and sand, and in some exposures constitute the major part of the mass. As on the James, the clay is massive, obscurely bedded, or finely laminated, and sometimes contains abundant leaf impressions; and here, as elsewhere, silicified and lignitized wood are common in the sand and clay respectively.

Thus, south of the Rappahannock the formation consists of an indivisible mass of arkose, sand, clay and gravel, generally overlapped by the Tertiaries, and exposed only along waterways and over a limited area between the two Anna rivers.

North of the Rappahannock the formation increases in volume and in diversity, and forms the surface over a zone several miles in width between the Eocene margin and the Piedmont crystallines. Near the mouth of Acquia creek it has an observed thickness of 180 feet, mainly of lithified arkose (long known as a fairly valuable building stone and extensively used in old structures in Washington, Alexandria, and Fredericksburg), intercalated with plant-bearing clay beds. Midway between Fredericksburg and Acquia creek the characteristic phases of the formation as developed in the south are found to be overlain by a bed of clay of obscure or inconstant structure, containing occasional intercalations of arkose or beds of pebbles; and this clay deposit, which lies beneath the Eocene and is generally unfossiliferous, increases in thickness northward. At the same time, isolated patches of gravel identical with that of the body of the formation, and evidently outliers insulated by erosion, begin to appear along the marginal portion of the Piedmont zone, generally capping eminences of circumdenudation. These outliers are sometimes 25 or 30 miles within the fall-line.

Between Acquia creek and Washington the formation continues to form the surface over a considerable zone; its lower part maintains the characters exhibited farther southward, as shown by excellent outcrops at many points on the Potomac river, and in ravines and railway cuttings to the westward; and the superjacent clays progressively increase in thickness without material change in character. On Occoquan river quartzite pebbles, which are absent southward nearly to the James, again appear, and at Pohick creek become an important element in the formation; while the leaf impressions so abundant to the southward disappear.

About Washington the formation comprises two members sometimes discriminated with difficulty but apparently unconformable, the lower consisting of friable arkose or more heterogeneous sandstone, with lenticular partings and intercalated beds of clay and notable accumulations of quarzite pebbles (which in the westernmost outcrops become respectable bowlders), and the upper consisting of irregularly and discontinuously bedded clays, with occasional intercalated beds of sand and pebbles. The clays comprising the greater part of the upper member, like those intercalated within the lower, are of obscure or inconstant structure, variable in composition, and diverse in color: they are sometimes massive and again finely laminated, now silty and unctuous, again made up of flakes and pellets of kaolin, and elsewhere intermingled with sand and grit; they are commonly gray, whitish, or lead-colored, but again pure white, blue, black, pink, red, brown, purple, or mottled with part or all these colors, generally in soft and delicate tints. Silicified and lignitized wood and even lignitized stumps *in situ* occur in both members; but identifiable plant remains are not here found. Both members are locally stained and cemented by ferruginous infiltrations. Isolated outliers, made up principally of well-rounded quartzite and vein-quartz pebbles up to six or eight inches in diameter, crown eminences on both sides of the Potomac river, some of those on the south occurring fully twenty miles west of the continuous formation boundary. In this latitude the formation generally constitutes the surface over a belt fully fifteen miles in with, from the Piedmont gneiss on the west to the overlapping Eocene beds on the east; but the eastern boundary cannot be accurately drawn by reason of the puzzling graduation into newer deposits, sometimes filling ravines and sometimes covering considerable areas, made up of redeposited Potomac materials. Attention was called to the deposits of the formation at Washington by W. B. Rogers in 1875.*

Between Washington and Baltimore the upper division of the formation (the "Iron Ore Clays" of Tyson †) forms the surface generally and is extensively exposed in the cuttings on both railways and in the numerous workings from which disseminated nodules of carbonate of iron are extracted, and has recently yielded abundant dinosaurian remains; and at Balti-

* Proc. Bost. Soc. Nat. Hist., vol. xviii, 1875.

† 1st Rep. State Agricultural Chemist of Md., 1860, 30, 42.

more, as well as on the Patuxent and Patapsco rivers and their tributaries, the lower division is exposed and occasionally yields plant remains closely allied to those found in Virginia.

Both members of the formation appear in the precipitous shores of the head of Chesapeake bay, the sandstone only on the north, but the white, blue, purple and varigated clays on both east and west; and along Sassafras river these clays are unconformably overlain by the pyritous clays and greensands of the Maryland Cretaceous. Identifiable fossils have not been found in the sandstone member at this locality; but a few plant remains were found in the clays. The magnificent exposures of both the Potomac and Columbia formations here are described in detail and fully illustrated elsewhere.*

Extensive outliers of gravel occur on both sides of the Susquehanna several miles from the body of the formation, notably at Webster on the south and Woodlawn (or Battle Swamp) on the north of the river.

In extreme northeastern Maryland and in northern Delaware the sandstone member of the formation is not exposed as a continuous body, though it is represented by occasional isolated outliers of gravel upon the marginal Piedmont hills; but the superjacent clays appear in a number of localities, and form the subterrane over a considerable zone parallel with the Piedmont escarpment. They have been studied by Chester, who designates them "Plastic Clays," and refers them to the "Lower Cretaceous (Wealdon?)."†

So between the Rappahannock and the Brandywine the formation is a continuous terrane, consisting of a series of clays reposing perhaps unconformably upon a series of sands and gravels, while outliers of the inferior division crown the crests of the Piedmont plateau many miles from the main body; but northward it contracts and is again represented only by isolated remnants and exposures.

In southeastern Pennsylvania both members of the formation have been recognized by different geologists and have been variously classed. Clays apparently representing the upper member occur in the northeastern part of Philadelphia county where they have been referred to the Wealden;‡ the gravelly outliers representing the lower member in the vicinity of Philadelphia have been designated the "Bryn Mawr Gravel" (from a locality of typical outcrop) and referred to the Tertiary by Lewis;§ and similar exposures in Delaware county have been

* "Notes on the Geology of the Head of the Chesapeake Bay," 7th Ann. Rep. U. S. Geol. Survey (in press).

† Proc. Acad. Nat. Sci., 1884, 250–1.

‡ 2nd Geol. Surv. Pa., Report X, Hand Atlas of Pa., J. P. Lesley, 1885, Plate 46.

§ Proc. Acad. Nat. Sci. Phil., xxxii, 180, 269, 272; Ibid. 296, *et seq.;* Journ. Franklin Inst., xcv, 1803, 371–73; and elsewhere.

mapped by C. E. Hall, who designated the deposit "Ferruginous Conglomerate," and followed Lewis in referring it to the Tertiary.* The low-lying clays in the valley of the Delaware are not well exposed, have yielded no fossils, are not known to be connected with the plastic clays of Délaware, and cannot be certainly correlated with the upper member of the formation; but the gravelly outliers belong to a series traced from the Rappahannock river northward, everywhere sustaining identical relations to the underlying rocks and to the topography, and everywhere petrographically similar to a characteristic phase of the formation as typically developed in Maryland and Virginia, and may be confidently correlated with the lower member. Indeed, in the exposure in Media the most abundant materials are characteristic kaolinic arkose and more heterogeneous brown ferruginous sands such as occur about the head of Chesapeake bay, coarse gravel being but a subordinate element.† In the vicinity of the Susquehanna the gravel of the outliers is generally coarse and abundant; over the plateau between that river and the Schuylkill it is finer and less abundant: and toward the latter stream it again grows coarse and the outliers become more conspicuous.

North of the Schuylkill the lower member is typically developed at several localities in Rose valley, in the northwestern part of the village of the same name. The deposit is an obscurely bedded arkose, generally friable but sometimes lithified, containing well worn quartz and quartzite pebbles both disseminated irregularly and in lines, together with pellets and flakes of clay, the whole similar to the deposits found in Virginia; and silicified wood occurs in small quantities, but neither leaf-impressions nor the bands of clay in which they are commonly preserved were found. The mass is irregularly stratified and evidently undisturbed, and rests directly upon tilted Triassic sandstone. Again, three or four miles north of Conshohocken, extensive deposits of white, pink, and mottled plastic clay, petrographically indistinguishable from the upper member of the formation where typically developed, are found overlying gravelly arkose. The clay beds are largely worked for pottery, while the subjacent arkose is excavated and screened for building sand and road metal—indeed there is a considerable area north of Conshohocken and Norristown in which the proximity of the Potomac is proved by the presence of its materials in roadways and foot-paths, and in the mortar of houses and barns. Still farther northward outliers of gravel generally finer than that found in the vicinity of the Schuylkill occur,

* 2nd Geol. Surv. Pa., Report C5, 1885, 10–13, and map.

† C. E. Hall notes pebbles 6 inches in diameter at this point; but so large pebbles are probably rare, and were not found by the writer.

as in the neighborhood of Broad Axe, near Three Tuns, three miles northeast of Hatboro, and indeed generally on the subordinate divides and eminences northwest of Chestnut Hill and Edge Hill. The gravel in these outliers is fine (seldom over an inch in diameter), well rounded, generally of quartzite, and commonly imbedded in a scant matrix of arkose. A compact pinkish quartzite is abundant and gives distinction to the gravel.

The substantial continuity of the formation as represented by outliers is here broken, no exposures being known between the east-flowing tributaries of Neshamin creek (near Churchville) and the Delaware river, a distance of nearly twenty miles; but two miles above Trenton on the New Jersey side of the Delaware there is a distinctive deposit locally known as the "Yellow Rocks," made up of arkose, sometimes lithified but generally friable, containing abundant well rounded (but frequently disintegrated) quartzite pebbles, disseminated, arranged in lines, or accumulated in pockets, together with pellets and flakes of white plastic clay. The deposit is irregularly stratified and inclines northwestward, but at a considerably less angle than the immediately subjacent Triassic strata. No fossils were found in the beds, but they are petrographically similar to those everywhere characteristic of the lower division of the Potomac formation, totally unlike those of the Triassic sandstones in structure, composition, and attitude, equally unlike the Raritan clays found in the vicinity, and quite distinct from the gravels and loams of the Columbia formation by which they are overlain; and on the whole it seems evident that the deposit represents the sandstone member of the Potomac formation. Somewhat similar and probably contemporaneous deposits of stratified sand occur two miles below Trenton beneath the Raritan clays.

Midway between Princeton and New Brunswick, N. J., an anomalous and hitherto unclassified deposit of friable ferruginous sandstone crowns the southernmost of the Triassic trap ridges, and is locally known as the "Sand Hills."* It consists of massive or irregularly stratified and sometimes cross laminated brown sands, occasionally cemented by ferruginous infiltration, with a few intercalated lines of white or pinkish plastic clay, and is strikingly similar to the non-kaolinic sands of the Media outlier and of the body of the formation as exposed north of the head of Chesapeake Bay. This outlier is completely isolated and unfossiliferous; but it is distinct from the Triassic sandstone on both sides of the ridge in all diagnostic features, and is, moreover, manifestly newer than the trap dike, which was itself formed after the sandstone was de-

* Geology of N. J., 1868, 227, 342.

posited. At the same time it is too unlike the well-defined Cretaceous and Tertiary formations found a few miles to the southeast to warrant correlation with, and is therefore evidently older than, any of these formations. In short, it appears to be a remnant of a formation largely removed by erosion before the later Cretaceous submergence, just as are the Potomac outliers in Virginia and Maryland; and on this indirect evidence of its chronology together with that of its petrography it may be provisionally referred to the lower member of the Potomac, although nearly twenty miles from its nearest supposed, and thirty-five miles from its nearest known, homologue.

It should be noted that the Raritan clays, which are perhaps equivalent to the superior member of the Potomac, and almost certainly newer than the sands and gravels of the two exposures just mentioned, are tentatively regarded as Jurassic by Whitfield.*

Briefly, the Potomac formation consists of two perhaps unconformable members, of which the upper is an inconstantly bedded and protean clay of variegated colors, either clean or sandy and pebbly, and the lower a generally friable sandstone, arkose, or gravel of irregular and inconstant structure. The upper member extends from the Rappahannock at least to the Delaware and probably to the mouth of the Hudson, either forming or closely approaching the surface over a somewhat sinuous zone 275 miles long and only ten miles or less in maximum width, overlooked throughout by the Piedmont escarpment. As a continuous terrane the lower member forms a still narrower zone flanking the Piedmont escarpment from the Appomattox to beyond the Susquehanna, and reappears in isolated exposures southward to the Roanoke and northward to beyond Delaware, over a total length of 300 miles; while as a series of insulated remnants crowning the hills of circumdenudation toward the coastward margin of the Piedmont region it occurs occasionally from near the James certainly to the Delaware and probably to the Raritan, over a zone from five to forty miles in width. The tenuity of these zones of outcrop is but an accident of degradation and deposition. Studies about the head of Chesapeake Bay led to the conclusion that the former westward extension of the formation can be reliably inferred from the topographic configuration of the Piedmont region, the western part of which has a drainage evidently determined by lateral heterogeneity of the vertically-bedded terrane and a characteristic topography resulting therefrom, while the eastern

* Brachiopoda and Lamellibrachiata of the Raritan Clays and Greensand Marls of N. J., Monog. U. S. Geol. Surv., ix, 1885 (Mem. Geol. Surv. N. J., 1885), 23.

part has a drainage independent of the varying obduracy of the terrane and therefore evidently superimposed by a formation (which could only have been the Potomac) now generally removed by erosion; this conclusion has since been verified by the discovery of isolated remnants of the Potomac formation on many parts of the area of supposed superimposed drainage; and it may be confidently inferred from the configuration of the Piedmont plain that about half of its area north of the James River (but not much more than half) was submerged beneath the Potomac sea and at one time covered by its deposits. A great extension of the formation eastward may also be inferred from the Fort Monroe boring, fifty miles from the nearest outcrops, in which undoubted Potomac deposits were found in considerable volume. The thickness of the formation, either original or present, has not been accurately ascertained; the upper member must approach 350 feet and the lower 250 feet near Baltimore and Acquia creek respectively, from which points both attenuate gradually, giving an aggregate (the maxima being nearly 100 miles apart) of perhaps 500 feet; and while the loss by erosion at the localities of maximum thickness has not been great, it cannot be readily evaluated.

Stratigraphic Relations.—South of the James river, the Potomac deposits rest upon an irregularly eroded and sometimes deeply ravined surface of highly inclined crystalline rocks, the inequality in altitude of the base within a mile on the same meridian (the formation and its subsurface having a considerable eastward inclination) reaching 100 feet or more. On that river the formation rests upon the irregular surface of the Richmond granite at the "fall-line," and upon the truncated edges of highly tilted gneisses and schists down the river for 20 or 30 miles; while to the westward outlying gravel patches repose unconformably on the tilted and faulted Rhætic* beds forming the Richmond coal field. Near Hanover Junction, the upturned Piedmont crystallines and the faulted, tilted, and diked strata of the Rhætic are alike overlain by the Potomac arkose which fills deep ravines in, and conceals irregularities of, the subjacent surface; and thence northward to the river from which they take their name, the Potomac sandstones repose unconformably upon irregularly eroded surfaces of gneiss, except at Drainesville (25 miles west of Washington), where a gravelly outlier rests on the planed edges of tilted Triassic sandstones. At Washington the inequality in altitude of the base of the formation, which evidently filled the valley of the Mesozoic progenitor of the Po-

* Fontaine, "Older Mesozoic Flora of Virginia," Monog. U. S. Geol. Surv., VI, 1883, 2, 96, 128.

tomac river, is fully 200 feet within a mile and a half. North of the Potomac river, the deposits, both in the main body and in the outliers, generally repose upon the eroded surface of the Piedmont crystallines, the depth of local ravining reaching some 250 feet about the mouth of the Susquehanna and proportionately less depths on the smaller streams; but the great outlier north of the Schuylkill in Pennsylvania, which exhibits all of the characteristics of the main body of the formation, rests in part upon crystallines, in part upon folded Silurian limestones, shales, and quartzites, and in part upon degraded Triassic sandstones and shales. On the Delaware the "Yellow Rocks," believed to represent the formation, rest upon a planed surface of tilted Triassic sandstone and highly inclined gneiss; and the still more doubtfully identified outlier forming the "Sand Hills" near the Raritan, rests upon an apparently eroded Triassic trap dike. In short, the formation everywhere reposes on a deeply degraded surface of upturned Piedmont crystallines, folded Silurian strata, tilted, faulted, and diked Triassic sandstones, and diked and displaced Rhætic beds; and it is significant that this surface is a generally uniform plain, inclined seaward and deeply incised by great waterways, coinciding closely with those of the present.

South of the Rappahannock the Potomac formation is overlain by the Appomattox formation, the fossiliferous Miocene, and the Eocene; between the Rappahannock and the Patapsco it is overlain by the Eocene; north of the Patapsco it is overlain so far as known by the upper Cretaceous; and in the abscence of these, and up to certain altitudes indicated later, it is overlain by the Columbia formation; the relation generally, but not invariably, being one of visible unconformity. The unconformity between the Columbia and the Potomac is well exhibited in representative sections at Fredericksburg, Washington, Baltimore, and the head of Chesapeake bay, but over the interfluvial plains and on certain slopes about Washington the formations, though widely diverse in age, intergraduate so imperceptibly that it is impossible to demark them; there is notable unconformity between the Appomattox and Potomac formations on the Roanoke and in some sections on the Appomattox and James rivers, but in other sections on the last named rivers (at Fredericksburg and elsewhere), there are deposits of composite character certainly belonging to one or both of these formations which cannot be discriminated even in the same section; the Miocene rests on the Potomac in the local absence of the Eocene at Petersburg and Richmond, but no noteworthy unconformities have been observed; the Eocene is unconformable to the Potomac on the Nottoway and generally about Richmond, and notably in a railway cutting near Brooke (where two deep ravines in the Potomac are filled with fossiliferous Eocene deposits), though in some sections at Richmond the two cannot be discriminated, and at Good Hope Hill, near Washington, Eocene fossils occur in deposits made up of Potomac materials supposed to be *in situ* before the discovery of the fossils; and on Sassafras river there is a marked unconformity between the pyritous clays and greensands of the upper Cretaceous and the subjacent Potomac clays, while in the best section about the head of Chesapeake bay (Maulden's Mountain) the sequence from massive Cretaceous greensand above to iron-bearing Potomac clay below is unbroken save by arbitrary lines. In short, it is evident that the Potomac terrane has ever lain near sea-level, and has alternately suffered less by denudation and accretion by sedimentation during oft-repeated oscillations, has been deeply ravined during one epoch only to have the ravines filled largely with its own materials but with some foreign matter and more recent fossils during the next, and has contributed material to each newer formation of the Coastal plain. Its characteristic pebbles have indeed been successively transferred to the newer Mesozoic beds, to several of the Cenozoics, and finally incorporated in the Quaternary.

There is an apparent unconformity between the two members of the Potomac, marked by beds and pockets of gravel superimposed upon erosion planes, as in a noteworthy section three miles southeast of Washington; but since local unconformities, including both erosion planes and accumulations of gravel and bowlders, occur at various horizons in each member, there is some doubt as to the importance of this apparent unconformity.

Fossils.—Until recently animal remains were believed to be exceedingly rare in the formation: fragments of a rib of a cetacean and part of the teeth and bones of a reptile supposed to be related to the Iguanodon are recorded by Tyson from the upper member in Maryland,* the latter being the *Astrodon Johnstonii* of Leidy;† six undescribed species of the fresh water genera *Unio* and *Anodonta* and several "ctenoid fish scales" associated with "leaves of dicotyledonous trees" are noted from the upper member in western New Jersey, and identical *Unios* "from the banks of the Potomac" by Cope;‡ Conrad described from the plastic clays of New Jersey (which are either equivalent to or newer than the upper division of the Potomac formation, but which he regarded as Triassic), two lamellibranchiates, *Astarte veta*, and *A. annosa*;§ and

* First Report Maryland Agricultural Chemist, 1860, 42; cf. Uhler, Johns Hopkins University Circulars, vol. ii, No. 21, 1883, 53.

† Cretaceous Reptiles of the U. S., Smithsonian Contributions to Knowledge, vol. xiv, 1865, 102.

‡ Proc. Acad. Nat. Sci., xx. 1868, 157. § Am. Jour. Conch., iv, 1868, 279.

Whitfield has more recently recognized from the same clays (which he, too, is disposed to refer to the Triassic) five lamellibranchiates—*Astarte veta*, *Ambonicardia Cookii*, *Corbicula emacerata*, *Corbicula annosa* (Conrad's *Astarte annosa*), and *Gnathodon tenuides*.* In the course of an examination of the formation extending over some years, Fontaine has found but a single animal fossil, viz: the posterior portion of a homocercal fish about the size of a salmon from the lower member on James river. Careful search during the past three months has led to the discovery of moderately abundant dinosaurian remains of upper Jurassic type and the upper member between Washington and Baltimore, some of which have already been described by Marsh.†

At several points on the Appomattox and James rivers, on both Anna rivers, about Fredericksburg, on Acquia creek, at Baltimore, and at a number of other localities the laminated beds of clay intercalated within the lower member yield abundant and well preserved leaf impressions; and throughout the whole extent of the formation both members abound in silicified and lignitized wood. Fontaine has collected and investigated the plant remains, and has just sent to press a monograph containing descriptions of over 370 species, of which more than 300 are new. Extensive collections of silicified and lignitized wood have also been made from both members and have been investigated by Knowlton; and eight new species belonging to two new genera have been discriminated and are described and illustrated in a memoir now in press.‡

Viewed as a whole, the Potomac flora is unique. It is, moreover, of special interest in that it records a stage in the development of plant life not known to be represented elsewhere on the globe. The plant history of the earth falls naturally into two eons, instead of the three represented by animal life, during the first of which the various non-dicotyledonous forms (the cryptogams, cycads, conifers, and monocotyledons) of archaic type prevailed, while throughout the second dicotyledonous forms of modern type have greatly predominated,—the transition from the archaic to the modern type being sudden, and the bipartite division being consequently stronger and more trenchant than the tripartite division based chiefly on animal remains. Now the exact period of transition from the archaic flora to the modern one (hitherto placed about the middle of the Cretaceous) § appears to be represented in the Potomac flora; there is a commingling of primitive and recent types in nearly every plant bearing clay bed; the types

* Monog. U. S. Geol. Surv., vol. ix, 1886, 23–27.

† This Journal, xxxv, 1888, 89–94.

‡ Bulletin U. S. Geol. Surv. (in press).

§ Ward, 5th Ann. Rep. U. S. Geol. Survey, 1885, Plate lvi.

are about equally represented in the entire section; and the transition is recorded not only in the commingling of types but in a measure by the assumption of modern external forms while the plants yet retained the archaic internal structure.

It is significant that well preserved leaf impressions are not found in the formation about Washington, in the lower member at the head of Chesapeake bay, in the deposits near the Schuylkill, in the "Yellow Rocks" at Trenton, nor in the immediate vicinity of Richmond—the plant-bearing localities on the James being several miles from the fall-line,—i. e., about the mouths of the Mesozoic prototypes of the great rivers of the region.

Taxonomy.—The general facies of the wonderfully rich flora most closely approaches that of the middle and lower Neocomian of Greenland and Europe, and Fontaine is disposed to refer the formation to the lower Cretaceous on this evidence; but since the flora is manifestly too nearly unique to permit precise correlation, and since Marsh finds the vertebrate remains to be distinctly upper Jurassic, the formation must be at least provisionally assigned to the latter period.

The Tuscaloosa formation of Alabama appears to be the precise equivalent of the Potomac;* and Hill has recently collected data indicating that the Trinity formation (Dinosaur Sand)† of Texas and Arkansas is coeval with the Potomac and Tuscaloosa.‡

Sources of Materials.—Roughly classified, the materials of the Potomac formation are (1) quartzite pebbles, (2) quartz pebbles, (3) arkose, (4) quartzose sand, (5) plastic clay, and (6) various combinations of these.

1. The distribution of the quartzite pebbles is significant: They are abundant and large on James river but diminish rapidly both in abundance and size about to the Appomattox on the south and the South Anna on the north, where they finally disappear—none occurring on the Nottoway or Roanoke, nor on the North Anna, the Rappahannock, or the intermediate smaller streams. They reappear near the Occoquan, and increase rapidly in abundance and size to the Potomac, where they form a predominant element in parts of the formation; but they again diminish in size and abundance northward, becoming inconspicuous north of Baltimore, to once more increase in size and number about the Susquehanna, where the outliers consist almost exclusively of well rounded quartzite pebbles and bowlders. North of the Susquehanna like relations obtain, so far as size is concerned, the pebbles gradually diminishing in size over the Susquehanna-Schuylkill divide, enlarging

* Bulletin U. S. Geol. Survey, No. 43.

† American Naturalist, vol. xxi, 1887, 172.

‡ Science, vol. xi, 1888.

again about the Schuylkill, once more decreasing in size in the outliers lodged behind Chestnut hill and Edge hill, and again assuming considerable dimensions on the Delaware; but in this part of the area of the formation the quartzite pebbles occur on the smaller streams and over the divides as well as on the great rivers. Finally, in the Sand Hills quartzite is nearly or entirely absent. In short, the quartzite pebbles occur only in the vicinity of those rivers which flow through the quartzites of the Appalachian and upper Piedmont regions, and their abundance and size vary with the dimensions of the rivers and the proximity of the ridges.

The composition of the pebbles is equally significant: Those found about Washington and Richmond sometimes exhibit *Scolithus* borings and casts of brachiopods, etc., identical with those found *in situ* in the axial quartzites of the Blue Ridge and adjacent Appalachian ranges in their less metamorphosed portions; the pink quartzite of the pebbles found over the Schuylkill-Delaware divide is in all respects similar to that of certain exceptionally obdurate ledges in the quartzitic axes of the low ranges here encroaching upon the Piedmont region; and the distinctive pebbles are in both these as well as in other cases confined either to the vicinity of the distinctive ledges or to the lower reaches of the rivers transecting them.

So by distribution and composition, the quartzite pebbles of the Potomac formation may be traced to their parent ledges in the Appalachians; and their distribution indicates at the same time the ancient river-courses and the shore lines along which they were transported.

2. The quartz of the second class of pebbles (which sometimes assume the dimensions of respectable bowlders) is petrographically identical with the vein quartz everywhere intersecting the Piedmont crystallines; the pebbles, like those of quartzite, are generally largest in the greater valleys and toward the western margin of the formation, though considerable bowlders occasionally occur in all parts of it; they are most abundant where the quartz veins are large and numerous; and local peculiarities in the vein quartz are reflected in the leeward pebbles. It is evident, in short, that the pebbles are derived from adjacent veins. Indeed in a section in the northwestern part of Washington a train of fragments of a quartz vein intersecting the Archean gneiss and projecting into the superjacent Potomac gravels, is traceable in the gravels for some distance before the fragments so far lose their angles as to become undistinguishable from the neighboring erratic pebbles.

3. The arkose is made up of angular grains of quartz, crystals of feldspar or flakes of kaolin, scales of mica, etc., the

whole sometimes so similar to disintegrated granite or gneiss as to be distinguished only with difficulty. It reaches its best development toward the base of the formation, and especially in the smaller valleys and ravines or on the subjacent gneissic surface; and it is not found in perfection along the lines of the larger rivers. Its petrography and distribution alike justify the inference that it is granitic debris, not far transported.

4. By far the larger part of the quartzose sand, whether in homogeneous beds or intermingled with other constituents of the formation, consists of rounded quartz grains of doubtful origin, but evidently worn by transportation; a smaller part consists of angular quartz grains and flakes such as might be produced by impact of masses during transportation; a yet smaller part is made up of rudely crystalline grains such as result from the disintegration of vein quartz; and the least important element in volume, though it is locally conspicuous and significant, consists of more or less perfect crystals of quartz such as might form the residue of disintegrated granite after the solution and removal of the less obdurate constituents. All of these sources are doubtless represented in the sands of the Potomac.

5. The clay occurs in minute flakes (sometimes of crystalline form) in the arkose, in rounded and irregular pellets and balls up to an inch or more in diameter in the arkose and sand beds, in lenticular or sometimes continuous bands intercalated with sand, and again in considerable beds exhibiting more or less definite structure planes; but whenever pure it is clean, plastic, kaolin-like, and evidently derived from a common source, and the smaller flakes retain the shapes of feldspar crystals undistinguishable from those of the adjacent Piedmont gneisses. The clay in the larger masses it is true appears to be thoroughly triturated, and was evidently deposited in finely divided condition; and the pellets and balls appear to have been washed from such beds and redeposited in conjunction with other materials; but the structural differences between the pseudo-crystalline and the water-laid phases of the clay are no greater than would inevitably result from the trituration and assortment accompanying the breaking up of gneiss or arkose and the separation of the materials of unlike specific gravity and solubility.

6. The heterogeneous and ever varying accumulations of composite character which constitute the larger part of the formation are, qualitatively, just such as would be formed by the assortment and deposition of the different materials by powerful currents; but the quantity of coarse materials in the Potomac formation is greater than would result from simple admixture of the disintegrated gneiss of the Piedmont zone and such

proportion of Blue Ridge quartzite, vein quartz, etc., as appear to be mingled with it, suggesting that the portions of the formation now exposed were littoral, and that the finer materials were swept into deeper off-shore waters.

The History recorded in the Formation.—The conditions of deposition of the lower member of the Potomac formation may be inferred from its structure and composition: the coarseness of the predominant materials is proof of the prevalence of powerful currents or violent waves; the local accumulations of arkose and of finely laminated clay are indicative of quiescent periods, of slack-water eddies, or of sheltered spots on a stormy coast; the frequent alternation of coarse and fine deposits, the broken up and re-deposited clay beds, and the local unconformities, all suggest repeated alternations of slack water and strong currents throughout the area of deposition; the distribution of the quartzite pebbles proves that this material was brought down from the easternmost Appalachian mountains by rivers coincident with the great rivers of to-day, and the unequal altitude of the base of the formation along the rivers and the prevalent coarseness and inconstant structure of the deposits there indicate that the ancient rivers embouched into deep turbulent estuaries, while the interosculation of some of the estuarine deltas and the coarseness of the deposit connecting others prove violent wave action along the intermediate shore; the dearth of remains of marine and estuarine animals is suggestive of turbulent waters; and the peculiar distribution and preservation of the plant remains suggests encroachment of the Potomac ocean upon lands covered with a luxuriant flora. The conditions of deposition of the upper member appear to have been similar but quieter.

From the relations of the formation to the foundation upon which it rests, from structure and composition and indirectly from the conditions of deposition indicated thereby, the physiographic conditions attending the deposition of the Potomac formation may be inferred: The surface upon which the deposits rest is formed of dislocated strata of Archean, Cambrian, Silurian, Triassic and Rhætic age, all degraded to a plain as uniform as the Piedmont zone of to-day—a plain destitute of noteworthy eminences despite the great heterogeneity of the rocks, and one which accordingly must have been reduced to base level; yet the unequal altitude of the deposits about the waterways indicate that this plain was ravined as deeply as is the present Piedmont plain; and the slight sinuosity of the shore line, despite the depth of the ravines, is proof of pronounced seaward inclination of the surface.

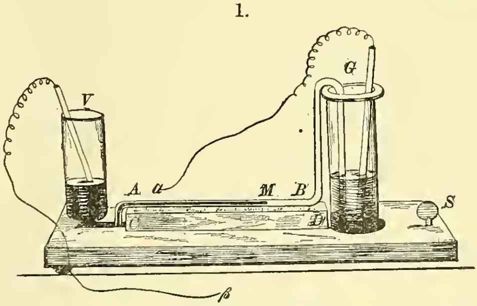
Thus the structure, composition, and stratigraphic relations of the Potomac formation, when freely interpreted, give the outlines of an intelligible and harmonious picture of the Atlantic slope during and for some time antecedent to the Potomac period: Before the initiation of Potomac deposition, but subsequent to the accumulation of the Triassic and Rhætic deposits and to the displacement and diking by which they are affected, there was an eon of degradation during which a grand mountain system was obliterated and its base reduced to a plain which, as its topography tells us, was slightly inclined seaward and little elevated above tide—the Piedmont zone alike of the later Mesozoic and the present; and over this plain meandered the prototypes of the Delaware, the Susquehanna, the Potomac, the James, and the Roanoke, within a few miles at most of their present courses and but a few hundred feet above their present channels, flowing slack and in shallow valleys because at base level. There followed a slight elevation of the land, when the rivers attacked their beds and excavated valleys as deep as those to-day intersecting the Piedmont plain; but whether or not there was concomitant tilting of the land, the phenomena thus far fail to indicate. Then came the movement by which the deposition of the Potomac formation was initiated—the deeply ravined base level plain was at the same time submerged and tilted oceanward; its waterways became deep but short estuaries; deep oceanic waters extended quite to the intermediate shores; the declivity and transporting power of the rivers was increased; and the accumulation of coarse delta and littoral deposits progressed rapidly. With continued deposition the sea gradually shoaled, the declivity of the land decreased, the materials became finer and finer; there was probably temporary emergence of the land about the middle of the Potomac period, followed by renewed submergence without seaward tilting during which the clays of the upper member were laid down; and the period was finally closed by an emergence represented by the unconformity between the upper Potomac and the glauconitic deposits of the Maryland Cretaceous.

There is a great hiatus in the geologic history of the Atlantic slope: The history is fairly legible up to the termination of the Paleozoic deposition, and it is even more clearly legible from mid-Cretaceous time to the present; but the hiatus includes the most interesting period in the evolution of the eastern portion of the continent. The transfer of sea and land; the elevation and corrugation of the Appalachians, and the profound displacement and metamorphism of the Piedmont rocks; the degradation of thousands of feet if not miles of strata and the transportation of the materials whither no man knows; the deposition of the Triassic and Rhætic rocks under conditions which no geologist has ever clearly pictured in imagination—at least to the satisfaction of his fellow geologists; the Triassic displacements and diking; the post-Triassic degradation of thousands of feet of strata and the removal of the debris to other regions—these and many other remarkable episodes have been completely blotted out of the geologic record as commonly interpreted. But the Potomac formation narrows the hiatus: the formation itself carries the record back from mid-Cretaceous time to the earliest dawn of the Cretaceous or the closing episodes of the Jurassic; and the post-Rhætic and pre-Potomac degradation will tell the story of the Jurassic as eloquently, when men have come to read geologic history in erosion as well as in deposition, as if the deposits of the period were exposed to observation instead of lying beneath the thousands of feet of newer strata forming the Atlantic bottom. So while the hiatus is not yet closed it is reduced by a fifth, a fourth, or perhaps a third of its length.

ART. XII.—*Experiments with the Capillary Electrometer of Lippmann*;* by JULIUS HOWARD PRATT, JR.

THE objects of this investigation have been, first, to determine the limits within which the given form of electrometer can be used; secondly, to ascertain whether the polarization of the mercury surface is such as to prevent the passage of a current while the instrument is in use; and, thirdly, to determine the amount of charge retained at the polarization surfaces when the mercury column is in equilibrium.

1.



The instrument used in these experiments was constructed as follows: V is a thistle tube, the tubing of which (A B) was bent in the manner indicated (fig. 1); G is a small glass vessel

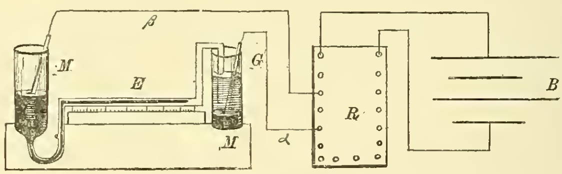
* Abstract of a thesis presented for the degree of Doctor of Philosophy at Yale University, June, 1887.

containing mercury and dilute sulphuric acid; *α* and *β* are platinum wires which serve as conductors for the electric current. They pass through the glass tubes in vessels G and V, and are fused into the tubes at the end; the platinum electrodes, accordingly, have only a small area. The end of A B itself is filled with sulphuric acid to M, the mercury meniscus. S is a leveling screw. The whole is mounted on a wooden base to give it stability. C D is a millimeter scale on which the readings are made.

For most of the work done the unaided eye, or a small magnifying glass was sufficient to make the readings,—as the differences of deflection for slight differences in E. M. F. were comparatively great. For instance, the difference of deflection between ·02 Daniell and ·03 Daniell was, for a given adjustment, 2·4 millimeters; hence, ·1^{mm} (which can easily be read) showed a difference of about ·0004 Daniell. For the experiments in quantity of electricity a micrometer was used, by which readings could easily be made to $\frac{1}{200}$^{mm} with accuracy.

I. Lippmann states * that the value of the capillary constant in his instrument increases for increasing potentials to about ·9 Dan. and then diminishes. The same results are obtained with the form here given.

2.



Two Daniell's cells are connected as shown in figure 2. R is a resistance-box of 10,000 ohms, through which the current passes. By the wires *α* and *β*, fractions of the current are made to pass through the electrometer. The accompanying table and plot (No. I, fig. 4) will exhibit the results. Column I gives the fraction of the E. M. F. of a Daniell cell which produces the deflections given in column II.

TABLE I.—March 1, 1887.

E. M. F.	Deflect.	E. M. F.	Deflect.	E. M. F.	Deflect.	E. M. F.	Deflect.
·008 Dan.	1^{mm}	·16 Dan.	28·2^{mm}	·60 Dan.	77·4^{mm}	1·2 Dan.	80^{mm}
·016	2·3	·20	34·7	·80	88·0	1·4	64
·04	7·2	·30	49·5	·892	90·3	1·6	50·2
·08	14·5	·40	60·7	1·0	89·0	1·8	42·5

In taking the deflections for the higher of these potentials 1·2 to 1·8, electrolytic action was noticed and bubbles of gas

* Annales de Chim. et de Phys., Ser. V, vol. v; E. Mascart, Traité d' Électricité Stat., ii, p. 550.

formed on the mercury surface. It is necessary in all these investigations that the current pass in such a way as to produce hydrogen polarization. Oxygen polarization does not change the capillary constant in any regular manner. Moreover the use of even comparatively low potentials with oxygen polarization causes chemical action so that the surface of the mercury is fouled, which seriously interferes with the action of the instrument. Two series of deflections of the meniscus for given electro-motive forces were made. In one series hydrogen polarization was used, and in the other, oxygen. The series with hydrogen polarization, was regular, as before; but that of oxygen, except for very low potentials, was so irregular that no conclusions could be drawn. Apparently the position of the meniscus depended largely on the chemical action caused by the current.

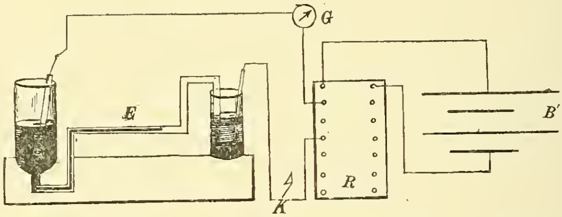
In using Lippmann's electrometer it might be convenient to dispense with the mercury contact and employ only sulphuric acid and platinum. A set of observations was accordingly taken, in which the mercury was removed from the vessel G and the platinum wire served as electrode. The surface of the platinum in contact with the sulphuric acid being so small, it was found that, owing to polarization of the platinum-sulphuric acid surface, a given potential would produce a deflection only a fraction of that produced with mercury as electrode. With the platinum electrode the maximum point on the curve was for potential about 1·5 Dan. instead of 0·9 Dan. as was the case with the mercury electrode. The small capacity of the platinum electrode will sufficiently account for this. If, then, platinum electrodes be used in place of mercury, care should be taken to have their capacity great compared with the capacity of the mercury meniscus.

It should be noted, then, that, in actual use, Lippmann's electrometer makes a good means of measuring low potentials, up to 0·6 or 0·7 Dan.; that care must be taken to avoid oxygen polarization and employ hydrogen polarization only; that the inner surface of the glass tube should be kept free from dust and traces of acid, which occasion irregularities in the deflection of the mercury. The instrument in this form can be used to advantage for comparing E. M. F. of different batteries. Only a part (a known fraction) of the current should be used; as, otherwise, the limits of the instrument might be exceeded. By using a micrometer for reading deflections, about $\frac{1}{20000}$ Daniell's cell E. M. F. can be detected. The electrometer might be used successfully in many cases for a galvanometer, especially where it is desirable not to alter the main current by a derived galvanometer circuit. It may be recommended for such service, first on account of its comparative rapidity in coming to a state of equilibrium; secondly, because it is practically a dead-beat instrument; and, thirdly, because the readings may be made directly, and show immediately their relation to E. M. F. The ease with which the instrument is constructed puts it within reach of all who have some ability in glass-blowing.

II. *To ascertain whether a current passes when the mercury surface is polarized.*

For this purpose the instrument was connected as before, and, in addition, a reflecting galvanometer and a key were placed in the branch with the electrometer. The deflections were observed by means of a telescope and millimeter scale about four feet from the galvanometer. It was easy to detect a deflection amounting to $0{\cdot}1^{mm}$ which, for the distance of the galvanometer from the scale meant an exceedingly minute deflection; and hence an insignificant current. The arrangement can be seen from figure 3. B is the battery of two Daniell's cells. R is a resistance-box of 10,000 ohms. E is the electrometer; K, the key; and G, the galvanometer.

3.

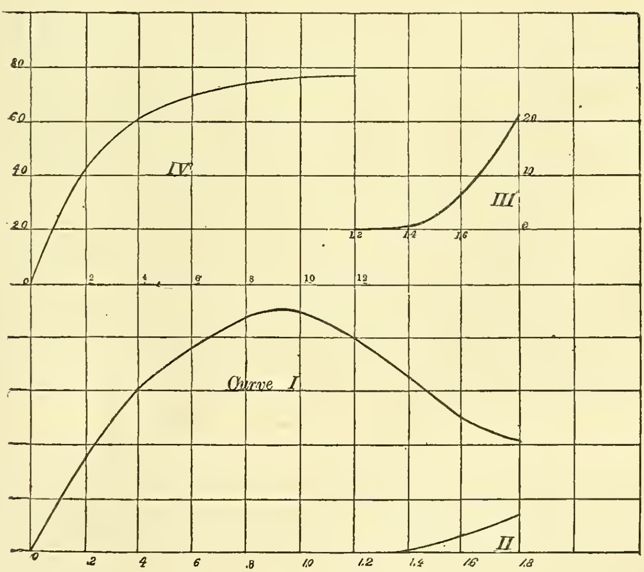


The current from the battery was passed through the resistance-box. Known fractions of this current made the circuit through the electrometer and galvanometer. Before the mercury reached the position of equilibrium, there was evidence of a current through the galvanometer; but when once the mercury came to rest, the deflections of the galvanometer ceased. This was true for low potentials and until the E. M. F. reached about 1·4 Dan. Plot II. and Table II., given below, will show the results obtained for hydrogen polarization. The first column gives the potential of the current passed through the galvanometer, and the second gives the final deflection of the galvanometer needle, measured in scale divisions (^{mm}) and indicating the strength of the current through the galvanometer.

TABLE II.—March 22, 1887.

E. M. F.	Deflect.	E. M. F.	Deflect.	E. M. F.	Deflect.
·01 Dan.	0	·40 Dan.	0	1·41 Dan.	1·0^{mm}
·02	·1^{mm}	·60	·1^{mm}	1·42	2·0^{mm}
·04	0	·80	0	1·50	3·0^{mm}
·08	0	·90	0	1·60	7·0^{mm}
·10	·2	1·00	0	1·80	13·0^{mm}
·20	0	1·40	·5^{mm}		

The deflections obtained for the E. M. F. 0·02 D., and 0·1 D. 0·6 D. are evidently accidental. Neglecting these, it is evident that no appreciable current passes through the electrometer until the potential of its surface reaches 1·4 Daniell. This, it will be remembered, is not the highest point of the curve showing the deflection of the mercury in the electrometer. That point is reached when the potential of the mercury surface is 0·9 Daniell. The point at which conduction begins is about the point at which electrolysis begins. The collection of gas bubbles (before mentioned), when potentials of something over one volt were used, indicate that electrolysis actually does take place. The results of this investigation will prove that conduction through the electrometer begins about the same time.



On April 1, 1887, a series of measurements was taken to determine the exact point at which conduction begins. In this series, before each observation, the sulphuric acid was run through the tube to cleanse the surface; and the bubbles of gas, if any, were driven from the tube. The arrangement of the instrument was the same as before, and the readings were taken with great care.

TABLE III.—April 1, 1887.

E. M. F.	Deflect.	E. M. F.	Deflect.	E. M. F.	Deflect.
1·20 Dan.	0	1·32 Dan.	·25 mm	1·44 Dan.	1·30 mm
1·21	0	1·34	·35	1·50	2·30
1·22	·05 mm	1·36	·45	1·60	6·70
1·24	·10	1·38	·55	1·70	12·90
1·26	·15	1·40	·60	1·80	21·20
1·30	·20	1·42	1·20		

Since in a Daniell's cell the replacement of one gram-equivalent of zinc evolves 24,200 cal. of heat; and, when one gram of hydrogen and 8 grams of oxygen unite to form one gram-equivalent of water, 32,462 cal. of heat are evolved,* therefore a cell of potential $\frac{32462}{24200}$ Dan. (equals 1·34 Dan.) would be just sufficient to decompose water. For about this potential (1·34 Dan.) it might be supposed that conduction through the electrometer would take place. Molecular changes which accompany electrolytic action may, very probably, slightly precede it and cause variations in the electrical conditions which allow a current to pass. If, moreover, there were any leakage in the instrument, this would be evidenced by a current through the galvanometer, when the potential was below 1·34 Dan. Defective insulation would cause leakage, and conduction would begin at a somewhat lower potential. It will be seen by reference to the table that conduction begins not far below the electrolytic limit, i.e., at 1·22 Daniell; and that, at first slowly and then rapidly, it increases with the potential.

When the mercury was treated with oxygen polarization, conduction began at very low potentials. An E. M. F. of 0·01 D. gives a permanent deflection of 6^{mm}; and other higher potentials gave higher deflections; which, however, seem to follow no uniform law. This, like the former experiments with oxygen polarization, shows that such polarization cannot be too carefully avoided.

III. *To determine the capacity of the electrometer.*—Three methods of making this determination were tried. The nature of the instrument makes it impossible to secure rigorously accurate results. However, several not inconsistent values of the instrument's capacity were secured, and the final determinations should be regarded as fair approximations. By the first method a condenser of one microfarad capacity was charged with electricity at a known potential (V), and the charge was

* Daniell's Physics, p. 609. London, 1885.

then passed through the electrometer and the deflection noted. By reference to the E. M. F. curve for the electrometer the potential (V') for the given deflection was found. The electricity being divided between the two instruments the proportion will hold $V : V' :: C+C' : C$, where V equals the potential of the condenser, V' equals the potential of the electrometer, and C and C' the capacities of each. By division, $V-V' : V' :: C' : C$, or $C'=\frac{V-V'}{V'}C$. As V' is found to be small compared with V, the equation $C'=\frac{V}{V'}C$ will be approximately true. This method has some disadvantages which make it impracticable for accurate results. The discharge from the condenser being practically instantaneous, its full force is exerted at once on the mercury, the inertia of which is apt to carry it beyond the position to which an equal amount of electricity, in the ordinary use of the instrument, would bring it.

On the other hand, the tendency of the electrometer to discharge itself acts in the opposite direction and prevents the exact determination of the deflection. The results from this method cannot be accepted as satisfactory. The only safe conclusion is that the capacity of the electrometer is great compared with that of the condenser.

By the second method employed, the condenser and electrometer were placed in the same circuit, and the current passed through both in series. The ratio of the E. M. F. of the current to the potential indicated by the deflection of the electrometer gives the capacity of the electrometer compared with that of the condenser. The self-discharge of the instrument acted very disadvantageously. When the current, passing through the electrometer, had charged the condenser, the latter acted like an infinite resistance in the circuit, and the mercury of the electrometer, instead of remaining at the point to which it had been deflected, moved from it and gradually returned to zero. As the readings were made with a micrometer, and could not be taken immediately, this movement prevented accuracy. The indication was, as in the other method, of a capacity far greater than that of the condenser.

To secure more satisfactory results a third method, without condenser was resorted to. A resistance box of 250,000 ohms, of which 240,000 ohms were used, was put in circuit with the electrometer, and currents of known potentials were passed through the two. As the passage of a definite amount of electricity through the electrometer is necessary to bring the meniscus to a given position, the movement of the mercury was retarded by the introduction of the large resistance. The slow motion made it possible at any instant to determine the position of the meniscus. The deflections for equal successive intervals of time were thus obtained. Series were made for various E. M. F. from 0·2 D. to 1·0 D. with accordant results. The table and curve IV (fig. 4) will show the results when a current of 0·6 Dan. was used. With a large resistance in the circuit, the mercury never reaches the point to which a current of the same potential with small resistance would bring it. The deflections of 0·6 Dan. without large resistance is 81^{mm}. That found after thirty minutes passage of the current with resistance was 78^{mm}.

TABLE IV.—May, 1887.

Deflect.	Time.	Deflect.	Time.	Deflect.	Time.	Deflect.	Time.
$24·8^{mm}$	1 min.	$66·2^{mm}$	5 min.	$75·2^{mm}$	9 min.	$76·8^{mm}$	13 min.
43·0	2	69·8	6	76·2	10		
54·0	3	72·2	7	76·5	11		
61·0	4	74·0	8	76·8	12		

Since the movement of the mercury is slow we may assume that, during the excursion of the mercury, the E. M. F. at the surface of polarization varies according to the curve of the potentials, and that at any instant the position of the meniscus determines the E. M. F. We have, thus, a means of computing the capacity of the instrument for a given potential. By Ohm's law $I=\frac{E}{R}$. Also C (capacity) $=\frac{Et}{R}$. By reference to curve IV, it will be seen that a portion of the curve between any two points taken sufficiently near to each other will differ but slightly from a straight line; hence the mean of the E. M. Forces at the beginning and end of any short interval of time will give the mean potential of that interval. If E_1 equals E. M. F. at the beginning of the first interval of time; E_2 that at the beginning of the second, etc., the capacity is represented by the equation

$$C=\frac{t}{R}\left(\frac{E_1+E_n}{2}+E_2+E_3+\ldots\ldots\ldots+E_{n-1}\right)$$

R is the inserted resistance plus the resistance of the electrometer. The latter was found to be, approximately, 10,000 ohms; so that R equals 250,000 ohms. The interval of time (t) was 60 seconds Computation gives for potential 0·2 Dan., C equals 314 mfds.; 0·4 Dan., C equals 445 mfds.; 0·6 D., C equals 605 mfds.; 0·7 D., C equals 648 mfds.; 1·0 D., C equals 730 mfds. The values for the capacity are approximate and will apply only to the instrument in question. In this the radius equals $0·64^{mm}$ about, and hence the surface of the mercury, regarded as hemispherical equals about 2·572 sq. mm. The radius of the tube was found by measuring the length of a column of mercury (for the hemispherical shape of whose ends due allowance was made) in the tube, and weighing the mercury. From these two factors the radius of the tube was computed.

In regard, then, to the Lippmann's Electrometer it has been shown: First, that, when hydrogen polarization is used, the deflections of the meniscus may be taken as proportional to the E. M. F. for very low potentials, and that for potentials up to 0·9 D. an empirical curve will show the relation between the E. M. F. and the deflection. Secondly, that polarization is complete, and that no appreciable current passes through the electrometer until it be charged to a potential near that at which electrolytic action begins. Thirdly, that the capacity of the Lippmann Electrometer is very considerable, compared, for example, with that of the Thomson Quadrant Electrometer, being in the particular instrument studied, several hundred microfarads.

The investigation, of which a summary is given in the preceding pages, was carried on at the Sloane Physical Laboratory of Yale University under the direction of Prof. A. W. Wright, to whom I would here express my grateful acknowledgment for his encouragement and advice.

Cornell University, Ithaca, N. Y., November, 1887.

Art. XIII.—*On the Period of the Rotation of the Sun as determined by the Spectroscope;* by Henry Crew, Assistant in Physics, Johns Hopkins University.

Zöllner* and Vogel were the first to measure the rotation of the sun by the use of Doppler's principle. For this purpose, they employed the so-called "reversion spectroscope" of the former. This had two prisms with their refracting edges turned in opposite directions, thus forming two spectra, side by side, in opposite directions, the one serving as a vernier for the other; any displacement of a line will be doubled, since the deviation in one spectrum is the opposite of that in the other. For their results, however, the authors claim little more than a qualitative value.

Hastings,† two years later, by a very ingenious device compared the spectra of the center and the limb of the sun, but gave no *quantitative* observations on the displacement of the lines which he observed in passing from one of these regions to the other. Langley‡ has devised an instrument which gives, in juxtaposition, the spectra of light from any two points, distant 180° on the circumference of the solar disc. He has noted, in rather an incidental way, the displacement due to rotation of

* Zöllner: Pogg. Ann., cxiv, 449, 1871.
† Hastings: this Journal, v, 369, 1873.
‡ Langley: this Journal, xiv, 140, 1877.

the sun, when examining an *equatorial* diameter, and the absence of any displacement when comparing the extremities of the *polar* diameter, and has also commented on this as a means of separating the solar and telluric lines.

In 1876, Prof. Young* published the first accurate measurements of the linear velocity of a point on the solar surface. These were made with a spectroscope attached to a 9½ inch equatorial, and fitted with a Rutherfurd grating, ruled with 8640 lines to the inch. His result is for a mean latitude of 7° and is reduced to the equator by Faye's formula for the proper motion of sun spots. The velocity thus obtained, 1·42 miles per second, is so large as to suggest a physical significance, viz: that the reversing layer, whatever and wherever it may be, has a greater angular velocity than that layer of the solar surface in which the sun spots lie, a conclusion very interesting considering that the observations of De la Rue,† Stewart, and Loewy at Kew appeared to show a lagging behind of that layer of the solar atmosphere in which the faculæ occur, a layer probably at no inconsiderable distance *above* the altitude of sun spots.

Carrington,‡ by a magnificent series of laborious observations, extending over seven years, has determined what may be called the proper motion of the photosphere, or more strictly, the law according to which sun spots move relatively to one another in latitude and longitude.

Have the different parts of the *reversing layer* a relative motion, and if so, what is the law which governs it?

It was in the hope of obtaining at least a partial answer to this question that the following observations were made.

Apparatus.—The light was furnished by an equatorial heliostat with an auxiliary plane glass mirror. Leaving the heliostat, the ray next fell upon a condensing lens of 8^{cm} diameter and 135^{cm} focal length, thus giving upon the slit of the collimator, an image 12·5^{mm} in diameter. For the following apparatus to move the image across the slit, I have to thank the kindness and skill of Prof. Rowland. The condensing lens was screwed into a rectangular wooden frame which was fastened at the bottom by a single bolt to a larger iron frame. This bolt was parallel to the optical axis of the lens, and the lens could be made to rotate about it through an arc of 5 or 10 degrees, the arc being limited by adjustable stops. The iron frame was, in addition, capable of lateral motion, while the lens in the wooden frame could also be adjusted vertically. These adjustments enabled the observer to bring either limb of the

* Young: this Journal, xii, 321, 1876. † Proc Roy. Soc., xiv, 37.
‡ Carrington: Observations on solar spots, London, 1863.

sun exactly on the slit, and to compensate for any slight error in placing the heliostat or in the rate of its clock. The levers by which these motions were accomplished were placed convenient to the observer at the eye-piece. The collimator and telescope each had an achromatic objective of 6½ inches diameter, made by Prof. Hastings; the former had a focal length of 7 feet and 3 inches, the latter of 7 feet and 10 inches. The angle made by their optical axes was 12°. Both were firmly attached to a long heavy cast iron frame. For the purpose of holding and rotating the grating, this iron frame carried upon it the tripod, circle (14 inches in diameter), and platform of a spectrometer. This whole system rested on a solid brick pier supported on heavy beams. These beams rested upon two partition walls of the new physical laboratory, making altogether a rigid, convenient, and accurate instrument, in which the relative position of the collimator, telescope, and grating, could be maintained perfectly constant.

The eyepiece of the telescope was fitted with a micrometer screw by Grunow; in its focal plane was fixed a very thin vertical glass scale, ruled in half millimeters. By this means the width of the narrow band of the spectrum during any one reading was measured, and a slight correction corresponding to this overlapping of the sun's image on the slit was introduced into the final value of each set of observations. The grating, a plane one ruled by Prof. Rowland, was 4 inches in length and had 14436 lines to the inch. The spectrum of the fourth order on one side gave superb definition, widely dividing b_3 and b_4 and the lower component of E. The definition in the fifth order was, of course, not so good—though better than most of the Rowland gratings ruled with this number of lines; but in this and higher orders it was found that about as much was lost by poorer definition as was gained by increase of displacement.

To determine the angle which the slit of the spectroscope makes with the projected solar axis, the following method was suggested by Prof. Rowland. Between the slit and the condensing lens was inserted a Steinheil prism mounted in a brass tube with a divided head. This tube was so placed as to have its axis in the prolongation of the optical axis of the collimating telescope, and was made so as to rotate about this axis carrying with it the prism. The prism was placed with its refracting edge perpendicular to the ray. Before the mirror of the heliostat was suspended a fine wire plumb line. The image of this plumb line was brought to focus on the slit plate by a spectacle lens temporarily placed between the prism and the condensing lens. The angle between this image and the slit could now be measured by rotating the prism; the zero position of the prism being that in which two fine plumb lines, the one before, the other behind, the prism, were brought to coincidence. Having obtained this angle (by formula given below), we have but to add to it the parallactic angle, and the position angle of the sun, with their proper signs, to obtain the required angle, viz: the angle which the projected axis of the sun makes with the slit. This angle must finally be corrected for the inclination of the solar axis to the plane of the ecliptic; a correction never amounting to one per cent.

Theory and Observations.—Let V = velocity of light, 186328 miles per sec. (Newcomb and Michelson).

λ = wave length of ray observed (Rowland's Standards).

$v'-v''$ = relative linear velocity of the two limbs of the sun *at the equator.*

χ = heliocentric latitude of any point on the sun's limb at which the slit of the spectroscope is tangent; call this the "latitude of observation."

$\varDelta$ = displacement of the line as measured on the micrometer.

c = value of one revolution of the micrometer screw in Ångstrom's units, *for the line observed.*

h = half the angle subtended at the center of the sun's image by the length of slit covered by the image.

θ = inclination of plane of solar equator to plane of eliptic.

φ = angular semi-diameter of the sun.

a = linear velocity of the earth in its orbits, expressed in miles per second.

Then, by Doppler's principle, we have

$$v'-v''=\frac{c\varDelta V}{\lambda \cos\chi}\cdot\frac{1}{\cos h}\cdot\frac{\sqrt{1-\sin^2\chi\cos^2\theta}}{\cos\chi\cos\theta}+a\sin\varphi$$

where the factor $1/\cos. h$ is the correction for the overlapping of the sun's image on the slit; this correction is sufficiently approximate except for very high latitudes, where a slight correction depending upon χ must be introduced. The factor involving the radical is the correction for the inclination of the solar axis to the plane of the ecliptic. The addition of the last term on the right (first suggested by Prof. Oliver) reduces the velocity from the *synodic* to the *true* period* of rotation. The correction due to the rotation of the earth is so small as to be negligible.

The following are two specimens of the individual observations; the quality of the one being above, that of the other below, the average.

* In comparing my final results with those of Young and Vogel it must be borne in mind that they have not made this reduction, and that therefore their values are for the synodic period.

July 16th, 1887.

Spectrum of 4th order; line, E_2;
Width of spectrum, 2^{mm};
Definition, good:
Half angle between plumb line and slit,
at $1^h\ 02^m = 24°\ 30'$
at $1^h\ 44^m = 37°\ 00$
Readings on micrometer were
begun at $1^h\ 29^m$
ended at $1^h\ 40^m$

Micrometer reading.		Displacement.
Eastern limb.	Western limb.	
rev.	rev.	
17·698	17·777	0·079
·710	·779	69
·719	·799	80
·692	·774	82
·718	·799	81
·716	·797	81
·701	·760	59
·692	·765	73
·673	·726	53
·675	·742	67
·682	·762	80
·661	·719	58
·656	·739	83
·665		
Mean ·6899	·7645	
rev. ∴Δ=0·0746		

June 18th, 1887.

Spectrum of 4th order, line, E_2
Width of spectrum, $2\frac{1}{2}^{mm}$
Definition, fair;
Half angle between plumb line and slit,
at $10^h\ 39^m = 29°\ 54'$
at $11^h\ 53^m = 3°\ 36'$
Reading on micrometer were
begun at $10^h\ 59^m$
ended at $11^h\ 14^m$

Micrometer reading.		Displacement
Eastern limb.	Western limb.	
rev.	rev.	
17·147	17·231	0.084
·187	·267	·080
·208	·276	·068
·212	·284	·072
·196	·266	·070
·191	·273	·082
·212	·290	·078
·204	·293	·089
·212	·283	·071
·211	·284	·073
·212	·294	·082
·218	·296	·078
·214	·283	·069
17·2018	17·2785	
rev. ∴Δ=0·0767		

To compute the "latitude of observation," χ, for these two sets, we have

$$\chi = g + p + q$$

where
- g=angle between projected image* of plumb line and slit, at the mean time of observation.
- p=position angle, taken from Secchi's table; *Le Soleil*, 2d Ed., p. 22.
- q=parallactic angle, tabulated for the latitude of Baltimore.

Thus on July 16th, at $1^h\ 35^m$ P. M. we have

$$g = -68°·64;\ p = -4°·40;\ q = +41°·94$$

whence $\chi = 31°·10$.
and on July 18th, at $11^h\ 07^m$ A. M.

$$g = +39°·90;\ p = -5°·26;\ q = -32°·64$$

whence $\chi = 2°·00$,

* It must be noted that during the micrometer readings the prism was removed for the sake of definition and that, when the prism was in position, the *image* of the plumb line was rotated throguh twice the angle the prism was turned.

The following table includes all observations made; they are arranged in order of increasing latitudes. In the sixth column, are given the equatorial velocities, corresponding to the synodic period; these are obtained by dividing each of the *observed* velocities by the cosine of its respective latitude, given in column five, i. e., on the assumption that the sun rotates as a solid body. In column 7 will be found the differences between each value in column 6, and the mean of all the values in column 6.

TABLE I.

Date.	Mean Time of Observation.	Line Observed.	No. Settings.	Latitude of Observation.	$(v'-v'')-a \sin \phi$ (miles per sec.)	Differences.
July 16	11^h 23^m	"1474"	13	0°·47	2·223	—·128
Feb. 28	1 29	b	6	1·05	2·177	—·174
July 18	11 07	E_2	13	2·00	2·150	—·201
July 18	11 42	D_1	13	6·35	2·297	—·054
July 12	11 11	D_2	13	6·64	2·070 ?	—·281
Mch. 8	1 06	5173·8	10	6·81	2·293	—·058
Feb. 28	1 42	b	8	6·96	2·408	+·057
July 12	11 52	"1474"	13	7·37	2·309 ?	—·042
July 18	10 54	E_1d	10	8·66	2·219	—·132
Mch. 8	12 50	D_1	9	10·35	2·327	—·024
Mch. 15	12 45	5173·8	10	10·37	2·531	+·180
Mch. 30	12 16	D_2	15	11·84	2·405	+·054
July 15	11 53	E_1d	13	11·86	2·067 ?	—·284
July 22	12 33	"1474_2"	13	14·47	2·371	+·020
Mch. 8	12 33	D_1	9	14·74	2·434	+·083
Feb. 28	12 25	5173·8	12	15·37	2·543	+·192
July 16	1 16	D_2	13	15·83	1·950	—·401
Mch. 15	12 25	D_1	9	16·06	2·272	—·079
Mch. 30	1 59	D_2	12	16·18	2·406	+·055
July 15	1 26	"1474"	13	18·36	1·914 ?	—·437
July 15	11 54	D_2	13	18·44	2·093 ?	—·258
July 18	12 37	"1474"	13	19·58	2·228	—·123
Feb. 28	12 41	5173·8	7	20·75	2·756	+·405
July 22	1 00	D_1	13	21·89	2·083	—·268
Mch. 8	12 41	5166·3	8	22·19	2·670	+·319
Mch. 26	1·55	D_1	10	23·17	2·720	+·369
Mch. 8	12 19	D_1	7	23·28	2·570	+·219
Mch. 16	11 47	5173·8	10	24·51	2·727	+·376
Mch. 8	11 53	5171·7	7	24·96	2·719	+·368
Mch. 11	11 53	D_1	6	26·34	2·514	+·163
Mch. 30	11 18	"1474"	22	27·16	2·565	+·214
Mch 11	11 35	5173·8	6	27·45	2·691	+·340
Mch. 8	11 38	5171·7	14	28·87	2·496	+·145
Mch. 16	11 28	D_1	10	29 00	2·360	+·009
July 12	1 41	E_1d	13	30·00	2·475	+·124
Apr. 8	11 24	D_1	10	30·64	2·366	+·015
July 16	1 35	E_2	13	31·10	2·427	+·076
July 18	1 33	E_1	13	33·51	2·211	—·140
Apr. 8	11 03	D_2	10	34·74	2·519	+·168
Apr. 8	10 38	D_1	10	40·73	2·681	+·330
July 14	2 52	"1474"	13	45·28	2·070	—·281

The observations in latitudes 6°·64, 7°·37, and all those of July 15th were made when the definition was marked "poor," "very poor," "sky covered with thin clouds," etc.; I have therefore marked these doubtful, but have not rejected them entirely. The values of $v'-v''$ above given are for the synodic period. The weight given to each observation is proportional to the "number of settings."

Reducing by the method of least squares, we have (since $a \sin \varphi = 0·086$ miles per sec.) for the mean equatorial velocity,

$$v'-v'' = 2·437 \pm ·024 \text{ miles per sec.}$$

which corresponds to a true period of 25·88 days.

Errors.—When it is considered that the total displacement amounts to only $\frac{1}{77}$ of the distance between the D lines, it will not be surprising if the largest error is that made in setting the cross hairs on the lines. Two smaller errors may have been introduced by the unequal heating of the jaws of the slit; and by a slight vertical displacement of the sun's image when shifting from one limb to the other. But these must have been of the second order, for immediately before making an observation, the adjustment of the instrument was tested by setting on a sharp atmospheric line. Not the slightest motion could ever be detected. Since we require only the *difference* of the readings on the two limbs, and since these are taken in rapid succession, and under conditions practically identical, it will be observed that all the ordinary errors of the spectrometer, except that of setting the cross-hairs, are eliminated. Errors of this kind are, however, such as would, to a great extent, counterbalance each other in a large series of observations. On the contrary, a single setting differed from the mean of the series to which it belonged, on the average, by 11 per cent, while 41 sets of observations (of eleven settings each) still differ from their mean by as much as eight per cent. This leads one to suspect the presence of irregular horizontal currents. For the *regular* variation of angular velocity with latitude, described below, is certainly not sufficient to account for an average error of eight per cent. Currents having velocities, very moderate indeed, compared with some already observed by Prof. Young,* would more than account for all the irregularities of these observations even if they were perfect in other respects.

Results.—When beginning this work, I expected to find the angular velocity *decreasing* as the latitude of observation increased, as in Carrington's curve for the motion of sun spots, figured in Lockyer's *Chemistry of the Sun*, p. 425. On the

* See also Schellen: Spectrum Analysis, (London, 1885), pp. 378–388.

contrary, it will be seen that, taking either of the observations made during the month of March, or those made in July, there appears to be a gradual *increase* of daily angular motion with latitude. For the values of $v'-v''$, given in column 6, Table I, are equatorial values, reduced from higher latitudes of observation, on the assumption that the sun rotates as a solid body; they are therefore proportional to the angular velocities in their respective latitudes of observation. From column 7, Table I, it is seen that the differences, between each particular value of the equatorial velocity of rotation and the mean of them all are, for the lower latitudes, mostly negative; for the higher latitudes, mostly positive. If there is any physical meaning to be attached to this, it would seem that while the sun-spot layer (or photosphere, if they be the same) is *accelerated* in the neighborhood of the equator, the layer, which by its absorption gives rise to the Fraunhofer lines, tends to *lag* behind, having here a smaller angular velocity than in higher latitudes. I have drawn through the observations the straight line which most nearly represents this change of angular velocity with latitude, and find, by the method of least squares, its equation to be

$$v=1{\cdot}158 \cos \chi^{\circ} \ (1+0{\cdot}00335\chi^{\circ})$$

where v is the linear velocity in miles per second of any point in latitude χ° of the sun's reversing layer. This gives for the daily angular motion of any point on the reversing layer

$$\theta=794' \ (1+0{\cdot}00335\chi^{\circ})$$

while from sun-spots, Carrington* obtains for the photosphere

$$\theta=865' \ (1-0{\cdot}191 \sin \tfrac{7}{4}\chi^{\circ})$$

As will be seen from Table I, the greatest irregularities in the value of $v'-v''$ occur between the latitudes 15° and 25°. May this not be connected with the fact that this is the region most favored with sun-spots, the *zone royale?*

Two neighboring lines† in the solar spectrum are often so differently affected by disturbances on the sun's surface as to indicate that the absorbing layers to which they respectively belong are situated at widely different heights.

That locus of absorption which is highest will, if we assume the sun a solid, rotate with the greatest equatorial velocity, and one might think that the values of $v'-v''$ for different lines should therefore arrange themselves in the same order as their corresponding metals in the sun's atmosphere. But with a tangential slit, as used in these measurements, it will be seen that the section of the solar sphere made by a plane passing through the slit and line of sight cuts each layer (for any given latitude) in a different heliocentric longitude; so that however

* Carrington: Observations on Solar Spots, p. 224. † Young: Sun, p. 100.

these different absorbing loci may differ in their distance from the center of the sun, the velocity of each portion of the section, *resolved in the line of sight*, will be the same.

It will not be surprising, therefore, if in the following table no connection is seen between the order of the velocities and the order in which the elements are generally supposed to be distributed* in the solar atmosphere.

TABLE II.

Line.	No. obs.	Substance.	$v'-v''$
E_2	26	Fe	2·289
"1474"	74	Helium + Fe	2·291
E_1 (double)	36	Fe + Ca	2·302
D_2	50	Na	2·320
D_1	106	Na	2·420
5173·838	55	Ti (?)†	2·590
5171·714	21	Fe	2·608
5166·3	8	Fe ‡	2·670

As a further possible test, I selected the "1474" line, of which the upper component is helium, and the lower, iron. It, if any, might be supposed to vary in width in passing from the eastern to the western limb of the sun. Accordingly one limb was brought upon the slit, and the micrometer run from one component to the other; the image was next shifted so that the other limb could be observed and the width again measured. The result, however, was entirely negative; not the slightest difference could be found. With this instrument a displacement as great as $\frac{1}{600}$ of the distance between D_1 and D_2 would have been detected with certainty. Hence we conclude that, if the locus of absorption for helium is different from that for iron, and if the one be drifting with reference to the other, the rate of this motion is less than one-third of a mile per second.

All attempts to measure the displacement of the helium line, D_3 resulted in failure, the line as seen in the fourth order not having sufficient sharpness to admit of any accuracy whatever.

In the absence of other evidence, the fair inference from these observations appears, therefore, to be that there is a lagging of the locus of absorption in the equatorial regions, and that the amount of this drift is approximately expressed by the following equation for the daily angular motion of any point whose heliocentric latitude is χ, expressed in degrees.

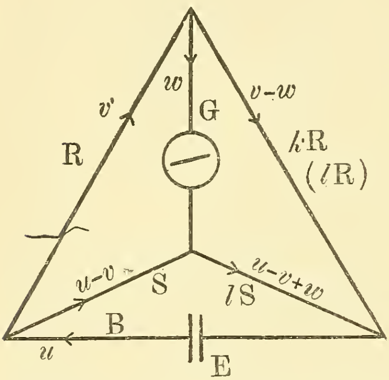
$$\theta = 794' \, (1 + 0{\cdot}00335\chi^\circ).$$

* For this distribution, see Lockyer's Chemistry of the Sun, pp. 161–169.
† Schellen's Spectrum Analysis, p. 598. ‡ Chemistry of Sun, p. 320.

ART. XIV.—*Theory of the Bolometer;* by HARRY F. REID, Ph.D.

THE bolometer consists of a Wheatstone's bridge in which the resistances are first adjusted so that no current passes through the galvanometer. Two arms of the bridge are made of thin platinum strips; when one of these is exposed to the radiation of a hot body it grows hotter, increases in resistance, thus destroying the balance of the bridge and producing a deflection of the galvanometer needle, which measures the intensity of the radiation.*

1.



Let u, v, w, be currents and R, kR, S, lS, G, B, be resistances in the Wheatstone's bridge, as in the diagram (fig. 1); and let E be the E. M. F. of the battery. By Kirchhoff's law for the distribution of currents we find

$$w=\frac{\mathrm{ERS}(k-l)}{\Delta},$$

where Δ is a function of the resistances in the various parts of the bridge.

The ordinary thermoelectric forces at the various junctions balance each other and do not affect the currents in the bridge. The thermoelectric forces due to the Peltier effect are very small and are quite negligible; when the four arms of the bridge are equal, their effect is merely to change slightly the total E. M. F.; we shall see later that this is unimportant.

We can replace E by its equivalent in terms of the current passing through the arm kR, which contains the exposable bolometer strip. (For convenience we shall designate the various arms of the bridge by their resistances). This current is essentially equal to the current v in the branch R when the bridge is balanced, since w is always very small in comparison to v.† We have

$$v=\mathrm{E}\frac{\mathrm{GS}(1+l)+\mathrm{S}l(\mathrm{R}+\mathrm{S})}{\Delta},$$

$$\therefore \quad w=\frac{v\mathrm{R}(k-l)}{\mathrm{G}(1+l)+l(\mathrm{K}+\mathrm{S})}$$

* For a detailed account of this instrument, see Proc. Am. Acad., 1881; this Journ. III, vol. xxi. p. 187, March, 1881.

† Professor Langley "On Hitherto Unrecognized Wave-lengths;" this Journ., III, vol. xxxii, Aug., 1886, foot note p. 94.

If δ is the deflection of the galvanometer needle, and D a constant depending on the form of the galvanometer, the period of the needle, etc., for small deflections

$$\delta = \mathrm{D}\frac{v\mathrm{R}(k-l)\sqrt{\mathrm{G}}}{\mathrm{G}(1+l)+l(\mathrm{R}+\mathrm{S})}.$$

A particular bolometer will have its greatest sensitiveness when for a given value of $k-l$, and a given percentage probable error of observation, the deflection, δ, is greatest. This is obtained by giving proper values to D, G and v. The proper values of D and G must be determined independently of the intensity of the current, v; for changes in these values will merely alter the sensitiveness of the galvanometer, and will change in the same ratio the total deflection δ, and the irregular deflections of the needle, but will *not* change the percentage probable error of observation. D should be made as large as possible; i. e. we should select the best form of galvanometer, have the needle strongly magnetised and highly astatic and its period long. The best value to give G is $l(\mathrm{R}+\mathrm{S})/(1+l)$. The current v must be increased to its greatest practical intensity; this limit, which is not at all well defined, is reached when the strip becomes sufficiently heated to set up *irregular* air currents, which cause fluctuations in its temperature and irregular movements of the galvanometer needle, thus increasing the probable error of observation.

Introducing the above value of G in the equation and writing $\mathrm{S}=n\mathrm{R}$ we get

$$\delta = \mathrm{D}\frac{v\sqrt{\mathrm{R}}(k-l)}{2\sqrt{(1+n)\,.\,l(1+l)}}.$$

We have supposed the arm $k\mathrm{R}$ to contain the exposable strip of the bolometer. When this is screened from radiation and the bridge properly balanced, $k=l$, and the resistance of this arm is $l\mathrm{R}$; when exposed to radiation let its resistance $k\mathrm{R}=ql\mathrm{R}$; then

$$\delta = \frac{\mathrm{D}}{2\sqrt{(1+n)(1+l)}}v(q-1)\sqrt{l\mathrm{R}}. \qquad (1)$$

$l\mathrm{R}$ is the resistance of the bolometer strip, and the wires connecting it to the bridge, when unexposed, and is of course a fixed quantity for any particular instrument. δ increases as l and n decrease. In order that the balance of the bridge should not be destroyed by the continued variation of the temperature of the room, it is found important to have the arms of the bridge, two and two, as nearly alike as possible; a second arm therefore is made of a platinum strip like the first and placed near it in the same case, but entirely covered up.

If the branch R contains this strip, $l=1$. What is the best value to give n? When n varies from 1 to 0, $1/\sqrt{1+n}$ varies from about 0·7 to 1; so that there is not a great advantage in making n less than 1; and there is a decided disadvantage. The currents in the branches R and S have the ratio $v/(u-v)=S/R=n$; the heat developed in R is v^2R; that in S is v^2R/n; if n is much less than unity, this becomes very large, the temperature of the branch S is raised too high and irregular movements of the needle are produced. If, on the other hand, the branch lS contain the covered strip, $n=1$; the heat developed in R and lR have the ratio $R/lR=1/l$; reasoning as above we conclude that in this case the most desirable value of l is unity.

To summarize: the bridge should be so arranged that $l=n=1$; the galvanometer resistance G should equal that of the bolometer strip R; B and E have disappeared from the equation; their actual values are therefore unimportant so long as v is fixed. This is applicable to the case in which we wish our instrument to have its greatest sensitiveness. If the quantity of radiant heat to be measured is so great that this is not desired we can diminish the sensitiveness by decreasing v or D or by adding a resistance to the galvanometer branch; it will usually be found advisable to change the first two quantities.

Let us now consider the strip itself. As the intensity of the current v is limited by the excess of temperature over that of the surrounding air to which we can raise the bolometer strip without producing inconvenient movements of the galvanometer needle, it will be convenient to replace v by its equivalent in terms of this excess of temperature. Let i be the ratio of the resistance of the exposed part of the strip to that of the whole arm in which the strip is; let t_0 be the temperature of the air and the enclosure surrounding the strip; t_1, the temperature of the strip when the current v is passing through it; $m'(t_1-t_0)$ and $m''(t_1-t_0)$ the loss of heat by radiation and convection per unit time per unit area of the blackened and metallic surfaces of the strip respectively (according to Newton's law of cooling, which is sufficiently accurate for the small changes in temperature under consideration); A′ and A″, the areas of these surfaces. We here suppose only a part of the strip to be blackened. The temperature of the strip will be constant when the amount of heat generated by the current equals the amount lost from the surface and by conduction, C_1; i. e. when

$$v^2iR=(A'm'+A''m'')(t_1-t_0)+C_1.$$

Putting the value of v derived from this equation in eq. (1), we find, writing $l=n=1$,

$$\delta=\frac{D}{4}(q-1)\frac{\sqrt{(A'm'+A''m'')(t_1-t_0)+C_1}}{\sqrt{i}}. \qquad (2)$$

q is the ratio of the resistance of the arm kR, when the strips are exposed to radiation (their temperature then being t_2), to their resistance when screened from radiation (their temperature then being t_1). According to Matthiessen's researches we have, for small changes in temperature,

$$q\mathrm{R}=\mathrm{R}+\alpha(t_2-t_1)i\mathrm{R}$$

$$\therefore \quad q-1=\alpha i(t_2-t_1).*$$

We may express (t_2-t_1) in terms of the quantities of heat absorbed and given off by the strip. When the strip is exposed to the radiation from a hot body, the heat falling on it is increased; we may, for convenience, consider that this latter radiation falls on the strip in parallel rays, as it approximately does. Let H be the increase of radiant heat passing unit area at right angles to the direction of propagation in unit time.

2.

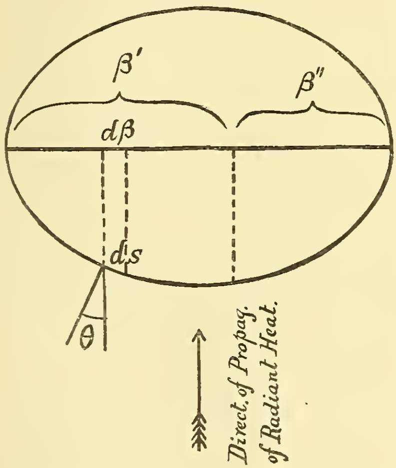


Fig. 2 represents the cross section of the strip; if λ is its length,† λds an element of the surface, θ the angle made by the normal to the surface with the direction of propagation of the radiation from the hot body; then H $\cos\theta\lambda ds$ will be the increase of heat falling on the element λds; if a' and a'' are the average coefficients of absorption for the different angles of incidence actually occurring, of the blackened and metallic surfaces of the strip respectively, the heat absorbed by the strip in unit time will be $a'\mathrm{H}\lambda\int\cos\theta ds+a''\mathrm{H}\lambda\int\cos\theta ds$, where the two integrals are to be taken respectively over the blackened and metallic portions of the strip, which are exposed to radiation from the hot body. If β is the breadth of the strip, $\cos\theta ds=d\beta$, and the expression above becomes $a'\mathrm{H}\lambda\beta'+a''\mathrm{H}\lambda\beta''$; $\lambda\beta'$ and $\lambda\beta''$ are the projection as shown in fig. 2 of the blackened and metallic parts respectively of the front surface of the strip.

* α is not the coefficient determined by Matthiessen but can be readily calculated from his results.

† The bolometer strip is usually made of a number of narrow strips placed side by side and connected in series. We look upon it as consisting of a single strip bent back and forth; λ and $\beta'+\beta''$ are the length and breadth the exposable part would have if it were straightened out.

The temperature of the strip will be constant when the heat developed by the current plus the heat absorbed equals that lost by radiation and convection plus that lost by conduction, C_2; i. e. when

$$(A'm'+A''m'')(t_1-t_0)+C_1+a'H\lambda\beta'+a''H\lambda\beta''=(A'm'+A''m'')(t_2-t_0)+C_2;$$

$$\therefore\ t_2-t_0=\frac{(A'm'+A''m'')(t_1-t_0)+H\lambda(a'\beta'+a''\beta'')+C_1-C_2}{A'm'+A''m''}$$

and

$$q-1=\alpha i(t_2-t_1)=\alpha i\{(t_2-t_0)-(t_1-t_0)\}=\frac{\alpha i\{H\lambda(a'\beta'+a''\beta'')+C_1-C_2\}}{A'm'+A''m''}.$$

Introducing this value in eq. (2) we obtain

$$\delta=\frac{D\alpha\{H\lambda(a'\beta'+a''\beta'')+C_1-C_2\}\sqrt{i(t_1-t_0)}}{4\sqrt{A'm'+A''m''}}. \qquad (3)$$

$H\lambda(a'\beta'+a''\beta'')$ is the quantity of radiant heat absorbed by the strip; a' and a'' will be greatest when every element of the exposed surface of the strip is at right angles to the direction of propagation of the radiant heat; i. e. when the front surface of the strip is flat. $A'm'+A''m''$ is the heat lost from the whole surface of the strip in unit time when its temperature is one degree higher than that of the surrounding air and case. Other quantities remaining the same, this will be smaller and δ larger as $A'+A''$, the whole surface of the strip is smaller. C_1 and C_2 are smaller, the smaller the cross section of the strip. The less metal in the strip for a given exposed surface the more rapidly will it reach its temperature equilibrium when exposed to radiation. All these considerations show that it is best to make the strip very thin.

If the strip is so thin that a further decrease in its thickness would only diminish the amount of heat given off by it by a small fraction of this amount, it does not appear that any advantage would be gained by making it thinner. In the case of a strip 1^{mm} wide the limit is probably fully reached when the thickness* is $0{\cdot}01^{mm}$.

Let us now determine how much of the strip should be blackened. There are but three practical cases:

I. None of the strip blackened.

II. The whole surface blackened.

III. The front surface only blackened.

Referring to eq. (3) we see we need only consider the term†

$$\frac{\lambda(a'\beta'+a''\beta'')}{\sqrt{A'm'+A''m''}}.$$

* In Professor Langley's instruments the thickness lies between $0{\cdot}01^{mm}$ and $0{\cdot}001^{mm}$. See his paper "On Hitherto unrecog. Wave-lengths," cited above.

† We suppose the strip to be thin enough to allow us to neglect C_1 and C_2.

Write $\beta'+\beta''=\beta$; our three cases give:

I. $A'=\beta'=0$; $\beta''=\beta$; $A''=2\lambda\beta$;

and $$\delta_1 \propto \frac{a''\sqrt{\lambda\beta}}{\sqrt{2m''}}.$$

II. $A''=\beta''=0$; $\beta'=\beta$; $A'=2\lambda\beta$;

and $$\delta_2 \propto \frac{a'\sqrt{\lambda\beta}}{\sqrt{2m'}}.$$

III. $\beta''=0$; $\beta'=\beta$; $A'=A''=\lambda\beta$;

and $$\delta_3 \propto \frac{a'\sqrt{\lambda\beta}}{\sqrt{m'+m''}}.$$

Suppose a black body, with coefficients of absorption and emission, a' and m', to be placed in a stream of radiant heat of intensity H, its rise in temperature will be given by the expression $(t_1-t_0)=\mathrm{H}a'/2m'$; if the same body should have a bright surface with coefficients a'' and m'', its rise in temperature would be $[t_1-t_0]=\mathrm{H}a''/2m''$. Experiments with blackened and unblackened thermometers show that $[t_1-t_0]<(t_1-t_0)$; $\therefore a''/m''<a'/m'$; we also know that $a''<a'$, and $m''<m'$; we see therefore that $\delta_1<\delta_2<\delta_3$.

The eq. (3) can now be written

$$\delta=\frac{\mathrm{D}\alpha\mathrm{HM}}{4}\sqrt{i\lambda\beta(t_1-t_0)}; \tag{4}$$

where M stands for $a''/\sqrt{2m''}$, $a'/\sqrt{2m'}$ or $a'/\sqrt{m'+m''}$, according as our strip belongs to case I, II or III.

In this expression for δ, D depends for its value on the form of the galvanometer, etc., as already noticed; α is ratio of the increase in resistance of platinum for one degree change of temperature above t_0, to its resistance at temperature t_0. Matthiessen found that this coefficient did not vary much for different metals. H is the intensity of the radiation to be measured. M has its greatest value when the front of the strip is very black and the back very bright; i can be given its greatest value by having the largest possible part of the strip exposable, and making the resistance of the rest of the branch kR very small. Since the resistance of the strip does not enter the equation, it is of no importance so long as the four arms of the bridge and the galvanometer all have the same resistance; but this should not be so small as to decrease materially the value of i, or to make the galvanometer connections an appreciable fraction of the resistance in the galvanometer branch. λ and β only occur multiplied together and under the radical sign; other things being equal δ varies as the square root of the exposable area of the strip; for a given area it does not matter then whether the strip be made of a single broad piece of platinum or of several narrow pieces arranged side by side and connected in series. This however is subject to the limitations mentioned in regard to the resistance of the strip. The thickness of the strip does not occur in the expression above; we have supposed the strip flat and so thin that the edges are only a very small fraction of the surface, and the heat lost by conduction negligable; as long as these are true, the actual thickness of the strip is unimportant; (t_1-t_0) is the increase in the temperature of the strip above the case due to the current passing through it; for a particular bolometer it is proportional to the square of the current. It is this quantity most probably which regulates the strength of current that can be used.* If we had two bolometers which were identical in all respects except in the thickness and blackening of the strips, we could apparently use currents in them respectively strong enough to give the same value of (t_1-t_0); and if we made M the same for the two instruments, the deflection produced on subjecting them to the same source of radiation would be equal. The relative values of t_1-t_0 for different bolometers can only be determined by experiment; perhaps no great error would be made if we supposed them equal for instruments which do not differ greatly in the exposed area of their strips.

Art. XV.—*Are there Deep-Sea Medusæ?* by J. Walter Fewkes.

In a report on the Medusæ collected by the "Albatross" in 1883–84† I have already considered the question whether there are zones of medusan life in the depths of the sea. I have not, however, from the nature of that paper, written all that may be said, even in the present condition of our knowledge of the facts bearing upon it. It is hoped that the present paper will, at least, point out the great interest attached to a scientific answer to the question which is taken as the title of this communication.

A study of the fauna of the deep sea is of comparatively

* It is possible that the total quantity of heat generated in the strip by the current and communicated to the air and sides of the case may effect the limiting value of the current intensity. If so this would be an additional reason for making the strip thin.

† Report on the Medusæ collected by the U. S. Fish Commission Steamer "Albatross" in the region of the Gulf Stream, in 1883–4. *Annual Report Com. Fish and Fisheries*, 1884, pp. 927–977, Plates I–X, 1886. Many of the ideas here presented are also noticed in this paper.

modern growth. It is barely thirty years ago that naturalists almost universally believed the abysses of the ocean to be deserts as far as life is concerned. Deep-sea exploration has, however, not only revealed the fact that the ocean bed at great depths is peopled by a rich and varied fauna, but also that the animals which constitute that fauna are peculiar and markedly different from those found in shallow waters.

It would seem a most extraordinary exception, if after the floor of the ocean at great depths had been found to be inhabited, the fathoms on fathoms of water through which the sounding weight passes to reach those depths are destitute of life. In mid-ocean, where there is a highly varied nomadic life upon the surface and where the dredge has brought up from the ocean bed a characteristic assemblage of animals, are we to suppose that between these places there is not a representative fauna, or must we conclude that after we sink a few fathoms below the surface, life ceases, and that it is not until we come to the floor of the ocean that life again appears? If between these two limits there is a fauna, is that fauna the same as that found at the surface, or is it characteristic? Can the animals which compose it be circumscribed in bathymetrical zones out of which they cannot pass with impunity? Do we, in short, have in the nomadic oceanic life a change of fauna as we sink below the surface?

Naturalists have been led to suppose that since we find peculiar modifications in animals living upon the sea bottom at great depths, we should necessarily look for the same variation among nomadic animals at intermediate depths. It would then seem probable that there are bathymetrical zones for free-swimming animals, and that these animals are characteristic as compared with others which live at the surface. An investigation of the character of this fauna, if such there be, has an interest to the evolutionist, for it might be supposed to acquaint him with facts bearing on the general characters of the ancestors of certain genera of surface life.

I can imagine few places on the earth's surface where the uniformity of physical conditions is greater than in the depths of the sea. I do not mean, as might be supposed, necessarily on the floor of the ocean, but at the depth of say one thousand fathoms separated from the ocean bed by a wall of water of the same depth. Here, if anywhere, we may look for uniformity of conditions and if environment has anything to do with modifications in the generic forms of animal life, here we can expect to discover animals which preserve ancestral features. On the surface of the ocean there are changes of temperature, and of light, and climatic variations; at the floor of the ocean there may be reactions of the interior of the earth upon its crust, perhaps lava flows or geological oscillations;* but midway between these two places, equally removed from both, disturbing causes only rarely penetrate and conditions remain more constant year by year. Can we not expect to find here a corresponding uniformity in the fauna as compared either with the highly organized animals of the surface or those of the depths of the ocean? Is that fauna more uniform than any other in the ocean?

No group of animals is better suited for a study of the questions which suggest themselves concerning the bathymetrical zones of characteristic animals, free-swimming at different depths in the ocean, than the medusæ. The group is a large and very variable one. It is confined, with but few exceptions, to the ocean. Moreover it is probable that its ancestors were oceanic animals. No group of marine animals presents fewer difficulties in studying the questions which we have stated than this.

It was with the impetus of a new enthusiasm for the study of these questions that I undertook, by the advice of Prof. Verrill, the examination of the rich collections of deep sea medusæ made in the Gulf Stream by the "Albatross." It seemed to me that the examination revealed much of general scientific interest.

I shall not consider in this discussion the Hydroida, as the members of this group are for the most part attached to the ground, and the problems connected with them are the same as those which pertain to all deep-sea animals attached or partially living on the ocean bed. We shall also pass by, in silence, the Ctenophora, no genus of which has yet been ascribed to the deep-sea. I propose to consider a few of those jelly-fishes which are known as the *Acraspeda* and incidentally the *Siphonophora.*

The history of the study of the deep-sea medusæ belonging to these divisions is a very brief one. In many of the monographs on these groups we have isolated mentions of medusæ which are ascribed to the deep-sea. The jelly-fishes thus mentioned were commonly washed into shallow water by ocean currents, by storms or unusual events in the ocean, and the depths at which they were supposed to live could only be conjectural. The specimens themselves were, for the most part, in a mutilated condition.

The first and only paper on the Siphonophora of the deep-sea is by Prof. Studer,† who describes new species and genera of these animals which were found twisted on ropes and wires

* Such changes might take place even if the oceans have practically been the same in past geologic times as at present.

† Zeitschrift für Wissenschaftliche Zoologie, vol. xxi.

used in deep-sea dredging and sounding. All of these are closely related to a genus called *Rhizophysa*, which is itself allied to a medusa called *Physalia*, or the "Portuguese-man-of-war," which habitually floats on the surface of the ocean.

The most important work which we have on the Acraspeda (the ordinary jelly-fishes found in shallow waters), of the deep-seas, is a report * by Prof. E. Hæckel on a collection made by H. M. S. "Challenger." No one has done more than he to elucidate the structure of the jelly-fishes, and he stands without an equal in his contributions to a knowledge of the deep-sea members of the group. This work of Hæckel is, up to the present, the greatest contribution of any naturalist to the study of the medusan representatives of the deep-sea fauna.

If space permitted, one or two other smaller contributions might be mentioned, but these two works are the most important additions to our knowledge of the deep-sea Acraspeda and Siphonophora.

We have no complete account of the deep-sea jelly-fishes of the Gulf Stream. That great body of water, which sweeps along our coast from the straits of Florida, northward, bears a nomadic life, of the wealth of which no one has yet a just conception. Those who have studied the stream in all latitudes have spoken of this fact, and one needs but lower a drag net in its waters for a few minutes to become convinced of its truth. The surface of the Gulf Stream has been but partially explored, the inhabitants of its depths, except on the very bed, are unknown.

The means which have been used for the collecting of animals from intermediate depths are not all that could be wished for. There is a call for greater refinement in this kind of collecting. A common way of obtaining this life is as follows. The dredge, trawl or drag-net drawn up from a great depth is found to bring with it a medusa. That medusa is recorded from the depth of the trawl. What then is the possibility that it entered the dredge on the passage up through the water? I think every one will acknowledge that the possibility is very great, and that the medusa may or may not have come from the deep-sea. A drag-net attached to a dredge-rope or wire is sometimes lowered to a certain depth and then drawn up. Here also we may ask how is it known that the medusa found in the net entered it at the recorded depth? A Siphonophore clinging to a wire rope used in sounding or dredging may or may not, as shown by A. Agassiz, have become twisted upon it at the depth at which the animal appears to be found when

* Report on the Deep-Sea Medusæ dredged by H. M. S. "Challenger" during the years 1873–76. Report on the Scientific Results of the voyage of H. M. S. Challenger during the years 1873–76, vol. iv, No. II.

brought on deck. "In most cases," writes Prof. Verrill, "it is impossible to say whether the novel forms of medusæ taken in the trawl and trawl wings are inhabitants of the bottom waters or the surface, or of intermediate depths. Eventually those that belong to the surface fauna will doubtless be taken in the surface-nets, but this will require much more extensive collecting of the surface animals than has yet been attempted."

It will thus be seen that the means of determining the depth at which the collecting of free oceanic animals takes place are too imperfect for any accurate knowledge of the bathymetrical limits of so-called deep-sea medusæ. We are in fact on the very threshold of this kind of research, and what is now most needed, in the study of bathymetrical zones of marine life, are improvements in methods of collecting at any depth, so that we can tell exactly at what distance below the surface a nomadic animal is captured. Devices have been suggested, one of which, the so-called "Gravitating Trap," of Lieut. Sigsbee, has been described in the Bulletin of the Museum of Comparative Zoölogy at Cambridge. I am not aware how extensively this apparatus, or others of similar kind, have been used by those who are in charge of deep-sea exploration, or whether it has been sufficiently tried to test its usefulness.* If medusæ were always as abundant at great depths as they sometimes are at the surface, a device might easily be invented for the successful capture of at least a few specimens. It seems more probable that medusæ are not common enough to warrant one in supposing them very numerous, and the difficulty in their capture thus becomes greater, rendering it necessary that some modification of the gravitating trap be invented.†

In a letter to Mr. C. P. Patterson (Bull. Mus. Comp. Zoöl., vol. vi, No. 8) Mr. A. Agassiz calls attention to the uncertain methods adopted for ascertaining at what depths free-swimming animals live, and from experiments with the "Sigsbee Trap" concludes (p. 153), while he does not deny that there are certain genera of deep-sea medusæ, that "The above experiments appear to prove conclusively that the surface fauna of the sea is really limited to a comparatively narrow belt in depth, and that there is no intermediate belt, so to speak, of animal

* Results of Explorations made by the Steamer Albatross off the Northern coast of the United States in 1883. *Annual Report Com. Fish and Fisheries*, 1883.

† The small amount of water which enters the Sigsbee gravitating trap is one great objection to it. Negative results with this apparatus do not necessarily show that life does not exist at the depth at which the door is opened, and the instrument does not collect from a large enough area for a successful determination of the abundance of life which it is intended to capture. From what has been published, and statements of those engaged in deep-sea exploration, I am led to suppose that the "Sigsbee Gravitating Trap" has given only negative data in regard to the problem of the existence of characteristic nomadic life in intermediate depths of the sea.

life, between those living on the bottom or close to it and the surface fauna."

This statement from such a high authority in the study of marine zoology would seem to effectually crush any murmur of belief in intermediate zones in the distribution of oceanic forms of life. While I have the highest respect for this view, I cannot help entertaining an opinion that more observations are necessary before we can accept the proposition that there are not characteristic belts of pelagic animals at different depths.

With the question whether the recorded depths at which the Medusæ which we shall consider are found, are accurate or not, we cannot deal. Indeed, at this stage of this kind of deep-sea exploration, an examination of these methods would be foreign to the purposes of this paper. We take the data as given by the collector and at present leave the improvement of the collecting apparatus to others.

Can we not approach this subject from another side? Are there any characteristics in the Medusæ themselves which show that they are preëminently fitted to live at the depths or approximate depths from which they are reported? Has their habitat left any traces in the modification of their anatomy? Has the uniformity of conditions in their habitat led to a corresponding simplicity in their structure and are they nearer the ancestral forms than others with a more varied environment? An account of the singular structure of one or two typical genera may help us to answer this question or at all events present certain facts which bear upon it. Let us therefore for illustration consider one or two representatives of the Acraspeda and Siphonophora discovered by the Albatross in the depths of the Gulf Stream.

Everyone familiar with the anatomical structure of the Siphonophores will recognize how difficult it is to find in those genera like *Rhizophysa* anything to point to an adaptation to a deep-sea life. The Albatross has discovered new Physophores closely allied to *Rhizophysa*, one of which, *Petrophysa*, reaches the enormous size of twenty feet in length in alcohol. The float of this animal is larger than that of any true Siphonophore except *Physalia*. The large size of the float in these Physophores would seem an effective argument against their adaptation to a life in deep water, especially as their nearest ally, *Physalia*, is preëminently a surface form.

It is extremely difficult to gather from the structure of the known Siphonophora ascribed to the deep-sea anything to indicate an adaptation to such a life. The group can afford little satisfaction in our answer to the question of whether there is a nomadic deep-sea life or not.

The nature of the argument for the existence of medusan life in bathymetrical zones may be best illustrated by considering a few examples of the Acraspeda. These are not the only instances which might be chosen and possibly are not the best. They are thought to be as suggestive as any among the Acraspeda which have been ascribed to great depths.

One of the most characteristic families of Acraspeda is called the *Collaspidæ*. The family is supposed to belong to the deep-sea and is represented by two genera, *Atolla* and *Collaspis*, which differ from each other rather obscurely in the regular or irregular arrangement of the sexual glands. It is a question whether we have more than specific differences in the features which have been pointed out by Hæckel as separating the two.

Up to the present the genus *Atolla* is represented by a single species collected by the Challenger (*A. Wyvillii* Hæck.) and two species from the Gulf Stream (*A. Bairdii* and *A. Verrillii* Fewkes).

The structure of *Atolla* is thought to be more primitive than the ordinary inshore genera, *Cyanea* and *Aurelia*. It is so characteristic that I repeat from my paper on the anatomy of this genus, a condensed notice of some peculiarities.*

If we compare *Atolla* with our common surface medusæ, as *Aurelia*, we notice many marked peculiarities.

In the former we have a coronal furrow, which is not represented in *Aurelia* although found in a well known surface medusa (*Periphylla*). We have in *Atolla* a variable number (generally twenty-two) of sense-bodies or peduncles of the same. In *Aurelia* we have always eight sense-bodies. The coronal muscle is peculiar to *Atolla*.

The sense-bodies of *Atolla* are spoken of by Hæckel as rudimentary, and it is supposed that we have in a deep-sea medusa an adaptation for a life in the depths into which the light never

* The umbrella when seen from the upper side is found to be divided by a deep ring-shaped groove into a central and peripheral region. The groove is called the coronal fossa, the central region, the *discus centralis*, and the periphery the corona. The corona is formed of a number of wedge-shaped, gelatinous blocks, joined together and bearing on their outer rim, alternately, tentacles and sense organs. These gelatinous blocks are designated by the term socle, taken from architectural nomenclature, and are of two kinds: those which bear the tentacles called the tentacular socles, and those which carry the sense-bodies (if such exist) the socles of the sense-bodies. The socles of the sense-bodies bear two thin flaps called the marginal lappets. On the under side of the disk we have, below the corona, a large ring-shaped muscle called the coronal muscle, which is highly characteristic and larger in this genus than in any other known medusa. Axially to this muscle there is a zone formed of eight kidney-shaped sexual glands, and a simple mouth, which opens into a bag-shaped stomach. In the interior of the body there is a circular cavity filling the central disk, which opens by four orifices into a ring-shaped sinus which lie in the gelatinous body of the corona. From the outer edge of this ring-shaped sinus simple, unbranched, peripheral tubes extend through the bell-substance, passing into the cavities of the tentacles and rudimentary marginal sense-bodies.

penetrates. We may have here, what we so often find in deep-sea animals, a reduction in the size and efficiency of the special organ of sense to fit the medusa for the conditions under which it must live in great depths. Stated in a startling way, we might speak of *Atolla* as a blind medusa. This statement would hardly be justifiable and we can at present go no further than to say that the special sense-bodies of sight * are supposed to be rudimentary. It must however be borne in mind that nowhere among Acraspeda do we have so many, twenty-two, sense-bodies as here. In some specimens there are twenty-eight sense-bodies in this genus.

It is extraordinary that one of the known species of *Atolla*, (*A. Wyvillii* Hæck.), comes from the Antarctic Ocean, while our two species were both from the *warm* (?) water of the Gulf Stream. In the southern hemisphere its lowest limit is about 2000 fathoms, while north of the equator it comes from the surface or within a few hundred fathoms.

Among the medusæ collected by Lieut. Greely in the icy waters of Lady Franklin Bay, is an interesting jelly-fish allied to *Atolla*. This genus (*Nauphanta*) has been found but once before and then by the naturalists of the Challenger in the neighborhood of the island of Tristan d'Acunha in the South Atlantic. In the latter locality it is recorded from about 1500 fathoms, while in Lady Franklin Bay it is found on the surface. From several differences in these two specimens, those from the Arctic and those from the South Atlantic, I have supposed the boreal form to be new and have called it by the specific name *polaris*.† The Challenger specimens were placed under a new genus called by Hæckel, *Nauphanta*.‡

Before we consider the relationship between *Atolla*, *Nauphanta* and other related medusæ, ascribed to the deep-sea, let me mention another new medusa collected by the Albatross in the Gulf Stream. The genus *Nauphantopsis*, is of interesting affinities, since it has the same central disk as *Nauphanta* and

* Whether the "eye" of the jelly-fish can distinguish form or not has not been demonstrated. Simple experiments made by passing rays of light through dishes in which they are confined, or the simple fact that they almost always congregate on the illuminated side of the same, are not conclusive to me that they distinguish *form*. Experiments with sensitive plates to show the depths to which light penetrates the water are most suggestive in this connection. It seems pertinent to the whole inquiry to ask whether looked at from the physical side there are not rays of light of such a nature that the vertebrate eye is not able to perceive them, but which may act upon the visual organs of other animals.

† *Nauphanta polaris* has a central disk as in *Atolla*, a coronal fossa, and a corona, which, however, is formed of sixteen socles. eight of which bear tentacles, tentacular socles, and eight sense-bodies. The outlines of these socles is more clearly marked than in *Atolla* on the upper surface of the corona, which they form, on account of the deep sculpture which separates them.

‡ The name Nauphanta was preoccupied in 1879, when applied to this Medusa, having been given to a worm in 1864.

Atolla, the same coronal fossa and coronal socles. It is most closely allied to *Nauphanta* but has thirty-two socles instead of sixteen, eight sense-bodies (?) and twenty-four tentacles.* These tentacles are therefore arranged in threes, each series of three alternating with eight sense-bodies.—All with gelatinous socles.

It is easy to interpret the three deep-sea Acraspeda, *Atolla*, *Nauphanta*, and *Nauphantopsis*. At first sight they closely resemble gigantic young *Aurelia* or *Cyanea* in a stage which is called the ephyra. This is especially true of *Nauphanta*, which has the same number and arrangement of tentacles as the young *Cyanea* or *Aurelia* in the ephyra stage. It is so close, in fact, that at first sight they seem identical. In *Nauphanta* we have mature ovaries, and this would seem to indicate the adult form. The existence, however, of ova, and a sexual maturity is by no means an indication of the acquisition of the adult form among medusæ, and many instances might be mentioned of a jelly-fish with mature ova even before embryonic appendages have been dropped. There is nothing then to prove that *Nauphanta* is not the young of some other medusa, and on the other hand there is no proof that it is not an adult. If it is an adult, it is a mature medusa with likeness to embryonic conditions of other medusæ. It would then be nearer the ancestral form of Acraspeda than any of the more common medusæ like *Cyanea* and *Aurelia*.

At first study, I was inclined to regard *Atolla* as a giant ephyra of some unknown medusa. Its affinities are certainly very close to *Nauphanta* and through the latter genus it is connected with ephyra, the young of *Cyanea*. We may therefore regard both these genera as embryonic in their structure and as close allies of the young of a higher jelly-fish. It is a most interesting fact that two genera with such marked characters are considered deep-sea genera. Exactly what the evolutionist would expect from the uniformity of conditions which exist in deep water, we find manifested in the simple anatomy of two of the more characteristic deep-sea genera of Acraspeda, a simplicity of structure of embryonic and therefore of ancestral nature. It is certainly strange that these two facts are associated. It is an extraordinary coinci-

* *Nauphantopsis* is an interesting genus in its relationship to the surface genus *Periphylla*, which has four sense-bodies and twelve tentacles in four series of three each. We likewise have in the same genus marked coronal socles, sixteen in number, while *Nauphantopsis* has thirty-two. *Nauphantopsis* then appears to be a connecting genus between *Nauphanta* and *Periphylla*. I believe we are justified in regarding *Nauphanta* as an adult, although when I first studied it I was strongly inclined to regard it an immature animal. It must be confessed that, with the exception that it has eight sense-bodies, while *Periphylla* has but four, there are strong resemblances between a young *Periphylla* and the genus *Nauphanta*.

dence if the deep water at which the medusæ were found and the embryonic affinities in their anatomy have not the relationship of Cause and Effect. The discovery of a *Nauphanta* in the icy waters of the Arctic,* while it shows that the genus may approach the surface when the temperature of the depth at which it lives becomes a surface temperature, would also indicate that the genus is not confined to the great depth at which it is reported from the South Atlantic. If *Nauphanta* cannot rise to the surface in the latitudes of Tristan d'Acunha, it may be that the elevation of temperature above its habitat keeps it at great depths. At the higher latitude of North Greenland, however, the cold zone, in which *Nauphanta* lives in the South Atlantic, is about the surface temperature. Here, then, as far as thermal conditions go, the medusa can rise to the surface. We here encounter what I believe will be found to be an influence of more important character in the modification of medusan life at great depths, than the depth of water itself. Medusæ are sensitive to changes of temperature in the ocean; so sensitive in fact, that for many genera the line of demarkation between warm and cold oceanic currents are often dead lines to these delicate creatures. It is well-known that certain genera can be frozen without being killed by the change, and that medusæ suffer less from a diminution in temperature than from an elevation of the same. This is particularly true of those genera like *Aurelia*, *Sarsia* and others which habitually inhabit cold water. A temperature of +70° F., is fatal to them, while many tropical forms will easily live even in higher temperatures. Temperature in the ocean has drawn invisible lines in the distribution of medusæ in depth as well as latitude, and it is at present very difficult to separate this cause from that of pressure in the bathymetrical limits of the jelly-fishes. The poverty of our knowledge of the ranges of temperatures which jelly-fishes can endure is too great to admit of any generalizations of value on this question. Still there are no facts of more vital importance in the discussion of the question of whether there are deep-sea Acraspeda than those which bring information of the thermal limits at which the medusæ can live.

It would be profitable, if space permitted, to consider other genera of Acraspeda made known by the Albatross, in their bearings on the question which is the title of this paper. The three genera already considered present us the strongest arguments which can be found in the modification of external and internal anatomy, as indicative of a deep-sea habitat.

* Report on the Medusæ collected by the Lady Franklin Bay Expedition, Lieut. A. W. Greely commanding. Appendix No. XI.

"Those Medusæ," writes Hæckel, "may be regarded with greater probability as permanent and characteristic inhabitants of the deep-sea, which have either adapted themselves by special modifications of organization to such a mode of life, or which give evidence by their primitive structure of a remote phylogenetic origin." He then enumerates those which he places in this category, among which are the two remarkable genera, *Atolla* and *Nauphanta*. "It is by no means certain," writes Hæckel, "that all the eighteen medusæ described below, (Report on Challenger Medusæ) are constant inhabitants of the deep-sea." We have discussed the argument drawn from two of the most characteristic of the Acraspeda, viz: *Atolla* and *Nauphanta*, and can readily subscribe to this statement as far as these are concerned.

The resemblance of *Nauphantopsis* and *Atolla* to Ephyra is believed to have a morphological significance; Ephyra is thought to be the ancestral form of the Acraspeda, and these so-called deep-sea medusæ still preserve the ancestral form with small modifications, except in size, repetition of organs, and certain other characters. Of the development of *Atolla* or of the *Collaspidæ* we know nothing, and yet a knowledge of this subject is possibly to reveal the solution of important questions. If the mode of growth should prove to be a direct development without a *Scyphostoma*, it would certainly increase my belief that these medusæ somehow resemble the ancestral forms. I have already elsewhere shown that among the hydromedusæ with alternation of generations and those with a direct development, the latter method is normal while the former is a secondary modification. Among Acraspeda, also, the direct development of *Pelagia* is the ancestral method, while the formation of a Scyphostoma is a secondary modification. We should expect to find in *Atolla* a direct development, if it be an ancestral genus. From its mode of life in the high seas we should also expect the same.*

Abandoning, for the present, as insufficient, any evidence which might be adduced from the structure of the medusæ

* I believe the Lucernarians are degenerate adult Acraspeda, which have attached themselves to the bottom much in the same way as *Cassiopea frondosa* and become modified in consequence. While it may be said that they are homologous to the Scyphostoma stage, it is not thought that they are ancestral. They are in reality secondarily modified, for the ancestral method of development is direct, without an attached young, in Acraspeda, as in Craspedota.

While the primitive structure and relationship of *Atolla*, *Nauphanta*, and *Nauphantopsis* would seem to ally them closely to Ephyra and stamp them as less modified than such genera as *Cyanea*, in certain anatomical details, they might be regarded as higher even than the last mentioned. We cannot, consequently, draw from their simple relationship to an embryonic form, the conclusion that they have retained that likeness on account of the simpler conditions of deep-water habitat. Nor is the argument drawn from the supposed abortion of the sense-body conclusive, as far as these medusæ are concerned, although it looks plausible.

themselves and passing to the recorded facts in relation to bathymetrical distribution, we find no more satisfaction from this consideration. It would appear that the strongest arguments for the existence of nomadic deep-sea medusæ of the Acraspeda are found by Hæckel in the following genera.* The names in brackets are authorities for distribution.

1. Pectanthis: Surface (Hæckel).
2. Pectyllis: 200–600 fms. (Hæckel).
3. Pectis: 1260 fms. (Hæckel).
4. Cunarcha: "Possibly captured in drawing up the lead," (Hæckel).
5. Aeginura: "2150 fms. apparently" (Hæckel).
6. Periphylla: Surface (Fewkes).
7. Periphema: 1975 fms. (Hæckel).
8. Tesserantha: 2160 fms. (Hæckel).
9. Atolla: 2040 fms. (Hæckel), surface (Fewkes).
10. Nauphanta: 1425 fms. (Hæckel), surface (Fewkes).

Of the above genera the Albatross has collected many specimens of *Periphylla* and *Atolla* from the surface of the ocean. Greely collected a species of *Nauphanta* from the icy waters of the surface of Lady Franklin Bay; *Periphema* is so closely allied to *Periphylla* that we may well hesitate to accept its limitation to the great depth at which it is recorded (2160 fms.); *Pectyllis* is recorded from 200 to 600 fms. In the present use of the word deep-sea this genus can hardly be regarded as preëminently a deep-sea medusa. There remains† *Pectis* (1260 fms.) and *Tesserantha* (2160 fms.) as the only genera in the above list which can be regarded as purely deep-sea in their habitat. Each of these is described from *single* specimens and the former is closely allied to well-known surface genera. The foundation in observation for a belief in the existence of nomadic deep-sea medusæ, as far as recorded depths go, is certainly not all that might be desired.

Possibly a stronger argument for the existence of deep-sea Acraspeda may be drawn from the structure of the interesting free genus of Lucernaridæ (*Lucernaria bathyphila* Hæck.). This species is recorded from 540 fms. The fixed *Lucernariæ* are found in shallow water. The argument drawn from the

* Op. cit., Introduction, p. ii.

† *Cunarcha* was "possibly captured in drawing up the lead," and *Aeginura*, 2150 fms., "apparently."

As a bit of positive evidence that *Atolla* is a deep-sea medusa, Mr. Thomas Lee, who has seen the genus when collected, informed me, after I had shown him a specimen of *Atolla*, that he remembers it in deep-water trawls. In new collections made by the Albatross in 1885–86, *Atolla* in several instances is recorded from the "Surface;" and one of those described in the collections of 1883–84 is recorded from the Surface.

structure of the free Lucernarian would be stronger if the so-called attached species had been brought up from great depths, or if *Scyphostoma* had been reported from the ocean bed. It is suggested that those who have in charge the collecting of deep-sea animals, observe with care the contents of the dredges for attached *Scyphostoma* and Lucernarians, and it is particularly desirable, from a morphological standpoint, that the development of such genera as *Atolla* be known. If it can be shown that this and related medusæ have an indirect development, with an attached *Strobila* living in great depths, they may rightly be called deep-sea medusæ. A nomadic jelly-fish, limited in bathymetrical habitat, could best fulfill its conditions of life by having a direct development without attached larval conditions.

Why cannot we suppose that deep-sea medusæ can live at the surface and also at great depths? Why look for bathymetrical zones in the ocean for nomadic animals? The main reason seems to be the exceptional nature of such a wide distribution in places so widely separated in physical characteristics. It may be possible for a medusa to live equally well at the surface and under a pressure of 2000 fms. of water, and in the different temperatures of these two regions, but if they can endure these widely different conditions, they do not resemble other animals and their own relatives from the shallow waters. The logical inference from what is known of the differences between the facies of deep-sea animals on the ocean bottom and those from the littoral zone, would seem to be true of animals which are not fixed to the ground nor dependent upon it, viz: that there are bathymetric limits in the ocean, even to nomadic animals apparently as helpless as the medusæ.

In closing my short discussion of the question of deep-sea nomadic medusan life, it can be said that as far as the data thus far gathered goes, neither the recorded depths, nor the structure of the genera considered, demonstrates that we have a serial distribution of free medusæ in bathymetrical zones. While our present information is insufficient to answer the question, *it seems* to me that the case is much stronger than the arguments which can be advanced in its support. There is little doubt that medusan life has bathymetrical limitations. Our well-known surface medusæ probably cannot live at great depths, and their places are probably taken there by others; still, until there are more exact data bearing on this conclusion, it cannot be demonstrated to be true. What is now needed is, in the first place, an accurate determination of the depth at which medusæ of different genera are captured, and secondly a more accurate study of peculiarities of anatomy and development of those which are supposed to be thus limited in habitat. It is also equally necessary that the surface fauna should be better known for comparison. There are at present a few marine stations in the Mediterranean and North Atlantic, where the study of surface life is zealously prosecuted, but it is only when the Müllers' net has been used with equal zeal in the South Atlantic, the Indian ocean and Pacific, that we can have a basis to work upon. An exploring vessel on a cruise through these waters is not enough. It is a reconnaissance. There must be established permanent marine stations where the study will be carried on year after year for a long time in one locality.

OBITUARY.

FERDINAND V. HAYDEN.—Dr. Hayden, whose death is announced on page 88, of the January number of this Journal, was born in Westfield, Mass., in September, 1829. He was a graduate of Oberlin College, Ohio, and received the degree of Doctor of Medicine from the Medical School of Albany, N. Y., in 1853. He was surgeon in the army during the civil war; and after it, for seven years, he held the position of Professor of Mineralogy and Geology in the University of Pennsylvania.

But the larger part of his time from 1853 to the close of 1878, an interval of twenty-six years, was spent in Rocky Mountain exploration, in which his special work was geological; and through his labors and the investigations of those associated with him, a wide extent of territory, until then little studied, was examined geologically and topographically, coal beds were found and a new coal flora made known, new fossil mammals and other species in great numbers were collected and described, the stratigraphy and paleontology of the Cretaceous and Tertiary and the intermediate Laramie or Lignitic beds were well investigated, and the Yellowstone Geyser region brought to notice, explored and described with full illustrations.

Dr. Hayden's personal work consisted in a general geological reconnaissance of the regions visited, the collection of fossils, which was the chief object of the earlier expeditions, and the supervision and direction of the surveying parties. He was the first to make known the facts as to the vast Tertiary lake-areas of the summit region and eastern slopes of the Rocky Mountains, whence he drew the conclusion that the elevation of the mountains went on slowly through the whole Tertiary, commencing with the Laramie, which afforded some brackish water fossils.

His first two expeditions were made in 1853 and 1855, to the Bad Lands on White River, in Dakota,—that of 1853 at the expense of Professor James Hall. Large collections of remains of fossil mammals were brought home, besides numerous other species. His paleontological friend, Mr. F. B. Meek, was with him. In 1857, he accompanied Lieut. G. K. Warren's expedition and made the discovery of the rich Niobrara Mammalian fauna, newer than the White River, and obtained a great number of specimens. In 1866 he was in the Bad Lands, making collections for the Academy of Natural Sciences of Philadelphia. The mammalian remains obtained in these various expeditions, along with those gathered by Dr. John Evans in 1849 and 1853, and Mr. Culbertson in 1850, were the material used by Dr. Leidy for his great work on the Extinct Fauna of Dakota and Nebraska (1869).

During 1859 and 1860, Dr. Hayden was connected, as geologist, with Capt. Raynold's expedition to the headwaters of the Yellowstone and Missouri. In 1867, after the civil war, the series of government expeditions under his charge was begun that continued through the consecutive years to the close of 1878. By these expeditions his explorations became extended over large parts of Nebraska, Dakota, Colorado, Utah, Wyoming, Montana, New Mexico and Kansas. The first appropriation was only $5,000 ; but the later were more liberal; and besides his regular corps, a number of other scientists sometimes accompanied the expedition. Mr. Meek was usually with him, and through him large numbers of invertebrate species of the Cretaceous, Tertiary, Jurassic and other formations were figured and described; and precision was thus given to the facts for success in laying down the subdivisions of these formations and mapping their distribution. After the death of Mr. Meek, in December, 1876, his department passed under the charge of Dr. C. A. White. Mr. L. Lesquereux investigated, figured and described the fossil plants of the Laramie and other formations. Dr. Cope joined the expeditions of 1872 and 1873, and afterward described the vertebrate fossils, collected in these and later years, in two quarto volumes. In 1877, the parties of exploration included the geologists Dr. C. A. White, Dr. A. C. Peale, Dr. F. M. Endlich, O. H. St. John, the accomplished artist Mr. W. H. Holmes, the topographical surveyors A. D. Wilson, G. R. Bechler, G. B. Chittenden, H. Gannett, the excellent photographer W. H. Jackson; and also Dr. S. H. Scudder and Mr. F. C. Bowditch of Cambridge, Dr. Leidy of Philadelphia, and the first botanists of England and America, Sir Joseph D. Hooker and Dr. Asa Gray.

The many volumes of the expedition in octavo and quarto, and the atlases, need not be here enumerated. Dr. Hayden had reason for feeling gratified with the great scientific results of the expeditions and his own earlier labors, and the wonderful developments made with regard to the ancient life of the continent, and the display of the country's resources and topographic features.

The office work of the expedition closed in June, 1879. Since then Dr. Hayden has lived in Philadelphia. He has had in course of preparation a final geological report on his expedition work; but what progress was made is unknown to us.

Dr. Hayden was a member of the National Academy of Sciences, and received various honors from academies abroad.

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[THIRD SERIES.]

ASA GRAY

Our friend and associate, Asa Gray, the eminent botanist of America, the broad-minded student of nature, ended his life of unceasing and fruitful work on the 30th of January last. For thirty-five years he has been one of the editors of this Journal, and for more than fifty years one of its contributors; and through all his communications there is seen the profound and always delighted student, the accomplished writer, the just and genial critic, and as Darwin has well said, "the lovable man."*

Asa Gray was born on the eighteenth day of November, 1810, at Sauquoit, in the township of Paris, Oneida County, New York, a place nine miles south of Utica. When a few years old, his father moved to Paris Furnace, and established there a tannery; and the child, one account says, was put to work feeding the bark-mill and driving the horse, and another, riding the horse that ground the bark. "At six or seven he was

* In the preparation of this sketch I have been much aided by the papers of Prof. Goodale, Prof. Sargent and Prof. C. R. Barnes, the last in the *Botanical Gazette* for January, 1886.

a champion speller in the numerous 'matches' that enlivened the District school." At the age of eleven, nearly twelve, he was sent to the Grammar school at Clinton, where he remained for two years, and the following year, to the Fairfield Academy, both of the schools places where all the classics and mathematics were taught that were required for entering the colleges of the land. But his instruction was cut short by his father's desire that he should enter the Fairfield Medical School. This school, of high repute, was established at that place in 1812, as the College of Physicians and Surgeons of the Western District of New York. Dr. James Hadley was the Professor of Chemistry and Materia Medica, and his lectures of 1825–6, while Gray was in the Academy, and 1826–7, after he had taken up medicine, gave the young student his first instruction in science. During the following winter at Fairfield, that of 1827–8, the article on Botany in the Edinburgh Encyclopædia attracted young Gray's attention, and excited his interest so deeply that he at once bought a copy of "Eaton's Botany" and longed for spring. As spring opened, "he sallied forth early, discovered a plant in bloom, brought it home and found its name in the Manual to be *Claytonia Virginica*, the species *C. Caroliniana*, to which the plant really belonged not being distinguished then." From this time, collecting plants became his chief pleasure. He finished his medical course, and, in the spring of 1831, took his degree of Doctor of Medicine—to him the basis for a title, but not for future work.

This ended his school and college days. As Gray's scientific education was carried forward without the aid of a formal scientific school, so it was with his literary studies. He had not the benefit of university training, and yet became eminent for his graceful and vigorous English, the breadth of his knowledge, his classical taste, and the acuteness of his logical perceptions.

Before the close of the medical course, he had opened correspondence about his plants with Dr. Lewis C. Beck, a prominent botanist of Albany, and had had a collection named for him by Dr. John Torrey of New York. Moreover, about this time, he delivered his first course of lectures on Botany, as substitute for Dr. Beck, and made use of the fees that he received for the expenses of a botanical excursion through western New York to Niagara Falls. Gray also delivered a course of lectures at Hamilton College, Clinton, on mineralogy and botany, for Prof. Hadley, in the college year of 1833–4, a biographical sketch of Prof. Hadley, of Fairfield, by his son, the eminent Professor of Greek at Yale, stating that his father, who gave up his lectures at this college in 1834, "supplied his place during the last term by a favorite pupil and much valued friend, Dr. Asa Gray, who commenced under Professor Hadley the studies which were to make him preëminent among the botanists of his time." Prof. Hadley, the sketch says, had studied botany at New Haven, Ct., in 1818, under Dr. Eli Ives, an excellent botanist of that place, and mineralogy and geology under Prof. Silliman

In the autumn of 1831, Gray became Instructor in chemistry, mineralogy and botany at "Bartlett's High School" in Utica. The scientific department of the school had been under the charge of a graduate of Eaton's "Rensselaer School," at Troy—the earliest school of science in America—and Professor Eaton's practical methods of instruction in chemistry, mineralogy and botany were there followed. Great was the delight of the boys in botanical and mineralogical excursions with Mr. Fay Egerton, and their pleasure, too, in the lectures on chemistry. In 1830, the writer left the Utica High School for Yale College; and a year later, Mr. Egerton having resigned on account of his health, Gray took his place. We had then no acquaintance and knew nothing of one another's interest in minerals and plants. My minerals and herbarium went with me to New Haven; and while I was there Gray was mineralizing as well as botanizing, during his vacations, in New Jersey and western and northern New York. His first published paper is mineralogical—an account of his discoveries (along with Dr. J. B. Crawe) of new mineral localities in northern New York. It is contained in the twenty-fifth volume of this Journal,* and the title gives Utica as his place of residence. He had previously made

* Page 346. The article is in the second number of the volume, which was issued January 1st, and is without date; the one following it is dated Sept. 6, 1833. The paper therefore was probably written in the autumn of 1833, after a summer's excursion.

excursions after plants, fossils and minerals in New Jersey, and in 1834, joined Dr. Torrey in botanizing, besides collecting for him in the "pine barrens" of New Jersey and other places.

In the autumn of 1834, Gray accepted the position of assistant to Dr. Torrey in the chemical laboratory of the Medical School of New York. Botany was at first his study *under* Dr. Torrey, but soon his work *with* Dr. Torrey; and here commenced their long-united labors and publications. From the first he showed himself an adept in his methods of investigation and in his terse and mature style of scientific description. During the year 1834, while Torrey was preparing his monograph on the North American sedges, the Cyperaceæ, Gray had in hand an illustrated memoir on the genus Rhynchospora, in which he doubled the number of known North American species; and another also on "New, rare, and otherwise interesting plants of northern and western New York." Both papers were read before the Lyceum of Natural History of New York in December of that year (1834), and are published in volume iii of the Annals of the Lyceum. Dr. Torrey's monograph was read on the 8th of August, 1836; and in it he says that the part on the genera Rhynchospora and Ceratoschœnus was prepared by Dr. Gray, and that his descriptions are so full that he gives only his list of the species with such alterations as he has thought it advisable to make, and some additional matter received since the publication of his paper. During 1834, 1835, two volumes of a work on North American Gramineæ and Cyperaceæ were issued by him, each containing a hundred species, and illustrated by dried specimens—now rare volumes, as only a small edition was published through private subscription. The first of these volumes, issued in February, 1834, only three years after his graduation at the Fairfield Medical School, is dedicated to his instructor and friend, Dr. James Hadley. The preface acknowledges his indebtedness to Dr. Torrey and to Dr. Henry P. Sartwell of Penn-Yan. Of the species described as new in the work, the first one, No. 20, from specimens collected by Dr. Sartwell, turned out to be Nuttal's *Calamagrostis confinis.* But the next one, No. 28, *Panicum xantho-*

physum, from the vicinity of Oneida Lake, stands, and is the first of the thousands of good Asa-Gray species. Thus Gray's botanical investigations were well begun before his twenty-fifth year had passed.

In February or March of 1835 he gave his last instruction at the Utica High School. He expected to continue as Dr. Torrey's assistant the following season; but "the prospects of the Medical School were so poor that Dr. Torrey could not afford to employ him." He nevertheless returned to New York in the autumn, took the position of curator and librarian of the Lyceum of Natural History, and continued his botanical investigations. During the summer he had begun the preparation of his "Elements of Botany," and in the course of 1836 the work appeared. It showed the scholar in its science and in its style. The subjects of vegetable structure, physiology and classification were presented in a masterly manner, though within a small compass. The book, moreover, showed his customary independence of judgment and clear head in various criticisms and suggestions—later investigations sustaining them, much to his gratification.

The Wilkes Exploring Expedition came near making a profound impression on Gray's life. In the summer of 1836 the position of Botanist in the expedition was offered him, and accepted. But delays occurred in the time of sailing, and changes were threatened that threw uncertainties over the cruise, and for these reasons, and on account of the work on the North American Flora, of which, by invitation of Dr. Torrey, he was to be joint author, his resignation was sent in the following year. The expedition changed its commander from Commodore Patterson over a ship of the line, to Lieutenant Charles Wilkes with a squadron of two sloops of war (better adapted for the purpose), besides other vessels, six in all, and sailed in August, 1838. The four years abroad would have given him an opportunity for observations and discoveries that would have rejoiced him—excursions in Madeira, the Canaries, to the Organ Mountains in Brazil, a brief look about Orange Bay near Cape Horn, excursions to the Andes of Chili and about lower Peru, over Oregon and Washington territory, and parts of California, through numerous island groups of the South and North Pacific, in Australia and New Zealand, about

Luzon in the Philippines, at Singapore, at Cape of Good Hope and St. Helena—and his open mind would have gathered in facts on the relations and geographical distribution of species that would have been to him a mine of wealth as science advanced under Darwin's lead. The place of botanist in the expedition was well occupied by the most excellent, indefatigable and many-sided zoologist, Dr. Charles Pickering, and by Mr. Wm. D. Breckenridge, a Scotch gardener and zealous collector, and Mr. Wm. Rich; but with Dr. Gray, devoted to the one subject, great results would have been accomplished. North American botany, however, would no doubt have suffered.

By October of 1838, a couple of months after the sailing of the Exploring Expedition, two parts of the projected "Flora" were already out. But so many doubtful points had been brought to light, that a study of foreign herbaria had become imperative. Dr. Gray had accepted, during the summer, the chair of botany in the recently founded University of Michigan, but with the condition that he should have a year abroad for study; and the year was given to this object. All the herbaria of Europe were carefully examined with regard to the type-specimens of American plants, and full notes taken for use in the discrimination and identification of species. The fortieth volume of this Journal (April, 1841) opens with a highly interesting paper by him, giving accounts of these herbaria, their contributors, condition, and special characters, commencing with that of Linnæus and the story of its career before reaching the Linnean Society of London. His labors abroad involved an immense amount of detailed and exact observation, requiring thorough knowledge, excellent judgment, and a retentive memory; and he came home well stored for the work which he and Torrey had in hand.

Moreover, he made during the trip the personal acquaintance of the leading botanists of England and the Continent, and had from all a cordial reception.

"In Glasgow he made the acquaintance of William Jackson Hooker, the founder of the greatest of all herbaria, the author of many works upon botany, who had already published a large part of his "Flora Boreali-Americana," in which were described the plants of British North America, a work just then of special interest to the young American, because it first systematically displayed the discoveries of David Douglas, of Drummond, Richardson, and other English travelers in North America. At Glasgow, too, was laid the foundation for his lifelong friendship with the younger Hooker, then a medical student seven years his junior, but destined to become the explorer of New Zealand and Antarctic floras, the intrepid Himalaya traveler, the associate of George Bentham in the authorship of the "Genera Plantarum," a president of the Royal Society, and, like his father, the director of the Royal Gardens at Kew. At Edinburgh he saw Greville, the famous cryptogamist; while in London, Francis Boott, an American long resident in England, the author of the classical history of the genus "Carex," and at that time Secretary of the Linnean Society, opened to him every botanical door. Here he saw Robert Brown, then the chief botanical figure in Europe, with the exception, perhaps, of De Candolle; and Menzies, who fifty years before had sailed as naturalist with Vancouver on his great voyage of discovery; and Lambert, the author of the sumptuous history of the genus "Pinus," in whose hospitable dining-room were stored the plants upon which Pursh had based his North American Flora. Here, too, he met Bentham and Lindley and Bauer, and all the other workers in his scientific field.

"A visit to Paris brought him the acquaintance of the group of distinguished botanists then living at the French capital: P. Barker Webb, a writer upon the botany of the Canaries; the Baron Delessert, Achille Richard, whose father had written the Flora of Michaux; Mirbel, already old, but still actively engaged in investigations upon vegetable anatomy; Spach; Decaisne, then a young *aide naturaliste* at the Jardin des Plantes, of which he was afterward to become the distinguished Director; Auguste St. Hilaire, the naturalist of the Duke of Luxembourg's expedition to Brazil, and at that time in the full enjoyment of a great reputation earned by his works upon the Brazilian flora; Jacques Gay; Gaudichaud, the naturalist of the voyage of L'Uranie and La Physicienne; the young Swiss botanist, Edmond Boissier, the Spanish traveler, and, later, one of the most important contributors to systematic botany in his classical "Flora Orientalis;" Adrien de Jussieu, grand-nephew of Bernard, and son of Laurent de Jussieu, himself a worthy and distinguished representative of a family unequalled in botanical fame and accomplishment.

"At Montpellier, Dr. Gray passed several days with the botanists Delile and Dunal, and then hurried on to Italy, where at Padua, in the most ancient botanical garden in Europe, he made the acquaintance of Visiani, at that time one of the principal botanists in Italy. At Vienna he saw the learned Endlicher, the author of a classical "Genera Plantarum;" and at Munich, Von Martius, the renowned Brazilian traveler, the historian of the palms, and the earliest contributor to that stupendous work, the "Flora Brasiliensis," which bears his name; and here, too, was Zuccarini, the collaborator with Von Siebold in the "Flora Japonica." Geneva then, as at the present time, was a center of scientific activity; and there he made the personal acquaintance of the De Candolles, father and son, and worked in their unrivalled herbarium and library. He saw Schlechtendal at Halle; and at Berlin, Klotzsch, Kunth, and Ehrenberg,—familiar names in the annals of botanical science. Alphonse De Candolle and Sir Joseph Hooker alone are left of the brilliant group of distinguished naturalists who cordially welcomed the young American botanist in 1839."*

Dr. Gray also, while abroad, performed a great service for the University of Michigan, in superintending the selection of works for the nucleus of its library; and the University showed its appreciation of his judgment, and of the benefit to the institution, by honoring him, and itself, at its semi-centennial celebration the past summer, by conferring on him the degree of Doctor of Laws.

Again at home, and now well equipped for conquering difficulties about American species, he went at the Flora with new vigor. The first volume was completed by Torrey and Gray in 1840, and the second in February, 1843. In the interval between these dates, during the summer of 1841, Gray spent five to six weeks in a botanical excursion through the Valley of Virginia to the summits of the high mountains of North Carolina. A letter about the trip, addressed to Sir William J. Hooker, published in this Journal in 1842, first gives an account

* From a sketch of Dr. Gray by Prof. C. S. Sargent.

of the excursions into these regions by his predecessors, Bartram, Michaux, and John Fraser, of the last century, and John Lyon, Michaux the younger, Pursh, Nuttall, Curtis and others, of this, mentioning their discoveries, with critical remarks on the species they observed and on their distribution; and then he describes his own journey, adding notes on the plants met with by the way and in the mountains, commencing his observations at Harper's Ferry. His journey among the North Carolina Mountains included the ascent of the "Grandfather," 5897 feet in elevation, and the Roan Mountain, 6306 feet. This is one among a number of such excursions.

Another labor of this period was the revision of his "Elements of Botany," which, without much change of general method, he made a far more comprehensive and thorough treatise, and in 1842 issued, under the title of the "Botanical Text-book." Since then successive editions have appeared with large advances, as the science required. By the fifth edition, that of 1879, the subject had so expanded that it was divided, and the work made to include only Structural Botany, covering Morphology, Taxonomy and Phytography, leaving Physiological and Cryptogamic botany to other hands. The second volume, an exposition of Physiological Botany, appeared in 1885, from the pen of his colleague, Prof. G. L. Goodale. A third volume on Cryptogamic Botany is promised by another colleague, Prof. W. G. Farlow.

Gray never entered on duty at the Michigan University, it being impossible for him to carry on his publications so far away from the New York herbaria and botanical libraries. In 1842, he was invited by the Fellows of Harvard College to the Fisher Professorship of Natural History, recently founded on a bequest of Dr. Joshua Fisher. The duties of the professorship included the delivery of a course of lectures on Botany, and the direction of the small botanic garden which had been established in Cambridge in 1805, under the auspices and with the assistance of the Massachusetts Society for promoting Agriculture. Thomas Nuttall had charge of the garden from 1822 to 1828, and after that it was without a head until the appointment of Dr. Gray. The garden was still poor in funds, and had not even an herbarium to aid Gray in his botanical studies. But he entered on the duties with zeal, conducted the required lectures in the most lucid and attractive manner, freely gave the use of his study to such students as wished to learn more of the science than they could acquire from the lectures, and gathered a vast herbarium. And all the time he carried on an enormous correspondence with promptness, and answered all social demands with unfailing courtesy, besides continuing his botanical investigations and writing books and memoirs. These duties continued until 1872, when he was relieved from that of teaching and the charge of the garden. In 1864, he made the offer to Harvard College of the herbarium and library which he had gathered, already very large, on the condition of their erecting a fire-proof building to contain them, which was accepted.

Botanical work was always in progress in some form. One of the very valuable parts of it consisted in his contributions to this Journal—which were continued, with scarcely any interruption, for the love of the science and of the men engaged in it. Every important work as it was issued was here noticed, with often critical remarks, or additional facts and illustrations, or modifications of opinions, that gave them great scientific value. And not the least instructive and attractive part were the biographical sketches of deceased botanists, European as well as American; for to him the world was all one, and all botanists were akin. He was sure to criticise what he believed to be wrong; but it was done so fairly, with so evident a desire for scientific accuracy, and in so kind a spirit, that offense was rarely given. A botanist of eminence says that "these notices form the best history of the botanical literature of the last fifty years, and of the progress and development of botanical science, that has been written."

The fortieth volume of this Journal (1841) contains an admirable example of his kindly method of reviewing an author that has faults, and of his critical study among great difficulties. It is a review of the botanical writings of Rafinesque, that enthusiastic naturalist, poet, etc., with reference, not to his faults, but to the value to be attached to his numerous genera and species and their recognition in American Botany. Throughout, there is a full appreciation of Rafinesque's sagacity in many of his discriminations, a fair presentation of his scientific claims, of his love of nature and greater love of self, without a harsh word for his errors or egotism; and only a citing of a sentence here and there, or a fact, that enables Rafinesque to make his own presentations as to his species and genera, with a bare mention of his "twelve new species of thunder and lightning."

The publication of the second volume of the "Flora," in 1843, ended that work. The territory of the United States afterward took larger dimensions, and new fields were to be explored before a complete "Flora" could be published. Torrey was engaged on these studies until his death in 1873; and Gray also was publishing memoirs that were contributions to the subject. Gray's various memoirs include: descriptions of the collections made by Lindheimer, in western Texas (1843–48); by Fendler, in New Mexico (1846–7); by Wright, near the boundary of Texas and Mexico (1849 and 1851–2); by Thurber, along the United States and Mexican boundary (1851–2); the Botany of various Government surveys, and other Government reports, and a portion of the Botany of California. Other papers are distributed through the publications of learned societies, especially the American Academy of Arts and Sciences of Boston, which contains hundreds of pages of them, the Proceedings of the Philadelphia and California Academies, the Boston Society of Natural History, the Linnean Society of London, etc.

Further, the plants of the Wilkes Exploring Expedition, exclusive of the ferns and those from western North America, were early sent to him for description; and in 1854 appeared his Report, in quarto, accompanied by a folio atlas, containing a hundred plates.

Gray was three times over the Rocky Mountain region to the Pacific Coast. On the second trip he was accompanied by Sir Joseph Hooker; and an important paper on the "Vegetation of the Rocky Mountain Region" by them is published in the Reports of the Hayden Geological Survey for 1878. He was in Europe again in the years 1850–51. A note from Mrs. Gray says: "He went abroad especially for the plants of the Wilkes Expedition. After traveling in Switzerland (going up the Rhine to Geneva, where he worked awhile in DeCandolle's herbarium), we went to Munich and saw Martius, and then back to England by Holland. On the first of October we went into Herefordshire to the country place of George Bentham, and spent two months there, Mr. Bentham going over with Dr. Gray the collection which had been sent out from America, a most generous piece of work." It was at this time, while at the Kew Gardens, near London, that he had the passing introduction to Darwin, alluded to in Darwin's first letter to him.*

In 1868, he crossed the ocean the fourth time, going in September and returning in November of the following year. He was hard at work over herbaria at Kew during both autumns; and worked also in Paris, Munich, Geneva, and elsewhere, but with more holiday than in any journey he took except the last. In this visit he was twice with Darwin, first in the autumn of 1868, and then in October, 1869.

After forty years of studying and discriminating among the older species of the continent and their representatives abroad, and of describing species from late discoveries, and of work at classification, with experimental work at Flora-making during the years 1838 to 1843, he was finally ready, in 1878, with the first part of a new North American "Flora," to which he gave the name of "Synoptical Flora of North America." This first part contained the Gamopetalæ after the Compositæ. A second part was published in 1884, comprising the Caprifoliaceæ to the Compositæ inclusive, or the ground of the second volume of Torrey and Gray's Flora; so that the middle half of the entire Flora is now completed. The two parts cover 974 closely printed pages. "They are masterpieces of clear and concise arrangement, and of compactness and beauty of method, and display great learning and analytical power." The progress of the science since the time of Michaux is well exhibited in the fact that while this author knew 193 species of Compositæ when he published his Flora, Gray, seventy-five years later, describes no less than 1636 species under 239 genera.

During these years, Dr. Gray added to the resources of the instructor in Botany by the publication of his "Manual," a

* Darwin's Life and Letters, p. 420.

descriptive work including all species growing east of the Mississippi and north of Tennessee and North Carolina. It was first issued in 1848, and its fifth and last edition in 1868. The "Elementary Lessons in Botany and Vegetable Physiology," also, was published first in 1868, as an accompaniment to the Manual, and has had its five editions at nearly the same dates. The first volume of another companion work to the Manual was issued in 1848—his "Genera Illustrata," containing descriptions of the genera of the United States Flora, with illustrations of great beauty by I. Sprague; and in 1849 a second volume was published, carrying the works nearly to the Leguminosæ; and here it stopped, on account, mainly, of the expense. His "Field, Forest and Garden Botany," a useful flora for schools, came out in 1868; and the charming smaller volumes "How Plants Grow," and "How Plants Behave," respectively in 1858 and 1875. The latter was prompted by Darwin's works on Insectivorous Plants, the Orchids, and Dimorphism, and both are well adapted to the young student and all uninitiated readers.*

Besides the subjects of Gray's investigations already mentioned, two others of a wider philosophical character interested him deeply: one, in which he was pioneer, the other, the Origin of Species, after Darwin.

The first of these subjects was the Geographical Distribution of Plants, and particularly the species of the Northern United States both within and beyond the bounds of the continent, and the bearings of the facts on variation and origin.

His first paper on the subject is contained in volumes xxii and xxiii of this Journal, the numbers for September, 1856, and January and May, 1857. It was written partly in compliance with the request of "an esteemed correspondent" for a list of American alpine plants, who, as now appears, was Darwin. Darwin's Life contains, on page 420, the letter, and shows that its date was April 25, 1855; and, also, a second letter of June 8, 1855, which opens thus: "I thank you cordially for your remarkably kind letter of the 22d ult., and for the extremely pleasant and obliging manner in which you have taken my

* A list of Dr. Gray's publications will be given in another number of this Journal.

rather troublesome questions. I can hardly tell you how much your list of alpine plants has interested me." And then Darwin puts more questions to his genial correspondent.

The long paper, modestly entitled "Statistics of the Flora of the United States," contains numerous tables, comparing as regards plants the Northern United States with Europe on one side, and Asia and Japan on the other; the eastern part of the country with the western, and with the adjoining continents in the north-temperate zone; the plants of alpine and subalpine regions in the Northern United States, and their distribution southward, and eastward and westward over the other continents; the distribution of species common to this country and Europe, as to size of orders and genera; also, as regards related and representative species, and the same for Eastern and Western America; lists of species of widely sundered habitation; with numerous other points, and abundant explanatory remarks; making thus a thorough philosophical digest of the subject of geographical distribution, having all the completeness as respects the northern United States that the existing state of the science admitted of. He closes with a general review of the characteristics of the North American flora.

In the course of the pages, he advocates the idea of a single area of origin for a species, with dispersion at an epoch more or less ancient, to account for distribution; sustains Darwin's "surmise" as to the species of large genera having a greater geographical area than those of small genera; observes that a large percentage of the extra-European types of Eastern America are shared with Eastern Asia; and finds, "that curiously enough, eleven, or one-third of our strictly alpine species common to Europe—all but one of them arctic in the Old World—are not known to cross the Arctic circle on this continent; so that it seems almost certain that the interchange of alpine species between us and Europe must have taken place in the direction of Newfoundland, Labrador and Greenland, rather than through the polar regions" (xxiii, 73).

Two years later, in 1859, Dr. Gray had studied a collection of plants from Japan (alluded to in the former paper, xxiii, 369, as in hand), which had been collected by Mr. Charles Wright; and his memoir on the subject, read that year before the American Academy of Arts and Sciences, closes with a sequel to the subject of Geographical Distribution, bringing out conclusions of still higher interest. He starts off with the then new announcement and its evidence, that among the plants of Japan, more species are represented in Europe than over the nearer land, western North America ; more in eastern North America than in either of the other two regions; and adds, that hence, there has been a peculiar intermingling of the eastern American and eastern Asia floras, which demands explanation. The explanation he finds in the idea of migrations to and from the arctic regions, determined in part, at least, by the climate of the preglacial, glacial and postglacial eras ; and that the alpine plants of the summits of the White Mountains, Adirondacks, Black Mountains and Alleghanies, are species left by the retreating glacier.

Dr. Gray returned to this subject in his presidential address, in 1872, before the American Association for the Advancement of Science,* and, owing to the progress that had been made in the paleontology of the continent, the arctic portion as well as the more southern, and developments elsewhere also, he was enabled to trace out the courses of the migrations of plants, the Sequoias or Redwoods and many other kinds, by positive facts with regard to the arctic and more southern floras ; and showed that the distribution southward into the western United States, into eastern Europe or western Eurasia, and into Japan and Asia or eastern Eurasia, was not only dependent, as he had before put forth, on change in continental climates, but also that the particular direction southward was determined to a large extent by fitness of climate as to heat and dryness. The surprising revelations are now so generally known that this brief reference to them is all that is here needed.

Gray's comprehensive knowledge of the plants of the world, of their distribution, and specifically of the relations of North American species, genera and orders to those of the other continents, and the precision of his knowledge, enabled him to be of much service to Darwin in the preparation of the first edition of the Origin of Species, and afterward, also, in the elab-

* This Journal, III, iv, 282, 1872.

oration of Darwin's other publications. His mind was not very strongly bound to opinions about species, partly because of his natural openness to facts, his conclusions seeming always to have only a reasonable prominence in his philosophical mind, rarely enough to exclude the free entrance of the new, whatever the source, and to a considerable extent from the difficulties he had experienced in defining species and genera amidst the wide diversities and approximate blendings which variation had introduced.

Darwin first mentioned to Gray his view that "species arise like varieties, with *much* extinction," in a letter to Gray of July 20th, 1856.* At this time all men of science with a rare exception believed in the permanence of species. J. D. Hooker's Flora Indica of 1855 "assumes that species are *distinct* creations."† Prof. Huxley, in his history of the reception of Darwinian ideas, says, with the perfect fairness that always has characterized him, that "within the ranks of the biologists, at that time [1851–8], I met with nobody [and he here includes himself] except Dr. Grant, of University College, who had a word to say for evolution; and his advocacy was not calculated to advance the cause. Outside of these ranks, the only person known to me whose knowledge and capacity compelled respect, and who was, at the same time, a thorough-going evolutionist, was Herbert Spencer. . . . But even my friend's rare dialectic skill and copiousness of apt illustration could not drive me from my agnostic position." Lyell, he shows, was leaning that way, but not himself. So it was in 1857, and in 1858 up to the publication of Darwin's and Wallace's papers of that year.‡

Gray therefore knew of Darwin's views before the biologists of Britain, unless we except Lyell and J. D. Hooker. Darwin acknowledged Gray's "remarkably kind letter" on the 5th of September, 1857,§ and is prompted by his "extraordinary kindness," and, evidently, by his assurances, that he had no objections to facts from any source, had great interest in the subject, and only saw some "grave difficulties" against his doctrine, to

* Darwin's Life and Letters, p. 437.

† Gray's review, this Journal, xxi, 135, Jan., 1856.

‡ Darwin's Life and Letters, chapter xiv of vol. i, by Prof. Huxley.

§ Ibid, p. 477.

explain to Dr. Gray with detail, under six heads, the prominent facts and arguments in the theory of "Natural Selection," which he says is the "title of his book." This letter is the first exposition that Darwin had made of his theory, and hence it has proved to have great documentary value.

A letter which the writer received from Gray in the interval between Darwin's two letters, dated December 13, 1856, shows well the state of his mind at that time. He says: "On the subject of species, their nature, distribution, what system in Natural History is, etc., etc., certain inferences are slowly settling themselves in my mind or taking shape; but, on some of the most vexed questions, I have as yet no *opinion* whatever, and no very strong *bias*, thanks partly to the fact that I can think of and investigate such matters only now and then, and in a very desultory way."*

In a letter of a year later, subsequent in date to Darwin's letter, Gray wrote me with reference to my paper on "Species" read at the meeting of the American Association in August, 1857—which paper may be taken, perhaps, as a culmination of the past, just as the new future was to make its appearance—pointing out to me the fatal objection to my argument.

His words (dated November 7th) are worth quoting: "Taking the *cue* of species, if I may so say, from the *inorganic*, you develop the subject to great advantage for your view, and all you say must have great weight in 'reasoning from the general.' But in reasoning from *inorganic species* to *organic species*, and in making it tell where you want it, and *for what* you want it to tell, you must be sure that you are using the word *species* in the same sense in the two; that the one is really the equivalent of the other. That is what I am not yet convinced of; and so to me the argument comes only with the force of an *analogy*, whereas I suppose you want it to come as demonstration. Very likely you could convince me that there is no fallacy in reasoning from the one to the other to the extent you do. But all

*Gray has some important observations on the bearing of hybridization on variation, in a review of Hooker's Flora Indica in the number of this Journal for January, 1856, (xxi, 134).

my experience makes me cautious and slow about building too much on analogies; and until I see further and clearer I must continue to think there is an essential difference between *kinds of animals or plants* and *kinds of matter.*

"How far we may safely reason from the one to the other is the question. If we may do so even as far as you do, might not Agassiz (at least plausibly) say that as the *species Iron* was created in a vast number of individuals over the whole earth, so the presumption is that any given species of plants or animals was originated in as many individuals as there are now, and over as wide an area; the human species under as great diversities as it now has, barring historical intermixture; thus reducing the question between you to insignificance? because, then, the question whether men are of one or of several species would no longer be a question, or of much consequence. You may answer him from *another starting point*, no doubt; but he may still insist that it is a legitimate carrying out of your principle."

In the same letter Gray prophesies as follows,—from actual knowledge, it now appears: "You may be sure that before long there must be one more resurrection of *the development theory* in a new form, obviating many of the arguments against it, and presenting a more respectable and more formidable appearance than it ever has before."

The Origin of Species was out in November, 1859. Gray received an early copy of it from Darwin, and therefore his very valuable review was ready for this Journal early in 1860.*

With regard to the sufficiency of the argument brought forward in Darwin's work, Gray says that "To account upon these principles for the gradual elimination and segregation of nearly allied forms—such as varieties, sub-species and closely related or representative species—and also for their geographical association and present range, is comparatively easy, is apparently within the bounds of possibility, and even of probability." But as to the formation of genera, families, orders and classes by natural selection, Gray simply states Darwin's arguments on the subject, and some objections on a few weak points, without expressing further his own views. He

* It occupies 32 pages in the March number, vol. xxix, pp. 153 to 184.

concludes with some remarks on the religious bearing of a theory that refers creation to natural law and declares rightly, in accordance with his firm faith to the end, that "Natural law is the human conception of continued and orderly Divine action."

Darwin, in a letter to Gray written during the following summer, having in view Gray's article in this Journal, and another discussion of his published in the Proceedings of the American Academy, says, "I declare that you know my book as well as I do myself, and bring to the question new lines of illustration and argument in a manner which excites my astonishment and almost my envy." "As Hooker lately said in a note to me, you are, more than *any one* else, the thorough master of the subject."

Gray's "Darwiniana," published in 1876, is composed of a number of his essays and reviews, from this Journal, the "Nation" and the "Atlantic Monthly," together with a closing chapter, written for the volume, entitled "Evolutionary Teleology." The last chapter brings out Gray's adherence to the doctrine of Natural Selection, and also his divergence from true Darwinism. These divergences are thus expressed:

"We are more and more convinced that variation, and therefore the ground of adaptation, is not a product of, but a response to, the action of the environment. Variations, in other words the differences between individual plants and animals, however originated, are evidently not from without, but from within; not physical, but physiological." And elsewhere he has said that the variation in a species is apt to take place in particular directions and make linear ranges of varieties, as often exemplified among plants; which accords with the preceding conclusion, pp. 386.

Again, speaking of the forms of Orchids and their connection with, and relation to, insect fertilization, he says: "We really believe that these exquisite adaptations have come to pass in the course of nature, and under Natural Selection, but not that Natural Selection alone explains or in a just sense originates them. Or, rather, if this term is to stand for sufficient cause and rational explanation, it must denote or include that inscrutable something which produces, as well as that which results in the survival of, 'the fittest,'" p. 388.

Both of these doctrines are anti-Darwinian, though not at variance with Natural Selection. They take away what has often been urged against Darwinism: the idea that the environment under natural selection dominates in the determination of the direction of variation, and hence that evolution comes chiefly through external conditions; and substitutes the idea that the environment works under organic control through Natural Selection. One view implies that the environment influence is superior to organic law in the process; the other, that organic law is superior to the environment. Moreover, Gray's last sentence expresses the opinion that Darwin's Natural Selection cannot produce the "survival of the fittest," though "survival of the fittest" is the *result* brought about. There is an "inscrutable something" that "produces." The writer would go a little farther and say that the "survival of the fittest," under "natural selection," is *survival*, not the *production* of "the fittest;" but this substitute I have reason to believe that Gray would not accept.

Further, Gray was a theistic Darwinian, as abundantly shown in his Darwiniana, and alike also in his "Natural Science and Religion." Here is his creed in his own words, as published in the Preface to the Darwiniana: "I am scientifically and in my own fashion a Darwinian, philosophically, a convinced theist, and religiously, an accepter of the 'creed commonly called the Nicene,' as the exponent of the Christian faith."

Gray's various literary or less scientific papers, contributions mostly to the "North American Review," "Nation," and the "Atlantic Monthly," always show the clear thinker, the graceful writer and the well-stored head, whatever the topic; and when it is scientific, his method of popularizing and illustrating his views is of the most attractive kind. His last contribution to the "Nation" was a long characteristic notice of Darwin's Life and Letters, in November, showing no waning in his faculties; on the contrary, there is manifest the same clear-headed, judicial and sprightly reviewer, as honest as ever in his opinions and in his modesty amid Darwin's profuse (he says effusive) commendations.

The last visit to Europe was made during the past year. He went with the intention of doing but little of his herbarium work, and, finding pleasure among friends, old and new. Mrs. Gray, as usual, was with him. It proved to be a triumphal time to the modest botanist; for he received the honor of doctorate from each of the great Universities of Britain, that of Oxford, of Cambridge and of Edinburgh. He returned in October, in excellent spirits and health—an apparent promise of some years more of work. He was soon again occupied with his "Flora," the completion of which was the earnest desire of all botanists. Yet while wishing to see its last page himself, his anxiety about it had lessened in later years, because aware that his colleague in charge of the Herbarium, Dr. Sereno Watson—one of the students that he had gathered about him—was capable of taking up the lines whenever he should lay them down.

Gray's standing among philosophers abroad is manifested in his recent reception in Great Britain. It is further shown in his having been elected an honorary member of all the principal Academies or Societies of Science in Europe, including the Royal Society of London and the Institute of France. He was President of the Association for the Advancement of Science in the year 1871, and has been one of the Regents of the Smithsonian Institution since 1874; and for ten years, from 1863 to 1873, he was President of the American Academy of Arts and Sciences. In 1884 his portrait in bronze, made by St. Gaudens, was presented to Harvard College.

One of the most gratifying testimonials from his fellows in science was received on his seventy-fifth birthday. To his surprise there came greetings or notes of congratulations from every American botanist, old and young, and, along with the notes, a silver vase embossed with figures of the plants more particularly identified with his name or studies. It was delightful to witness, says one of his associates, his child-like pleasure as he received the gift. Among the letters were some from friends who were not botanists. The following lines were from Mr. Lowell:

JUST FATE : prolong his life, well spent,
Whose indefatigable hours
Have been as gaily innocent
And fragrant as his flowers.

The vase is about eleven inches high exclusive of the ebony pedestal. The pedestal is surrounded by a hoop of hammered silver on which is the inscription

1810 November eighteenth 1885
ASA GRAY
In token of the universal esteem
of American Botanists

Among the flowers, in raised figures about the vase, the place of honor on one side is held by *Grayia polygaloides*, and on the other by *Shortia galacifolia*. On the Grayia side, the prominent plants are *Aquilegia Canadensis*, *Centaurea Americana*, *Jeffersonia diphylla*, *Rudbeckia speciosa* and *Mitchella repens;* and on the Shortia side, there are *Lilium Grayi*, *Aster Bigelovii*, *Solidago serotina* and *Epigæa repens*. The lower part of the handles runs into a cluster of Dionæa leaves, which clasps the body of the vase, and their upper part is covered with *Notholæna Grayi*. *Adlumia cirrhosa* trails over the whole back-ground, and here and there its leaves and flowers crop out. The greetings, in the form of cards and letters, that had been sent by the givers of the vase, were placed on a simple but elegant silver plate, which had within the engraved inscription: BEARING THE GREETINGS OF ONE HUNDRED AND EIGHTY BOTANISTS OF NORTH AMERICA TO ASA GRAY, ON HIS SEVENTY-FIFTH BIRTHDAY, NOVEMBER 18TH, 1885.*

Botanists have, as their common object of interest, that part of Nature which seems by its free gift of beauty and fragrance (without a trace of self, the dominating element in the animal) fully to reciprocate affection; and there is hence a reason for that feeling of fraternity which such a gift so beautifully expresses, independently of the tribute in it to the botanist of botanists. Plants seem thus to select from among enquiring minds those which are to be their investigators, or the botanists.

* This description of the vase is from the "Botanical Gazette" of December, 1885, which contains also good figures of the vase.

It is a case of Natural Selection. But Dr. Gray was more to botanists than a friend and leader. He was the "Beloved Gray"—the object of their admiration and devotion on account of his goodness, his high principle, his frank independence, his unfailing cordiality, and the clearness of his intellectual vision, like that of a seer. He stands before the world as a lofty example of the Christian philosopher.

Dr. Gray was married, in 1848, to the daughter of the late eminent lawyer of Boston, Charles G. Loring. His excellent and accomplished wife, who survives him, was in full sympathy with him in all his pursuits and pleasures, a bright, cheerful and helpful companion, at home and in his travels abroad.

In a letter to the writer in 1886, Gray says:

—— I have had a week in old Oneida, which still looks natural. I am grinding away at the Flora, and shall probably be found so doing when I am called for. Very well: I have a most comfortable and happy old age.

Wishing you the same,

Yours ever, A. GRAY.

November last, the month after his return from Europe, he put aside his nearly completed revision of the "Vitaceæ, or Grapevines of North America" to write his last words about Darwin in the review of Darwin's Life and Letters, and to prepare his usual annual Necrology for this Journal. The latter manuscript lay unfinished on his table, when, on the 27th of the month, a paralytic stroke put an end to work, with every prospect then that his name also would have to be added to the list of 1887. He lingered until the 30th of January, without a return, at any time, of his powers of speech, and toward evening of that day passed quietly away.

Asa Gray's remains lie buried in the Mt. Auburn Cemetery. American botanical science, wrought out so largely in its details, its system, and its philosophical relations, by his labors, is his monument. J. D. D.

ART. XVII.—*Calibration of an Electrometer*; by D. W. SHEA.

THE mathematical theory* of the quadrant electrometer leads to the general formula:

$$\Theta = \alpha\ (A-B)\ (C-\tfrac{1}{2}\ (A+B),$$

in which θ represents the moment of the couple which turns the needle, A, B, C, the potentials of the two pairs of quadrants and of the needle respectively, and α is a constant which defines the sensibility of the instrument. The deflection of the needle is proportional to the moment θ. Hence, if α is a constant † as the theory supposes, the deflection of the needle should be proportional to the product

$$(A-B)\ (C-\tfrac{1}{2}\ (A+B),$$

and the curve of calibration obtained in any given method of setting up the electrometer should have a perfectly definite and constant form. But in the various forms of the quadrant electrometer, and in the different methods of setting up the same instrument, the curves of calibration obtained correspond in a very irregular manner with the curves given by theory.‡

Some observations with an electrometer of the Mascart form, which show variations apparently due to change in the sensibility with variation in the temperatnre,§ are given in the following pages. It is possible that they may be of interest to those who use this form of electrometer.

The results here given were obtained with the electrometer set up in the following manner:

The needle was suspended by a bifilar suspension consisting of a single fiber of cocoon silk, the ends of which were fastened to the drum and the loop to the hook on the upper end of the rod carrying the needle. The two parts of the fiber were separated as widely as the construction of the instrument admits of. The needle was charged by a water-battery. The positive pole of the battery was attached to the electrode connecting with the inner coating of the Leyden jar, and the negative pole and the electrometer case were to ground. The water-battery was made up of four hundred cells of zinc-copper elements, arranged in boxes of eighty cells each. The difference of poten-

* Maxwell, Electricity and Magnetism, vol. i, p. 311.
† Hopkinson, Phil. Mag., V, xix, p. 297.
‡ Mouton, Journal de Physique, vi, p. 13.
Benoit, Journal de Physique, vi, p. 118.
Boltzmann, Pogg. Ann., bd. cli, p. 487.
Hallwachs, Wiedemann's Ann. der Phys. und Chem., xxix, p. 35.
§ Hallwachs, ibid., p. 41.

tial between the positive pole of any one of these boxes of cells and the ground, with the negative pole to ground, was about forty volts.

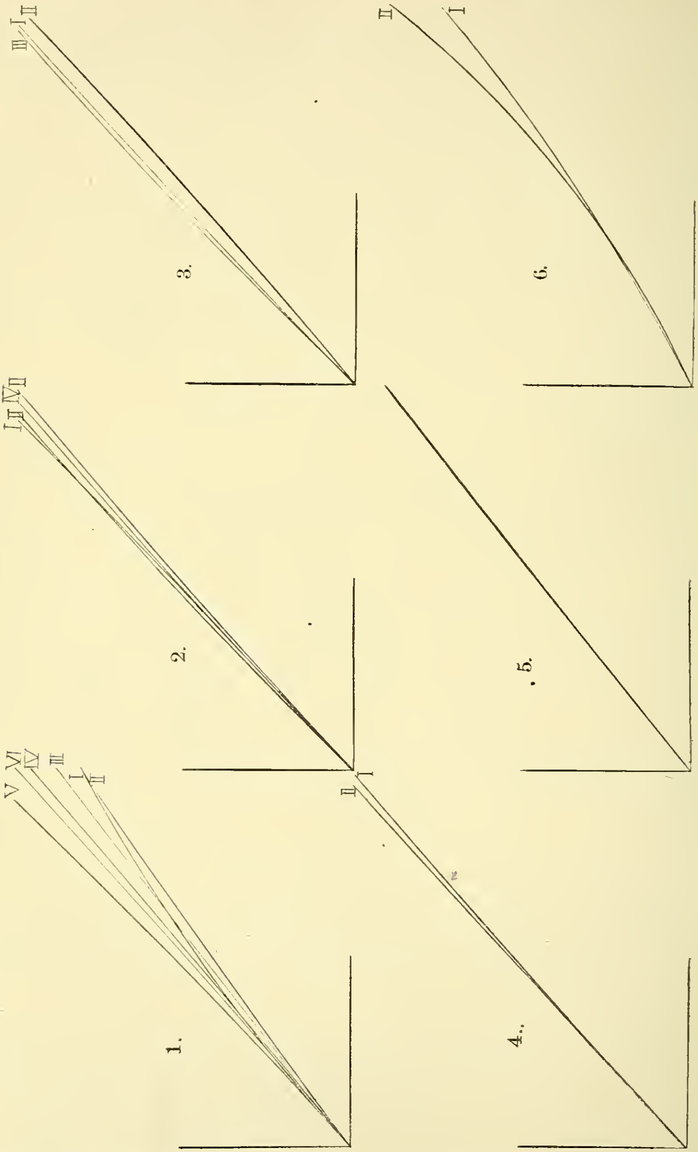
In making the calibration, a battery of small gravity cells was used, with circuit closed through an external resistance of ten thousand ohms. One and the same end of the set of resistance coils was to ground in all observations. Points on the box of coils such that one, two, three, etc., thousand ohms were included between them and the point to ground were successively connected to one pair of quadrants, while the other pair of quadrants was to ground, and the quadrant connections were alternated in order to get readings on the right and left of the zero, which was placed at the middle point of the scale. The needle was charged by one, two, three, etc., boxes of cells successively, and the number of cells in the gravity battery was decreased, as the charge of the needle was increased, so as to keep the difference of potential between the ends of the set of resistance coils such that the spot of light always remained on the scale.

It was found that the form of the curve for a given charge of the needle did not long remain constant, and that even the direction of curvature changed. The change in the form of the curve was greatest when the charge of the needle was smallest, and it was not until the whole water-battery of four hundred cells was employed that a curve was obtained which changed so little as to admit of accurate work. The change in the curves was most rapid when the temperature of the room was changing rapidly between certain limits. Beyond these limits there was little change in the curves. But for any given temperature between the limits the form of the curve was not constant, even though the temperature of the room had been so constant for several hours that all parts of the electrometer could reasonably be supposed to have the temperature of the room.

The changes in the form of the curves for various charges of the needle were followed through the range of temperature attainable, at the time, in the room where the electrometer was set up. The following tables will serve to show these changes.

In all the observations the scale was at a distance of 126^{cm} from the mirror.

The curves shown in the plate were plotted by taking the potentials of the quadrants as abscissas and the deflections of the needle in degrees as ordinates. Fig. 1 shows curves when charge of needle was forty volts; fig. 2, when charge was eighty volts; fig. 3, when charge was one hundred and twenty volts; fig. 4, when charge was one hundred and sixty volts; fig. 5, when charge was two hundred volts; fig. 6, I, when



charge was twenty volts, and II, when charge was ten volts. The Roman numerals in the figures refer to the tables.

Charge of Needle, 40 *volts.*

I.

TEMPERATURE, 6° C.

Resistance between point to ground and point to pair quadrants in ohms.	Charge of quadrants in volts.	Scale readings in cm. Right.	Left.	Mean of two scale readings.	Deflection of needle in degrees.
1000·	2·5	2·13	2·17	2·15	0° 29′·5
2000·	5·0	4·30	4·20	4·25	0 58
3000·	7·5	6·28	6·20	6·24	1 25
5000·	12·5	10·07	9·85	9·96	2 15·5
7000·	17·5	13·46	13·34	13·40	3 2
8000·	20·0	15·05	15·00	15·02	3 24
9000·	22·5	16·49	16·41	16·45	3 43
10000·	25·0	17·92	17·94	17·93	4 2·5

II.

TEMPERATURE, 8° C.

1000·	2·5	1·93	1·92	1·925	0 26
2000·	5·0	3·81	3·79	3·80	0 52
3000·	7·5	5·64	5·61	5·625	1 17
5000·	12·5	9·17	9·12	9·145	2 4
7000·	17·5	12·85	12·84	12·845	2 54
8000·	20 0	14·60	14·68	14·64	3 19
9000·	22·5	16·29	16·23	16·26	3 40·5
10000·	25·0	17·79	17·78	17·785	4 1

III.

TEMPERATURE, 11° C.

1000·	2·5	2·03	2·04	2·035	0° 28′
2000·	5·0	4·03	4·03	4·03	0 55
3000·	7·5	5·94	6·02	5·98	1 22·5
5000·	12·5	9·95	9·99	9·97	2 16
7000·	17·5	13·70	13·76	13·73	3 6·5
8000·	20·0	15·76	15·84	15·80	3 34·5
9000·	22·5	17·89	17·91	17·90	4 2
10000·	25·0	19·81	19·87	19·84	4 28

IV.

TEMPERATURE, 12° C.

1000·	2·5	1·91	1·89	1·90	0 26
2000·	5·0	3·85	3·87	3·86	0 52·5
3000·	7·5	5·90	5·95	5·92	1 20·5
5000·	12·5	10·08	10·12	10·10	2 17·5
7000·	17·5	14·30	14·33	14·315	3 14·5
8000·	20·0	16·50	16·54	16·52	3 44
9000·	22·5	18·71	18·80	18·75	4 13·5
10000·	25·0	20·79	20·82	20·805	4 47

V.

TEMPERATURE, 14° C.

Resistance between point on coils to the ground and point to quadrants in ohms.	Charge of the quadrants in volts.	Scale readings in cm. Right.	Left.	Mean of the two scale readings.	Deflection of needle in degrees.
1000·	2·5	2·12	2·14	2·13	0° 29′
2000·	5·0	4·29	4·29	4·29	0 58·5
3000·	7·5	6·58	6·58	6·58.	1 29·5
5000·	12·5	11·30	11·32	11·31	2 34
7000·	17·5	16·41	16·44	16·425	3 43
8000·	20·0	19·02	19·06	19·04	4 18
9000·	22·5	21·86	21·97	21·915	4 56

VI.

TEMPERATURE, 16° C.

1000·	2·5	1·93	1·89	1·91	0 26
2000·	5·0	3·90	3·94	3·92	0 53
3000·	7·5	6·00	6·03	6·015	1 22
5000·	12·5	10·37	10·37	10·37	2 20·5
7000·	17·5	15·15	15·18	15·17	3 26
8000.	20·0	17·64	17·71	17·68	3 59·5
9000·	22·5	19·85	19·88	19·865	4 28·5
10000·	25·0	22·15	22·24	22·20	5 0·0

Charge of Needle, 80 *volts.*

I.

TEMPERATURE, 6°·5 C.

1000·	1·3	2·35	2·35	2·35	0° 32′
2000·	2·6	4·72	4 69	4·705	1 4
3000·	3·9	7·15	7·13	7·14	1 37
5000·	6·5	12·01	12·04	12·025	2 43·5
7000·	9·1	16·94	16·95	16·945	3 49·5
8000	10·4	19·32	19·30	19·31	4 21·5
9000·	11·7	21·72	21·72	21·72	4 53·5

II.

TEMPERATURE, 9° C.

1000·	1·3	2·26	2·26	2·26	0 31
2000·	2·6	4·57	4·57	4·57	1 2
3000·	3·9	6·83	4·75	6·79	1 32
5000·	6·5	11·34	11·34	11·34	2 34
7000·	9·1	16·13	16·14	16·135	3 38·5
8000·	10·4	18·40	18·35	18·375	4 8·5
9000·	11·7	20·59	20·53	20·56	4 37

III.

TEMPERATURE, 12° C.

1000·	1·3	2·47	2·46	2·465	0° 33′·5
2000·	2·6	4·90	4·85	4·875	1 6·5
3000·	3·9	7·31	7·26	7·285	1 39·5
5000·	6·5	12·12	11·95	12·035	2 44
7000·	9·1	16·74	16·73	16·735	3 46·5
8000·	10·4	19·08	19·07	19·075	4 18
9000·	11·7	21·43	21·36	21·395	4 49

IV.

TEMPERATURE, 17° C.

Resistance between point on coils to ground and point to quadrants in ohms.	Charge of the quadrants in volts.	Scale readings in cm. Right.	Left.	Mean of the two scale readings.	Deflection of the needle in degrees.
1000·	1·3	2·60	2·59	2·595	0 35·5
2000·	2·6	5·05	4·97	5·01	1 8
3000·	3·9	7·60	7·51	7·555	1 43
5000·	6·5	12·55	12.41	12·48	2 47
7000.	9·1	17·35	17·23	17·29	3 54·5
8000·	10·4	19·50	19·57	19·535	4 24·5
9000·	11·7	21·85	21·78	21·815	4 54·5

Charge of Needle, 120 *volts.*

I.

TEMPERATURE 8° C.

1000·	0·7	2·29	2·30	2·295	0°31′
2000·	1·4	4·62	4·61	4·615	1 3
3000·	2·1	7·04	6·99	7·015	1 35·5
5000·	3·5	11·77	11·82	11·795	2 40·5
7000·	4·9	16·47	16·41	16·44	3 43
8000·	5·6	18·84	18·79	18·815	4 14·5
9000·	6·3	21·22	21·20	21·21	4 46·5

II.

TEMPERATURE 12° C.

1000·	0·7	2·23	2·24	2·235	0°30′·5
2000·	1·4	4·37	4·32	4·345	0 59
3000·	2·1	6·56	6·49	6·525	1 27·5
5000·	3·5	10·99	11·01	11·00	2 27
7000·	4·9	15·52	15·56	15·54	3 31
8000·	5·6	17·99	18·00	17·995	4 3·5
9000·	6·3	20·20	20·20	20·20	4 34

III.

TEMPERATURE 17° C.

1000·	0·7	2·43	2·44	2·435	0°33′
2000·	1·4	4·86	4·87	4·865	1 6
3000·	2·1	7·25	7 26	7·255	1 39
5000·	3·5	12·02	12·01	12·015	2 44
7000·	4·9	16·74	16·76	16·75	3 47
8000·	5·6	19·03	19·12	19·075	4 19·5
9000·	6·3	21·51	21·53	21·52	4 51

Charge of Needle, 160 *volts.*

I.

TEMPERATURE 7° C.

1000·	0·55	2·28	2·28	2·28	0°31′
2000·	1·10	4·53	4·52	4·525	1 1·5
3000·	1·65	6·80	6·79	6·795	1 32·5
5000·	2·75	11·28	11·21	11·245	2 33
7000·	3·85	15·78	15·67	15·725	3 33·5
8000·	4·40	18·00	17·93	17·965	4 4
9000·	4·95	20·30	20·20	20·25	4 34·5

II.

TEMPERATURE 18° C.

Resistance between point on coils to ground and point to quadrants in degrees.	Charge of quadrants in volts.	Scale readings in cm. Right.	Scale readings in cm. Left.	Mean of the two scale readings.	Deflection of the needle in degrees.
1000·	0·55	2·30	2·33	2·315	0°31′·5
2000·	1·10	4·61	4·65	4·63	1 3
3000·	1·65	6·87	6·97	6·92	1 34
5000·	2·75	11·41	11·61	11·51	2 36·5
7000·	3·85	14·98	15·20	15·09	3 25
8000·	4·40	18·21	18·49	18·35	4 8
9000·	4·95	20·50	20·73	20·615	4 37·5

Charge of Needle, 200 *volts.*

TEMPERATURE 17° C.

1000·	0·46	2·00	1·99	1·995	0°27′
2000·	0·92	3·99	3·99	3·99	0 54
3000·	1·38	5·99	5·96	5·975	1 22·5
5000·	2·30	9·98	9·94	9·96	2 15·5
7000·	3·22	14·00	13·96	13·98	3 10
8000·	3·68	16·02	15·96	15·99	3 37
9000·	4·14	18·00	17·96	17·98	4 3·5
10000·	4·60	20·00	19·90	19·95	4 30

It was found that the curve of calibration, when the charge of the needle was 200 volts, was practically constant for a range of temperature from 6° to 25° C.

The curves of calibration for the cases where the needle has charge of 10 and 20 volts were not examined very carefully, but it was observed that the variation was much greater than in the other cases. The following tables will serve to show the form of the curves for these cases:

Charge of Needle, 10 *volts.*

TEMPERATURE 18° C.

Resistance between point to ground and point to quadrants in ohms.	Charge of quadrants in volts.	Scale readings in cm. Right.	Scale readings in cm. Left.	Mean of two scale readings.	Deflection of needle in degrees.
1000·	4·3	1·02	1·04	1·03	0°15′
2000·	9·6	2·24	2·24	2·24	0 30·5
3000·	12·9	3·69	3·71	3·70	0 51
5000·	21·5	7·41	7·39	7·40	1 41
7000·	30·1	11·83	11·81	11·82	2 41
8000·	34·4	14·25	14·27	14·26	3 13·5
9000·	38·7	17·21	17·16	17·185	3 53
10000·	43·0	20·25	20·26	20·255	4 34·5

Charge of Needle, 20 *volts.*

TEMPERATURE 17° C.

Resistance between point to ground and point to the quadrants in ohms.	Charge of the quadrants in volts.	Scale readings in cm. Right.	Scale readings in cm. Left.	Mean of two scale readings.	Deflection of needle in degrees.
1000·	3·2	1·19	1·22	1·205	0°16′·5
2000·	6·4	2·55	2·55	2·55	0 35
3000·	9·6	3·95	3·93	3·94	0 53
5000·	16·0	7·07	7·04	7·055	1 36
7000·	22·4	10·50	10·53	10·515	2 23·5
8000·	25·6	12·44	12·45	12·445	2 46·5
9000·	28·8	14·42	14·41	14·415	3 16
10000·	32·0	16·61	16·63	16·62	3 44·5

In making the calibrations, examinations for leakage were frequently made by charging the quadrants and breaking their connection with the battery circuit. The constancy of the gravity and water batteries was determined by means of a constant cell, devised by Dr. Willson.* The electro-motive force of this cell, which was taken as the standard in these observations, is 1·085 to 1·088 volts. This variation is so small that it is not observable with the electrometer, which is not capable of measuring less than ·01 of a volt, when set up in the manner described, and the needle having a charge of 200 volts.

It will be noticed that the variation in the sensibility decreases as the charge of the needle becomes great relatively to that of the quadrants. The mathematical theory supposes that the charge of the needle is high when compared with that of the quadrants, but it gives no idea of what the order of the charges should be. These observations seem to show that in making use of an electrometer for electrical measurements, we should ascertain by experiment what charge the needle must have, in order that the sensibility may remain constant for the range of charges to be given the quadrants.

Much trouble was experienced at first through the electrometer being set up in a room in which several students were at work upon various experiments in electricity. This trouble seemed to be due to induction effects on the quadrants, which the electrometer case did not very completely shield, for on enclosing the electrometer in a box coated with tin-foil, and put into connection with the ground, the trouble was removed. After removing another difficulty, i. e., leakage, due to use of glass rods in the construction of a commutator, by substituting paraffine for the glass, it was found that the electrical zero suffered a displacement to the side to which the spot of light was deflected.† This displacement increased with

* Über Daniell'sche Normal-Elemente, Inaugural Dissertation von Robert W. Willson, aus Cambridge, U. S. Würzburg, 1886. Pamphlet.

† Thomas Gray, Phil. Mag., V, vol. xxiii, p. 46.

the magnitude of the deflection, and was as great as one centimeter, at the end of two or three minutes, for a deflection of twenty centimeters. The suspending fiber had been in the instrument for some time, inquiry showed that it was drawn from floss silk.* On substituting a fiber drawn from cocoon silk which had been well washed, no displacement of the zero was observed except where the room had been kept at about 0° C. for several hours. Some trouble was experienced from sudden movements of the needle, apparently caused by the working of a dynamo, from which wires extended through the various parts of the building in close proximity to the pipes for gas and water, the pipes being made use of as ground connections for the electrometer and batteries. These deflections of the needle were most marked in the cold, dry weather of winter; from this it seems probable that the pipes did not serve as very good ground connections at the time and under the circumstances.

Jefferson Physical Laboratory, Dec. 5th, 1887.

Art. XVIII.—*On the so-called Northford, Maine, Meteorite;* by F. C. Robinson.

Various cabinets in this state and doubtless elsewhere contain specimens of a black rock showing signs of external fusion, labeled "Meteorite which fell in Northport, Maine." A specimen recently received from Mr. W. H. Sargent, of Brewer, Maine, has been analyzed in my laboratory by Mr. Charles Fish, with the following results:

Fe	Al	Cu	Mg	Co	SiO_2	S	P	Mn	
43·37	4·19	0·88	2·05	0·25	27·68	1·10	0·03	*tr*	= 79·55

The Mg, Al and most of the Fe were evidently combined as silicates. The rest of the Fe was present as sulphide and oxide, and the copper as sulphide. Calculating them as such the analysis comes up to 98·36 per cent omitting the small amount of P, Co, Mn. The piece I have and others I have seen are nearly or quite black in color, and seem to have been broken from a nearly spherical mass of about 1½ or 2 feet in diameter, whose outer surface was fused. Sections under the microscope closely resemble those made from furnace slag from the reduction of iron or copper ore. It will be noticed too that the analysis corresponds quite closely to some published analyses of slag. (Compare "Kerl's Handbuch," p. 856, vol. i.)

* Boltzmann, Pogg. Ann., cli, p. 487. Ayrton and Perry, Jour. Tel. Engineers, vol. v, p. 481.

A specimen of the copper slag from the old "Revere Copper Works" in Massachusetts, obtained through the kindness of Dr. Wadsworth, is microscopically and chemically nearly identical with the so-called meteorite. That it is not of meteoric origin thus seems to be settled, but notwithstanding the most positive stories are told about "seeing it fall," "getting pieces while still hot," etc., I have not been able to trace all such stories down. In regard to one of them I learned from the finder of a fragment which came into my hands that "in 1850, while standing upon the shore at Northport in the evening, suddenly the region was lighted and a ball of fire passed over his head from west to east, fell into the water and exploded with a loud noise." Failing to find any fragments he concluded that it struck too far out. In 1881, having heard that pieces of a meteor had been found there, he revisited the spot and at dead low water picked up several, one of which I have. Although the pieces he found were probably old copper slag brought by some vessel in ballast, still the fall of a meteor there cannot be questioned, and it is possible that true meteoric fragments may have been or may yet be found in that reigon.

ART. XIX.—*History of the Changes in the Mt. Loa Craters*; by JAMES D. DANA. Part I. KILAUEA. Continuation of the Summary and Conclusions.

[Continued from xxxiii, 433; xxxiv, 81, 349; xxxv, 15 (Jan., 1888).]

II. SIZE OF THE KILAUEA CONDUIT.

To appreciate the power at work in Kilauea and understand its action we should know, if possible, the diameter of the lava-conduit; and for this we have to look to its condition both in times of eruption and in periods of relative quiet.

In view of the greatness of the discharge in 1823—so undermining, owing to its extent, as to drop abruptly to a depth of some hundreds of feet the floor of the crater, leaving only a narrow shelf along the sides—we reasonably conclude that, at that time, the conduit beneath was of as large area as the Kilauea pit itself—or nearly seven and a half miles in circuit. We may also infer that, immediately before the discharge, wherever there was a lava-lake, the liquid top of the conduit was up to the floor of the crater, and elsewhere not very far below it. The inference is similar from the eruptions of 1832 and 1840. When the floor of the pit fell at the discharge in 1840, it was not thrown into hills and ridges, as it might have been had it dropped down its 400 feet to solid rock in consequence of a *lateral* discharge of the lavas beneath; on the contrary, it kept its flat surface, thus showing that it probably followed down a liquid mass, that of the subsiding conduit lavas.

But it is probable that the conduit had then, and has still, a larger area than that of Kilauea

At the eruption of March, 1886, when the emptying of Halema'uma'u and its bordering lake, at the south end of Kilauea, was all the visible evidence of discharge, the Solfatara at the north end, two and a half miles from Halema'uma'u, showed sympathy with the movement. For the escape of vapors from its fissures suddenly ceased, as if the *source* of the hot vapors had participated in the ebb, while a few hours before the discharge the vapors were unusually hot, so as to prevent the use of the bath-house (xxxiv, 351). Thus, even now, during a comparatively small discharge, we have evidence that the two distant extremities of the crater are underlaid by inter-communicating liquid lava. Mr. Brigham speaks of hearing, in 1880 (xxxiv, 27) when at the vapor-bath house in the Solfatara, sounds from below, "rumbling and hard noises totally unlike the soft hissing or sputtering of steam," a fact that seems to favor the above conclusion. Further, through all known time, as now, several of the fissures in the Solfatara region have discharged, besides steam, sulphurous acid freely, and this can come only from liquid lavas.

The summit of the conduit must, therefore, be even larger than all Kilauea. To this may perhaps be added the bordering region of fissures and abrupt subsidences; for subsidences or down-plunges indicate undermining, and undermining here means the removal of liquid material from beneath. With this addition to the limits, the width is 16,000 feet and the length as much, *plus* a mile or more to the southwest, where the fissures of 1868 if not also of earlier date, are giving off hot vapors abundantly.

But while this may be the area of the upper extremity of the conduit, the top surface is not a level plane, as the condition of the region above it indicates. A small part of it at all times (with short exceptions after an eruption) has extended up to the surface in Halema'uma'u, and occasionally in other lava-lakes during times of special activity; for each such lake, however small, must have its separate conduit reaching down to the general liquid mass and giving upward passage to the working vapors. We learn hence that whatever the number of these conduits, they may act independently, that is overflow, and rise and fall in level, because the size is very small compared with that of the reservoir from which they rise.

III. THE ORDINARY WORK OF KILAUEA.

By the ordinary work of Kilauea is here meant the work which is carried on between epochs of eruption. A large part of it is the living work of the volcano, the regular daily action, never permanently ceasing except with the decline and extinction or withdrawal of the fires. The deep-reaching conduit of lavas, which is the source of the heat and center of this living activity, owes a large part of its power to act the volcano, and make a volcanic mountain, to the presence of something besides heat and rocks. Vapors are ever rising and escaping from the conduit, and though lazy in the clouds above where the work is done, they carry on nearly all the *ordinary* action of a crater, even that of greatest brilliancy and loftiest fiery projection as well as the gentler play of the fires. But these vapors have not produced the great eruptions in Kilauea since 1822; they occasion only its quiet or lively activity in periods of regular work between eruptions. I add also, lest I be misunderstood, that the vapors are bad for fuel, as they tend to put the fires out, but good for work.

There is another source of work, perhaps a perpetual source during the active life of a volcano as it is a perpetual source of heat, namely, the ascensive force of the conduit lavas. But, unlike the vapors, it is an invisible agency, slow in its irresistible movements. What are its limitations, and what its source still remain undetermined.

The other agencies concerned in the ordinary work have only occasional effects. They include heat in work outside of the conduit, and hydrostatic and other working methods of gravitational pressure.*

Tabulating the agencies, they are as follows:

A. The vapors.
B. The ascensive force of the conduit lavas.
C. Heat, displacing, disrupting, fusing.
D. Hydrostatic, and other gravitational pressure.

All these agencies do their work around the lava conduit, or its branches, as their central source of energy. Unlike non-vol-

* The following account of Kilauea in December, 1874, was omitted from page 94 of vol. xxxiv. It is from a brief note by Mr. J. W. Nichols, of the British Transit of Venus Expedition of 1874, published in the Proceedings of the Edinburgh Royal Society for 1875–6, pp. 113–17. A low cone around Hale-ma'uma'u about 70 feet high; diameters of the basin ⅓ m. and ¼ m.; within it, four lava lakes, the largest 200 yds. in length; in the largest, 7 to 8 fountains of white-hot lava playing to a height of 30 to 40 feet, one of them sometimes stopping, and then commencing in another part of the lake; the fountains in every case playing around the edges of the lake; lava of largest lake about 50 feet below the brim; one of the smaller lakes brim full of lava when in the others the lava surface was 30 or 40 feet below the brim; in one, a single fountain bursting from a cavern in its side. The summit crater is stated to have been in action about a month before the visit.

canic igneous eruptions and nearly all other geological operations, the results are *pericentric.* Overflows and outflows, aerial discharges and their depositions, fissure-making, subsidences, elevations, everywhere illustrate this fundamental principle in volcanic action. As the volcanic mountain with its crater is its emphatic expression, so is almost every little heap of lavas, or cinders, that may form within the crater or over the mountain slopes.

A. *The work done by vapors.*

Only part of the work of vapors is of the permanent kind, carried on, as above described, by the vapors rising *through* the lavas of the conduit. Another efficient part, but most efficient in times of eruption, is dependent on vapors generated *outside* of the conduit. In addition, there are the chemical effects of vapors. The work includes:

(1) The effects of the expansive force of vapors in their escape from the liquid lavas: projectile action and its results.

(2) The effects of the expansive force of vapors within the liquid lavas: vesiculation and its results.

(3) The effects of vapors generated outside of the conduit: fractures, displacements, etc.

(4) The chemical action of vapors; which is considered only as regards certain metamorphic effects, in connection with the account of the Summit crater.

1. THE VAPORS CONCERNED: THEIR KINDS AND SOURCES.

The vapors of Kilauea have not yet been made a subject of special investigation. Still, there is no question that the chief *working* vapor is the vapor of water; besides which there is a little sulphur gas, and probably some atmospheric air. Investigations elsewhere have shown the vast predominance of water-vapor among aerial volcanic products proving that less than 1 part in 100 is vapor of any other kind. The statement of Mr. J. S. Emerson (xxxiii, 90) that on the west margin of Halema'uma'u, at one of his surveying stations in April of 1886, to leeward of a "smoke-jet," he continued his work "without regard to the smoke which the wind carried over him within a few feet of his head," is proof that the air held little sulphurous acid. Great volumes of vapors were constantly rising from Halema'uma'u in August, 1887.

Mr. Brigham was led to conclude from his seeing so little vapor rising from the Great Lake during his visit, that too much influence had been ascribed by others to water;* and this view is presented also by Mr. W. L. Green, of Honolulu,

* Brigham, Memoir, p. 450, and this Journal, xxxiv, 24.

who refers part of the movements in the lake to escaping atmospheric air; the air being supposed to be carried down by the splashing and jetting lavas, there to become the source of the splashing; and to become confined in this and other ways, and be carried deeper for other work.* But the amount of vapor escaping from a lake in times of moderate activity, when it is mostly crusted over, is very small—being only that from the vesicles (p. 194) and breaking bubbles in the actively liquid portion; and in a state of brilliant action, the hot air above, up to a height where the temperature is diminished from that of the liquid lavas to 300° F. will dissolve and hold invisible nearly 5 times as much moisture as at 212°; up to 440°, 16 times as much; and to 446°, 27 times. The absence of vapors over a flowing lava stream is made evidence against the presence of water; but if all is from one source, *there should be none* except at the source (ibid.)

The amount of sulphur in the vapors, and its condition before the escape from the lava, whether as sulphur vapor simply or as sulphurous acid (sulphur dioxide), are questions for the future investigator. Pyrite, or some iron sulphide, being its probable source, I add that I have detected pyrite in the lava of a dike on Oahu, but not in the lavas of the crater, where we should hardly expect its presence. Chalcopyrite (copper pyrites) may also be present; for, in 1840, I found, at the southwestern sulphur banks, some blue copper sulphate.† The faintly greenish tint of the flames which have been seen (xxxiv, 24, 356) may have this source.

Carbonic acid has not been observed escaping from fumaroles about any part of the Hawaiian Islands, and no fragments of limestone have been found among the ejectamenta of Kilauea or Mt. Loa The volcanoes stand in the deep ocean, and the conduit must come up through old lavas for thousands of feet, and hence carbonic acid is only a possible not a probable product. The position of the volcanic region in mid-ocean, where continental geological work has, most probably, never gone forward, makes it questionable whether limestone is passed through by the hot lavas at any depth.

The presence of *hydrogen* among the escaping vapors remains to be determined. The pale, hardly bluish flames seen about the Great Lake may come from the burning of escaping hydrogen, or of sulphur vapor, or of hydrogen sulphide.

The *source of the water or moisture*, whence comes the chief part of the escaping vapors, is probably atmospheric. On this point the arguments appear to be as strong now as in 1840.

* Vestiges of the Molten Globe, Part II, 8vo, Honolulu, 1887.

† My Exped. Report, pp. 180, 201, 202, the last containing an analysis.

Kilauea is situated, like Hilo, in a region of almost daily mists or rains, and if approaching Hilo in the precipitation, as is probable, over 100 inches of rain fall a year. Tables give over 200 inches some years for Hilo. The whole becomes subterranean except what is lost by evaporation; for, owing to the cavernous and fissured rocks, there are no running streams over the eastern or southeastern slopes of the island south of the Wailuku river which comes down from the northwest to Hilo. That which falls into the crater and on its borders gives moisture to the many steaming fissures; and sometimes it makes a steaming area of the whole. But this part has very little to do with the volcanic action.

A part of the subterranean waters follow the underground slopes seaward, as shown by copious springs in some places near the shores; and these also take no part ordinarily in the volcanic work. But another part must descend by gravity vertically, or nearly so, and keep on the descent far below the sea level. It has been shown on a former page (p. 16) that much the larger part of the eruptions have occurred in the months from March to June, and this appears to indicate a dependence of the action to some extent, on the abundance of precipitation.*

Moisture may be gathered also from all moist rocks along the course of the conduit in the depths miles below the reach of superficial waters, as suggested by different writers on volcanoes. But any dependence on the amount of precipitation would show that this is not its chief source.

Another source of water is the sea. But sea-water could not ordinarily gain access to the conduit except at depths much below the sea-level, on account of the abundance of subterranean island waters pressing downward and outward. Further, no one has yet reported evidence of the presence of marine salts, or chlorides, beyond mere traces, among the saline products of Kilauea or Mount Loa after an eruption.

A third source of moisture is the deep-seated region in or beneath the crust whence the lavas come. Of this we know nothing. The fact that the presence of such moisture below would make this a dangerous earth to live on has been urged against the idea of such a source.

Since all ordinary action in Kilauea, and also in Mt. Loa, is of the quiet non-seismic kind, the introduction of water into the conduit must be an ordinary and a quiet process, not one of sudden intrusion through fissures. Sudden intrusions may

*This view with regard to the sources of the waters is sustained by several writers. It is well presented, with explanations at length as to the water line in the volcanic mountains, in a paper on "the Agency of Water in Volcanic Eruptions," by Prof. Joseph Prestwich, Proc. Roy. Soc., xli, 117.

sometimes take place for eruptive effects, but of these we are not speaking. The facts from the vesiculation of some lava-flows of Mt. Loa brought out beyond (page 195) give further evidence as to the quiet molecular occlusion of the waters. Moreover, the possibility of this method of imbibition appears to be demonstrated by Daubrée's experimental work, which proves that the process will go on through capillarity or molecular movement, against the opposing pressure of vapors within.* He uses the fact to explain the origin of volcanic vapors.

The water seeking entrance in the depths below, moreover, is under pressure from above, and, whatever the temperature, the forcing of it back against this pressure and friction is impossible; the expansive force generated by the heat only forces it into the rising lava of the conduit, as urged by Mallet, and sustained by Prof. Prestwich.

I proceed now with the consideration of

2. THE EFFECT OF THE EXPANSIVE FORCE OF VAPORS IN THEIR ESCAPE FROM THE LIQUID LAVAS: PROJECTILE ACTION.

All the lava-lakes of the crater, whether one alone exists or many, and the smaller vents over fires that are concealed but not at too great depths, send forth vapors, which, in their effort to escape as bubbles through a resisting medium, that is, the lavas, do projectile work. The vapors thus produce the play of jets over lava lakes with the muffled sounds and tremor of ebullition; and also the splashing and the throwing of spray from open fire-places in the crusted lakes. They dash up the melted fragments from a blow-hole with a rush and roar "rivalling sometimes a thousand engines," thus introducing the coarser effects of gunnery into Kilauea. They make the thin crust of the crusted lake to heave and break, press into rope-like folds the lava along the red fissures, or start a new play of fiery jets, high or low, and frequently several in alternate play; or, they make openings and push out a flood of lava; and occasionally, when rising in unwonted volume, they make lava-fountains of unusual heights over the lakes, with at times loud detonations.

The projectile force required to throw up jets of lava to the ordinary height they have in times of brilliant activity, thirty feet or so (see pages 31, 32), is even less than a calculation from the height, diameter and density would make it, because the

* Géologie Expérimentale, 2 vols., 8vo, Paris, 1879, p. 235.

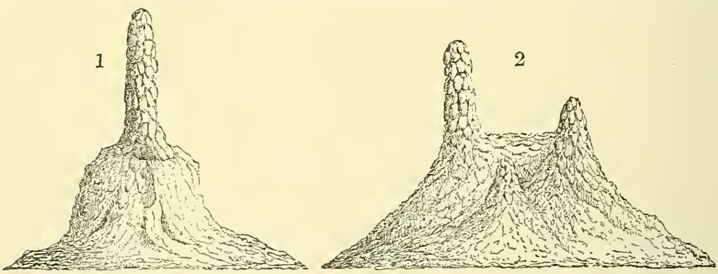
The temperature of the liquid lava is nearly that of the dissociation temperature of water—1985° F. to 2370° F. according to M. H. St. Claire Deville,—and higher than this no doubt at depths below. But that dissociation takes place within the conduit, under the pressure there existing, is not satisfactorily proved.

jets before they reach their limit usually have become divided into clots, instead of remaining a continuous stream.

The fact that the throw in the projectile action of a crater is usually vertical is well shown in some of the columnar driblet-cones This is the case in that of fig. 1 below, in which the column was elongated vertically, although a result of successively descending drops. In the figure referred to, the place of ejection was at the base of the vertical part, and it is probable that the force which determined the slight obliquity in the throw required for so uniform a fall on one side of it, was that of the prevailing wind. This vertical throw,—due to the fact that the top of the bubble is the weak, and, therefore the exploding spot—makes the projectile action good for throwing up, but not good for a destructive bombardment of a crater's walls.

Common observations would lead us to expect that in a low state of the fires, when the large lake is for the most part thinly crusted over, the point of greatest heat and action would be toward the center; instead of this it is usually at the margin, and often in oven-like places partly under the cover of the border rocks. The only explanation that now appears is this: that along the border, the outside cold, or that of the atmosphere, is much less felt than over the central portion.

One of the *secondary results*, over the floor of the crater, of the projectile work is the making of the fantastic *driblet cones*, formed often about blow-holes out of the descending clots and drops, as already explained. The forms of two of these cones are shown in the following figures: the first from my



Driblet Cones.

Expedition Geological Report (page 177) representing a fountain-like structure about forty feet high made of lava-drops; the other from Mr. Brigham's Memoir (page 423), representing "the Cathedral" as seen by him in 1864, and also earlier and later by Mr. Coan (xxxiv, 88).

Occasionally the particles of the projected lava are small and descend in small showers of loose smooth-faced but variously shaped bullets and granules around the vent; and this is the nearest the crater at present comes toward producing cinder-cones.

Besides making driblet-cones, the projectile work raises somewhat the borders of the lakes. Further, the small over-flows, lapping in succession over the borders, often make them steep, and keep increasing their height until a heavier out-flow sweeps one side or another away.

A third incidental result of the projectile action is the making of *capillary glass*, or *Pele's hair*, from the glassy part of the lavas. In the jetting and splashing of the lavas, the flying clots and drops pull out the glass into hairs, just as takes place in the drawing apart of a glass rod when it is melted at middle. This is the explanation of Mr. Coan and others who have observed the action. Mr. Brigham says that "the drops of lava, thrown up, draw after them the glass thread, or sometimes two drops spin out a thread a yard long between them." His new observations of 1880 (xxxiv, 22) accord with this explanation but are remarkable for the length and size of Pele's tresses that he reports as hanging from the roofs of the fiery recesses. In my visit in 1840 to one of the smaller boiling lakes, I saw the rising and falling jets, and the work of the winds in drifting the spun glass; but my conclusion erred in attributing the spinning also to the winds.

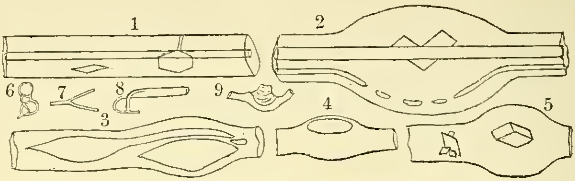
Captain Dutton's observations led him to another explanation, as follows:* "The phenomenon of Pele's hair has generally been explained as the result of the action of the wind upon minute threads of lava drawn out by the spurting up of boiling lava. Nothing of the sort was seen here, and yet Pele's hair was seen forming in great abundance. Whenever the surface of the liquid lava was exposed during the break up the air above the lake was filled with these cobwebs, but there was no spurting or apparent boiling on the exposed surface." He then speaks of the vesicles made by the energetic escape of water-vapors, as solidification at the surface commences, and of their "walls as capable of being drawn out into threads as in the case of glass." The descending of the pieces of cooled crust "produces eddies and numberless currents in the surface of the lava;" and as a consequence "the vesicles are drawn out on the surface of the current with exceeding tennity, producing myriads of minute filaments" and the air agitated by the heat "lifts and wafts them away." "It forms almost wholly at the time of a break-up; the air is then full of it."

The microscopic structure of the capillary glass has been studied with care by C. Fr. W. Krukenberg.† In his fifty

* Report, p. 108.

† Micrographie der Glasbasalte vom Hawaii; petrographische Untersuchung, 38 pp. 8vo, with 4 plates; Tübingen, 1877.

figures, a few of which are here copied, the glassy fibers are sometimes forked or branching; sometimes welded at crossings; often contain air-vesicles (3, 4), and microscopic crystals (1, 2, 5); often tubular (1, 2) through the drawing out of a minute



Pele's Hair. (Krukenberg.)

air-vesicle. They also show that the air-vesicles sometimes continued expanding as the glass was drawn out; and that the hair is often enlarged about enclosed crystals. The crystals are rhombic, as in the figures. The facts make it evident that the glass is far from being pure glass.

3. THE EFFECTS OF THE EXPANSIVE FORCE OF VAPORS WITHIN THE LAVAS: VESICULATION AND ITS MECHANICAL EFFECTS.

a. Origin.—Vesiculation, the making of bubble-like cavities in a melted rock, is a noiseless unseen effect of the vapors that are rising and expanding *within* the lavas. The expansion necessary to produce them is resisted by the cohesion in the lava, and by the pressure. Consequently it is a very common feature of the easily fusible volcanic rock, basalt, but not of trachyte or rhyolyte, except in pumice, the glassy scoria of these rocks; and even this glass (obsidian) commonly holds to its moisture, if it contains any, without vesiculating.

Owing to superincumbent pressure, the maximum depth of vesicles is small, as has long been recognized; but how small in basalt, or any other rock, has not been ascertained by experiment. It probably does not occur in the Hawaiian Islands below a depth of 200 feet. Above the lower limit, vesicles may increase in number and size toward the surface, and be largest in the scum or crust, as within Kilauea; but this variation upward is not always a fact.

b. Kinds.—Five styles of vesiculation may be distinguished in the Kilauea ejections, two of which characterize stony lavas, and three scorias.

(1) That of the ordinary lava-stream of the floor of the pit. The vesicles are oblong and of irregular shape, and constitute from less than 1 to 50 or 60 per cent of the mass of the rock. The form is spherical when the vesicles are very few and small.

(2) That of the common stony *spherically-vesiculated* lava. The vesicles make 30 to 60 per cent of the mass, and are too

small to be elongated much by the flow. This kind of lava occurs in streams outside of Kilauea, and in many about the slopes of Mt. Loa.

The best example of it I have seen, and the basis of the following description, is that of the 1880–'81 Mt. Loa flow, near Hilo. The small uniformly crowded vesicles constitute about 40 per cent of the mass. They characterize the lava, with scarcely any change in size and numbers, to a depth (as I found in a tunnel within the lava stream whose floor was similar) of 10 or 12 feet. Below this depth of 10 or 12 feet, the lava, as I learned from Rev. E. P. Baker of Hilo, is probably more solid, this being usually the case.

The scoriaceous kinds are:

(3) That of the glassy scoriaceous crust of the lava stream inside of Kilauea, and of the scum of its lava-lakes (xxxiv, 354). The vesicles are 65 to 75 per cent of the mass; they are elongated; those at top mostly closed; those of the bottom of the crust commonly very large. The crust of the lake is sometimes so thin that stones thrown on it slump through. The glass is easily fusible and hence its rapid fusion and cooling. An analysis of this scoria-crust made, at my request, by Professor O. D. Allen, proved it to have the composition of ordinary basalt.* No analysis has been made of the stony lava of Kilauea for comparison.

(4) Ordinary scoria, such as is common about cinder-cones outside of the crater, mostly stony in texture; the vesicles 65 to 95 per cent of the mass.

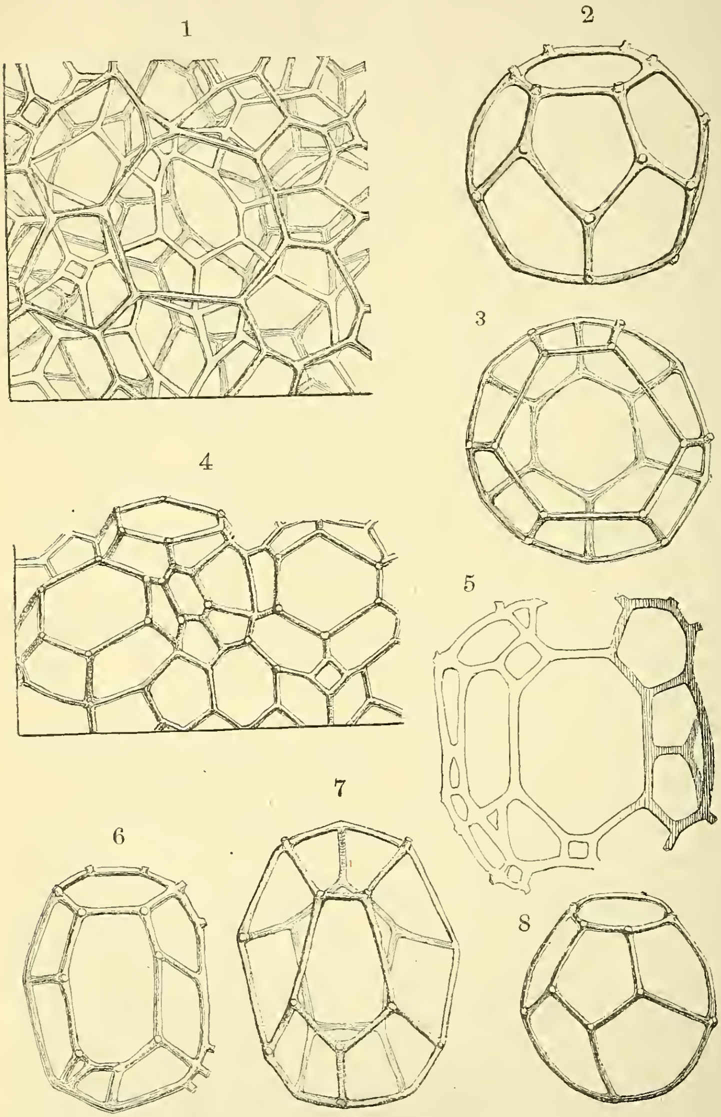
(5) Spongy, thread-lace glass scoria, occurring as a layer 12 to 16 inches thick over the southwestern border of Kilauea (xxxiv, 359); the vesicles 98 to 99 per cent of the mass; their walls in the coarser varieties sieve-like or reticulated; in the finer, like thread-lace in texture. Similar spongy scoria is reported as occurring at the summit of Mt. Loa and about the sources of some of the Mt. Loa lava-flows; but I have seen no specimens. Since a cubic inch of the finer thread-lace scoria contains only 1·7 per cent in bulk of rock material, a layer of solid

* Professor Allen's analysis (this Journal, III, xviii, 134, 1879) is in column A, below. For comparison, the composition is added of (B) the doleryte (diabase) of West Rock, New Haven, Conn., of Triassic age, by Mr. G. W. Hawes (Ibid., ix, 186, 1875), and of (C) a "typical" basalt from Buffalo Peak, east of the west fork of the Platte, between the two Parks, by R. W. Woodward (Geol. 40th Parallel, vol. ii, Descript. Geol., p. 126, 1877).

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	ign.		P_2O_5	
A	50·75	16·54	2·10	7·88	*trace*	7·65	11·96	2·13	0·56	0·35		----	= 99·92
B	51·80	14·21	3·55	8·26	0·42	7·63	10·68	2·15	0·39	0·63		0·14	= 99·86
C	49·04	18·11	2·71	7·70	*trace*	4·72	7·11	4·22	2·11	1·29	TiO_2	2·46	= 99·47

I add that I do not cite here the analyses of the rocks and volcanic glass of Kilauea made by another for me and published in my Expedition Report, because they are erroneous and should be rejected.

basalt glass one inch thick would be sufficient to make a 60-inch layer of the spongy material; and probably a 75 to a 100-inch



Cells of the Thread-lace Scoria.

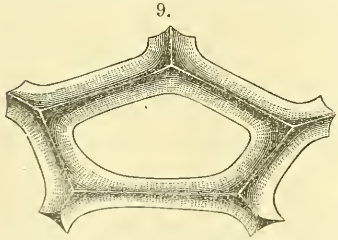
layer of the much more common, coarser variety, in which are some large vesicles occasionally half a cubic inch in size.

The vesicles of the finer kind are mostly $\frac{1}{30}$th to $\frac{1}{40}$th of an inch in diameter, like those of the 1880–'81 Mt. Loa flow; but their walls are reduced to threads corresponding to the edges of polygonal vesicles. Figure 1 shows the general appearance of the surface in a magnified view. The forms of the skeleton polygonal cells are, for the most part, either 12-sided or 14-sided figures, having a perimeter of ten or twelve pentagonal faces in two alternating rows, and bases of five or six sides. The 12-sided cells are bounded by the edges of pentagonal dodecahedrons such as come from the mutual pressure of spheres, except that they are distorted usually by compression, and by elongation or abbreviation. The 14-sided, which are much the most common, are similar to the 12-sided in general form, but have hexagonal bases. Fig. 2 is a side view and fig. 3 an end view of one of the latter kind, and fig. 4 shows a group of such cells, as seen over the surface of the scoria (a cut or broken surface, for it is impossible to handle a piece of the scoria without breaking off bits of the brittle threads). Fig. 6 is another of the 14-sided kind of less symmetrical form, as is common. One of the pentagonal dodecahedrons is shown in fig. 7, and another in fig. 8.

There is often a more complex system of network through other crossing contour-threads, but the simpler forms are referable to those represented. The inside of the base of one of the large and therefore less regular forms is shown in fig. 5, the diameter was about $\frac{1}{20}$th of an inch. In the largest vesicles the walls are openly reticulated.

The threads of this thread-lace scoria are not rounded, but parts of the contours of the three elliptical cells that were there in contact; and fig. 9 shows a portion of one. Having this form, the glassy material of the threads is thickest, and therefore of darkest color, at the center; and they are still thicker and darker at the angles or junctions of three threads. This glassy scoria calls to mind the vesiculation of an obsidian by a high heat, converting it into pumice or scoria because of its occluded water, as illustrated by Professor Judd, and also by Mr. Iddings in experiments with the obsidian of the Yellowstone Park. The Kilauea glass must have been penetrated molecularly with water to have produced such a result. Its ejection took place after the violent projection of great stones; and apparently not long after, as it overlies directly the layer of stones. The conditions of origin in the cases about the summit of Mt. Loa I cannot give. But the descrip-

9.



tions seem to imply that the spongy scoria there is one of the results of high jettings or fountain-like throws of the lava during an eruption; it may be a light form of ordinary scoria.

The minute delicacy and brittleness of the threads in this scoria suggests a way of making fine dust by volcanic action, which is much more reasonable than that of mutual friction of projected fragments of scoria of the ordinary kind; it thus helps in the understanding of the lofty dust clouds of Krakatau and Tarawera.

c. Amount of moisture required for vesiculation, its distribution, and its origin.—The facts derived from the crowded vesiculated lava of 1880–1881, reaching from its source down to Hilo, over 30 miles, and throughout the whole range remarkable for uniformity and for depth in the stream, besides giving an opportunity to study the origin of the vesiculation and the amount of moisture it requires, presents also evidence as to the origin of the moisture in the conduit and its condition.

(1) As I learn from Rev. E. P. Baker, the vesicles change little toward the summit except in becoming coarser, with thinner walls, at the source. From the mean size, $\frac{1}{35}$ inch in diameter, we obtain for the *size of the particle of moisture* required at the ordinary pressure to fill one of the vesicles, ·000,000,007 of a cubic inch. What the size actually was, under the pressure and the temperature that existed at the time of vesiculation, cannot be determined. But this much we learn, that the moisture was distributed throughout the lava in a state of extreme division, actually or essentially that of molecular diffusion.

(2) The space in the vesicles is 40 per cent of the mass, as determined from the specific gravity of the rock-material, 2·98, and that of the mass with the surface varnished to exclude the water, 1·88. The required water is hence ·0003 per cent of the mass; or by weight ·0001 per cent; showing that, *the amount of water required for the vesiculation is exceedingly small.*

From the thread-lace scoria we find, since only 1·7 per cent of the mass is solid glass, that the amount of moisture required to produce the vesiculation, at the ordinary pressure, would be 3·125 per cent of bulk, and 1·1 per cent by weight The amount of moisture was hence not unusual for a rock, although the vesicles occupied 98·3 per cent of the mass.

(3) The source of the flow of 1880, 1881, according to Mr. Baker, was about 11,100 feet above the sea-level. This is 2575 feet below the summit of Mt. Loa, or about 1600 feet below the bottom of the summit crater. Before the outbreak, the liquid lavas were active within the crater; that is, the length of the conduit above the place of outbreak was then about 1800 feet. On account of the pressure of 1800 feet

of liquid lava no vesiculation could have taken place at this depth inside of the conduit; but at the discharge, the lavas escaped from the pressure, and the vesiculation by means of the diffused moisture must have then begun. Whether the vesiculation for the whole stream took place at or near the source cannot be decided without more knowledge of the flow and its actual sources than we now have. (See further on the Summit crater, in a future part of this paper.)

(4) The facts also tend to sustain the conclusion, before expressed, that the ingress of the subterranean waters, whatever their source, took place by molecular absorption; for it produced an essentially equable molecular distribution.

d. The distribution and functions of moisture after reception into the conduit.—(1.) The above conclusions from the vesiculation have prepared the way for additional deductions as to the distribution and movements of the moisture in the conduit. After its reception, it is exposed to a heat at least 1500° F. beyond the critical point of water (773° F.) and retains the temperature of fusion to the surface. If the expansive force has at the ingress under the pressure any effective value, the accession of the moisture will diminish somewhat the density of the lava, that is, increase its bulk; and this increase will be greatest along the central region of the conduit because this is the region of greatest heat. If dissociation takes place, the increase is still greater, as it adds to the bulk of the moisture. It is a question, therefore, whether the pressure of the denser *lateral* lavas of the conduit would not have some effect toward producing an upward movement along the hotter central region.

(2) The mechanism of the volcano, as regards these inside vapors, seems then to be this: (1) a molecular absorption, at depths below, of subterranean waters from regions either side; (2) a rise of the lavas, thus supplied with moisture, along the conduit from some cause (see beyond on "the ascensive force of the conduit lavas") and perhaps partly in consequence of the vapors present; (3) after reaching a level where the pressure is sufficiently diminished, a union of the molecules of water into gas-particles, *producing* by their expansive force *vesiculation;* (4) a further union of particles into bubbles, when the vapors are sufficiently abundant, in order to exert the greater expansive force required to escape through the surface of the lavas, *producing projectile results.*

e. Mechanical effects of vesiculation.—Vesiculation tends in a quiet way to increase bulk, as the above mentioned facts illustrate. It therefore will give increased height to the liquid lava in a conduit. How deep down this effect is appreciable is a point of much importance in its bearing on the movements and levels of the lavas of conduits. If only to a depth of 200 feet, an average of 20 per cent. of vesicles would add only 40 feet to the height or level of the surface.

But if the vapor particles at all deeper depths are, through their expansive force, undergoing gradual expansion as they work their way or are carried upward, we are still further in the dark as to the amount of effect of vapors on the bulk of the lavas in a conduit. After my observations of 1840, I was led to question, as I state in my Expedition Report, whether the effects from this means might not be sufficient to account for much of the excess of elongation of the Mt. Loa column over that of Kilauea. This is obviously not so. But how much the elongation, is an important question, and it has still to remain unanswered.

4. WORK OF VAPORS GENERATED OUTSIDE OF THE CONDUIT: FRACTURES, DISPLACEMENTS AND OTHER RESULTS.

The conduit has hot rocks around it; and beneath the floor of the crater there are hot rocks about and over its upper extremity. The descending waters are driven back as vapor, and usually in a harmless manner. But a sudden incursion of subterranean waters happening under any circumstances, might produce confined vapors of great force. The natural effects of the pressure of such confined vapors are fractures, elevations and subsidences, and, where pressure is brought to bear in a confined place on a source of liquid lavas, their injection into any open fissure at hand.

These effects belong mostly to times of eruption; but in a lighter form, they may be part of the ordinary work of the crater. The lava-lakes of the bottom, even in quiet times, often have large over-flows, and also out-flows through fissures, that is both *superfluent* and *effluent* discharges; and it is probable that the cause here considered may be the occasion of part of them.

Confined vapors are often generated also by the action of the heat of a lava-flow on moisture underneath. As rains fall almost every day at Kilauea, there must be more or less moisture underneath many parts of the cold floor; and if a few hours flow from the great lake should flood it with liquid rock, its 2000° F. which the bottom of the stream carries along and does not at once lose, would make vapor out of the moisture, having great expansive force. The large dome-shaped bulgings of the lava-streams and other undulations of the surface are thus accounted for on a former page (xxxiv, 356); and many of the steaming fractures of the floor as well as those of the domes may have the same origin.

The next topic under the head of the Ordinary work of Kilauea is "the Ascensive force of the conduit-lavas."

[To be continued.]

ART. XX.—*The Taconic System of Emmons, and the use of the name Taconic in Geologic nomenclature;* by CHAS. D. WALCOTT, of the U. S. Geological Survey. With Plate III.

THE nomenclature employed in classifying geologic formations and terranes should be based upon priority of definition and upon the accuracy of the original observations; the latter to be judged by the testimony of the formations within the areas where they were first made. If the original proposer of a name bases it upon such errors of observation and interpretation that subsequent observers cannot verify his work, and the name can only be used by dropping a name proposed as the result of accurate observation and definition, the latter should be retained.

There is another principle that has been frequently overlooked in discussions relating to the nomenclature to be applied to geologic formations and groups of formations forming terranes. It is this: In the evolution of stratigraphic and historic geology, stratigraphic geology preceded paleontologic stratigraphy: that is, the succession of strata for a given geologic province was first determined and then the succession of organic remains in the strata. This has been so far perfected that, in most instances, the known succession of life in a geologic terrane in one province can be compared with that in some other not geographically connected with it: also, different sections of strata in the same province may be compared with one another when the continuity of the strata is broken. From this it follows: First: that the unit of geologic nomenclature is the formation as lithologically determined, and the combination of these units in any given section builds up the greater geologic divisions. Second: that the means of correlation of the formations and terranes of one province with those of another, is by the order of succession, as stratigraphically determined, of the contained organic remains of the respective formations and terranes.

A paleontologist should rely largely upon the evidence of geologic age furnished by the fossils; but, at the same time, as a geologist, he should endeavor to obtain their stratigraphic position and order of succession in each geologic province. An example of the desirability of this is shown by the vertical distribution of the Devonian fauna in central Nevada, where several species of the Lower Devonian fauna of New York occur at the Upper Devonian horizon, in the Eureka district. (Introduction to Monograph viii, U. S. Geol. Survey).

With the preceding statements in mind, I take up the question of the "Taconic System" in geology, as one that can only be intelligently understood and decided by the application of the principles contained in them.

In pursuance of a general plan the subject matter is arranged under the following heads:

1. The Taconic Area and geologic work within it.
2. Geology of the Taconic Area as known at the present time.
3. Geology of the Taconic Area, as known to Dr. Emmons.
4. Comparison and discussion.
5. Nomenclature.

THE TACONIC AREA AND GEOLOGIC WORK WITHIN IT.

The Taconic Area.—The Taconic area includes the Taconic range which trends north and south, nearly on the boundary line between the States of New York, Vermont, Massachusetts, and Connecticut, and the country immediately adjacent to the range, on the east and west. In this area Dr. Emmons first studied and elaborated the theory of the "Taconic System" of rocks.

For the purpose of re-investigation the counties of Washington, and Rensselaer, N. Y., Bennington, Vt., and Berkshire, Mass., were taken as the typical Taconic area, as they contain sections of all the formations spoken of by Dr. Emmons and, also, nearly all the localities cited by him, where the facts sustaining the theory which he proposed could be verified.

*Geologic work within the Taconic Area.**—Quite early in the course of my study of the history of the investigation of the strata now referred to the Cambrian System in America I became acquainted with the voluminous literature of the Taconic controversy, and learned that two geologists only had studied the typical Taconic area with any considerable degree of thoroughness. They were: Dr. Emmons, who founded the "Taconic System" as the result of his observations, and Professor James D. Dana, who studied the strata referred to the "Lower Taconic" by Dr. Emmons. Before Dr. Emmons entered the

* For an historical review of the field work and also of the opinions relating to the "Taconic System" the reader is referred to Dr. Emmons's memoir in the Agric. N. Y., vol. i, 1847, and to the review of the Taconic System in his American Geology, pt. 2, 1856: also to the various publications of Prof. Jules Marcou on the Taconic System, especially "The Taconic System and its position in Stratigraphic Geology" (Proc. Amer. Acad. Sci. and Arts, vol. xii, 1885); to Dr. T. S. Hunt's memoir on "The Taconic Question in Geology" (Mineral Physiology and Physiography, pp. 516–686, 1886), also, "The Taconic Question Restated" (Amer. Nat. Feb., March and April, vol. xxi, 1887); Prof. Jas. D. Dana's paper on "The History of Taconic investigation previous to the work of Prof. Emmons" (Amer. Jour. Sci., III, vol. xxxi, pp. 399–401, 1886), and many references in the series of papers on the results of original investigations in the Taconic area, published from 1872 to 1887, by Prof. Dana.

field Professors Dewey and Amos Eaton had studied more or less of the Taconic region, and the data obtained by them were of material aid to Dr. Emmons.

Among others who have examined portions of the area studied by Dr. Emmons previous to 1844, are: Dr. W. W. Mather, of the geological survey of New York, who made a reconnoissance of the portion within New York State (Geol. N. Y., Rep. First Geol. Dist., 1842); Professor James Hall, who examined a section crossing from the Hudson River to the Green Mountains (Proc. Assoc. Am. Geol. and Nat., p. 68, 1845), and the Professors W. B. and H. D. Rogers who studied a section extending from the Massachusetts side of the Taconic area to the Hudson River (loc. cit., p. 67: also, Proc. Am. Phil. Soc., vol. ii, pp. 3 and 4, 1841). The Professors Edward and C. H. Hitchcock described and mapped the strata referred to the "Taconic System" in Vermont, and discussed the question of their geologic age (Geol. Vt., 1862). Subsequently, Professor C. H. Hitchcock made a series of sections, crossing the "Taconic System" in Vermont (Bull. Am. Mus. Nat. Hist., vol. i, 1884). The observations made by Mr. S. W. Ford, from 1874 to 1886, in the counties of Rensselaer and Columbia, N. Y., have furnished important data on the formations examined by him that will be referred to again. Some of the results obtained by the geologists mentioned will be spoken of under the head of "Comparison and Discussion."

Dr. T. Sterry Hunt, Professor Jules Marcou and Professor N. H. Winchell have all written at length upon the "Taconic System," but I have been unable to discover that either of these gentlemen have made any field observations in the typical Taconic area.*

In searching for data to aid me in forming an opinion respecting the value of the name Taconic in American geologic nomenclature, I found that there was such a wide divergence of opinion among the geologists who had studied the "Taconic System" in the field and those who had formed opinions upon it from partial observations in other areas, and the data given by Dr. Emmons and the Professors Hitchcock and Professor Dana, that there seemed to be no way to settle the questions at issue except by investigating the original Taconic area and identifying and mapping all the formations within it except the areas mapped by Professor Dana and the Professors Hitchcock. The necessity of ascertaining the age of the different

* Dr. Hunt's later opinions appear to have been influenced by his geologic observations in Pennsylvania, and by certain theoretic views founded on the lithologic characters of the "Lower Taconic" rocks. Professor Marcou examined the extension of the "Upper Taconic" strata in Northern Vermont and Professor Winchell appears to have studied the publications of Messrs. Emmons, Marcou and Ford.

formations by paleontologic evidence, was also imperative, as their lithologic characters were of little comparative value outside of the Taconic area owing to local differences in the original sedimentation and to the subsequent alteration of the strata by metamorphic agencies.

With the assent of the Director of the Geological Survey I began field work during the season of 1886 and continued it until the close of the field season of 1887. A few of the results of this work were given in a paper entitled "Geologic Age of the Lowest Formations of Emmons's Taconic System," and read before the Philosophical Society of Washington, January 15th, 1887, a brief abstract of which was published (this Journal, vol. xxxiii, p. 153, 1887). On the 22d of April, 1887, I read a paper before the National Academy of Sciences, at Washington, bearing the title: "The Taconic System of Emmons." In it were given the results of my studies up to that date; and I exhibited a geologic map, and a cross-section, of the Taconic area. As I was soon to return to the field this last mentioned paper was not published.*

Previous to studying the geology of the Taconic area I worked during portions of the field seasons of 1883–4 on the "Upper Taconic" strata of Northern Vermont and published a part of the results in the introduction to Bulletin Thirty of the U. S. Geol. Survey, 1886.

GEOLOGY OF THE TACONIC AREA AS KNOWN AT THE PRESENT TIME.

The section (see map)† crossing the Taconic area shows the general position and relation of the strata, and their geographic distribution is given on the map. In a report on the geology of Washington County, N. Y., I shall describe the geologic section in detail. For the present purpose, however, the section and map, supplemented by notes on the geologic formations, will I think give the data required for a clear understanding of the geologic terranes. Beginning on the east, the terranes will be mentioned in the order they are met with in passing westward from the pre-Cambrian crystalline gneisses of the Green Mountains to the Hudson River, and each will be given a number by which to identify it in subsequent references.

One of the best localities to see the contact between the pre-Cambrian crystalline gneiss and the overlying, bedded quartzite

* A short abstract of it was sent, June 8th, 1887, to Professor N. H. Winchell, reporter on the lower Paleozoic rocks to the American Committee of the International Congress of Geologists, and was subsequently withdrawn owing to the field work of the season of 1887 having negatived and rendered obsolete several of the conclusions therein expressed.

† To be inserted with the second part of this paper.

is on the western crest of Clarksburg Mountain, northeast of Williamstown, Mass. It is one of Dr. Emmons's typical localities, and it has also been examined by Professor C. H. Hitchcock, who, in speaking of the relations of the quartzite to the Green Mountain gneiss, says:

"3. Still more decisive is the fact that the lowest layer of the quartzite has been derived from the ruins of the gneiss. This stratum is a conglomerate, containing many pebbles of a peculiar blue quartz, and has been observed at Clarksburg, Mass., Sunderland, East Wallingford, Ripton, and in Lauzon conglomerate, at Bristol. (The Geology of Northern New England: royal 4to, p. 2, 1870).

When making observations during the summer of 1887 on Clarksburg Mountain, I found the unconformity between the quartzite and gneiss to be well marked. The lower layers of the quartzite series contain shales and thin beds of conglomerate, and there are no passage beds between the quartzite series and the gneiss in the localities where the bedding of the gneiss and quartzite series appears to be conformable. In accordance with this, the unconformity has been represented in the section.

The quartzite, including certain minor beds of schistose shale, conglomerate and limestone, I will call terrane number one.

Terrane No. 1.—Professor James D. Dana, in describing the Quartzite series, in a paper on the Geology of Vermont and Berkshire, says "Associated with the limestone belt and following mainly its eastern border there is a *quartzyte* series, consisting in Vermont of quartzyte and crystalline slate or schist (hydromica slate, sometimes chlorite slate), and rising at intervals into mountain ridges. This quartzyte formation commences just abreast of the northern limit of the 'Eolian limestone' in Vermont: and it follows it southward through Massachusetts, and into Connecticut, being, throughout, its close attendant" (Amer. Jour. Sci., vol. xiii, p. 38, 1877). And on p. 204: "(4) The age of the Quartzyte formation, and its relation in position to the adjoining limestone.—The quartzyte formation includes, as has been explained, strata of quartzyte and schists—sometimes one predominating, and sometimes the other. The special age of the formation is in doubt, equally with that of the eastern limestones. There may be quartzytes of different periods of the Lower Silurian: and so with the schists. The question of age can be positively answered only by the discovery of decisive fossils in the quartzyte of Vermont: and so many imperfect forms have already been brought to light (besides the unsatisfactory worm-burrows, and Fucoids or worm-tracks) that we feel sure the future will clear away the doubts."

Professor Dana considers that the evidence proves the existence of a limestone beneath the quartzite, in some sections, but in Vermont Mr. Wing makes the limestone superjacent to the quartzite (loc. cit., p. 204).

As all observers agree on the stratigraphic position of the quartzite series the paleontologic evidence of the age of the terrane, formed by that series, will be now considered.

The Professors W. B., and H. D. Rogers, Edward, and C. H. Hitchcock, James Hall, Dr. W. W. Mather and Professor Jas. D. Dana have all held the opinion that the quartzite (Terr. No. 1) should be referred to the Potsdam horizon and, from its stratigraphic position, the tentative reference was in accordance with the facts known; but, as Professor Dana has said (*ante*), the question of age can only be answered by decisive fossils in the quartzites of Vermont.

During the progress of the geological survey of Vermont, a few fossils were found in the quartzite. On page 356, of the Geological Report, vol. i, 1862,* it is stated: that besides Scolithus, a straight-chambered shell occurs in a hyaline quartz, on the west side of Lake Dunmore, and a species of Lingula in Starksboro, near Rockville; and, on page 357: "In the southwestern part of Woodford there seem to be traces of organisms resembling bivalve shells, about the size of a three-cent piece." I have, through the courtesy of Professor Dana, examined two of the specimens referred to, that are now in the collection of the Peabody Museum, at New Haven, and I find the "Modiolopsis-like shell" to be *Nothozoe Vermontana*, and the straight-chambered shell to be, to all appearances, a cast of *Hyolithes communis*, a Middle Cambrian species.

Professor B. K. Emerson kindly sent to me for examination the specimens from the Amherst college collection mentioned in the Geology of Vermont, and which were collected at Salisbury, Vt. I find one to be *Nothozoe Vermontana* and the other species to be a cast of *Hyolithes communis*, or a closely allied species. In a small collection of fossils, received from Professor H. M. Seely, of Middlebury college, Vermont, who found them in quartzite bowlders on the west slope of Sunset Hill, near Lake Dunmore, there occurs the *Nothozoe Vermontana* described as "from the Potsdam sandstone,"† and, with it, heads of a species of Olenellus undistinguishable from *O. Thompsoni* of the Georgia formation in Franklin County, Vermont; and in other specimens of the quartz rock, collected at the same locality and containing *N. Vermontana* and *O. Thompsoni*, a species of Hyolithes occurs that is undistinguishable from *H. communis*.

An investigation of the reported localities of fossils, made by the writer in June and July, 1887, resulted in the discovery

* Dated 1861, but issued in 1862.

† Bull. Am. Mus. Nat. Hist., vol. i, p. 145, 1884.

that only the Scolithus had been found *in situ*. Professor H. M. Seely had traced the Rockville "Lingula" to a bowlder, taken from a stone wall, and also the reported Lake Dunmore specimens to bowlders on Sunset Hill: no fossils being found *in situ*. In company with Professor Seely, I visited the Lake Dunmore locality, and found fossils in rounded quartz bowlders, but the quartz ledges gave no traces of them. The Woodford locality was too indefinitely described to be found; but as transported bowlders afforded me Nothozoe and traces of trilobitic remains, similar bowlders were probably the source of the specimens mentioned. In Sunderland, east of Arlington, on Roaring Branch, Scolithus occurs abundantly *in situ*, in the quartzite; and angular blocks of quartzite were found, one mile up the ravine, that contained Hyolithes and fragments of trilobites; but they were not traced to the beds from which they were derived. Two miles east of Bennington, however, success attended my search for fossils *in situ*. The section begins in the woods on the west slope of the mountain on the old Weeks farm north of the old Windham turnpike.

Wooded slope, above pasture	75 feet.
1.—Light-gray, nearly white, compact, fine-grained massive-bedded quartzite, with alternating beds of hyaline quartz. Dip 0° to 5° S. E.; strike, N. 35° E. (magnetic)	35 "
2.—Light-colored, bedded quartzite, with brown spots; showing grains of sand and fossils: the latter also in the compact rock. Fossils: Nothozoe, Hyolithes and Olenellus*	40 "
3.—Alternating bands of layers of light-gray and hyaline quartzite, becoming more massive near the summit	325 "
The dip increases from 5° to 10,° 15° and up to 25° S. E., on the line of the section, and a little farther south, to 45° S. E. Strike, N. 45° E. (magnetic)	
	400 feet.

The quartzite was traced north into the valley of Roaring Branch, and it is a continuation of the deposit on the western slope of Bald Mountain; to the south it extends along the west side of the ridge leading to Dome Mountain, in Pownal, northeast of Williamstown, Mass. It caps the latter and crosses the narrow valley on the south to the Clarksburg group of mountains, along the slopes of which it extends to a point opposite Williamstown, where it bends eastward along the south face of

* I have shown elsewhere that the genus Olenellus is characteristic of the Middle Cambrian horizon, over wide areas in North America, and that it is a pre-Potsdam type. (Bull. U. S. Geol Survey, No. 30, 1886.)

the mountain, reaching into the valley north of North Adams, Mass. On the western summit of the mountain, toward Williamstown, the quartzite series come in unconformable contact with the pre-Cambrian gneiss; and fragments of a trilobite, apparently the genus Olenellus, were found about one hundred feet above the contact.

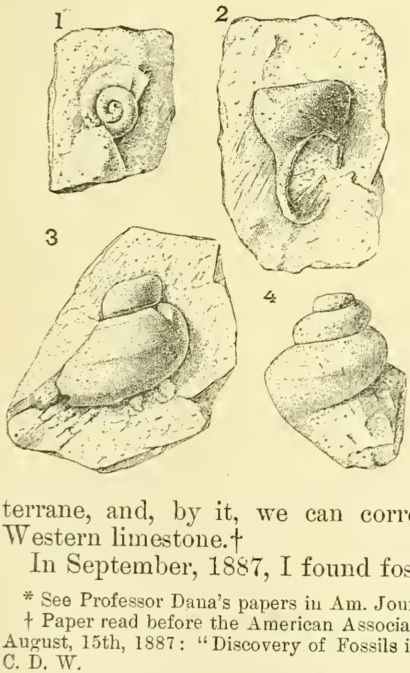
As a result of the discovery of fossils, *in situ*, in the quartzite east of Bennington, the fossiliferous bowlders are given a value, as they were undoubtedly derived from the quartzite formation, and were distributed in the valley to the west during Quaternary time and even at the present by floods occurring in the gorges and valleys that cut through the quartzite. It is now a question of search to trace the fossiliferous horizon in the quartzite from Starksboro, to Bennington, Vt. and to Dutchess County, N. Y., where Dr. Mather considered the "Quartzite" metamorphosed Potsdam sandstone, and he so called the compact sandstone of Stissing Mountain, in the northeastern part of Dutchess County, N. Y. (Geol. N. Y.; First Geol. Dist., p. 418, 1843). During the field season of 1886, I had the opportunity of visiting the Stissing Mountain sandstone locality, in company with Professor W. B. Dwight, and we found *Hyolithellus micans* in the limestone layers, resting immediately on the sandstone; and the heads of *Olenellus Thompsoni* in the sandstone, fifty feet or more below the limestone. *Hyolithellus micans* is known only in the Georgia terrane of New York, Vermont and Canada. A species of Triplesia is associated with the Olenellus at Stissing Mountain, but it has little value in the correlation of strata.

If we now turn to the geologic map, we find that all the localities I have mentioned are on the line of outcrop of the quartzite (Terr. No. 1).

Résumé.—The stratigraphy shows the quartzite series (Terr. No. 1) to be the oldest of the Paleozoic sediments known on the eastern side of the Taconic area, and the contained fauna correlates it with the middle division of the Cambrian, but not as low in position as the fauna of the lower strata of the Georgia Terrane. (See Terr. No. 5.)

Terrane No. 2.—Dr. Emmons, when describing the sections of Graylock (Am. Geol., vol. i, pt. 2, p. 17, paragraph 16), states that the "rock overlying the quartzite is again talcose slate, siliceous at its base, but purely a talcose slate as a mass and which requires no further description. It is between 400 and 500 feet thick and extends up the limestone which constitutes the seventh member of the Lower Taconic system." It is this belt of shales that I have numbered 2 on the sections: and it is assumed to represent, at this point, the Potsdam sandstone of the western side of the Champlain basin. This ter rane is so much more extensively developed farther west, in the section, that I will omit its description until passing down the western side of the synclinal formed by terrane number three. (See Section on the map.)

Terrane No. 3.—This is the limestone and marble belt that outcrops both on the eastern and western side of the Taconic range. Its distribution is shown on the map and in the section, and I think it unnecessary to restate the evidence given by Professor Dana to prove that this limestone belt is the representative of the limestones of the Trenton-Chazy-Calciferous series of the western side of the Champlain basin. His conclusions are based on the stratigraphy, supported by paleontologic evidence,* discovered by Messrs. Wing, Dana and Dwight on the western side of the Taconic range, north and south of the typical area. The fossils have been referred, however, to the sparry limestone or "Upper Taconic" by those writers who favor the view of the pre-Cambrian age of the "Lower Taconic." Prior to August 5th, 1887, determinable fossils had not been found in the limestone series *east* of the Taconic range. At that date, I found, in the eastern limestone, in the town of Pownal, Vt., about half a mile north of the Massachusetts line, a number of fossils that were weathered out in relief on the surface of a compact, clouded marble. The collection gives Euomphalus? (fig. 1); the lower whorl and aperture of a shell like *Murchisonia bellicincta* (fig. 2); two whorls of a form identical or closely allied to *Murchisonia Milleri* (fig. 3). (fig. 4 is a cast of *Murchisonia Milleri*, from the Cincinnati formation, for comparison with fig. 3): a cross-section and lower whorl of a Raphistoma-like shell, and a large, crushed gasteropod shell. The fauna belongs to the Trenton terrane, and, by it, we can correlate the Eastern with the Western limestone.†



In September, 1887, I found fossils in the limestone on both

* See Professor Dana's papers in Am. Jour. Sci., 1872 to 1887.

† Paper read before the American Association for the Advancement of Science, August, 15th, 1887: "Discovery of Fossils in the Lower Taconic of Emmons."—C. D. W.

the eastern and western side of Mt. Anthony, on the line of strike of the Taconic range. The strata of Mt. Anthony are conformable and form a southwardly-sloping synclinal of limestone and marble, carrying, above, a considerable thickness of shales. On the west side the limestones dip eastward and are well exposed one mile south of the Hoosic post office, N. Y. About 400 feet of limestone are shown in the section, and, near the upper part of it, shales appear which have a schistose structure. The shales are in thin beds alternating with the limestones at first, and then they increase until the interbedded limestone disappears and the typical Taconic "talcose slates" of Emmons are the prevailing rock. In the limestones, nearly 200 feet below the shales, a stratum of limestone from two to four feet in thickness is crowded with shells of the genera Maclurea and Murchisonia. The limestone is compact and hard, so that sections only of the shells could be secured. To any one conversant with the Trenton-Chazy limestones of Washington County, N. Y., both the lithology and fossils of the Mt. Anthony limestone, at this point, would prove the geologic horizon to be that of the Trenton-Chazy. Crossing the mountain to the eastern side, at a point three miles south of Bennington Centre, Vt., abundant fragments of crinoids occur in a dark bituminous limestone, above a band of clouded marble. In fig. 5, a few sections of a column is shown and also the calyx and portions of the arms of a crinoid, allied to *Homocrinus gracilis* of the Trenton limestone of New York. Above the dark shale and dipping westward with it, there is a band of arenaceous limestone upon which I noticed a fragment of an Orthoceras, an Euomphalus-like shell and sections of what appeared to be a Rhynchonella. This limestone is lithologically similar to that conformably overlying a bed of marble that dips toward and passes beneath Mt. Anthony at a quarry, two miles west of Bennington Centre.

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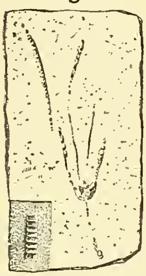

I next visited the limestone at the entrance of the Hopper on the north side of Graylock peak, a typical locality of Dr. Emmons's. The limestones and marbles are of the same lithologic character as those of Mt. Anthony with the exception of the bituminous limestone, carrying the crinoids. Several traces of fossils were observed, but only one that could be recognized. It appears to be the inner whorl of a gasteropod related to Euomphalus or Maclurea (fig. 6).

6

Having verified the stratigraphy as published by Dr. Emmons and Professor Dana, and having found Trenton-Chazy fossils in the marble belt, I crossed the Taconic range to its western base, in the town of Berlin, N. Y. The schists of the range dip to the eastward, have a greenish color, feel talcose to the touch, and appear unlike the dark shales of the Hudson Terrane. Continuing on over the range and down the western slope, I found that the schistose character of the rock was gradually disappearing and that it was becoming more shaly. The greenish color continued, but, toward the western base of the range, a mile north of the village of Berlin, the color began to change, the green and dark shales appearing in the same stratum, and even in hand specimens, and soon the dark shale of the Hudson Terrane was the prevailing rock. A little lower down, the characteristic brown sandstones of the Hudson Terrane began to appear in the shales; and, just east of Berlin village, the limestones appeared from beneath the shales. In other words, it is a repetition of the Graylock and Mt. Anthony sections with the exception of less alteration in the lower part of the shales, and in the limestones. One mile south of South Berlin post office, on the eastern side of the valley, the limestones dip to the east and northeast. At the base of the section there is a considerable thickness of dark argillaceous shale, upon which the limestone rests conformably. Continuing up the west slope of the mountain, more or less impure limestones are met with in which I found *Solenopora compacta*, plates of crinoidal columns, *Murchisonia gracilis?* (fig. 7), and fragments of indeterminable gasteropods. The

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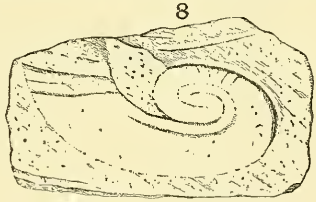

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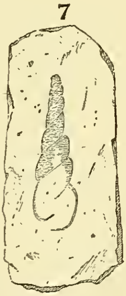

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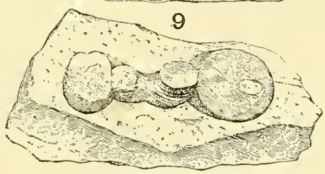


Lituites sp?

fossil-bearing limestone is subjacent to, and interbedded with, shales that are succeeded by arenaceous limestones which, in turn, are conformably subjacent to the shales and schists of the Taconic range.

The next locality examined was one described by Dr. Emmons as showing fossiliferous limestones of the Champlain series, resting unconformably upon the "Taconic" schists (Am.

Geol., pt. 2, pp. 73–77, 1856). He studied the section, where it is very much broken and disturbed, and found evidence that sustained his view. If he had gone a mile to the north, he might have discovered that the shales pass conformably beneath the limestone and, also, that shales occur conformably above it. Fossils were abundant at a point one mile north, northwest of Hoosick Falls, and the following species were recognized: *Solenopora compacta*, *Maclurea* sp.?, *Lituites* sp.? (figs. 8 and 9), and *Orthoceras* sp. undet.

On the map the localities, where fossils have been found in this terrane, are indicated by the letter F.

Résumé.—The stratigraphic and paleontologic evidence unite to prove that the limestones and marbles of Terrane No. 3 are the geologic equivalent of the Calciferous-Chazy-Trenton limestones of the Champlain and Hudson valleys, and belong to the system of strata characterized by the second fauna of Barrande.

Terrane No. 4.—This terrane directly overlies and rests in synclinals of the limestones of Terrane No. 3, at Graylock and at other points; and there is no apparent reason to differ from Professor Dana in referring it to the Hudson Terrane.

In regard to the graptolites found in it, near Hoosick, N. Y., I wish to state that I visited that locality and collected specimens of the flattened and distorted graptolites from the smooth shales. On comparing the specimens with those of *Diplograptus pristis*, from the Hudson Terrane, at Fort Edward, N. Y. and, also, from the Hudson Terrane in the western part of the township of Greenwich, Washington County, N. Y., I fully concur with the opinion given by Professsor James Hall, in 1847 (Pal. N. Y., vol. i, pp. 321, 322, pl. 72), that the Hoosick shale graptolite is identical with the *Diplograptus pristis* found in the Hudson Terrane, within the Hudson valley.

Terrane No. 2.—In speaking of this terrane as the shale above the quartzite of Terrane No. 1 and beneath the limestone of Terrane No. 3, it was assumed that it represented the Potsdam horizon (*ante*); and we now have to search for the evidence of that horizon between the recognized Georgia horizon of Terrane No. 1, and the Chazy-Trenton horizon of Terrane No. 3. Unfortunately, on the east and west sides of the synclinal, on the line of the section, the shales beneath the limestones are unfossiliferous; but, from the data afforded by the Potsdam or Upper Cambrian strata of Saratoga, Dutchess and Washington counties, N. Y., we obtain a fairly satisfactory identification of the Potsdam horizon in the Taconic area.

In Saratoga County a section occurs where a pure limestone, carrying a well-marked Potsdam fauna, rests directly on a massive-bedded sandstone.* The sandstone is of Potsdam age, and contains typical fossils in its extension north in the valley of Lake Champlain: in Washington County I found, at Dewey's Bridge, south of Whitehall, fossils in the Potsdam sandstone, and at Whitehall, numerous Potsdam fossils in the limestone layers resting upon the sandstone and beneath the Calciferous formation. The Calciferous formation was subjacent to the Chazy limestone.

In Dutchess County Professor Dwight found the Potsdam fauna in a limestone, three species of which are identical with those at the Saratoga and Washington County localities. This proves the presence of the Potsdam fauna in Dutchess County, not far distant from the sandstone and limestone carrying the Georgia fauna. Although no direct stratigraphic connection is yet known at this point between the limestone carrying the Potsdam fossils, and the limestone resting on the the sandstone carrying the Georgia fossils, there is little doubt, from the known succession of faunas elsewhere, that the Potsdam formation was deposited in its usual position, between the Georgia and Calciferous formations, and that it has been displaced by the subsequent faulting of the strata.

In Saratoga County, the Calciferous-Trenton terranes are superjacent to the Potsdam, and, also, in Dutchess and Washington counties. In all the sections given in Bulletin 30, U. S. Geological Survey, the Potsdam is superjacent to the Georgia Terrane; and I find that Terrane No. 5, beneath the 2,000 feet of greenish schistose shales of Terrane No. 2, is characterized by the Georgia or Middle Cambrian fauna. I think, then, that we may conclude that Terrane No. 2 represents the Potsdam horizon: also, that the latter may be represented in part by sandstone or quartzite on the west side, near the limestones, or, if the same conditions prevail as in Dutchess County, the lower portion of the limestone; the shales and schists beneath the limestone all belong to the Middle Cambrian. To the east of the limestone, the Potsdam Terrane may be represented in part by either (1) the upper part of the quartzite of Terrane No. 1, (2) the lower part of the limestone of Terrane No. 3, or (3) the hydromica shale between the quartzite and limestone, or Terrane No. 2, or by the combination of two or more of these parts.

Terrane No. 5.—In my field work of 1886–'87, I studied with care the slates, shales and interbedded limestones and sandstones that form Terrane No. 5. On the map an interruption is shown midway, by the presence of a broad belt of

* Bull. U. S. Geol. Survey, No. 30, pp. 21, 22, 1886.—I found several species of this same fauna (Dicellocephalus, Ptychaspis, etc.) in sandstone in the upper beds of the Potsdam sandstone, in the vicinity of Chateaugay Chasm, Franklin County, N. Y.; also in a calciferous sandrock of the Potsdam Terrane, at Whitehall, N. Y.

the Hudson Terrane (No. 6), but I did not find that the two parts of Terrane No. 5 are a repetition of the same strata except possibly for a short distance, near the break between them. The upper or eastern portion is formed of green, purple and drab slates, with thin interbedded limestones, carrying characteristic Middle Cambrian fossils ; the lower and western part consists of dark and drab shales with interbedded sandstones, calcareous sandrock and limestones that contain Middle Cambrian fossils. About 2,000 feet from the base, the fauna begins to show the presence of the Lower Cambrian or Paradoxides fauna, but not in sufficient force to overbalance the predominating assemblage of Middle Cambrian species.—(See this Journal, vol. xxxiv, p. 188, 1887). Fossils occur more or less abundantly at over 100 localities as now known to me within the typical Taconic area, and they are distributed at various horizons throughout the 14,000 feet or more of strata referred to this Terrane.

An examination of the sections and the faunas of Terrane No. 1 and Terrane No. 5, shows that the former is stratigraphically and faunally the equivalent of the upper or eastern part of Terrane No. 5, Terrane No. 1 being the sandy deposit of the shore line, and No. 5, the off-shore accumulation of finer sediment.

Terrane No. 5, like No. 1, is referred to the Middle Division of the Cambrian.

Terrane No. 6.—This is a belt of red, black and green slates, cherts and sandstones faulted in between the two parts of Terrane No. 5. The contained graptolites show it to be a portion of the Hudson Terrane. Its distribution and relation to the other terranes is shown on the map and in the section.

Résumé.—I have briefly noticed the strata included within the Taconic area with the exception of the beds west of the great fault line, separating Terrane No. 5 from the recognized strata of the Calciferous-Chazy-Trenton and Hudson terranes. Along the line of the fault, the strata of Terrane No. 5 are usually thrust against, and, sometimes, over and upon, the latter, but in no instance have I been able to find an unconformity by original deposition between the strata of Terrane No. 5 and the strata of any of the superjacent terranes. This will be more fully described later under the head of Comparison and Discussion.

In the preceding pages, the strata of the Taconic area are grouped under six terranes and identified as follows .

Terranes Nos. 1 and 5=Middle Cambrian.*

Terrane No. 2=Upper Cambrian.*

Terrane No. 3=Calciferous, Chazy and Trenton limestones.

Terranes Nos. 4, and 6=Hudson shales, sandstones, etc.

[To be continued.]

* For a description of the term Cambrian as used in this paper see this Journal, III, vol. xxxii, pp. 138–157, 1886.

ART. XXI.—*On the crystalline form of Polianite;* by EDWARD S. DANA and SAMUEL L. PENFIELD.

THE true crystalline form of manganese dioxide, MnO_2, and the relation to each other of the two minerals having this composition—the common soft variety and the rarer hard form—have long been uncertain points in Mineralogy. The name *pyrolusite* was given by Haidinger* in 1827 to the mineral which had been earlier called Grey Manganese Ore (Grau Braunstein in part of Werner, 1789, and Hausmann, 1813). Haidinger also gave a partial description of crystals, with a figure which is reproduced in Dana's System (1868, fig. 171, p. 165). The only angle given is that of the prism 86° 20′, to which Hausmann (1847) added that of a brachydome $d = 40°$ (over the base).

In 1844 Breithaupt† gave the name *Polianite* to the anhydrous MnO_2 from Platten, Bohemia, which, as he showed, had a hardness almost equal to that of quartz. He insisted, further, that the common soft MnO_2 (*Weichmangan*, Germ.) was not an independent species but only an alteration product from other minerals, chiefly manganite, but also in part from polianite. Breithaupt's description of the form of polianite is very imperfect; he gives the angle of the prism as 87° 8′, and mentions the occurrence of the three pinacoids, a brachydome inclined to the brachypinacoid 62°, and two macrodomes.

The subject has been repeatedly discussed since this time by different authors but very little light has been thrown upon it, although the general correctness of Breithaupt's opinion has been usually accepted. The most recent contribution is that of Köchlin‡ who, while concluding that Breithaupt was right in his general position, failed to obtain material suitable for an accurate determination of the form. He was able to show a certain relation between the crystals examined by himself and the axial ratio deduced from Breithaupt's angles, but his measurements varied widely and only an appeal to a twinning hypothesis sufficed to bring them into partial agreement.

The paper of Köchlin has led us to carry on to completion some work on these minerals undertaken a year or more ago. Our results serve to establish the independent position of polianite beyond all question, and to show that in form it is tetragonal and *isomorphous with cassiterite*, and the allied species of the RO_2 group.

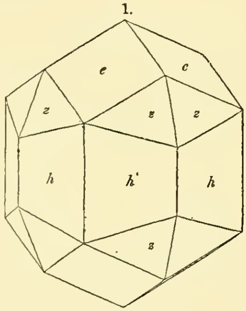
* Trans. Roy. Soc. Edinburgh, xi, 119, 1827; Pogg. Ann., xiv, 204, 1828.

† Lichtes Graumanganerz, Charakt. Mineralsystems. 103, 241, 1823; Pogg., lxi, 191, 1844.

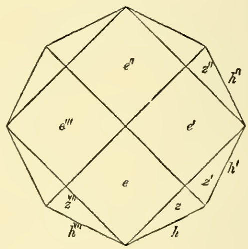
‡ Min. petr. Mitth., ix, 22, 1887.

Of the half dozen specimens in hand, one (A) was especially suited for accurate crystallographic and chemical work (Y. U., 2143). It exposed a crystalline surface consisting of closely compacted composite individuals, and upon this were thickly implanted numbers of small highly modified bead-like crystals with more or less brilliant faces. The relation between these small crystals and the mass of the specimen was not obvious at once, but as soon as the former had been made out it was seen that the composite crystals were identical with the others in form, each one being made up of a multitude of individuals in parallel position. Closer inspection showed also that the apparently simple small crystals were also often composite. The larger crystals were often rhombic in habit and were terminated by a large basal surface formed of the vertices of the closely compacted pyramids. The form of these crystals is shown in figs. 1 and 2.

1.



2.



The planes present are :

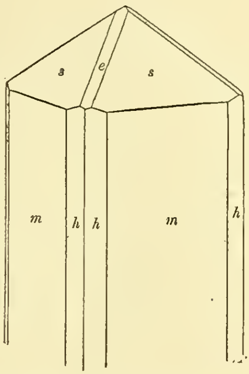
h (210, *i*-2), *e* (101, 1-*i*), *z* (321, 3-$\frac{3}{2}$), and also the form *m* (110, *I*) in traces.

The planes of the prism *h* are rather rough and uneven; those of *e* are brilliant but uniformly rounded on either side of the vertical diagonal, showing a tendency to develop into two vicinal pyramidal planes; the planes of the zirconoid *z* are usually brilliant and give good reflections. Having before us the description of Breithaupt and the apparently confirmatory results of Köchlin, our attention was especially directed at first to the question as to the system to which our crystals belonged and their relation to Breithaupt's form. A large number of measurements consequently were made, some of which are given beyond, but while they showed considerable variation among themselves, more than the character of the faces seemed to justify, they did not conform to the orthorhombic form, although approximating to the angles of Köchlin.

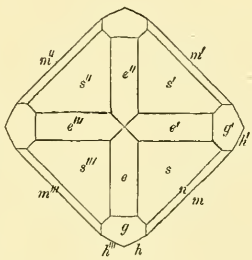
A second specimen in hand (Y. U., 2154) showed a mass of quartzose rock, and in a cavity in it a considerable amount of a rather open aggregate of manganese dioxide in part developed into distinct prismatic crystals. The mass proved upon examination to be anhydrous MnO_2 with a hardness of 6 to 6·5. This was throughout distinctly crystalline in structure, consisting of minute tetragonal pyramidal and prismatic crystals built up together into parallel position.

The prismatic crystals were in part hollow shells with the termination often gone, but the prism sufficiently preserved to show that the original mineral was without question manganite with its usual prismatic angle of 80°. In others of the crystals the rebuilding process had gone farther with the result of giving a complete tetragonal crystal with the habit shown in figs. 3 and 4.

3.



4.



The planes here present, being referred to the same fundamental form as variety A, are:

m (110, *I*), *h* (210, *i*-2), *s* (111, 1), *n* (221, 2), *e* (101, 1-*i*), *g* (201, 2-*i*).

In consequence of the fact that the crystals are all composite growths the planes were none of them perfectly smooth and simple. The best faces for measurement were those of the pyramid *s*, though here there is commonly an oscillation with *e* and sometimes the crystals are much elongated in this zone and rounded over from *s* to the adjacent *s'*.

As the fundamental angle for the species the following was accepted from the variety B:

$$s \wedge s' \quad 111 \wedge \bar{1}11 = 57° \; 56' \quad \text{whence} \quad \overset{|}{c} = 0·66467.$$

Two of the other pyramidal angles on the same crystal gave 58° 2′ and 58° 5′. The following angles, measured on crystals from the first specimen, will serve to show the variation mentioned:

					Calc.
hh'	210 ∧ 120	36° 12',	36° 3',	35° 56'	36° 52'
hh^{vii}	210 ∧ 2$\bar{1}$0	54° 10',	54° 43',	54° 50'	53° 8'
ee'	101 ∧ 011	46° approx.			46° 5'
zz'	321 ∧ 231	19° 58',	20° 53',	20° 38'	20° 51'
zz^{vii}	321 ∧ 3$\bar{2}$1	62° 11',	60° 46',		61° 35'
zz^{viii}	321 ∧ 32$\bar{1}$	45° 28',	45° 50',		45° 18'
zz^{ix}	321 ∧ 23$\bar{1}$	50° 10',	50° 34',		50° 22'

All the above angles were measured with a Fuess goniometer with two telescopes. In addition, two subordinate planes *n* and *g* were determined by approximate measurements as follows: *eg*=19°, calc. 19° 26'; *sn*=18°-20°, calc. 18° 46'.

As shown above the measured angles vary somewhat widely, but when carefully discussed it is found that no better agreement is obtained when an assumption is made that the crystals belong to a system of lower symmetry. On the contrary the best angles lead to the tetragonal system, to which the symmetry in the development and character of the individual planes emphatically conforms. An explanation of the variation of angle is doubtless to be found in the fact stated that the crystals are all composite, and the individuals of which they have been built up are not absolutely in parallel position. A comparison of the angles given with those of Köchlin shows that he must have had crystals resembling figure 1 in hand, in fact he says that for a time he was inclined to consider his crystals as tetragonal. He was unfortunate in his material, for he adds that he was rarely able to use the telescopes of the goniometer. Köchlin's planes referred to our fundamental form are as follows: 310=*h*, 110=100, 334=*e*. If, however, the measurements left any doubt as to the system to which polianite should be referred, this is removed by the relation brought out by the above measurements, namely, that polianite is isomorphous with cassiterite and the allied species rutile and zircon. The relations between them are as follows.

		c	*ee'*	*ss'*
Cassiterite,	SnO_2	0·6732	46° 28'	58° 19'
Polianite,	MnO_2	0·6647	46° 5'	57° 56'
Rutile,	TiO_2	0·6442	45° 2'	56° 52½'
Zircon,	$\left\{ \begin{array}{l} ZrO_2 \\ SiO_2 \end{array} \right.$	0·6404	44° 50'	56° 40½'

The interesting group of oxides having the general formula RO_2 thus receives an important addition, a result which was not anticipated when our work was begun but which can occasion no surprise.

The hardness of both specimens of the polianite is 6 to 6·5. The specific gravity of A was found to be 4·992, the mean of three determinations, 4·971 on 0·833 gr., 4·965 on 0·813 gr., 5·040 on 6·092 gr. The first two determinations were made on a chemical balance the last in a pycnometer. These results, which are somewhat higher than those of Breithaupt, were obtained with great care, the material being first boiled in water for some time to drive off the air. The crystals show perfect cleavage parallel to *m*.

The chemical examination (Penfield) showed that the material was pure MnO_2, free from all but a trace of water. The analytical results are given below together with the analysis of Plattner of the original polianite:

	A.	Ratio.	B.	Plattner.	Ratio.
MnO	80·81	1·138		81·17	1·143
O	18·16	1·135		[18·21]	1·132
Fe_2O_3	·16			·17	
SiO_2	·36				
Insol	·16		trace	·13	
H_2O	·28		trace	·32	
	99·93			100·00	
Loss by ignition	12·44		12·42	12·43	

The ratio of MnO : O is almost exactly 1 : 1 and the mineral is therefore a very pure MnO_2. The material which was analyzed was almost wholly soluble in HCl, leaving a very slight residue 0·16 per cent, the remaining 0·36 per cent SiO_2 separated from the solution by evaporation to dryness.

The method of analysis was as follows: a weighed quantity of material was ignited over the blast lamp till a constant weight was obtained, the MnO_2 being converted into Mn_3O_4. After dissolving the oxide in HCl the Fe_2O_3 and SiO_2 were determined and the solution tested for Ba, Ca and Mg. From the weight of the Mn_3O_4 after deducting Fe_2O_3 and SiO_2 the MnO was calculated. The excess of O over MnO was determined by converting oxalic acid into CO_2 and collecting and weighing the same in potash-bulbs. The H_2O was determined by igniting the mineral in a hard glass tube and collecting the water in a chloride of calcium tube. The chemical identity of B was proved by the fact that it gave only traces of water in a closed tube and lost 12·42 per cent by strong ignition. The ignited oxide was soluble in HCl, and gave traces of SiO_2 after evaporation to dryness.

We purpose in a later article to present some observations upon pyrolusite and the related minerals braunite and hausmannite, especially with reference to the relation of pyrolusite to polianite.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Stalagmometer and its use in quantitative analysis.*—Two years or more ago, Traube observed the markedly greater effect of iso-amyl alcohol, in lowering the height of a capillary column, over that of ethyl alcohol, even when both were diluted with water to the same extent. He based upon this observation a method for estimating the amount of fusel oil in alcoholic liquors, and constructed an instrument, called a capillarimeter, by which the capillary elevation could be easily measured. In a liquid containing twenty per cent of alcohol, one-tenth of a per cent of fusel oil would lower the column a millimeter. As this instrument did not prove convenient in practice, the author adopted a modified method of testing, also founded on the principle of surface tension, consisting simply in counting the number of drops contained in a given volume of the liquid. To facilitate the process, a bulb tube was used, having marks above and below the bulb, the volume between the two marks being known. Below, the tube was bent at right angles, united to a short capillary tube, then bent downward again, terminating in a flat disk having a small hole in the center. This instrument he calls a *stalagmometer*, and by its means drops may be counted with an error of not more than 0·2 of a drop in 100 drops. To use it the alcoholic liquid to be tested is diluted to contain about 20 per cent of alcohol by volume, the stalagmometer is filled with it, the number of drops in the given volume counted and compared with the corresponding number given by pure 20 per cent alcohol. An excess in the former case of 1·6 drops in 100 corresponds to 0·1 per cent fusel oil, of 3·5 drops to 0·2 per cent, etc. Since the maximum error is 0·2 of a drop in 100, as small a quantity as 0·05 per cent of fusel oil can thus be certainly detected. In order to increase the delicacy of the method, the author concentrates the solution as follows: about 300 c. c. of the alcoholic liquor, previously diluted to a 20 per cent strength, is placed in a stoppered separating funnel furnished with a tap, from 110 to 120 grams of pure ammonium sulphate is added and the whole is shaken, until on standing for a minute or two, it separates into two well-defined layers. The upper of these is diluted with water and two-thirds of it distilled off. The distillate is made up to 100 c.c., its density is determined, and after dilution to 20 per cent it is placed in the stalagmometer and the number of drops compared with that obtained with pure alcohol of the same strength. In a series of comparative tests, fusel oil being added to pure alcohol to the extent of 0·05, 0·10, 0·18 and 0·3 per cent respectively, the stalagmometer method gave 0·04, 0·07, 0·18 and 0·26 per cent. In general, the influence of the compound ethers and etherial oils is too

slight to affect the result. But even this influence may be entirely eliminated by previous distillation with an alkali solution.

In subsequent papers Traube has extended this method to the estimation of the strength of ethyl alcohol and of acetic acid, and to the determination of the alcoholic strength of wine, beer and liqueurs. He gives carefully prepared tables of the number of drops given by mixtures of absolute alcohol and water varying by tenths from 0 to 10 per cent by weight, and in temperature by degrees from 10° to 30°; those given by pure water at 15° being 100. At a concentration of 20 per cent, an error of 0·2 drop in 100, corresponds to an error of only 0·1 per cent in the amount of alcohol. The acetic acid table is similar, but its range in temperature is only from 11° to 29° in 2° stages. The results of the method as applied to wine and beer are given and show that it may be relied on within 0·1 per cent, when used on the distillate.—*Ber. Berl. Chem. Ges.*, xx, 2644, 2824, 2829, 2831, Oct., Nov., 1887.

G. F. B.

2. *On Apantlesis; a Separation of the Constituents of a Solution by Rise of Temperature.*—Having observed that on several occasions the upper part of an alcohol thermometer column, after having slowly risen from a considerable contraction, was colorless, and that no deposit of the coloring matter (probably cochineal) had taken place, Mallet was led to make further experiments in this direction. It seemed as if the colorless alcohol had by its expansion separated itself from a still perfect solution left behind. The solutions used were partly aqueous partly alcoholic, of several colloid substances, starch, tannin, caramel, albumen and gelatin. Each solution was placed in a flask of about half a liter capacity, surrounded with ice, the mouth of the flask being closed with a cork carrying a glass tube about 4^{mm} in diameter and 15 or 20^{cm} long, having a glass tap near its middle point. The ice being removed the liquid was allowed to rise in temperature until the column, originally a centimeter or two below the tap, was as much above it. The tap was now closed and the liquid above it submitted to examination in comparison with an equal volume of the original solution. In all cases the liquid above the tap contained a less amount of material in solution, in some cases very notably less; while in two or three cases there was practically none. As all the solutions were carefully filtered at the outset, there could have been no settling of particles. The conditions influencing the result seem to be: first the proportion of the colloid solid in solution; and second, the time occupied in the rise of temperature. The author has given the name *apantlesis* to this phenomenon, signifying a draining away of some of the molecules of the solvent from those of the colloid while the solution was undergoing expansion. —*Chem. News*, lvi, 146, Oct., 1887. G. F. B.

3. *On the Properties of Fluorine.*—Moissan has published in full his investigation upon the isolation of fluorine, made in Debray's laboratory. As we have already noticed his methods*

* See this Journal for March, 1887, p. 236.

we give here his conclusions on the properties of fluorine. It is a colorless gas, having an odor recalling that of hypochlorous acid. It combines directly with hydrogen even in the dark and without the aid of heat; being the only instance where two gases unite directly without the aid of external energy. Sulphur, selenium and tellurium are inflamed on contact with it. Phosphorus takes fire in it, and yields a mixture of oxyfluoride and of fluorides of phosphorus. Iodine burns in it with a pale flame; arsenic and antimony unite with it with incandescence. Crystallized silicon, cold, burns brilliantly in it, yielding the gaseous fluoride. Adamantine boron also burns in it, but with more difficulty. Potassium and sodium become incandescent when cold, iron and manganese when slightly heated. Mercury absorbs it completely, but gold and platinum are not attacked by it at ordinary temperatures. Melted potassium chloride and iodide are at once attacked by it, the chlorine and iodine being set free, the latter in the form of crystals. Water is decomposed by it in the cold, forming hydrogen fluoride and setting free ozonized oxygen. Carbon disulphide is at once inflamed by fluorine; and when this gas is received in carbon tetrachloride, it produces a continual evolution of chlorine. Organic bodies containing hydrogen are violently attacked by fluorine. A fragment of cork is carbonized at once and ignited if placed in front of the evolution tube. Alcohol, ether, benzene, turpentine, petroleum take fire on contact with this gas. In a word, fluorine appears justly to occupy the place hitherto assigned to it at the head of the group of halogens, as a substance whose activity surpasses that of any other element.—*Ann. Chim. Phys.*, VI, xii, 472–538, Dec., 1887.

G. F. B.

4. *On Oxygen Carriers.*—LOTHAR MEYER has made a series of experiments to test the alleged function of certain substances as oxygen carriers. Oxygen and sulphur dioxide gases were passed for four hours, as a rule, through solutions of the salts to be tested, of known concentration, heated in flasks placed on the water bath. After expelling the excess of sulphur dioxide by carbon dioxide gas, the sulphuric acid which had been formed in the solution by oxidation was determined by analysis. The results confirmed the alleged fact. The most active salt was manganous sulphate, $MnSO_4 . (H_2O)_5$, 2·404 grams of which dissolved in 200 c.c. of water, produced five times as much sulphuric acid as the salt itself contained; i. e., $(H_2SO_4)_5$ for $MnSO_4$. Manganous chloride was also active and produced 4·3 molecules H_2SO_4 in the same time. The salts of copper, iron, cobalt, nickel, zinc, cadmium and magnesium were also active but in a less degree; while thallium and potassium salts gave no result. The author attributes this action to alternate oxidation and reduction, since those metals are the most active which pass most readily from one stage of oxidation to another.—*Ber. Berl. Chem. Ges.*, xx, 3058, Nov., 1887. G. F. B.

5. *On the Atomic Weight of Zinc.*—REYNOLDS and RAMSAY by measuring directly the hydrogen set free by the solution of a

known weight of zinc in acid have obtained the value 65·50 for the atomic weight of this metal. This method has the advantage of being independent of any other atomic weights.—*J. Chem. Soc.*, li, 854, Dec., 1887. G. F. B.

6. *A Text-book of Inorganic Chemistry.*—By Prof. VICTOR VON RICHTER. Authorized translation by Prof. EDGAR F. SMITH. Third American from the fifth German edition. 12mo, pp. xvi, 428. Philadelphia, 1887. (P. Blakiston, Son & Co.)—This book has been for some time in the hands of American readers, and the demand for a third edition is evidence that it has been well received. In the thirty pages of introduction, the author sketches the province of chemistry, its symbols and formulas, the principles of energy, and the conservation of energy, the energy-relations of chemical changes and crystallography. The elements are then taken up, beginning with hydrogen, and the philosophy of chemistry is gradually worked in as it is required. For instance, after the hydrogen compounds of the halogens, the law of definite proportions, the atomic theory, and the volume relations of the elements are discussed. A hundred pages later come atomic and molecular values, valence and chemical structure; and at the close of the non-metallic groups, the periodic system is considered. An excellent feature of the book is the considerable space given to the energy relations of chemical changes, particularly to heat relations. The distinction drawn by Berthelot between epothermic and endothermic reactions is emphasized and the great importance of such reactions as $H + Cl = HCl + 22000$ cal. and $H + I = HI - 7000$ cal. is maintained firmly. We are glad to note an extension of this thermal discussion, as well as of other physical relations, intimately associated with chemistry, in this third edition. The section on Mendelejeff's periodic system of the elements is carefully written and gives an excellent account of this remarkable classification. In an appendix is given the heat of formation of the most important metallic compounds according to J. Thomsen. Dr. Smith has performed well the part of a translator, although a want of perfect smoothness in flow sometimes betrays the difficulties he has had to contend with. The printing and mechanical work are good, but the woodcuts seem hardly up to the standard of the rest of the book. G. F. B.

7. *A Manual of Analytical Chemistry;* by JOHN MUTER. Third edition. 200 pp. Philadelphia, 1887. (P. Blakiston, Son & Co.).—Muter's Analytical Chemistry appears in the third edition in compact form but enlarged in scope. Of the host of works of its kind, dealing simply with the outlines of the subject, it is one of the fullest and best.

8. *A new instrument for measuring heat.*—Prof. WEBER at a meeting of the Helvetii Society of Sciences described the following very sensitive micro-radiometer. One arm of a Wheatstone bridge is formed by a thin tube, which is filled in its middle part with mercury, and at its ends, for about 5^{mm}, with a solution of zinc sulphate. To each end of the tube is fitted a metallic case, one side of which consists of a plate of rock salt. This case is

filled with air, which dilates under the influence of radiation, forces back the zinc sulphate solution in the tube, and thus greatly increases the electrical resistance on that side. The apparatus is made symmetrical to eliminate variations of pressure and temperature. This radiometer will indicate one hundred millionth of a degree. The moon's radiation gives a galvanometer deflection of five divisions.—*Nature*, p. 157, Dec. 15, 1887. J. T.

9. *Velocity of Sound.*—At a meeting of the Physical Society, London, Nov. 12, Prof. A. W. RUCKER exhibited an apparatus for determining the velocity of sound on the principle employed by Fizeau for measuring the velocity of light. "A vibrating reed is used as the source of sound and a sensitive flame as the receiver. A long U-shaped tube has its two ends placed near and parallel to the plane of a perforated disc, which is capable of rotating about an axis perpendicular to its own plane. The reed and sensitive flame occupy similar positions on the opposite side of the disc. On rotating the disc the sensitive flame flares or is quiescent according as the time taken to travel the length of the tube is an even or an odd multiple of $\frac{T}{2n}$, where T is the time of one revolution and n the nnmber of holes in the disc."—*Nature*, p. 119, Dec. 1, 1887. J. T.

10. *On the transmission of power by alternating electrical currents.*—Mr. T. H. BLAKESLEY, in a communication to the Physical Society, London, Nov. 12, discussed the relative efficiency of the transmission of power by direct and by alternating dynamos, and concludes that the ratio of power to weight is much greater for a direct than an alternating current motor. The author considers this a great drawback to the employment of the latter. He also showed that by placing a condenser between the terminals of the recipient machine a greater current could be passed through the receiver than that in the generator and line.—*Nature*, p. 119, Dec. 1, 1887. J. T.

11. *Measurement of Electromotive Forces.*—Sir WILLIAM THOMSON has employed his new deciampere balance to the determination of the electromotive force of a Clark cell. The result obtained was 1·436 volts at 15° C. The result obtained by Lord Rayleigh was 1·435 at 15° C.—*Phil. Mag.*, p. 514, Dec., 1887. J. T.

12. *Influence of Magnetism on the Thermo-electric behavior of Bismuth.*—Dr. GIOVANNI PIETRO GRIMALDI shows that the thermo-electric behavior of bismuth in relation to copper is weakened by magnetism. The diminution of the electromotive force was about $\frac{1}{30}$ —, and seemed to be of the same order of magnitude as the variations in electrical resistance investigated by Righi.—*Rendiconti della R. Accademia dei Lincei*, Feb., 1887. J. T.

13. *Coincidences between lines of different Spectra.*—The difficulty of deciding upon the existence of a metal, like cerium, in the sun, is very great, since, on account of the number of lines in the spectrum of the metal, the probability of many of its lines coinciding in position with lines in the solar spectrum is very great.

This coincidence may be only accidental. Schuster has employed a criterion which depends upon a supposed harmonic relation between the lines of a spectrum. Mr. LOVE employs a method of discrimination based upon the law of error. The differences between the wave-length of the lines compared are arranged in groups, each group containing those observations, the errors of which lie within certain narrow limits. The number of observations in each group is then plotted as an ordinate of a curve, the average error of the group being the abscissa. This curve is then compared with the law of error $y = a\varepsilon - ^{c^2x^2}$. To show the applicability of the method, various curves are given, notably those due to observations on cerium and the spectrum of water.—*Phil. Mag.*, Jan. 1888, pp. 1–6. J. T.

14. *Influence of thickness and luminosity of light-producing layers, upon the character of spectra.*—Certain authors, notably Wüllner in his work on Experimental Physics, maintain that line and banded spectra can be made interchangeable by modifying the pressure of the gases or increasing or diminishing the extent of the layer which is made luminous by electrical discharges. EBERT, by a series of experiments, is brought to the conclusion that the experiments adduced by Wüllner and other writers, merely show that banded spectra can be reduced to line spectra by diminishing the illumination. No increase or diminution of density or thickness of luminous layers can account for the change of one class of spectra with another. This change must be rather attributed to a change in the molecular grouping.—*Ann. der Physik und Chemie*, No. 1, 1888. J. T.

15. *On the measurement of force of gravitation.*—The determination of the force of gravitation by means of a pendulum, it is well-known, requires great skill and the employment of many corrections. In a note presented to the Academy of Science, M. DEFFORGES shows that we can eliminate the effects of the support and that due to the curvature of the knife-edges by making use of two pendulums which oscillate within the same limits of amplitude upon the same support and the same knife edges. These pendulums have the same weight, but are of different lengths. Their centers of gravity are similarly placed in regard to the sides of the knife-edges.—*Comptes Rendus*, Jan. 9, 1888, p. 126. J. T.

16. *Influence of temperature on Magnetization.*—In studying this subject, M. Ledeboer made use of the novel plan of placing the bars of iron or steel in platinum spirals which were heated to suitable temperatures by means of an electrical current. The soft iron examined by M. Ledeboer, lost its magnetism entirely at 770° C. and had barely any at 750° C. In a recent study upon the specific heat of iron at high temperatures, M. Pionchon has shown that iron undergoes a change of state between 660° and 720°. Iron loses its magnetic properties also between 680° and 770°. M. Ledeboer calls attention to this remarkable fact.—*Comptes Rendus*, Jan. 9, 1888, p. 129. J. T.

II. Geology and Mineralogy.

1. *Note respecting the term Agnotozoic.*—In the closing portion of the article in the November number of this Journal entitled "Is there a Huronian Group?" Prof. R. D. Irving has advocated the adoption of the term "Agnotozoic" as a comprehensive designation for the fragmental rocks which lie between the base of the Cambrian formations and the summit of the Archæan crystallines, and has credited me with the authorship of the term and the early advocacy of the desirableness of a distinct name for these formations. Concerning this I wish to file a disclaimer; not that I do not fully concur with Professor Irving in this advocacy, for I do most cordially, nor because I suppose it to be a matter of consequence to Professor Irving, since I know that he holds all questions of priority or proprietorship in nomenclature in little esteem, if not in light contempt. I wish to file the disclaimer not because of this special case but out of respect for a general principle in nomenclature, which I hope to see adopted to the displacement of a purely technical and indiscriminative application of the law of priority. I hold that nomenclature of the class in question should rest, not with some individual, who, standing by and looking upon the work of others, may see, perchance before they do, whereunto their labors are growing; nor with some one, who, on the basis of superficial observation and hasty conjecture, throws out first to the world a tentative nomenclature, leaving it to the future and to the labors of others to justify or reject; but on the contrary, I hold it should rest with the patient and thoroughgoing investigator, who by careful and comprehensive study develops an adequate basis for nomenclature, properly sanctioned by a broad and trustworthy array of facts. I have been in some senses a student of the formations to be embraced under the proposed term, but in no such sense as to give me the right of nomenclature under this principle. If, therefore, this term shall be adopted, as I sincerely trust it may, I earnestly desire that it shall stand to the credit of some one who has had a larger part in the actual development of the facts upon which its adoption must rest, among whom I know of no one who has contributed more than Professor Irving.

If it were needful I could take refuge behind the fact that although I have used the term in correspondence, conversation, discussion and other informal ways for the past two years, more or less, I have nowhere formally proposed it in a scientific publication; *but it is the principle of just nomenclature*, and not a specific result in this case that gives purpose to this note.

On this principle, as well as technically also, the name Keweenawian or Keweenawan should be credited to Major T. B. Brooks, or to Messrs. Brooks and Pumpelly jointly, since it was through their labors that there was first presented a sufficient body of specific facts, correctly interpreted, to justify the adoption of the term by those who accept the distinctness of that formation. The term Keweenian was not only proposed subsequently, but rested upon no extensive, careful and specific field investigation on the part of the author, which, on the principle above indicated, is the necessary sanction of acceptable nomenclature.

T. C. CHAMBERLIN.

University of Wisconsin, Nov. 15, 1887.

2. *Contributions to the Paleontology of Brazil*, comprising *descriptions of Cretaceous Invertebrate fossils, mainly from the Provinces of Sergipe, Pernambuco, Para and Bahia;* by CHARLES A. WHITE. From vol. vii of Arch. do Mus. Nacional do Rio de Janeiro. 274 pp. 4to, with 28 plates.—The Cretaceous fossils described by Dr. White were collected by the Geological Survey of Brazil while it was under the charge of Prof. C. F. Hartt, and were sent to Dr. White for description by Mr. Orville A. Derby. The rocks occupy a coast region from the mouth of the Amazon southward for eighteen degrees of latitude. The fossils include many Cretaceous types, but it is remarkable, says Dr. White, that the conchifers, and especially the gasteropods, have little in common with those of North America. The fauna as a whole seems to be more nearly related to the Cretaceous of southern India than to any other that has been investigated—a fact apparently indicating that part of the peculiarities may be due to the equatorial temperature. The fauna is spoken of as having also a Tertiary feature in the presence of species of Fusus, Murex, Phorus, etc. The most of the species are new. They are beautifully figured on the 28 lithographic plates. The Cephalopods are referred to thirteen species and among them there is one Helicoceras. The Ammonites include *Ammonites Hopkinsi* of Forbes which agrees well with Stoliczka's figures of a specimen from India, and *A. planulatus* Sowerby, which also occurs in India, or a species very near it. Plates 27 and 28 are devoted to the Echinoderms, of which there are 15 species.

3. *Arkansas Geological Survey.*—The Geological Survey of Arkansas, under the charge of Dr. Branner, is going forward with vigor, through the aid chiefly of volunteer assistants. A report on Clarke County by Mr. R. T. Hill, with a geological map, will be finished this season, and another, on Washington County, by Dr. F. W. Symonds. Work is going forward also on the coal fields by Arthur Winslow.

4. *Fossils of Littleton, New Hampshire.*—The Littleton fossils were referred to the Niagara group by Prof. C. H. Hitchcock, in 1884, in a paper on Geological Sections crossing New Hampshire and Vermont, in the Bulletin of the American Museum of Natural History of New York.

5. *Palæolithic Man in Northwest Middlesex:* The evidence of his existence and the physical conditions under which he lived in Ealing and its neighbourhood, illustrated by the condition and culture presented by certain existing savages; by JOHN ALLEN BROWN, F.G.S. 228 pp., 8vo, with frontispiece and 8 plates. London, 1887. [Macmillan & Co.]—This interesting volume is

illustrated by figures of flint implements of various forms from the vicinity of Ealing. To these are added representations of similar implements from other beds of like age, and also from those now in use among existing men, as the Esquimaux, Australians, Fuegians and others; and the frontispiece represents, in an ideal picture, the method of chipping the flint into arrow-heads and other forms.

6. *On the Organization of the Fossil Plants of the Coal Measures.* Part XIII; by W. C. Williamson, LL.D., F.R.S. Philosophical Transactions of the Royal Society of London, vol. clxxviii, 1887.—Nearly six years have elapsed since the appearance in 1882 of the twelfth of this remarkable series of memoirs which, prior to that date had been issued at the rate of one every year since their commencement in 1871. The casual observer might infer from this that the powers of the distinguished author were failing, but when we learn what other work he has done during this interval we cannot wonder that the special investigations which are recorded in these memoirs have been somewhat interrupted.

One would suppose that the preparation of his splendid Monograph on the Morphology and Histology of Stigmaria ficoides, published by the Palæontographical Society in 1887, might have occupied the whole of this time, not to speak of his work for the British Association, as president of the Geological Section and on committees for the investigation of the Tertiary flora of the north of Ireland and of that of the Halifax coal measures, which, with his other collateral work aggregate a score or more of important contributions from his pen to the science of fossil plants during the past five years.

The present memoir deals with some new phases of his two genera, Heterangium and Kaloxylon, which he established in Part IV of this series in 1873. The most important fact now brought out is that these plants, while possessing most of the points of structure essential to ferns, have, nevertheless, at the proper period of their growth, a distinct exogenous zone with a cambium layer separating the xylem from the phloem. Relative to the systematic position of these remarkable plants he is only certain that they have no representatives among living plants. He suggests the possibility of their being the generalized ancestors of both ferns and cycads, and cites Stangeria with its fern-like dichotomous nervation linking these two families of plants by their foliage in a manner similar to that in which these extinct forms link them by their internal structure. L. F. W.

7. *Catalogue of the Fossil Mammalia in the British Museum;* by Richard Lydekker, F.G.S., part V, London, 1887.—This Part finishes the Catalogue. It includes the group Tillodontia, and the Orders Sirenia, Cetacea, Edentata, Marsupialia and Monotremata, together with miscellaneous notices in a supplement. The critical notes in this Catalogue give it very great value.

8. *The Geological Evidences of Evolution;* by Angelo Heilprin, Prof. Invert. Pal. and curator Acad. Nat. Sci. Philad.,

100 pp., 12mo., Philadelphia, 1888.—Prof. Heilprin has here presented a brief review of the more prominent facts in paleontology supporting the theory of evolution. It is a carefully prepared statement made with little technicality, and illustrated by good figures.

9. *Kilauea.*—In the paper by Mr. J. S. Emerson, in volume xxxiii, page 90, the words "Little Beggar," in line 27 from the top should be "New Lake."

10. *Allgemeine und chemische Geologie von* JUSTUS ROTH. 2nd volume, third part closing the volume. Crystalline Schists and Sedimentary Rocks.—The author opens his chapter on the Crystalline Schists with the remark that in his opinion, the schists are Plutonic, or the material of the earth's first-cooled crust. He has thus got back to old an error, through the help of the new facts put forward by Dr. Lehmann, just at a time when opposing facts are fast multiplying. The value of the work, however, is not much affected by the theoretical assumption, except that he cites statements that coincide with the view, and omits the facts that disagree with it. The rocks are described with fullness, many chemical analyses are given, and long lists of localities are added. Quartzite is placed rightly both under "crystalline schists" and "Neptunian rocks;" but among his *North American* localities those of the Taconic region of western New England are *omitted;* evidently because the associated mica schists of Western Massachusetts, alternating in some places with the quartzite, would throw them with the "Plutonic," and yet a Lower Paleozoic age is claimed for them, which puts the author in suspense.

11. *Mineral Resources of the United States.*—Calendar year 1886. DAVID T. DAY, Chief of Division of Mining Statistics and Technology. 813 pp. 8vo. Washington, 1887, (U. S. Geological Survey, J. W. Powell in charge). This fourth volume of the series of reports on the Mineral resources of this country, appears with commendable promptness, reflecting credit in this respect as in others upon the editor, Mr. David T. Day. Its scope is similar to that of its predecessor, and like them it contains an immense amount of valuable practical and scientific information not to be obtained elsewhere. A large part of the space is given to detailed discussions in regard to the important metals, fuels, building stones, etc., but there is also considerable fresh information as to the rarer substances of less economic value.

12. *Native Platinum from Canada.*—Mr. G. C. HOFFMANN, of the Canada Geological Survey, has contributed a series of analyses of native platinum from Granite Creek, a branch of the Tulameen River in British Columbia. The specimen in hand consisted of 98 per cent platinum with a little gold and pyrite; the specific gravity was found to be 16·656 after removing the foreign matter. It was separated into a magnetic portion (A), 37·88 per cent, with G.=16·095, and a non-magnetic portion (B) with G.= 17·017. The mean analyses gave:

	Pt	Pd	Rd	Ir	Cu	Fe	Iridosmine	Chromite
A. *Magnetic*,	78·43	0·09	1·70	1·04	3·89	9·78	3·77	1·27= 99·97
B. *Non-magnetic*,	68·19	0·26	3·10	1·21	3·09	7·87	14·62	1·95=100·29

The magnetic portion was distinctly magneti-polar, but it was not found to contain appreciably more iron than the others, although that might have been anticipated.—*Trans. Roy. Soc. Canada*, 1887.

13. *The Shepard Collection of Minerals.*—The very large and valuable collection of minerals and meteorites belonging to the late Prof. Charles U. Shepard, has been generously given, by his son, Dr. Charles U. Shepard, to Amherst College. The estimated value of the collection is ten thousand dollars.

14. *Natural Gas.*—Supplement of December 30, of the American Manufacturer and Iron World of Pittsburg, contains valuable papers, both geological and economical, on Natural Gas, by the best American writers on the subject, C. A. Ashburner and John F. Carll, of the Pennsylvania Geological Survey, with a map of western Pennsylvania, also of Kansas, and by Dr. A. J. Phinney, of Indiana, with a map of the Indiana gas field, and other notes on the subject.

III. Botany.

1. *Respiratory Organs of Plants.*—Ludwig Jost of Strassburg communicates to Botanische Zeitung, Sept., 1887, some interesting facts concerning organs of peculiar shape found on the roots of certain palms, and their allies, and a few other plants. These organs are outgrowths from roots, they point upward into the air, and are generally characterized by having a swollen portion conspicuously different from the rest. Experimental study indicates that these organs, like stomata and lenticels, are of use in the aëration of the plant. Jost suggests as a name for this group of organs, *pneumatodes.*

Among the possible cases alluded to by him but dismissed with hardly more than a word, is that of the enormous swellings on the roots of our Southern Cypress, *Taxodium distichum.* Many years ago, Professor Shaler of Harvard stated to the present writer that he believed these excrescences of the Cypress of the South to be related in some way to the aëration of the trees, since he had observed that where these had been submerged for a time by an overflow, the plants suffered and after a while died. In a recent paper in the publications of the Museum of Comp. Zool. at Cambridge, Professor Shaler has given his views in detail, making out a strong case; so that we can feel little hesitation in referring these extraordinary swellings on Taxodium to Jost's new class of *Pneumatodes.* G. L. G.

2. *On a Combination of the Auxanometer with the Clinostat.*—At the writer's suggestion, Albrecht, the well-known mechanician at Tübingen, has constructed a simple form of Auxanom-

eter which can be well employed as a serviceable Clinostat. In addition to the strong axis which carries the equipment of the ordinary Clinostat, there is a smaller spindle driven by the same machinery and at such rates of speed as may be wished. Upon the latter spindle, the common form of registering drum is carried with absolute steadiness. Although, on general principles, one must view with more or less distrust an apparatus aiming to reach two ends so widely diverse as the two just mentioned, the present appliance has thus far worked satisfactorily. But for ordinary use in the class room, it is inferior as an auxanometer to either of the two simple and excellent ones figured and described in the Botanical Gazette by Professors Bumpus and Barnes.

G. L. G.

3. *Die natürlichen Pflanzenfamilien*, von A. Engler und K. Prantl. Leipzig, 1887. (Now publishing in parts of which 12 have already been received).—The first number of this important work and the promise given by it were noticed in this Journal last summer. The numbers which have since come to hand redeem this promise in the most satisfactory manner. The text exhibits care in its preparation even down to the minute treatment of the economic plants, and, although the parts are of unequal merit, all are of a high order, placing the work in the front rank. The illustrations are excellent throughout, and are lavishly used. Serial publications demand from the recipients of the successive parts a fair degree of patience, since in most cases, the separate articles come to the reader in a fragmentary form. Until the disjecta membra are all before one, it is difficult to tell whether they can be united to form a symmetrical structure: everything depends upon the skill in editing and the sense of proportion possessed by the editors. To them belongs the ungracious task of contracting lengthy contributions and, more rarely, of suggesting increase in volume. From all that appears in the present publication, up to the present time, the editors have performed their work with great judgment. Thus far the chief burden has fallen on Professor Engler. A mere enumeration of the leading contributions is all that can be justly given at this early stage in the progress of the publication. Professor Drude has finished the Palms in 93 pages, with seven pages additional given to the Cyclanths; Haeckel carries the Grasses through 96 pages, with more to come; Engler has given 91 pages to Liliaceae; Gymnospermae were treated of in 127 pages by the lamented Eichler, whose notes have received some additions from both the editors. Other contributions are from Pax, Hieronymus and Wittmack. In the twelve numbers received, consisting of about six hundred pages, there are 421 illustrations containing about two thousand single figures.

Such a work is of the highest value to teachers of botany and ought even in its German form to command a large list of subscribers in this country. It is sincerely to be hoped that an English translation may be early undertaken. G. L. G.

4. *Botanical Necrology* of the year 1887, by Dr. GRAY: his last work for this Journal.—The first two names in the American list belong rather to the obituaries of the preceding year.

W. E. TOLMIE died in British Columbia, near the close of 1886, at an advanced age. A brief notice of his life and services to botany will be found in this Journal, vol. xxxiii, p. 244. To him was dedicated by Torrey and Gray, the Saxifrageous, genus, *Tolmiea*, a native of the country in which his life was passed.

JOHN GOLDIE, who was born near Maybole in Ayrshire, March 21, 1793, died at Ayr, Ontario, Canada, where he had long resided, in June, 1886, in his ninety-fourth year. From materials communicated by the family, a biography was published in the Botanical Gazette for October, 1886; but his name was accidentally omitted from our necrology of that year. Mr. Goldie was educated as a gardener; and most Scotch gardeners in those days were botanists. From the Glasgow Botanic Garden, then in charge of Sir Wm. Hooker, he came to America for botanical exploration in the year 1817. The interesting particulars of this expedition are entirely omitted from the biography mentioned above, and were probably unknown to the writer. They are here given in an abstract from his "Description of some new and rare Plants discovered in Canada in the year 1819," published in the Edinburgh Philosophical Journal, vol. vi, April, 1822. "Having had for many years a great desire to visit North America, chiefly with a view to examine and collect some of its vegetable productions, I contrived in 1817 to obtain as much money as would just pay my passage there, leaving when this was done but a very small surplus." He sailed from Leith to Halifax, went to Quebec, whence he despatched his collections of living roots and dried plants in a vessel bound for Greenock, "but never heard of them afterwards." At Montreal, he found Pursh, who advised him to explore the northwest country and promised to obtain for him permission to accompany the traders going to that region the following spring. "I travelled on foot to Albany, thence proceeded by water to New York. . . . . I explored the eastern part of New Jersey, a country which though barren and little inhabited, yet presents many rarities to the botanist, and gave me more gratification than any part of America that I have seen. At a place called Quaker's Bridge, I gathered some most interesting plants, and having accumulated as large a load as my back would carry, I took my journey to Philadelphia,"—thence to New York, whence a ship was about to sail to Scotland, "and, having again committed my treasures to the deep, I had again, as the first time, the disappointment of never obtaining any intelligence whatever of them. My finances being now extremely low and winter having commenced, I hardly knew what to do; but, after some delay, went up to the Mohawk river, where I found employment that season as school-master,"—thence in the spring to Montreal, and failing to make the connections necessary to reaching the northwest district, he "took to the spade" all summer long, except two days in the week which he devoted to botanizing. "In the autumn I shipped my collection of plants, and in two months had the mortification to learn that the vessel was totally wrecked in the St. Lawrence. During the next winter I did little, except employing myself with such skill as I was able in designing some flower-pieces, for which I got a trifle. Early the following spring I commenced labor again, and by the beginning of June, had amassed about 50 dollars, which, with as much more borrowed from a friend, formed my stock of money for the next summer's tour. I started in the beginning of June from Montreal, and passing through Kingston went to New York [meaning the State, evidently], to which, after an excursion to Lake Simcoe, I returned; then visited the Falls of Niagara and Fort Erie, and crossed over to the United States, keeping along the eastern side of Lake Erie," he crossed over to Pittsburgh, back by way of Olean, Onondago, and Sackett's Harbor to Montreal, and thence safely home to Scotland, "the plants I carried with myself being the whole that I saved out of the produce of nearly three years spent in botanical researches." Hard lines these and in those days for collecting botanists,—which those who "stay at home at ease" do not appreciate.

Among the fruits garnered in Goldie's paper of 16 pages, are *Primula pusilla*, *Xylosteon oblongifolium*, *Viola Selkirkii* (the name given by Pursh), *Drosera linearis*, *Stellaria longipes*, *Ranunculus rhomboideus*, *Corydalis* [*Dicentra*] *Canadensis*, *Habenaria macrophylla* [which is the *H. orbiculata*, Goldie and Hooker having unfortunately taken the smaller round-leaved species for that], and *Aspidium Goldianum*, that noble fern, named and about that time figured by W. J. Hooker. The latter's name has mistakenly been affixed to one or two of these species. But, although he doubtless examined the plants, and probably drew up the Latin characters and contributed the figures on the plate, there is no mention of his name in Goldie's paper except for the fern which well commemorates Goldie's name.

In the year 1824, he was commissioned to take charge of a cargo of living plants sent by the Edinburgh Botanic Garden to that of St. Peterburgh. On his return he went into the nursery business in his native country, during which he revisited Russia, bringing home, it is said, *Picea Pichta* and the double-flowered *Pæonia tenuifolia*. Then, with a laudable wish to better the prospects of his family, in 1844 he transported his home from the Scotch to the Canadian Ayr, in the province of Ontario, where he flourished and prospered for over thirty years of green old age, and died in the midst of numerous and prosperous children, grand-children, and great grand-children.

Albert Kellogg died at Alameda, California, on the 31st of March last, at the age of 74 years. We have few particulars of his life. It is said that he was born at New Hartford, Connecticut, and he had doubtless entered the medical profession before he went to California. He was one of the founders of the California Academy of Natural Sciences; and we may expect from that institution a full biography. As well as we can make out, Dr. Kellogg emigrated to California thirty-four or thirty-five years ago; and he resided at San Francisco for all the rest of his life. Upon the first page of the first volume of the Proceedings of that institution, under the date of September 4, 1854, we find that Dr. Kellogg was in the chair, and that he exhibited specimens and a drawing of a plant found on the shore of the bay. He drew plants remarkably well and devoted very much time to this work, even to the last. Unfortunately the rude wood cuts which largely illustrate his many papers in the Proceedings of the California Academy give a poor idea of his pictorial skill; while his want of books and of botanical resources greatly derogated from the value and authority of his determinations and descriptions of the very many plants which he published throughout a long series of years. But he did what he could, in his own way, and has left an indelible mark upon the botany of the Pacific coast. He was a man of the utmost simplicity of life and character, a most amiable, gentle and worthy soul. Dr. Torrey dedicated to him the genus *Kelloggia*, appropriately founded on a modest but quite peculiar Californian plant.

William Boott died in Boston, May 16th. He was born in that city on the 15th of June; 1805, consequently he had almost reached the age of 82. He was a younger brother of Dr. Francis Boott, of London, but born in Boston, who is still affectionately remembered by a few of the oldest surviving naturalists. William Boott was educated at Exeter Academy and Harvard University; but his health suffered and he was obliged to leave college before graduation. He traveled in Spain and other parts of the Continent, and studied medicine in Dublin and in Paris; but he did not complete his medical education. Returning to his native country, he lived a quiet and retired life, never marrying, nor taking any of the positions to which he might have aspired. But his excellent talents were sought by one of the western railway companies, to which for many years he devoted a portion of his time. His tastes and his accomplishments in early and middle life were literary, especially linguistic. Probably he took up botany at the instigation of his brother, and with the desire of helping him to the Carices of this country when Dr. Boott began the study of this vast genus, of which he became the illustrator and the highest authority; and William Boott, by a kind of *noblesse oblige*, after his brother's death, specially devoted himself to their study. His only publication is a short Caricological paper. But he studied other groups with great care and critical acumen, especially *Isoetes*, Grasses, and some tribes of *Cyperaceæ*. His health was delicate, but his tall and gaunt form seemed quite unaffected by inclement weather, which he braved to the last, with scant protection. A keen botanist, a most amiable man and trustworthy friend, he is greatly missed at the Cambridge Herbarium, to which he presented his botanical library and collections.

Ezra Michener, a physician, of Chester County, Pennsylvania, born November 24, 1794, died June 25, 1887, in his 93d year. He may have derived from Schweinitz his predilection for Fungi, which he cultivated at a time when few botanists of this country knew or cared for them. A genus of Fungi bears the name of this pioneer collector.

Henry William Ravenel, who was born in Berkeley District, South Carolina, May 19, 1814, died at Aiken, in that State—where he had long resided—on the 17th of July last. When we first knew this kindly and excellent man, he was a planter, upon an inherited estate in St. John's parish, a keen phanerogamous botanist, and a prized correspondent. About 30 years ago he removed to Aiken, in a higher and drier part of the State, now celebrated as a winter health resort. About this time the Rev. Dr. Curtis was well engaged in his notable Mycological career, and Mr. Ravenel was his most zealous follower. So that it is among the Mycologists that his name is most widely known at home and abroad. He published five volumes of *Fungi Caroliniani Exsiccati*, the sets of which are now rare and very valuable, and in later years he largely contributed the principal materials to the similar *Fungi Americani Exsiccati*, edited by Cooke, of London, in five centuries. He was for many years the botanist of the State Board of Agriculture, and also an agricultural editor. In 1859 he was joined to an U. S. Commission to examine into the cause of the cattle disease then prevalent in Texas. Deafness of many years' standing secluded him much from the world at large, and even from the social circles which he was most fitted to adorn. "The war swept away nearly all of his property"—we recall to mind a touching letter of adieu, when the secession of his State took place, and his hopeful prospects in that connection—"but he met his adversities with Christian fortitude and courage, doing his duty faithfully to the end." A good number of species bear his name, as well as the very peculiar genus of Uredinei, *Ravenelia*. In the Botanical Gazette for August last is an appreciative notice of his life by Dr. Farlow, to which is appended a list of eighteen papers which he published relating to various departments of botany.

III. Miscellaneous Scientific Intelligence.

1. *Hann's Meteorological Atlas.*—Twelve sheets of the new edition of Berghaus's Physical Atlas are devoted to meteorology under the editorship of Dr. Hann, of Vienna. These may be purchased separately, and if kept unbound they will be found extremely useful as study- and lectnre-charts for classes of moderate size, as well as invaluable for reference in all matters of geographic meteorology. The series of maps is remarkably full, including isotherms and isobars, with winds, where well enough known, for the year, January and July; thermic isanomals for the same period; Supan's chart of equal annual variations of temperature;

Buchan's chart of equal diurnal variations of pressure; special annual and seasonal temperature charts for Europe, the United States and the Arctic regions; a rain map of the world, with Loomis's data on a new projection; and a chart by Köppen of the distribution of rain throughout the year. Besides all these, there are several novel maps of a more physical nature; isotherms for Europe in warm (1880) and cold (1879) Decembers, with corresponding isobars in explanation of these weather-anomalies; Köppen's tracks of low-pressure areas over the North Atlantic and adjacent lands; examples of ordinary cyclonic storms in Europe and their accompanying fœhn, sirocco and bora winds, and so on. These latter are especially welcome as aids in calling attention to actual atmospheric phenomena as shown on synoptic charts, in contrast with those more statistical matters in which individual occurrences are lost sight of or concealed by averaging. Tracks of thunder-storms, so well studied out in Europe, and the distribution of tornadoes in cyclones, as discovered in this country, would be valuable additions to the series, but they were doubtless considered and excluded in order not to increase the size and cost of the atlas unduly. The same may be said of the cold waves in the Mississippi valley and the fœhn-like chinook winds on the northeastern plains, so fully illustrated in our weather maps; but even without these, the atlas is a decided advance on others of its kind, and is clearly the best series of meteorological charts ever published. The data employed come down to 1884, and, except concerning the winds and precipitation, seem to be sufficient on charts of the size here used to hold good for years to come over a large part of the world. The printing and coloring are beautifully executed, and worthily represent the high class of work done by the publisher, Perthes, of Gotha.

W. M. D.

2. *New Meteorites.* (Communicated)—The U. S. National Museum has recently received fragments of two new Japanese meteorites from the Educational Museum at Tokio. Both are grayish stones, showing a dull black crust. The first of the two fell at Fukutomi, Kinejima, Province of Hizen, March 19, 1882, at 1 P. M. Its total weight was 7680 grams. The second fell at Maêmê, Hislugari, Province of Satsuma, Nov. 10, 1886, at 3 P. M. Its original weight was 328 grams.

These specimens and the information regarding them were received from Prof. S. Tegima, Director of the Tokio Museum.

F. W. CLARKE.

West Coast Shells: a familiar description of the Marine fresh-water and land Mollusks of the United States found west of the Rocky Mountains. Adapted to the use of schools, private students, tourists and all lovers of nature; by Josiah Keep, A.M., Prof. Nat. Sci. Mills College. 230 pp. 16mo, with numerous illustrations. San Francisco, 1887 (Bancroft Brothers & Co.)—A convenient little work for the young student and collector of shells on the Pacific border.

Annual Report of the Geological Survey of Arkansas for 1887, by John C. Branner, Ph.D., State Geologist, Little Rock, Arkansas, 1887. 15 pp. 8vo. A brief report of progress.

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[THIRD SERIES.]

Art. XXII.—*The Absolute Wave-length of Light;* by Louis Bell.

This paper contains the final results of the research partially reported in this journal for March 1886. In view of the wide discrepancies in the value of this physical constant as determined by various observers and methods, it has seemed desirable to give in brief the history of the subject, and critically to discuss certain portions of the investigation which have proved stumbling-blocks in the past. I refer particularly to the verification of the standards of length employed, and to those errors of ruling in the gratings which may, and usually do, produce errors in the result obtained.

The first portion of this paper will be devoted to the methods and results of the pioneers in this work and the methods, apparatus, and standards of length employed in the present investigation.

The second portion will contain the details of the experimental work, together with a discussion of the final results and those questions of theoretical and practical interest which raise themselves in connection with the work of recent experimenters. With this preliminary notice is presented the first half of the paper.

Historical.—Fraunhofer's first paper on the lines which bear his name marks a new era in the science of optics. Up to that point any careful study of spectra had been impossible for lack of definite standards of reference, and because the apparatus was as yet very defective. Fraunhofer's research, "Bestimmung des Brechungs- und Farbenzerstreunngs-Vermögens verschiedener Glasarten," was presented to the Munich Academy of Sciences in 1814, and was published in the fifth volume of the "Denkschriften." It then became possible to study in detail the properties of rays of definite position and the work was taken up almost immediately. Almost the first step was to determine the wave-lengths of prominent points in the solar spectrum, and, as is well known, Fraunhofer himself took it, determining the wave-lengths corresponding to his lines B, C, D, E, F, G, H. As there seems to have been—noticeably in Verdet's papers—some confusion concerning his papers on this subject, it may be well here to clear the matter up.

Fraunhofer's first paper dealing with the subject was presented to the Munich Academy in 1821. It is entitled: "Neue Modifikation des Lichtes durch gegenseitige Einwirkung und Beugung der Strahlen, und Gesetze derselben," and was printed in the eighth volume of the "Denkschriften." It is of considerable length and deals with various diffraction phenomena, but its chief interest lies in the wave length measurements made with wire gratings. The experiments made with ten of these are given in detail and are remarkably careful and consistent. The gratings were quite various, the wires being from $0·04^{mm}$ to $0·6^{mm}$ in thickness and the grating space as ordinarily measured, from 0·0528 to $0·6866^{mm}$. From these proportions it is evident enough that the spectra must have been very imperfect, but in spite of this, Fraunhofer obtained results which agreed remarkably well with each other. The wave lengths of D as obtained from the above mentioned ten gratings were as follows: reduced to millimeters.

	mm		mm
(1)	0·0005891	(6)	0·0005888
(2)	0·0005894	(7)	0·0005885
(3)	0·0005891	(8)	0·0005885
(4)	0·0005897	(9)	0·0005882
(5)	0·0005885	(10)	0·0005882

The mean value adopted was $0·0005888^{mm}$, which considering the gratings and the fact that most of the angles of deviation were less than 1°, is certainly remarkably accurate. It should be noted too, that the finer gratings (1) to (4) gave even better results.

A brief discussion of this paper appeared in the seventy-third volume of Gilbert's Annalen and a French reprint in Schumacher's Astronomische Abhandlungen (ii, 46).

Fraunhofer's second and more complete paper appeared in 1823 in Gilbert's Annalen (lxxiv, 337). Its title is: "Kurzer Bericht von den Resultaten neuerer Versuche über die Gesetze des Lichtes, und die Theorie derselben." This paper gives a detailed account of his experiments with two glass gratings. Of these, the grating spaces were respectively 0·0033 and 0·0160^{mm}. The former was apparently much the better, and upon it Fraunhofer based his final result, which for D was 0·0005886^{mm} while the experiments with the coarser grating gave 0·0005890^{mm}. These values apply quite certainly to the mean of the two D lines, and not, as has been sometimes supposed, to one of them alone.

The experimental work with these glass gratings was much better than with the previous wire ones, since the angular deflections were very much larger and the gratings themselves were susceptible of far more exact measurement. But at best they were but indifferent instruments and the terminal lines were so bad that they had to be retraced before the grating space could be determined. So, between poor gratings and indifferent standards of length, Fraunhofer's determination of absolute wave length left very much to be desired. However, nothing much better could be accomplished until the art of making gratings was very much improved, and it was not until Nobert's gratings became tolerably well known, that any serious attempt was made to improve on Fraunhofer's results. From time to time various investigators worked on the problem, both with Nobert's earlier gratings and by utilizing various interference phenomena. When, however, the great investigations of Bunsen and Kirchhoff revolutionized spectroscopic work and emphasized its great importance, the attention of scientific men was called to the need for accurate measurements, and for half a dozen years investigators were active, and Mascart, Ditscheiner and Ångström appeared on the field almost simultaneously. Each published a paper in 1864, and of these that of Mascart is probably the most accurate and painstaking, though now it is quite certain that the values he obtained were considerably too small. He employed four or five of Nobert's gratings and instead of placing the grating perpendicular to either the collimator or the observing telescope, used it in the position of minimum deviation, that is to say, so that the plane of the grating should bisect the angle formed by the incident and diffracted rays. This position has certain advantages, but as the experimentation is rather more difficult than in the ordinary position, the method appears to be of somewhat questionable utility. It avoids, to be sure, the necessity of placing the grating normal to the axis of either telescope, but as there is very little trouble in making this adjustment with a high degree of accuracy, and keeping it through a series of measurements, the gain is by no means considerable. Aside from this question, Mascart's spectrometer read only to five seconds, and while his results with different gratings agree very well individually they are certainly collectively in error by quite a large amount, very possibly owing to bad standards of length.

It is a fact to be noted in discussing all these earlier wave-length determinations, that sufficient attention was not paid to the measurement and study of the gratings—by all odds the most difficult part of the problem. The angular measures of any one of the above investigators were good enough to have given very exact results had they been combined with proper investigations of the grating spaces. As most of Nobert's gratings were small and by no means accurately ruled there was peculiar need of care in measuring them, and when one considers that the defining lines on most standards of length are far from being good, it is clear that the chances for error were numerous. In Ångström's first paper he even relied on the grating space assigned by the maker. Ditscheiner employed a grating which had belonged to Fraunhofer himself, but the number of spaces was uncertain and this led to a large error which he corrected, in part, in a supplementary paper some years later. Ditscheiner's principal paper was published in 1866, and was followed in 1868 by an elaborate discussion of the whole problem by van der Willigen, whose paper is valuable mainly for a particularly elaborate review of sources of error. Like his predecessors he used Nobert's gratings, but as the construction of his spectrometer confined his angular measurements to the deviation on one side of the normal, their accuracy may be open to some question, while his standard of length was anything but reliable, as it was a glass scale only three centimeters long and the only assurance of its accuracy was the certificate of the maker that it was "tres exacte" at 50° Centigrade. For one or both of the above reasons van der Willigen's results were larger than any which have been obtained, before or since his time.

In the same year appeared Ångström's great research which has so long served as the standard in all questions of wave length. It is hard to say too much of the conscientious and painstaking experiments on which his results were based, and any want of accuracy in the final result was due to no lack of skill or care on his part but rather to the imperfect instruments with which he was obliged to work. Like every one before him he used Nobert's gratings and in spite of the fact that like all Nobert's gratings they gave very imperfect definition and showed numerous "ghosts," his results were more than usually consistent. But in spite of all Ångström's care the event has shown that his wave lengths are in error by as much as one part in seven or eight thousand mainly through an error in the assumed values of his standards of length. Ångström measured his gratings by means of a dividing engine the screw of which was very exactly determined by comparisons resting on the Upsala meter which, in turn, had been compared by M. Tresca with the prototype of the Conservatoire des Arts et Metiers. Had this comparison given the correct value of the Upsala meter Ångström's wave-lengths would have been very nearly exact except for corrections due to errors of ruling in the gratings.

After Ångström's research the question of absolute wave-length was not seriously raised for ten years, when Mr. C. S. Peirce under the auspices of the United States Coast Survey again attacked the problem, armed with Rutherfurd gratings far superior to those used in any previous research. No official report of his very elaborate and exhaustive experiments has ever been published save a very brief preliminary report in the American Journal of Science in 1879. Such of his results as have been made in any way public will be discussed in the experimental part of the present paper.

Meanwhile Thalén, who so efficiently aided Ångström in his work, has taken up the part of it left uncompleted by the latter's death and in his paper "Sur le Spectre du Fer," published at Upsala in 1885, has discussed the corrections which must be applied to Ångström's values by reason of the error in the Upsala meter. It seems that through the experiments of Professor Lindhagen, Ångström became aware as early as 1872 that the assumed value of his standard was considerably too small. His death prevented his verification of M. Lindhagen's results and nothing further was done till Thalén took up the work. Tresca's comparisons had shown that the true length of the Upsala metre at 0° was 999·81^{mm}. But the very exact experiments of M. Lindhagen have shown the above to be somewhat too small and that the correct value is 999·94. This difference makes, of course, a marked error in the wave-lengths based on Tresca's results. Applying the appropriate correction, the wave length of E, the line most carefully determined by Ångström, becomes

5269·80,

instead of the original 5269·12.

This final result of Ångström is certainly entitled to considerable respect and seems to be subject only to those corrections which may be due to irregularities in the gratings. These were, however, so poor compared with the gratings of to-day, that such corrections would necessarily be of uncertain magnitude.

At all events it is quite sure that of the wave-length determinations made up to 1880, those of Peirce, and Ångström corrected by Thalén are by all odds the best. Of the two, Peirce's is probably the better by reason of better gratings, but his work will be discussed in another part of this paper in connection with the very recent works of Müller and Kempf and Kurlbaum, which merit more extended study than would be in place at this point.

A tolerably complete bibliography of the subject up to date is annexed. Many of the papers are of little except historical value, but they will at least exhibit the various methods employed and the growth of exact experimentation.

1821 Fraunhofer. Denkschr. d. Akad. d. Wiss. zu München, viii, Heft. II, 38. "Neue Modifikation des Lichtes durch gegenseitige Einwirkung und Beugung der Strahlen und Gesetze derselben."

1823 Fraunhofer. Schumacher's astronomische Abhandlungen, ii, 46.

1823 Fraunhofer. Gilbert's Annalen, lxxiv, 337. "Kurzer Bericht von den Resultaten neuerer Versuche über die Gesetze des Lichtes und die Theorie derselben."

1835 Schwerd. "Die Beugungserscheinungen" (Mannheim).

1849 Stokes. Athenæum No. 1143. Inst. xvii, 368. "On the Determination of the Wave Length corresponding with any Point of the Spectrum."

1851 Nobert. Proc. Roy. Soc., vi, 43; Phil. Mag., IV, i, 570. "Description and Purpose of the Glass Plate which bears the Inscription: Longitudo et celeritas undularum lucis cum in aere tum in vitro."

1851 Nobert. Pogg. Ann., lxxxv, 83. "Ueber eine Glasplatte mit Theilungen zur Bestimmung der Wellenlänge und relativen Geschwindigkeit des Lichts in der Luft und im Glase."

1852 Drobisch. Pogg. Ann., lxxxviii, 519. "Ueber die Wellenlänge und Oscillationszahlen der farbigen Strahlen im Spectrum."

1853 Esselbach. Berlin Monatsber. 757. "Ueber die Messung der Wellenlänge des ultravioletten Lichts."

1856 Esselbach. Pogg. Ann., xcviii, 513. Ann. de Chim. e. d. Phys., III, l, 121, "Eine Wellenmessung im Spectrum jenseits des Violetts."

1856 Eisenlohr. Pogg. Ann., xcviii, 353, xcix, 159. Ann. de Chim. e. d. Phys., III, xlix, 504. "Die brechbarsten oder unsichtbaren Lichtstrahlen in Beugungspectrum und ihre Wellenlänge."

1863 Müller. Pogg. Ann., cxviii, 641. "Bestimmung der Wellenlänge einiger heller Spectrallinien."

1863 Mascart. C. R., lvi, 138. "Détermination de longueur d'onde de la raie A."

1864 Mascart. C. R., lviii, 1111. Détermination des longueurs d'onde des rayons lumineux et des rayons ultraviolets.

1864 Mascart. Ann. de l'École normale, i, 219. Recherches sur la détermination des longueurs d'onde.

1864 Bernard. Mondes, v, 181. "Theorie des bandes d'interférence * * * Longueur d'onde de la raie A." * * *

1864 Stefan. Ber. d. Wien. Acad., l, Heft 2, 31. Pogg. Ann., cxxii, 631. "Ueber die Dispersion des Lichtes durch Drehung der Polarizationsebene im Quarz."

1864 Bernard. C. R., lviii, 1153; lix, 352. "Memoire sur la détermination des longueurs d'onde des raies du spectre solaire au moyen des bandes d'interférence."

1864 Ditscheiner. Ber. d. Wien. Acad., l, Heft 2, 296. "Bestimmung der Wellen länge der Fraunhofer'schen Linien des Sonnenspectrums."

1864 Ångström. Pogg. Ann., cxxiii, 489. Œfvers. af Förhandl. (1863) 41. "Neue Bestimmung der Länge der Lichtwellen nebst eine Methode auf Optischen Wege die fortschreitende Bewegung des Sonnensystems zu bestimmen."

1866 Ditscheiner. Ber. d. Wien. Acad., lii, Heft 2, 289. "Eine absolute Bestimmung der Wellenlänge der Fraunhofer'schen D Linien."

1866 Mascart. Ann. de l'Ecole normale, iv, 7. "Recherches sur la détermination des longueurs d'onde."

1868 Mascart. Ann. de Chim. e. d. Phys., IV, xiii, 186. "Note sur différents travaux relatifs aux longueurs d'onde."

1868 van der Willigen. Arch. du Museé Teyler, i, 1, 57, 280. "Memoire sur la Détermination des longueurs d'onde du Spectre Solaire."

1868 Ångström. Upsala, 1868. "Recherches sur le Spectre Solaire."

1871 Ditscheiner. Ber. d. Wien. Acad., lxiii, heft 2, 265. "Zur Bestimmung der Wellenlänge der Fraunhofer'schen Linien."

1879 Peirce. Am. Jour. Sci., III, xviii, 51. "Note on the Progress of Experiments for comparing a Wave length with a Metre."

1884 Thalén. Upsala, 1885. "Sur le Spectre du Fer obtenu a l'aide de l'arc électrique," p. 18.

1886 Müller and Kempf. Publicationen des Astrophysikalischen Observatoriums zu Potsdam, v. "Bestimmung der Wellenlänge von 300 Linien im Sonnenspectrum."

1886 de Lépinay. Jour. de Ph., II, v, 411. "Détermination de la valeur absolue de la longueur d'onde de la raie D^2."

1887 Bell. Am. Jour. Sci., III, xxxiii, 167. "On the absolute Wave length of Light."

1887 Kurlbaum. Berlin, 1887. "Bestimmung der Wellenlänge einiger Fraunhofer'schen Linien."

In general the determination of absolute wave-length involves two quite distinct problems—first the precise determination of some quantity which is an exact function of the wave-length and some other linear dimension; and second, the reduction of this dimension to terms of some recognized standard of length. The first process can be made to give relative wave-lengths with a very high degree of accuracy, and is, in nearly every case, more exact than the second, which constitutes the main difficulty of the investigation. It is because the diffraction grating lends itself readily to linear measurement, that its use is preferable to the other interference methods which involve, usually, the exact determination of a single very small linear quantity. The ingenious attempt of M. de Lépinay* to avoid this difficulty is interesting theoretically but practically it involves a quantity even more uncertain than the average standard of length—the relation between the kilogram and the meter—to say nothing of the experimental difficulties of the method. The angular measurements of nearly all the later investigators have been quite good enough to furnish very exact values of wave-length, but in every case it has been the measurement of the grating space that has produced the manifold errors and discrepancies

* Journ. Phys., II, v, 411.

in the results. It has been the aim of the present research to investigate this fruitful source of errors and as far as possible to avoid the difficulties springing from it.

In a previous paper,* I briefly discussed the advantages of transmission and reflection gratings. It only remains to add that further experience has convinced me that not only are the speculum metal gratings far superior in brilliancy and sharpness of definition, but that it is possible, contrary to what one might suppose from their large coefficient of expansion, to rule them with almost perfect uniformity, over a length as great as a decimeter. This large size too, gives a great advantage in determining the grating space, aside from the fact that speculum metal has a coefficient of expansion not widely different from that of any one of the materials usually employed for standards of length, and that its temperature can be obtained with comparative ease.

Methods and Instruments.

The plane grating can be used for wave-length measurement in a variety of ways according to the preference of the investigator or the arrangement of the spectrometer. Five tolerably distinct methods may be enumerated. The general relation between the wave-length and the angles of incidence and diffraction is

$$\lambda = s(\sin i + \sin(\varphi - i))\frac{1}{n}$$

Where λ is the wave-length, s the grating space, i and φ the angles of incidence and diffraction respectively, and n the order of the spectrum observed. Making $i=0°$ this at once becomes the ordinary formula

$$\lambda = \frac{1}{n} s \sin \varphi$$

which applies to the two methods of normal incidence, one in which the grating is kept accurately perpendicular to the collimator; the other in which it is kept perpendicular to the observing telescope.

Next is the method used by Ångström in which i is not reduced exactly to 0°, but measured and retained in the formula, the grating in this case being kept nearly perpendicular to the collimator. In this method a reading on the slit is necessary, and if a and a' are the readings on the circle, and M that on the slit, the working formulæ are:

$$\frac{\alpha + \alpha'}{\alpha} - \mathrm{M} = \delta \text{ and } \frac{\alpha - \alpha'}{2} = \varphi$$

* Am. Jour. Sci., III, xxxiii, 167.

then, if i is as before, the angle of incidence,

$$\lambda = \frac{1}{n} s \sin \varphi \cos (i + \delta)$$

$$\sin i = \sin(i + \delta) \cos \varphi$$

$$\tan i = \frac{\cos \varphi}{1 - \cos \varphi} \delta$$

In the fourth method also, i is retained, but given a definite value. Putting the general formula in the form,

$$\lambda = \frac{1}{n} \cdot 2 s \sin \frac{\varphi}{2} \cos \left(i - \frac{\varphi}{2}\right)$$

the deviation represented by the angular term will evidently be a minimum when $i = \frac{\varphi}{2}$. If then one observes in the position of minimum deviation,

$$\lambda = \frac{1}{n} 2 s \sin \frac{\varphi}{2}$$

In the fifth method collimator and observing telescope are kept at a fixed angle with each other and the grating is turned. In this case if φ is the angle of deviation and θ the angle between the telescopes

$$\lambda = \frac{1}{n} 2 s \sin \varphi \cos \frac{\theta}{2}$$

These methods are general and the choice between them is simply a question of the convenient application of the apparatus at hand. Probably the first and the second methods are the most generally useful, while the third is the most objectionable. The method of minimum deviation slightly increases the experimental difficulties, but often improves the definition of the gratings and is capable of giving very exact results. The last method is applicable only when the spectrometer is so rigid as to ensure the permanence of the angle between the telescopes. When this condition is fulfilled, however, the method is very valuable, since it reduces the moving mass to a minimum and allows the method of repetition to be readily used.

In the present research for the work with glass gratings the second method was selected as best suited to the arrangement of the spectrometer. This was a very good instrument by Meyerstein. The circle is 32^{cm} in diameter, divided on silver to $6'$ and reading by two microscopes directly to $2''$ and by estimation easily to within $1''$. The collimating and observing telescopes are of 4^{cm} clear aperture and about 35^{cm} focal length, well corrected and firmly supported.

For the second part of the work, with speculum metal gratings, it was desirable to use gratings of the largest size practicable, far larger than could be used on the above described instrument, both by reason of the small aperture of the telescope and the inability of the grating holder to carry the requisite mass steadily. This part of the work was, therefore, carried out on a very large instrument, designed by Prof. Rowland especially for using gratings of the largest sizes as yet ruled. This instrument has virtually fixed telescopes, solidly clamped, with a small lateral range of adjustment, to a T-shaped casting bedded in cement which in turn forms the top of a large brick pier resting on a stone slab.

The telescopes are of 16·4^{cm} clear aperture, and about 2·5 meters focal length and the objectives are of excellent quality. Each telescope is fastened to an arm of the T, which has a total length of over 2 meters, and bears, at the extremity of the shaft the spectrometer proper. This is an instrument by Schmidt and Haensch, having a circle 32^{cm} in diameter divided to 6′ and, as in the other spectrometer, reading by two microscopes directly to 2″ and by estimation to less than half that amount. The original central platform had been removed and replaced by a grating holder large enough to carry if necessary a 6 inch grating. Such an apparatus limits one, of course, to the fifth method, but so rigid is the whole affair that experience soon showed that the angle between the telescopes did not change by any appreciable amount. The circle, however, was not finely enough graduated, nor were the microscopes of sufficient power to derive the fullest benefit from the size of the telescopes; over and over again has the line in the spectrum appeared slightly displaced from the crosshairs, when no difference whatever could be detected in the micrometer readings. However, there was gained the great advantage of using gratings of a decimeter in length, giving spectra of great brilliancy and superb definition, and which could be measured with vastly greater exactness than is possible with the small gratings generally employed.

Gratings.

Four gratings have been used in my experiments—two of glass and two of speculum metal. The former are probably the best of the very few glass gratings that have been ruled on Prof. Rowland's engine. They are ruled on plane sextant mirrors of rather hard glass.

Grating I, contains 12,100 spaces in a length of very nearly thirty millimeters, the lines being nineteen millimeters long. It was ruled in Jan., 1884, at a temperature of 6°·7 C. gives spectra of excellent definition, quite free from ghosts or false lines, and having almost exactly the same focus on both sides of the normal.

Grating II has 8600 spaces with almost exactly the same length and breadth as I, is free from ghosts and false lines and like I, is very smoothly ruled, though it is somewhat inferior to I in the matter of regularity. The definition is excellent and the spectra alike in focus on both sides of the normal. It was ruled in Nov., 1884 at 11°·6 C.

Gratings III and IV are on speculum metal. The plates are five inches square and five-eighths of an inch thick, and were worked plane with especial care. The ruled surface is of the same size in each, four inches long by two inches length of lines.

Grating III was ruled in April, 1885, at a very nearly constant temperature of 10° C. It contains 29,000 spaces, having very nearly the same grating space as II. It is a phenomenal grating both in its superb definition and extraordinary regularity of ruling, and was selected from a large number because of its very unusual perfection. The focus of the spectra on each side of the normal is the same and the ruling is flawless.

Grating IV was ruled on the new dividing engine just completed by Prof. Rowland, and was one of the first large ones completed. While the new engine has even now not received the finishing touches, it has turned out a few gratings of remarkable excellence. One of these is IV, which was ruled in Dec., 1887, at a constant temperature of 17°·2 C. It contains 40,000 spaces within the same dimensions as III, is equal to it in definition, and but very little inferior in regularity of ruling. It has very nearly the same focus on both sides of the normal, and the ruling is wonderfully even and perfect.

It should be noted that these four gratings are widely diverse, being ruled at different temperatures and under different conditions. I and II were ruled to widely diverse grating spaces on different parts of the screw, III was on speculum metal and with more than six times the ruled surface of I or II, and finally IV was ruled to a new grating space on a new dividing engine. These differences may not favor close agreement in the experimental results, but they certainly serve to eliminate anything like systematic errors due to the gratings.

The above gives a general view of the gratings employed, but some further details will be mentioned in the second part of this paper in connection with the determination of the grating spaces.

On the Standards of Length.

Very many of the discrepancies in the determinations of absolute wave-lengths are the direct result of uncertainty in the standard of length employed. The cases of Ångström and van der Willigen have been already alluded to, and the same source of error is common to all other determinations. It seems, therefore, desirable to give at some length the various comparisons on which the wave-length as given by my experiments is based. Reserving for the present the actual measurement of the gratings, which is a comparatively simple matter, I will therefore discuss the standards directly employed, their relations to the Metre des Archives as found by various comparisons, and finally the changes which have taken place in those relations since they were first determined.

The standards with which the gratings have been directly compared are two double decimeters on speculum metal, designated respectively S^a_1 and S^a_2. They were graduated and compared by Prof. W. A. Rogers in 1885. The bar S_1 is 23^{cm} long and bears near its edge the double decimeter S^a_1, subdivided to centimeters. The defining lines are less than 1 μ in width and beautifully sharp and distinct. S_2 is 27^{cm} long and is graduated in the same way, with lines of the same width. Both standards are of the same speculum metal, and are of very nearly the same mass, while the surfaces and graduation leave little to be desired. The coefficient of expansion of these bars was very thoroughly investigated by Prof. Rogers and was found to be,

$$17{\cdot}946\mu \text{ per meter per degree C.}$$

The absolute lengths of S^a_1 and S^a_2 depend on long series of comparisons with Prof. Rogers's bronze yard and meter R_2 and steel copies thereof. Upon the relation existing between R_2 and the Metre des Archives depends then the absolute value assigned to the wave-length of light, since the close agreement of the various series of comparisons executed by Prof. Rogers between R_2 and the speculum metal standards show that no sensible uncertainty exists in the relations between them.

The yard and meter R_2 is of the alloy known as Bailey's metal, this being the material of the Imperial Yard and many other standards. The graduations are upon platinum iridium plugs, the polished faces of which are in the plane of one surface of the bar when supported at its neutral points. The relation of the meter R_2 to the Metres des Archives rests on a very large number of comparisons made with two entirely independent secondary standards; the copper meter designated T, and the brass yard and meter designated C. S. A full account of these comparisons is contained in vol. xviii of the Proceedings of the American Academy of Arts and Sciences.

The meter T is on platinum plugs in a pure copper bar and was traced and compared by M. Tresca in 1880, from the Conservatoire line meter No. 19, the relation of which to the Metre des Archives was very exactly known.

The yard and meter C. S. has its graduations on silver plugs in a brass bar. The yard was compared directly with the Imperial Yard in 1880, and the standard was then sent to Breteuil where it was compared with the International Meter by Dr. Pernet.

There were thus two completely independent sources from which the relation of R_2 to the Metre des Archives could be obtained. The results derived by very elaborate comparisons with each of these were as follows:

$$\left.\begin{array}{ll}\text{From T} & R_2-A_0=+\ 1{\cdot}5\mu \\ \text{From C.S.} & R_2-A_0=+\ 1{\cdot}1\mu\end{array}\right\}\text{ at } 16^\circ{\cdot}67 \text{ C.}$$

Where A_0 is the Metre des Archives. In addition to the very close agreement of the above, further evidence was obtained by deriving the relation between the yard and meter from R_2, the yard R_2 having been exactly determined by comparisons with C. S. and with "Bronze 11," one of the primary copies of the Imperial Yard, which had been recompared with that standard in 1878.

From the comparisons of S_1 and S_2 made in 1885 the following value of those standards were deduced:

$$S^a_1 + 0{\cdot}98\mu = \tfrac{1}{5}A_0, \text{ and}$$
$$S^a_2 + 0{\cdot}2\mu = \tfrac{1}{5}A_0. \text{ Hence}$$
$$S^a_2 = S^a_1 + 0{\cdot}78\mu, \text{ and for the first decimeters}$$

were found the relations:

$$Dm_1S^a_1 + 0{\cdot}05\mu = \tfrac{1}{10}A_0$$
$$Dm_1S^a_2 - 0{\cdot}01\mu = \tfrac{1}{10}A_0 \quad \text{Whence,}$$
$$Dm_1S^a_2 = Dm_1S^a_1 + 0{\cdot}06\mu$$

On these equations were based the results embodied in my former paper. In the latter part of May, 1887, these standards were very carefully compared with each other and with a speculum metal bar graduated by Prof. Rowland, as I desired to take one or more of the standards to Berlin during the summer in order to get a comparison with the standard used by Müller and Kempf.

The results of this examination were of a somewhat startling character, as follows:

$$S^a_2 = S^a_1 + 1{\cdot}2\mu, \text{ direct}$$
$$S^a_2 = S^a_1 + 1{\cdot}1\mu, \text{ through the Rowland bar}$$

designated R_B. Also,

$$Dm_1S^a_2 = Dm_1S^a_1 + 1{\cdot}7\mu, \text{ through } R_B$$

In 1885 Rogers had found for the relation between the two decimeters of each bar:

$$Dm_2S^a_1 = Dm_1S^a_1 - 0{\cdot}56\mu$$
$$Dm_1S^a_2 = Dm_2S^a_2 + 0{\cdot}46\mu$$

I now found for the same quantities:

$$\begin{aligned} Dm_2S^a_1 &= Dm_1S^a_1 + 0{\cdot}64\mu, \text{ direct,} \\ Dm_2S^a_1 &= Dm_1S^a_1 + 0{\cdot}60\mu, \text{ from } R_B \\ Dm_1S^a_2 &= Dm_2S^a_2 + 1{\cdot}60\mu, \text{ direct} \\ Dm_1S^a_2 &= Dm_2S^a_2 + 1{\cdot}65\mu, \text{ from } R_B \end{aligned}$$

All these relations being for 16°·67 C.

The standard S^a_2 was taken to Berlin during the summer and through the kindness of Dr. Nieberding, Director of the Normal Aichungs Commission, I was enabled to have it compared with R_{78} the standard meter to which the wave length measurements of Müller and Kempf, and Kurlbaum had been referred. From this comparison was derived the relation:

$$S^a_2 - 1{\cdot}68\mu\ (\pm 0{\cdot}15\mu) = \tfrac{1}{5}A_0$$

On returning to Baltimore the first step was to redetermine the length of S^a_2. A series of comparisons was therefore instituted between it and the steel yard and meter A_4, the relation of which to R_2 was accurately known, A_4 having been traced and determined by Prof. Rogers and furnished by him to the Johns Hopkins University. Only half of this standard is subdivided to decimeters but a series of comparisons with the various pairs of decimeters gave the relation,

$$S^a_2 + 1{\cdot}3\mu = \tfrac{1}{5}A_0$$

This result taken together with the relations found between S^a_1 and S^a_2 made it tolerably clear that a change had taken place in the speculum metal standards, and to obtain a further confirmation Prof. Rogers kindly consented to give them a rigid examination and again compare them with all attainable accuracy to R_2. His results for S^a_2 were as follows:

$$\begin{aligned} Dm_1S^a_2 &= Dm_2S^a_2 + 1{\cdot}70\mu \\ S^a_2 + 1{\cdot}0\mu &= \tfrac{1}{5}A_0 \end{aligned}$$

There is no escape from the conclusion, therefore, that the speculum metal bars S_1 and S_2 have changed both in absolute length and the relative lengths of their parts. Here are two bars of the same shape, mass, material, and constant of expansion. Each had the relation between its halves determined in the early part of 1885. Two years later these relations are found to have changed by at least 1μ, and an independent determination by the original observer confirms this result in the most unequivocal way. Further, the original observer recompares one of these standards with the standard from which it was originally determined and finds a change of 1μ.

It should be borne in mind that with the comparator used by me in this work, 1μ is completely outside of any possible errors of observation. The microscope used was especially made for micrometric work and has a power of two hundred and fifty diameters, while one division of the micrometer equals $0{\cdot}28\mu$. The average error of a single comparison between two decimeters is rarely greater than $0{\cdot}1\mu$, while the temperature of the observing vault can be kept for several days constant within $0^{\circ}{\cdot}5$ C. and during a day's observations usually remained constant within half that amount. The bars under comparison were side by side, symmetrically placed with reference to the illumination, and were at temperatures very near to $16^{\circ}{\cdot}67$, at which they were standard.

The facts then concerning the speculum metal bars are these: In about two and a half years S^a_2 has shortened by very nearly $1{\cdot}0\mu$ and S^a_1 by a little over that amount. In S^a_2 this change has taken place exclusively in the last decimeter and in S^a_1 it has been confined to the first decimeter.

The apparent slight increase in $Dm_1S^a_2$ and $Dm_2S^a_1$ I do not regard as beyond the effect of the experimental errors. The changes in the lengths of the subdivisions of these standards are very curious and some explanation may be offered by the fact that the bars were cast in a nearly vertical position and annealed in sawdust, a method hardly sufficient for a material so strongly crystalline as speculum metal. I think, however, one is justified in drawing the conclusion that speculum metal, so tempting on account of its beautiful surface and the exquisite sharpness of the graduations drawn upon it, is a material thoroughly unsuitable for standards of length by reason of its tendency to change with time. I have thus entered into somewhat minute details in the case of these bars, because the whole question of changes in standards of length is in a somewhat unsettled state, and it seems desirable to put on record this case, which has been investigated with more than ordinary care by both Prof. Rogers and myself, and in which the changes found have taken place within a comparatively short time.

It is quite well-known that in 1855 this question was raised by Mr. Sheepshanks, then engaged in constructing the new British standards. Discrepancies amounting sometimes to 2 or 3μ appeared in his measurements, but after a considerable amount of study, these differences appeared to be too irregular to be fairly ascribable to actual changes. Slight variations of temperature, especially when the standards compared were of different materials, the lagging of the real temperatures of the bars behind the thermometer indications, and particularly the effect of coarse and sometimes unsymmetrical defining lines, are perhaps enough to account for the observation.

The work, however, done on the U. S. bar "Bronze 11," as reported in the report of the Coast Survey for 1877, seems to show genuine change in that standard.

A long series of comparisons with the Imperial Yard and its copies in 1878, showed systematically a shortening relative to the Imperial Yard of over 4μ. Although further measurements have tended to somewhat lessen this discrepancy it seems to be sufficient, considering the fact that "No. 11" and the Imperial Yard are of the same shape, material and mass, and were compared on the same apparatus as during the original comparisons in 1857, and at nearly the standard temperature, to establish the fact of a real change. While 3 or 4μ is absolutely a small quantity, its systematic appearance under conditions almost identical with those of the original measurement can hardly be ascribed to experimental errors. The other cases cited in the above mentioned paper tend to confirm this conclusion.

The gradual and sometimes very irregular changes that are known to take place in both the bulbs and stems of thermometers, would lead one to expect that glass standards of length would be liable to similar changes, though probably in far less amount. It was, therefore, with special interest that I examined glass Decimeters III and IV belonging to the Coast Survey, and used by Peirce in his wave-length measurements. These scales are on plate glass, of the same dimensions, and having coefficients of expansion not widely different. A series of comparisons made at a nearly constant temperature of 16°·5 C. gave the direct relation

$$\text{III} = \text{IV} + 2{\cdot}1\mu$$

While the same relation deduced from Peirce's direct comparison by applying the coefficients of expansion assigned by him, is

$$\text{III} = \text{IV} + 1{\cdot}3\mu$$

The defining lines on both standards are fine and sharp, and unless Peirce's coefficients are grossly in error, the evidence of change between 1879 and 1887 is very strong indeed.

Having now the exact present relation of S^a_2 to the original standard R_2, it remained only to investigate the difference between this result and the length of S^a_2 as deduced from the Berlin comparisons. I have been unable to obtain the details concerning R_{78}, the standard used in these comparisons, but it was determined by comparison with the standard meter of the International Bureau. The comparisons of S^a_2 with R_{78} were carefully made by two observers, and it is probable that the result represents the relation between these standards with considerable exactness. It should, however, be borne in mind that the microscopes had power of only 50 diameters, and that the bars in question are of very different material and mass, thus giving a chance for small errors due to varying temperature.

It is possible, however, to check this result by referring S^a_2 to the Berlin platinum standard through the medium of the Coast Survey meter "No. 49." This latter standard was compared in 1876 with meter 1605 and directly with the platinum meter. The details are given in Prof. Foerster's report contained in the report of the Coast Survey for 1876. The result of the direct comparison was

$$Pl - \text{“}49\text{”} = +24{\cdot}4\mu.$$

But now Prof. Rogers has compared R_2 with "49," obtaining in terms of the assumed length of R_2

$\text{“}49\text{”} = A - 19{\cdot}3\mu$, the assumed value of R_2 was, $R_2 = A + 1{\cdot}3\mu$. Hence we have, $R_2 - \text{“}49\text{”} = 20{\cdot}6\mu$, from which follows, $Pl - R_2 = 3{\cdot}8\mu$. If now the equation between Pl and the Metre des Archives established by direct comparison in 1860 be correct:

$A_0 - Pl = -3{\cdot}01\mu$. And therefore,
$R_2 - A_0 = -0{\cdot}8\mu$, a result which is in close accordance with those derived from the Conservatoire meter and Type I of the International Bureau by means of the Standards T. and C. S.

In my final determination of wave-length, I have used the mean value of S^a_2 as derived by the foregoing methods. Collecting equations,

$S^a_2 + 0{\cdot}96\mu = \frac{1}{5}A_0$ From T.
$S^a_2 + 1{\cdot}04\mu = \frac{1}{5}A_0$ " C. S.
$S^a_2 + 1{\cdot}40\mu = \frac{1}{5}A_0$ " "49."
$S^a_2 - 1{\cdot}68 = \frac{1}{5}A_0$ " R_{78}.

Giving to the equations derived from C. S. and R_{78} twice the weight of the others, we have finally,

$$S^a_2 + 0{\cdot}27\mu = \tfrac{1}{5}A_0.$$

I have given the relations derived from C. S. and R_{78} double weight because these standards have been compared directly with the standard of the International Bureau, which now, probably, should be regarded as the ultimate standard of reference. Especially is this true, since it is rumored, apparently not without foundation, that the Metre des Archives is, at present, for some unassigned reason, undesirable as a direct standard of reference.

It is unfortunate that there is not more general uniformity in the material, shape and mass of standards of length. Difference in these particulars are fruitful sources of error in comparisons, and when one adds to this the trouble arising from bad defining lines and imperfect focus, the wonder is that the results are as good as they usually are. It is hard to say what material is least liable to changes, but it is quite certain that substances of crystalline structure, and alloys of which the physical properties are largely dependent on a nearly definite composition, should be avoided. Probably pure platinum, silver, and copper, annealed with the utmost care, and kept for some years before final graduation, are less likely to change than any other material which we know. For short standards, possibly bars of native copper, prepared with as few strains as possible, would give the closest possible approximation to a material which has arrived at a permanent state.

Physical Laboratory, Johns Hopkins University, Feb. 22, 1886.

[To be continued.]

ART. XXIII.—*History of the changes in the Mt. Loa Craters;* by JAMES D. DANA. Part I. KILAUEA. Continuation of the Summary and Conclusions. (With Plates IV and V).

[Continued from xxxiii, 433; xxxiv, 81, 349; xxxv, 15, 181, 1888.]

B. *The Ascensive Action in the Conduit lavas.*

1. *Evidence.*—The evidence in favor of an uplifting action by the ascensive force has been presented in volumes xxxiv, pp. 83, 89, and xxxv, p. 25. It is briefly as follows:

(1) The observations in 1846 by Mr. Chester Lyman demonstrate that in six years the lower pit of 1840, averaging 10,000 feet by 2,500 in its diameters and nearly 400 feet in depth, had gradually become obliterated, and chiefly through an uplift of the floor; for the floor bore on its surface the talus of lava blocks that had fallen from the walls. Overflows had done part of the work, but "subterranean force," as Mr. Lyman concluded, the larger part. Mr. Coan, who was with Mr. Lyman at the time, appreciated the evidence, and later described the lifting as "not uniform in all parts; as sometimes taking place here and there abruptly; but as producing nearly uniform results, except a greater rise toward Halema'uma'u."

(2) In 1868, Mr. Brigham gave further evidence as to the Lyman ridge by the representation of what remained of it in 1865 (xxxiv, 89, and xxxv, 24), on his valuable map, though not, as his memoir shows, understanding its origin. Besides this, the painting of the crater of about the same date (1864 or earlier) by Mr. Perry afforded confirmatory proof as to its position and extent at that time (xxxv, 25).

(3) In 1848, Mr. Coan observed that a cone of broken lava that had formed within the Halema'uma'u basin, was lifted by "subterranean action," as he argued, because only slight addi-

tions were made to its outside by ejections. It continued to rise bodily until it was as high as the near walls of Kilauea (xxxiv, 86). Between 1880 and 1882, another debris cone began in the basin of Halema'uma'u which, as he describes, rose in like manner without additions to its summit, and finally became 200 feet or more high; this cone continued to exist until the eruption of 1886.

The subterranean force appealed to was plainly force arising in some way from the lavas beneath. Mr. Coan, in his letters to me, supposed that the lifting was produced by the injection of the lavas of the conduit into open spaces between the solid layers below.

(4) Again, in the summer of 1886, three months after the eruption of that year, the debris from the falling walls of Halema'uma'u were *seen* to be made into a cone occupying a large part of the interior of the basin; and from August onward, it was apparent that the cone so made was slowly rising, though having little outside additions; in October, its top was on a level with the rim of the basin; in January, 200 feet higher, so as nearly to overtop the southeastern Kilauea walls. It was early apparent to visitors at the crater that the elevation was through action below; and soon the conclusion was general, among observers, that the cone, as expressed in the words of Mr. Dodge, of January 14, 1887, was "rising slowly as though floating on the surface of the new lava-lake.* The mean rate of elevation, according to the heights given, was about two feet a day.†

The ascensive force was thus proved to be great, and its effects to have fundamental significance.

2. *Method of Action.*—It is a question whether, in the lift of the floor of the great crater in 1823, 1832, 1840, 1868, the lavas of the lava-conduit acted by direct thrust, or through injections into spaces between the layers of solidified lava beneath it.‡ The facts favor strongly the former of these views. In the first place, the lateral thrust in the upper lavas of a conduit is necessarily feeble; for the conduit there, or near by, opens to the surface. Then secondly, it is quite certain that the breadth of the Kilauea conduit at top has been, at the times of these up-

* This Journal, xxxiv, 70.

† I was informed, when at Honolulu, by Mr. Parmelee, of that place, that in August of 1886, he made observations on the rate of change of level, by sighting from the Volcano House verandah over a post 100 yards in front of the house, and marking the change of the line of sight on a pillar of the verandah. His observations were made between the 19th and 21st of the month, on the first day of the rise, according to his calculated result, was 16 feet; on the second, 17; and on the third 8 feet. These numbers are large. They were not verified by observations near the cone. They at least prove progress in the elevation.

‡ The latter is the explanation adopted by Mr. Brigham in his paper of July, 1887, xxxiv, 19.

lifts of the floor, large enough to act somewhat equably against the floor. Thirdly, since the floor kept its even surface as it fell at the great eruption of 1840, it must have followed down, as already urged, the subsiding lavas (page 213). The flotation method, or that by direct thrust, seems therefore to be the right one. It is the obvious explanation of the lifting of the debris cones of Halema'uma'u.

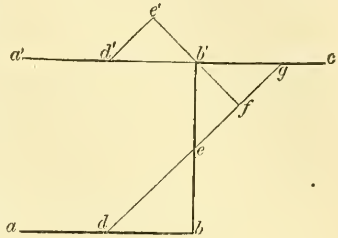
Kilauea affords, as has been indicated, facts illustrating the details connected with the lifting movement.

3. *Fault planes of the up-and-down movements about the pit.*—(1) The down-plunge of 1823, 1832, and 1840 left, for the most part, vertical walls bounding the "lower pit" so made. There is evidence that these were fault-walls, that is, planes of fracture with a vertical displacement along them equal to their height, or about 400 feet in 1840 and 600 or 800 feet in 1823. In the reverse movement, that is, the rise after the down-plunge of 1840, the old floor was carried up along the same fault-planes. The rate of rise, as shown on page 16, was 70 to 130 feet a year, which is to be divided between (*a*) overflows (*b*), vesiculation if this had any effect, and (*c*) ascensive force apart from vesiculation.

Further: these vertical fault-planes of 1840, and others subordinate to them along the border regions, appear to have determined the chief places of eruption, that is, of lava-lakes, cones, ovens and opened fissures in Kilauea *during the next thirty years.* They were plainly the occasion of the wonderful girt of fires, four miles long and half a mile wide, which was three times repeated after the year 1846 before the eruption of 1868 (in 1855, 1863, and 1866), while the interior plateau suffered relatively little change from erupting forces, and in some parts was growing ohelo bushes and ferns.

The position of the "canal" in Kilauea in 1846 described by Mr. Lyman and also by Mr. Coan, as extending around the crater, bounded by the outline of the old black ledge and the Lyman ridge of lava-blocks, and which became gradually filled by inflowing lavas and debris, has here its explanation. The circumferential fault-planes of the pit of 1840 coincided with the face of the lower wall or precipice. The debris which fell from the wall necessarily fell to the floor beyond the plane and there began the making of the talus. Through the fall of the face of the wall, the wall, and thereby the limit of the black ledges, retreated, and as the elevation of the floor went on, an interval was left between the talus and the limit of the black ledge, and along this interval lay the "canal." The annexed figure will serve to illustrate the point, notwithstanding the assumptions made in it. Let *bb'* be the wall of the lower pit, 400 feet high, and the course of the fault-plane;

ab the floor of the pit; *b'c*, the surface of the black ledge. Let now the falls from the wall above *e* make the talus *deb* with a slope of 45°, causing thereby the wall (and limit of the black ledge) to retreat to *g*. If the floor be now lifted 400 feet, to the position *a'b'*, the debris of the talus *deb* would make an elevation at top equal to *d'e'b'*, besides filling up *efb'*, ($efb' = d'e'b' = \frac{1}{2}deb$); the interval *b'fg* would represent the canal, and *d'e'b'*, 100 feet high, the ridge.



If the floor were raised 50 feet higher, the ridge would be lowered, say 25 feet, owing to material that would slip down into the canal; and consequently, the height of the ridge above the floor over the center of the crater would then be 25 feet less than before, while 25 feet more than it was above the black ledge. If no talus had been formed at the foot of the wall, an uplift of the floor of 500 feet would have made a precipice of 100 feet fronting toward the black ledge, the falls from which would have produced a steep talus. These are two conditions in the different parts of the ridge mentioned in Mr. Lyman's paper.

(2) *Fault-planes about Halema'uma'u.*—In Halema'uma'u at the eruption of 1886, there was a circumferential fault plane; this seems to be implied in the fact that the return of lava was mostly through vents toward the walls, little coming up at the center; and the fact that even a year and a half afterward, the action was greater outside of the cone than at its center. At the discharge, the debris from the tumbling walls fell beyond the fault-plane and made an accumulation of blocks, like the talus of the lower pit of 1840, and this, as Mr. Dodge's description shows and the photographs illustrate, was the material that became the cone as the lifting went forward.

(3) *Conclusion.*—By the above facts, it is proved that the conduit lavas of the volcano not only keep up the supply of heat, and carry on, by means of the vapors, projectile action and vesiculation, but also that they furnish power for lifting, in a quiet, unperceived way, the floors of craters with whatever is upon them, and thus raising the level of volcanic activity; and that this goes forward as part of the *ordinary* operations of the crater. The action has long been recognized as a means of supplying heat and lavas, but not as a mechanical agent to the extent here indicated. The force at work in making the Gilbert laccoliths must be the same, and Mr. Gilbert, in his

report on the Henry Mountains, gave the first intelligible idea of its power.

But there is nothing in the action that leads us to suppose that it can, under any probable conditions, make jets or fountains of lavas, or work in blow-hole style. Each jet over a lake, and each large jet in a lava-fountain, has its local projectile cause beneath the projected column of lava, and cannot be produced by any general upthrust movement in the great conduit. The imperceptibly slow uplift and fountain-making are incompatible effects. There seems to be, therefore, no foundation for the comparison of the lava fountains to the projectile effect in an "artesian boring made to a stratum of molten rock which had only been awaiting an opportunity to overflow."*

The *source of the ascensive movement* I have stated to be undetermined. It is most commonly referred to the pressure of the earth's crust on the lava reservoir beneath, arising from subsidence in the earth's crust from secular refrigeration. Another explanation appeals to vapors from the deep source of the lavas. The possibility of some addition to the force through ascending vapors is referred to on page 195 of this volume.

C. *Effects of Heat.*

1. *From change of temperature.*—Contractional effects from cooling, that is fractures and changes of level, should be common in the crater; for each stream has passed from a temperature of 2000° F. or more to 70° or 80° F. and the upper surface of a stream rapidly so. Besides ordinary shallow fractures, the cause produces also an imperfectly columnar structure in the cooled lava-stream below the upper foot. The cracks in the floor often expose quite good basaltic columns even when the thickness of the layer is hardly a dozen feet.

There should be also larger effects in the Kilauea region arising from change of temperature between periods of great and little activity, or from periodical variations in the heat below, and changes of level in the lava of the conduit. But we have no special facts to report in illustration, although there are cracks innumerable in view that probably have this source.

2. *The dissolving action of the liquid lavas.*

(1.) The *refusion of the crust* over the surface of a lava-lake by the liquid lavas is—as the history has shown—one of the common occurrences in Halema'uma'u and other lava-lakes.

* Mr. W. L. Green, Vestiges of the Molten Globe. pp. 168, 272. Mr. Green's examples are taken from action in the summit crater, and when speaking of that crater this point will be again considered.

The intervals of cooling and refusion vary in length from a few seconds to an hour and longer. The crust of a lava-lake is often only the thin, easily fusible glassy scum, but thicker crusts also yielded to the heat.

In the case of rapid transitions, the cooling and refusion may be due to the loss of heat by the expansion in the process of vesiculation; and if the vesiculation takes place intermittently for any reason (as from oscillating movement in the lava column, or other condition) it would occasion the alternations between the fused and crusted state. But for the crustings at longer intervals deeper movements may be concerned, and more study is needed before they are fully understood.

(2.) *The disappearance of floating islands* is another effect of heat and chiefly of refusion. For in some cases the islands have after a while—a year or more—disappeared.

(3.) *The destruction of debris-cones* in Halema'uma'u is dependent on undermining by the active lavas and vapors beneath; and, in one case, the destruction was probably completed before a period of eruption (xxxiv, 88).

The debris-cone, 1500 to 2000 feet broad at base, which now occupies the center of the Halema'uma'u basin is already in process of dissolution. It made no increase in height during the summer of 1887, but, instead, rather lost ground through the changes going on. This fact was obvious in August last; for the east wall, a single continuous ridge in October, 1886, had become divided into two ridges, and dense vapors rose from the interval between, with sounds of splashing lavas that were evidence of an active lava-lake below A photograph taken in October, 1886, copied on Plate IV, shows the condition of this side of the cone at that time when it had reached its maximum height; and Plate V, from a photograph taken nearly a year later, in September last (a month after I left the crater), exhibits the condition above described. Both views were taken looking westward, and the foreground in each is the bottom of Halema'uma'u on the east side of the cone. In Plate IV dense vapors may be seen issuing from a large aperture near its middle, and other vapors from a lower place to the right (north). In Plate V, the vapors escape copiously *all the way between* these two places and far southward, showing the subdivision nearly completed. A photograph taken in the spring of 1887 exhibits an intermediate stage in the process of division. A letter of Jan. 2 of the current year, from Mr. J. H. Maby, proprietor of the Volcano House, says that the bottom of the Halema'uma'u basin on the east side (that shown in the plates) has risen much and is now nearly on a level with the upper surface between it and "New Lake" and a lava-lake has opened in it, so that the fires and the overflows are visible from the

Volcano House, and "to all appearances, the lavas will soon be running into New Lake."

The description given by Professor Van Slyke of the cone as seen by him in July, 1886, gives particulars as to the steam-holes in and beneath the cone, and the blowing-cone work, which began this work of destruction and prepared the way for the subdivision. He states that he ascended the cone to a perpendicular well, which opened through its side by a hole "30 or 40 feet wide and 60 to 75 feet long," and looking down to the bottom 100 feet below, saw the lavas rising and falling in jets from a small vent. In another well of like depth, 20 to 30 feet in diameter, there was a cone and "lava boiling with intense violence" (xxxiii, 96).

This destructive work brings the cone to its end either before, or during, a period of eruption; and a floating island may be the last phase before its disappearance.

(4.) *Opening of new lava lakes.*—With the intensifying of the fires of the crater there has often been, as the history shows, an opening of lakes over the interior of the crater, and especially along the borders of Kilauea, or the region of the black ledge. Such facts signify, as I have explained, that the broad underlying conduit of Kilauea, which is like a great reservoir of lavas beneath the pit, reaches at such a time up to the surface, not only in the Halema'uma'u basin through the great conduit, but also in minor lakes through secondary conduits. It is a query whether this has ever been brought about by new sources of vapor starting in the underlying reservoir, as a consequence of subterranean conditions; whether hot vapors from such a source have not forced a way through to the surface in consequence of their own dissolving and fusing heat and that of the lavas, and thus have made a new lake;—as ascending air from the bottom of an ice-covered pond makes a hole through the covering of ice. But such lakes, as remarked on a preceding page, are generally begun over fissures, and it may be that fissures, under the general increased activity, are all that are needed for the result.

(5.) *Extending the limits of the conduit by fusion.*—Another suggestion comes from the fusing power of the Halema'uma'u lavas. If these lavas can slowly, even at their surface, fuse stoney lavas, what is the extent of the fusing power at depths below where there is greater heat? An increase in the heat from a subterranean cause would necessarily widen the limits of the conduit. It is a question whether an extended subterranean bed of liquid lava, thick enough to remain permanently liquid in spite of cooling agencies about it, can occupy its place without fusing and incorporating with itself any solid lavas directly underneath it, if such there be? A great lava-conduit, therefore, has probably its varying phases, like the fires at the surface, and includes extremes in breadth or enlargement as well as in contraction. The widest part should not be at the summit unless the cooling agencies are *less* effective, or the heat-making causes more so, there than elsewhere.

3. *The metamorphic action of the heat.*—Metamorphic action also may be part of the quiet work of the volcano. The lava-column has its enclosing rocks, and at temperatures varying from that just below fusion to that of the outside rocks; and vapors must be active in the hot regions. The throat of the conduit may well be, therefore, a region of recrystallizations, of the making of geodes, or lining fractures with crystals, out of whatever material was at hand, and differing somewhat according to the temperature. The effects of such metamorphism are exhibited, beyond question, in the various mineral crystallizations in the ejected masses of Vesuvius. They are found also at Kilauea and will be mentioned beyond.

D. *Hydrostatic and other Gravitational Pressure.*

1. The hydrostatic pressure of the column of liquid basalt is 2·8–2·9 times that of water, supposing the lavas while in fusion to be mainly in the glassy condition. This pressure was early recognized by Lyell as one of the possible causes of rupture in volcanoes. The cause may have its effects in a quiet way over the bottom of Kilauea, since the lavas often stand in the lakes at a height of 50 to 100 feet above the floor outside of the surrounding cone; but no facts yet observed can be positively referred to it.

2. Again, there may be *underminings* and therefore *subsidences* in the ordinary course of Kilauea changes, through discharges following small fractures. But such effects are not at present distinguishable from those of other modes of origin.

Having thus reviewed the ordinary operations of the crater, that is, those carried forward between times of eruptions in the way of preparation for an eruption, the next enquiry is, What is needed to produce a great eruption of Kilauea? The power of the rising vapors and that of the ascensive conduit-lavas, the two chief sources of ordinary activity, appear to be too feeble for any such result. Can eruptions take place without any increase of their activity within the crater beyond what has been described? If so, how?

Before discussing this subject, the history of the summit crater, Mokuaweoweo, may be first reviewed, as its facts afford important illustrations of the eruptive methods.

[To be continued.]

ART. XXIV.—*The Electromotive Force of Magnetization;** by
EDWARD L. NICHOLS and WILLIAM S. FRANKLIN.

AT the Ann Arbor meeting of the American Association for the Advancement of Science, we described some singular modifications in the relation of iron to acids which occur when the reaction takes place within the magnetic field. The present paper deals with the behavior of iron when that metal acts as one electrode in a voltaic circuit, and is at the same time subjected to magnetization.

A galvanometer placed in a circuit consisting of two electrodes of iron, metallically connected on the one hand, and dipping, on the other, into a cell containing any liquid capable of dissolving them, will indicate the existence of a current whenever the reaction between the metal and the liquid differs in character or rapidity at the two terminals. There are always at work a number of causes of such inequality of action, and the electro-motive force between iron poles in any liquid which attacks them freely is not inconsiderable. It amounts as a rule to several thousandths of a volt and even when special precautions have been taken to secure homogeneity in the elements of the circuit, a sensitive galvanometer will not fail to show the existence of a current. If one of the terminals be placed within a magnetic field, new differences of potential will be developed, both from the magnetization of the iron and from the change in the chemical relations between the metal within the field and the liquid. This electromotive force we have proposed to call *the electro-motive force of magnetization.*

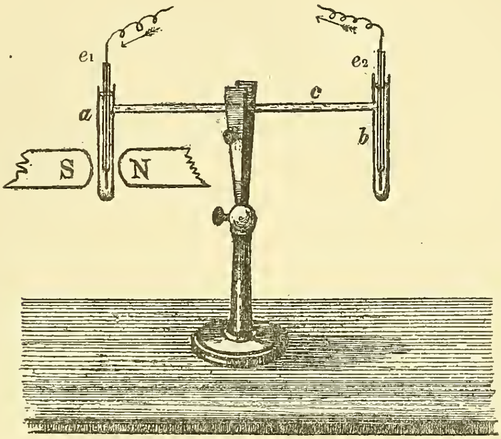
With the exception of two papers by Dr. Theodor Gross† of Berlin, which came to our notice too late to enable us to take advantage of their valuable contents in our investigation, we know of no observations of the effect of magnetization upon the voltaic behavior of iron. Dr Gross's research deals chiefly with the electro-motive force due to the magnetization of the iron, and touches only incidentally upon the nature of the currents produced when one of a pair of iron electrodes has its electro-chemical relations to the solution modified by being placed within the magnetic field. It is with the latter phase of the subject, principally, that our experiments have to do.

* Paper read at the New York meeting of the American Association for the Advancement of Science, August 11, 1887.

† Th. Gross; Ueber eine neue Entstehungsweise galvanischer Ströme durch Magnetismus: Sitzungsberichte der Wiener Academie, vol. xcii, 1885.

The first form of cell, which we used, consisted of two glass tubes, *a* and *b* (figure 1), about 1^{cm} in diameter and 10^{cm} long. These were closed at the lower end and were connected by a

1.



narrower glass tube (*c*), about 50^{cm} in length. The electrodes, e_1 and e_2, consisting of soft-iron wire, were inserted through the open ends of *a* and *b*. They were exposed to the liquid for about 1^{cm} at their lower ends. When this apparatus was filled with a liquid capable of dissolving iron, it formed a single cell, one terminal of which could be placed between the poles of an electro-magnet, while the other was well outside of the field. When the free ends of the wires, e_1 and e_2, were connected through a sensitive galvanometer, it was found that, although the terminals were taken from the same piece of wire, and were immersed in the same liquid, a measurable current was always flowing in the circuit. The electro-motive force was constant neither in amount nor in direction. In many liquids it changed but slowly, however, and could be balanced by means of a variable counter-electro-motive force introduced into the circuit. For this purpose a Daniell's cell was placed in circuit with two variable resistances, R and *r* (figure 2). The cell with iron electrodes was shunted around *r*, and the ratio R/*r* was so adjusted that the current in the shunt circuit, due to the Daniell cell, was just sufficient to reduce the galvanometer deflection to zero. The

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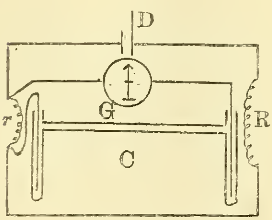


galvanometer could then be sensitized to any desired extent, but the fluctuations in the electro-motive force of the iron cell were such that the balance was never more than momentarily maintained, and the galvanometer drifted continually.

In very weak acids and in solutions of $FeSO_4$, $FeCl_2$ NH_4Cl, and similar salts, these fluctuations were not such as to preclude the possibility of making measurements, but in concentrated acids they were for the most part so rapid and irregular as to put galvanometer readings out of the question. In nitric acid, of considerable strength, these fluctuations were so remarkable as to deserve special mention. The electro motive force, amounting to a considerable fraction of a volt, changed sign continually, carrying the spot of light across the galvanometer scale, to and fro, with great rapidity. The frequent and irregular oscillations continued with undiminished violence until the electrodes were entirely dissolved or the acid nearly neutralized. Upon first closing the circuit one of the iron terminals would be slightly more active than its fellow. The tendency of the less active electrode would then be to protect the other from the attack of the acid, rendering it temporarily passive, as a piece of platinum would do under the same circumstances. The passive terminal would then react in like manner upon the first and electro-motive force would be reversed again and again until the electrodes were consumed.

In those cases in which the fluctuations were not such as to make the attempt at compensation ineffectual, we were able to make measurements of the initial electro-motive force of the cell and of the changes in electro-motive force caused by the action of the magnet.

One of the iron terminals was placed between the poles of a large electro-magnet. To obviate any direct effect of the magnet upon the galvanometer needle, the galvanometer was set up in a room several hundred feet distant from that in which the former instrument was located. The "iron" cell having been connected with the wires leading to the galvanometer room, the initial electro-motive force was balanced by the method already described, and the galvanometer was brought to the desired degree of sensitiveness by means of a governing magnet. One observer then proceeded to make galvanometer readings at intervals of fifteen seconds, while another magnetized and demagnetized the electro-magnet every two or three minutes, reversing the magnetizing current each time. The electro-magnet in question has been described in a previous paper.*

Like most large instruments of the kind, it required several seconds after the circuit had been closed to attain its full

* This Journal, vol. xxxi, p. 272.

strength; and it retained considerable residual magnetism when the circuit was broken. By the following very simple device, however, the residual magnetism was almost entirely destroyed. A reversing switch of Poggendorff's pattern and an ordinary telegraph key were placed in series in the magnetizing circuit. While the magnet was in function, a piece of soft iron wire about 1^{cm} long was suspended by magnetic attraction from the underside of one of the pole-pieces. The wire served as an indicator of the magnetic condition of the poles. Upon breaking circuit with the key the residual magnetism was sufficient to hold it in position. When, however, the current was first reversed by means of the Poggendorff switch, and then broken at the instant when the magnet was passing through the condition of neutrality, the proper moment being indicated by the dropping of the suspended wire, the magnet was left thoroughly demagnetized. The interval of time between reversal of the current and neutrality was about two seconds.

After each series of readings, the galvanometer was calibrated, the resistance of the iron cell was measured and the strength of the magnetic field was estimated by a modification of Rowland's method. The instrument used in most of these measurements was Edelmann's form of the Wiedemann galvanometer, read with telescope and scale. For some experiments in which a high degree of sensitiveness was necessary a Thomson reflecting galvanometer of 2500 ohms resistance was used.

It was found possible by this method, excepting when the fluctuations in the initial electro-motive force of the cell were very marked, to detect changes amounting to much less than ·00001 volts.

We experimented with a variety of reagents, including nitric, hydrochloric and sulphuric acids; ferrous sulphate, ferrous chloride, and ammonium chloride, in aqueous solutions, and finally, sulphuric acid, to which potassium bichromate had been added, and hydrochloric acid containing potassium chlorate. In every case there was unmistakable evidence of the development of a permanent electro-motive force due to the influence of the magnet. The smallest effect, ·000008 volts, was observed with terminals in concentrated nitric acid, the iron being passive—the largest effect in those solutions in which rapid oxidization took place. In a solution consisting of dilute sulphuric acid containing potassium bichromate, the electro-motive force of magnetization amounted to ·039 volts. In the same acid, the concentrated sulphuric acid of commerce diluted with ten parts of water, without the addition of the potassium bichromate, it was only ·0005 volts. Concentrated hydrochloric acid (sp. gr. 1·1768), gave ·003 volts, the same acid, diluted with four parts of water, only ·00002. When potassium chlorate was added to the dilute acid, the effect due to the magnet became very marked, amounting certainly to several hundredths of a volt; but the fluctuations in the initial electro-motive force were such as to make readings impossible. In nitric acid diluted with nine parts of water the effect was also very large, but it was so masked by the initial fluctuations described in a previous paragraph, that no quantitative determinations were secured. The strength of field during these experiments was about 10,000 H.

In the hope of eliminating these fluctuations in the initial electro motive force, two modifications of our apparatus were made. In the first, it was so arranged that a current of the fresh solution passed through both arms of the cell and the products of the reaction were carried away from the neighborhood of the terminals almost as soon as formed. In the second modification, terminals were prepared the surface of which consisted of pure iron, electrolytically deposited. When these prepared terminals were used, the fluctuations were somewhat less marked than when the original surface of the iron wire was exposed, but the adoption of these two modifications led to no new results. A more important modification consisted in the substitution of platinum or copper for the iron terminal outside of the field. These metals, being unaffected by the magnet, could be placed in close proximity to the magnetized terminal: the internal resistance of the cell was thereby greatly diminished and its form simplified. The iron-copper and iron-platinum cells were placed between the poles of the electro-magnet, and the investigation consisted in determining the electro-motive force before and after the magnet had been made active. The most satisfactory results were obtained with a cell patterned after the Daniell battery—a two-fluid cell in which copper immersed in sulphate of copper was separated from the iron pole by a porous diaphragm, the iron being submerged in a solution of ferrous sulphate or of ferrous chloride. A cell of this description, in which a neutral solution of ferrous sulphate surrounded the iron, and which possessed an initial electro-motive force of ·6072 volts, increased to ·6361 volts when placed within the field. Similar results were obtained with other solutions.

In the various forms of apparatus already described the currents due to magnetic action did not always flow in the same direction. The iron terminal within the field would sometimes act as zinc toward the unmagnetized electrode, sometimes as platinum. To determine the law governing the direction of the currents due to the electromotive force of magnetization we tried the following experiments. The terminals of iron wire used in our original apparatus were supplanted by cylinders of soft Norway iron 1^{cm} long and 4^{mm} in diameter. These were placed horizontally in the solution and were attached to the end of copper wires. The wire was in each case thoroughly insulated from the liquid, and the iron bar itself was protected by a coating of wax with the exception of a single portion of its surface, which to the extent of a few square millimeters was exposed to the action of the liquid. Under these conditions, the direction of the electro-motive force developed between the terminal within the field and a similar one outside was found to depend upon the portion of the bar exposed and the position of the latter with reference to the lines of force. Whenever the exposed surface was in the neighborhood of an induced pole within the soft iron electrode it became in its relations to iron outside of the field, as zinc to platinum. Whenever on the contrary the exposed surface was situated in a neutral portion of the bar, it became as platinum in its relations to unmagnetized iron. When platinum, carbon or copper was substituted for the unmagnetized electrode the electro-motive force of the cell thus formed was increased by magnetization, in the case in which a pole of the iron terminal was exposed to the liquid and diminished by magnetization when the surface acted upon lay in the middle of the bar. A reversal of direction in the current flowing between such a bar of iron in the field, one end of the bar being exposed to action, and an unmagnetized iron terminal, could be produced by turning the former in the field. When the axis of the bar was parallel to the lines of force and it was accordingly magnetized longitudinally, it acted as a zinc pole, the current flowing from its surface through the cell to the unmagnetized electrode. When turned through 90° upon an axis perpendicular to the line joining the poles of the electro-magnet, the bar became magnetized transversely and the direction of the current was reversed.

Between bars lying with their axes parallel to the lines of force, the end of one and the middle of the other of which was exposed, the effect was more marked than between either of them and a piece of unmagnetized iron; the bar with exposed pole acting as zinc, that exposed in the middle as platinum.

After having determined the conditions which govern the direction of the current, we turned our attention to the relation between the strength of the magnetic field and the electromotive force which it is capable of producing. The cell selected for this work was an iron-platinum element, containing a solution of potassium bichromate in dilute sulphuric acid. In this liquid the electro-motive force of magnetization was so marked that when the cell was placed between the pole pieces of the electro-magnet the influence of the residual magnetism of the latter upon its electro-motive force could easily be detected. Measurements were made in fields varying in intensity between 2000 H., and 20,000 H. The results are given in the following table. They show the manner in which the effect in question increases with the strength of the field.

TABLE.

Influence of the Strength of Field upon the Electro-motive Force of Magnetization.

Strength of field.	E. M. F. in volts.
2000 H.	·0008 volts.
3600	.0045
5040	·0208
7770	·0386
8400	·0424
12750	·0487
16300	·0510
19700	·0680

We had noticed in the course of our experiments that a layer of the more or less magnetic solution of the salts of iron, produced by the reaction, always gathered around the induced poles of the electrode within the field. In this way a two-fluid battery was formed between the iron within the field and that outside, whenever the surface nearest the poles of the magnetized electrode was exposed. The terminal within the field was thus surrounded by a concentrated solution of its own salts, and was in a measure protected against the direct attack of the acid. In the case however in which a neutral portion of the electrode within the field was exposed, the products of the reaction were continually withdrawn by magnetic attraction towards the pole-pieces, and the surface was left more open to attack than the opposing electrode outside of the field.

For the purpose of ascertaining whether this arrangement of the solution in the field would tend to produce the effects which have been described, measurements were made of a variety of batteries in which iron formed one electrode. The results were such as to make it evident that the influence of the magnet could, in part at least, be thus explained. An iron-carbon cell, the liquid being nitric acid diluted with one part of water, was found to have an E. M. F. of ·88 volts. When the acid was placed in a porous cup, containing the carbon pole, and the iron was submerged in weak sulphuric acid (1 : 10), the E. M. F. rose to 1·33 volts. The same metals in dilute sulphuric acid containing potassium bichromate gave 1·05 volts which was increased to 1·32 by placing the carbon and bichromate solution in a porous cup and the iron in dilute sulphuric acid. A cell with iron and platinum, in a solution consisting of 200^{cc} of strong hydrochloric acid, 200^{cc} of water and 20^{grms} of potassium chlorate, gave 1·17 volts. When converted into a two-fluid battery, the iron submerged in weak sulphuric acid, the platinum in the above solution, the E. M. F. became 1·39 volts. When the iron in the last case was submerged in dilute hydrochloric acid the result was nearly the same, the E. M. F. being 1·41 volts. In sulphuric acid containing potassium permanganate the same metals gave 1·44 volts, which rose to 1·60 volts when the platinum and solution were placed in a porous cup and the iron was dipped in sulphuric acid containing no oxidizing agent. Iron and platinum in ferrous chloride showed only ·74 volts, but a two-fluid battery with iron—dilute hydrochloric acid—ferrous chloride—platinum gave 1·07.

In all these cells the electro-motive force obtained by the solution of iron with ferric reaction was smaller than when a ferrous reaction occurred. The application of this fact in the explanation of the electro-motive force of magnetization is very manifest. When the *poles* of an electrode within the magnetic field are exposed to action, the gathering of the salts of iron around the exposed surface tends to bring about a change from *ferric* to *ferrous* reaction and to *increase* the electro-motive force. A corresponding *decrease* follows when a neutral surface is exposed within the field. The extent to which the electro-motive force of a cell in which a ferric reaction is taking place may be reduced by briskly stirring the solution and exposing the surface of the iron to the fresh acid, thus doing mechanically what is done magnetically when the reaction occurs, at a neutral surface, within the field, was shown by the following experiment. A one-fluid cell, consisting of iron and platinum in nitric acid diluted with four parts of water, had an electro-motive force of 1·07 volts. Stirring reduced it to ·95 volts. When left undisturbed it immediately regained its former intensity.

The electro-motive force developed between the poles of one iron electrode placed within the magnetic field and the neutral parts of a similar electrode in the same cell, will also exist between the poles and intermediate portions of a single piece of iron. Consequently there will always be local action between different portions of the surface of iron exposed to chemical action within the field, the currents passing through the liquid from the regions nearest the induced poles.

It is doubtless to this local voltaic action, which has its source in the electro-motive force of magnetization, that the various phenomena, described in our papers on *the chemical behavior of iron in the magnetic field*,* and on *the destruction of the passivity of iron by magnetization*,† are to be ascribed.

* This Journal, vol. xxxi, p. 272. † Ibid., vol. xxxiv, p. 419, Dec., 1887.

ART. XXV.—*Notes on certain rare Copper Minerals from Utah;* by W. F. HILLEBRAND and H. S. WASHINGTON.

[Read before the Colorado Scientific Society, Jan. 2d, 1888.]

SOME time since analyses and partial descriptions of several rare copper minerals, from the American Eagle Mine, Tintic District, Utah, were published* by one of us. These minerals had been found by Mr. Richard Pearce in ore shipments from that mine to the Boston & Colorado Smelting Works, near Denver, Colorado. Later, in shipments from the neighboring Mammoth mine, in the same district, Mr. Pearce discovered a second series of minerals of similar character, most of the species, however, being distinct from those of the former occurrence. In recent papers† he has given the results of his examinations and enumerated the following species: enargite, olivenite, conichalcite, clinoclasite, brochantite, pharmacosiderite, tyrolite(?), erinite, chalcophyllite, malachite, azurite, and one or two others of doubtful identity, of most of which "enargite is the mother mineral."

In order that this interesting series, in part new to America, might receive fuller study than he was able to devote to it, Mr. Pearce with the assistance of Mr. Whitman Cross kindly selected a set of specimens for examination in the laboratory of the U. S. Geological Survey at Washington. The chemical work of this paper was there carried out by one ‡ of us, while the crystallographical and optical study was undertaken by the other § at New Haven under the guidance of Prof. E. S. Dana. The results of our work, both chemical and physical, failed to meet all the hopes induced by a first view of the material at disposal, although this was the best that could be found. They are of sufficient interest, however, to make public, especially in view of the meager state of our knowledge regarding a majority of the species herein mentioned.

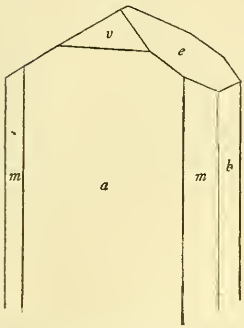
1. OLIVENITE.

This mineral occurs well crystallized; its habit is prismatic and tabular parallel to *a* (100, *i*-$\bar{i}$) and the crystals are, as usual, very simple as shown in the figure. The planes *b* (010, *i*-$\breve{i}$) and *v* (101, *i*-$\bar{i}$) as a rule are either absent or very small. Measurements were made for the purpose of obtaining a more exact axial ratio than we have at present, the old values of Phillips dating back to 1823.

* Proc. Colorado Sci. Soc., i, 112, and Bull. U. S. Geol. Survey, No. 20, p. 83.
† Proc. Colorado Sci. Soc., ii, 134, 150.
‡ W. F. Hillebrand. § H. S. Washington.

Upon examination and measurement with a Fuess horizontal goniometer it was found that $e \wedge e'$ ($01\bar{1} \wedge 0\bar{1}1$) was the only angle sufficiently accurate for the purpose, a and m being a little rough and uneven. The angle mentioned furnished a good value for $\dot{c}$, but to obtain the value for $\breve{a}$, use had to be made of a specimen of olivenite from the American Eagle Mine (No. 5684 in the Yale University collection). This olivenite was acicular in habit, the prism m ($110, i$) predominating. From these crystals good measurements were obtained of $m \wedge m'''$ ($110 \wedge 1\bar{1}0$) and a satisfactory axial ratio deduced. The measured angles are as follows:

Fig. 1.



$$e \wedge e',\ 011 \wedge 0\bar{1}1 = 67°51'$$
$$m \wedge m''',\ 110 \wedge 1\bar{1}0 = 86°26'$$

From these angles we obtain the following axial ratio,—

$$\breve{a} : \bar{b} : c = 0{\cdot}93961 : 1 : 0{\cdot}672606$$

The measurements above differ considerably from the fundamental angles of Phillips, which are,

$$e \wedge e',\ 011 \wedge 0\bar{1}1 = 69°10' \text{ and } m \wedge m''',\ 110 \wedge 1\bar{1}0 = 87°30'$$

giving the axial ratio,

$$\breve{a} : b : \dot{c} = 0{\cdot}9573 : 1 : 0{\cdot}6894$$

Measurements were made with the view of determining whether the species is really orthorhombic or not. The following are the angles obtained—

$$a \wedge e,\ 100 \wedge 011 = 89°4',\ a' \wedge e,\ \bar{1}00 \wedge 011 = 89°59'$$
$$a \wedge e',\ 100 \wedge 0\bar{1}1 = 89°9',\ a' \wedge e',\ \bar{1}00 \wedge 0\bar{1}1 = 90°1'$$

It is seen that the front angles are in each case a trifle less than the rear angles, but not much reliance can be placed on these results, owing to the poor surface of both a (100) and a' ($\bar{1}00$).

Under the microscope the tabular crystals showed parallel extinction and a slight pleochroism, the vibrations $\parallel \dot{c}$ being pale olive green, while those $\parallel \bar{b}$ were of a brownish yellow, with the absorption $b > c$.

The mineral was not analyzed because of the small quantity available and because its identity was otherwise clearly established.

2. Erinite.

Erinite occurs as a dark green crystalline lining of cavities, associated with and generally upon enargite, azurite, barite, or clinoclasite. Crystals of olivenite are frequently scattered over its surface, which shows often a somewhat satiny sheen due to minute crystal facets. Hardness 4·5. Sp. gr. undetermined. Because of its intimate association with azurite and olivenite it was very difficult to obtain pure material for analysis. Sample I contained 3·90 per cent of insoluble matter, not included in the analysis. Sample II was composed of a small lot of vitreous crusts, the only ones of the kind observed, which had been collected before shipment of the specimens and were thought to be erinite by Mr. Pearce, whose partial analyses of material similar to sample I are added, for comparison, under III.

	I.	II.	III.	
	Hillebrand.		Pearce.	
			a.	*b.*
CuO	57·67*	57·51	56·56	57·43
ZnO	1·06	0·59	----	----
CaO	0·32	0·51	0·43	----
MgO	tr.	tr.	----	----
As_2O_5	33·53	31·91	32·07	32·54
P_2O_5	0·10	----	----	----
H_2O	7·22	9·15	6·86	7·67
Fe_2O_3	0·14	0·20	0·85	----
SO_3	----	----	tr.	----
	100·04	99·87	96·77	97·64

Analyses I and II, and presumably those of Pearce, show the composition of air-dried powder. Sample I lost 0·67 per cent H_2O over sulphuric acid and a total of 0·78 per cent at 100° C. At 280° C. the total loss was 1·14 per cent, leaving 6·08 per cent firmly combined. Sample II lost 2·06 per cent over sulphuric acid and a total of 3·22 per cent at 2·80° C., leaving 5·93 per cent firmly combined. The molecular ratios, including all the water, are:

	CuO (CaO, ZnO)		As_2O_5 (P_2O_5)		H_2O
I.	5·08	:	1·00	:	2·74
II.	5·34	:	1·00	:	3·66
III. (mean)	5·13	:	1·00	:	2·87

If the weakly combined water be excluded from both I and II the ratio is brought considerably nearer to that derived from Turner's approximative analysis,† i. e., 5 : 1 : 2.

It is uncertain whether Turner's sample was air-dried or heated to 100° C.

3. Tyrolite. (?)

Regarding the identity of this species some doubt exists, as the analytical results obtained do not agree with those given by

* Mean of 57·61 and 57·74.

† Edin. Journ. Sci., ix, 95, 1828. Phil. Mag., iv, 154, 1828.

von Kobell* and Church†. In general appearance it seems to resemble tyrolite. It occurs in thin scales on quartz, but more often in radiating scaly masses, somewhat like the pyrophyllite from Graves Mt., Ga. It has a bright apple-green color, sometimes with a tinge of blue; a somewhat pearly luster; a hardness of 2·5 (1·5–2 for tyrolite in the text books), and perfect cleavage. Under the microscope it showed little or no pleochroism and extinction parallel and perpendicular to the radial line. In convergent light the cleavage flake showed the ordinary biaxial figure with the dispersion $\rho > \upsilon$. Its double refraction is negative, the acute bisectrix being perpendicular to the cleavage face, and coinciding with the crystallographic $\dot{c}$. The obtuse bisectrix lies parallel to the radial direction of the crystal, but whether it corresponds with $\breve{a}$ or $\bar{b}$ cannot be determined. It was unfortunate that a crystallographic investigation was impossible, as our knowledge of tyrolite in this respect is of the most meager description.

On heating it flies into fine fragments, which by gentle tapping of the tube collect into spongy masses. The mineral melts in the flame of a Bunsen burner.

The Sp. grav. of sample I (containing 2·25 per cent of insoluble gangue) was 3·27 at 20½ C. From sample II, which was the purest and best crystallized to be found, 1·25 per cent of gangue has been deducted.

	I.			II.	III.
	a.	*b.*	Hillebrand. Mean.		Pearce.
CuO	45·20	45·23	45·22	46·38	42·60
ZnO	----	0·04	0·04	tr.	0·97 ($Fe_2O_3Al_2O_3$)
CaO	6·86	6·82	6·84	6·69	9·10
MgO	0·05	----	0·05	0·04	----
As_2O_5	28·84	28·73	28·78	26·22	27·87
P_2O_5	tr.	----	tr.	tr.	----
H_2O	17·26	----	17·26	17·57	16·23
SO_3	?	?	?	2·27	2·45
	98·21		98·19	99·17	99·22

SO_3 was unfortunately not tested for in I. It may however reasonably be assumed to be present in about the same amount as in II, and if it be considered to be present as gypsum ($CaSO_4$, $2H_2O$) the following molecular ratios are obtained.

	CuO (CaO)		As_2O_5		H_2O						
I.	5·00	:	0·94	:	6·80	or	11	:	2·07	:	14·96
II.	5·00	:	0·84	:	6·81	or	11	:	1·85	:	14·98
III.	5·00	:	0·90	:	6·29	or	11	:	1·98	:	13·84

It appears herefrom that the As_2O_5 is somewhat less and the H_2O much less than required to satisfy the formula $5CuO$, As_2O_5, $9H_2O$, derived from von Kobell's (l. c.) analysis on the

* Pogg. Ann., xviii, 253. † Journ. Chem. Soc., [2], xi, 108.

supposition that the $CaCO_3$ found by him and later by Frenzel* and Church (l. c.) is not an essential constituent of tyrolite.

It is improbable that more than a very small quantity, if any, chalcophyllite was mixed with the material analyzed under I and II, although both appeared on some of the specimens marked tyrolite received from Mr. Pearce, and are not always easy to distinguish. In any mixture of tyrolite and chalcophyllite the water found must exceed its percentage in the former mineral. This is here not the case, whence it is to be inferred either that the present mineral is not tyrolite or that the older analyses do not represent its true composition.

A large portion of the water is very loosely combined. Of that in analysis I, 4·69 per cent escaped at 100° C., the most of it over sulphuric acid; and in analysis II, 4·15 per cent was removed by sulphuric acid, and further 0·91 per cent escaped at 100° C., making a total of 5·06 per cent. These amounts subtracted from the total percentage found leave 12·57 and 12·51 per cent respectively, or about five molecules (assuming five molecules, (CuO(CaO)). At 280° C. the loss on sample II was 10·34 per cent, in which is presumably included the water of the gypsum supposed to be present, leaving three molecules firmly combined. Church (l. c) likewise noticed a great loss of water in vacuo and at 100° C., but assumed that it was hygroscopic water included between the plates of the mineral. The second of his analyses with data for calculating the percentage composition is as follows:

Substance	0·4585	CuO	50·06
H_2O in vacuo	0·024	As_2O_5	29·29
H_2O at 100°	0·011	H_2O	[8·73]
$CaCO_3$	0·0505	$CaCO_3$	11·92
CuO	0·212		
$Mg_2P_2O_7$	0·205		100·00

whence he deduces the formula 5CuO, As_2O_5, $4H_2O$. Assuming that $Mg_2P_2O_7$ is an error for $Mg_2As_2O_7$, or for As_2S_3, in which latter form it appears that arsenic was usually estimated by him in minerals of a similar character, it is impossible to deduce the above given percentage for As_2O_5. But considering the latter correct, and including the water lost in vacuo and at 100°, the composition is:

CuO	46·24
As_2O_5	27·05
H_2O	15·70
$CaCO_3$	11·01
	100·00

which furnishes the molecular ratio CuO : As_2O_5 : H_2O as 5·00 : 1·01 : 7·43, not greatly differing from those derived from analyses I and II above.

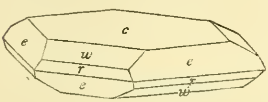
* Naumann-Zirkel, Elemente der Mineralogie, p. 540.

4. Chalcophyllite.

This mineral occurs in the form of small hexagonal plates arranged in rosettes, differing from the radial arrangement of the supposed tyrolite. It showed the same bright apple-green color, pearly luster, and perfect basal cleavage. An optical examination proved it to be uniaxial with negative double refraction.

These crystals showed several planes replacing the edges, and measurements were made of them as far as possible. The angles did not agree very closely owing to the imperfection of all the surfaces, but they were sufficiently exact to prove the presence of r ($10\bar{1}1$, R), e ($01\bar{1}2$, $-\frac{1}{2}R$), and two other rhombohedrons, new to the species, having the symbols w ($10\bar{1}6$, $-\frac{1}{6}R$), and d ($01\bar{1}3$, $-\frac{1}{3}R$). The figure shows the habit of the crystals, but with d absent, this plane being only observed in one instance. The very rough angles obtained are given below:

2.



	Observed.	Calculated.
$c \wedge r$, $0001 \wedge 10\bar{1}1$	=71° 27′	71° 16′
$c \wedge w$, $0001 \wedge 10\bar{1}6$	=26° 10′	26° 10′ 20″
$c \wedge e$, $0001 \wedge 01\bar{1}2$	=56° 51′	55° 51′ 10″
$c \wedge d$, $0001 \wedge 01\bar{1}3$	=41° 50′	44° 30′ 30″

The above observed angles are the means of several measurements which vary among themselves from one to three degrees. The fair agreement in the first two results therefore is merely accidental, and no value can be attached to these measurements, which are inserted because the measurements of this species are extremely few.

The mineral was not analyzed for want of sufficient material. On heating, it decrepitated as violently as the last mentioned mineral, and in the flame of the burner fused, though not with the same readiness.

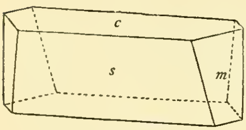
5. Clinoclasite.

The clinoclasite occurs in two distinct habits, one distinctly crystallized and the other in barrel shaped or globular forms. It is of a dark bluish green color, almost black by reflected light, bright green by transmitted light. Streak and powder bluish green. Specific gravity at 19° C., 4·38. (4·36 Pearce.) Hardness 2·5–3.

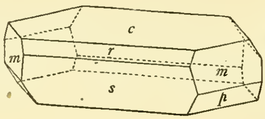
At first sight these crystals seemed to be very promising and likely to afford good fundamental measurements for the species. But on further examination they did not come up to our expectations, c (001, O) and s ($\bar{3}02$, $\frac{3}{2}$-i) being the only two planes giving even fairly good measurements. m (110, I), *r* (101, –1-*i*), *t* (ī11, 1) and *p* (ī13, ⅓), the other planes observed, were all dull or rounded, and only capable of giving angles accurate enough to identify the forms. Of the planes above, *t* and *p* are new to the species. Most of the crystals were apparently made up of two or more individuals in nearly parallel position but inclined slightly in the zone *c*/*b*. A measurement in one case gave the angle 4° 10′, but as it is not the result of twinning, this angle of course is not constant and only shows the very slight inclination of the individual crystals. A consequence of this method of growth will be described later.

The crystals were all simple; fig. 3, or a combination of that with *r*, being the most usual. Occasionally the lower half of *m*

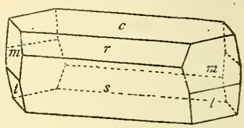
3.



4.



5.



is replaced by *t*, as shown in fig. 5, giving the angle 13° 20′ (calculated 13° 17′) for *m* ∧ *t*. The new plane *p* (ī13) was observed in several crystals and is shown in fig. 4. The following angles were obtained for it:

	Observed.	Calculated.
c ∧ *p*, 001 ∧ ī13	=61° 6′	61° 26′ 30″
s ∧ *p*, 3̄02 ∧ ī13	=50° 14′	51° 19′ 10″
p ∧ *p*′, ī13 ∧ īī3	=82°	85° 48′

The angles are merely approximate, but sufficient to establish the form. The crystals are for the most part elongated in the direction of the *b* axis, with a length of from 2 to 3^{mm}, and show easy cleavage parallel to *c*.

The other type of clinoclasite is interesting, as showing the consequence of the nearly parallel growth of the crystals mentioned above. In some of the specimens the crystals are grouped about the *b* axis, with *c* exposed. They are inclined a trifle in the zone *c*/*b* and also in the zone *a*/*b*, thus rounding off the group in two directions, but decidedly more in the latter zone, forming, with the elongation in the direction of *b*, distinctly barrel-shaped forms. Occasionally the curvature in the zone *c*/*b* is carried still further, producing globular forms. In all cases *c* forms the outer surface and the crystals are closely crowded together, producing a bright and coarsely rough surface.

The material analyzed consisted of the globular masses mentioned above, and was probably not as pure as the crystals and barrel-shaped forms. A trifling amount of insoluble matter (0·05 per cent) has been deducted. For comparison Mr. Pearce's partial analyses are also quoted.

	I. Hillebrand. *a.*	*b.*	Mean.	II. Pearce. *a.*	*b.*	Theoretical Composition.
CuO	62·34	62·54	62·44	61·68	61·22	62·65
ZnO	0·06	0·04	0·05	----	----	----
As_2O_5	29·59	29·60	29·59	29·36	28·85	30·25
P_2O_5	0·05	0·05*	0·05	----	----	----
H_2O	7·73	7·72	7·72	7·31	7·27	7·10
Fe_2O_3	0·12	0·12	0·12	----	----	----
SiO_2	0·06	0·06*	0·06	----	----	----
	99·95	100·13	100·03	98·35	97·34	100·00

These results reveal nothing worthy of remark except that the water, as in most earlier analyses, is found uniformly higher than that required by the formula 6CuO, As_2O_5, $3H_2O$, or $Cu_3[AsO_4]_2+3Cu[OH]_2$.

6. Mixite. (?)

On some specimens of ore, but apparently not in close association with the other minerals mentioned, was a mineral occurring in delicate tufts of silky needles of a whitish to pale geenish color as described by Mr. Pearce (l. c., p. 151, under the title "New Mineral"). It was impossible to procure enough of the needles free from an underlying non-crystallized greenish coating of cavities for a satisfactory analysis. A good deal of the latter was necessarily included in the sample tested, but qualitative tests showed that both needles and coatings contained the same constituents. It is hardly to be doubted that both have the same centesimal composition.

	I. Hillebrand. *a*	*b*	Mean.	II. Pearce.
CuO	43·89	43·88	43·89	50·50
ZnO	2·79	2·62	2·70	----
CaO	0·26	0·26	0·26	3·19
Bi_2O_3	11·14	11·22	11·18	----
As_2O_5	27·78	28·79	28·79†	27·50
P_2O_5	0·06	----	0·06	----
H_2O	11·04	11·04	11·04	12.55
SiO_2	0·36	0·48	0·42	----
Fe_2O_3	0·97	----	0·97	----
	98·29		99·31	93·74

That an error as to the CuO occurs in Pearce's analysis is beyond question. The above results agree fairly well with Schrauf's analysis of mixite,‡ which contained 43·21 CuO, 13·07 Bi_2O_3, 30·45 As_2O_5, and 11·07 H_2O, besides a little CaO and FeO, but the form of this mineral as given by Schrauf differs from that of the present one, and its color is given as

* Assumed the same as in *a*.
† The higher value was undoubtedly nearer the truth than the lower.
‡ Zeit. f. Kryst., iv, 277.

emerald to bluish green. Schrauf's number for the sp. grav (2·66) is unquestionably much too low. That of the material now analyzed was 3·79 at 23½° C. When treated with dilute nitric acid it becomes at once covered with the brilliant white coating of bismuth arseniate so characteristic of mixite. The latter mineral is stated to belong to the monoclinic or the triclinic system, while the observations of Mr. Whitman Cross would indicate that the present one can belong to neither of those systems. He says:* "The needles are very slender, with a length of more than 1^{mm} in some cases, by $0{\cdot}5^{mm}$. They are deeply striated vertically, and the crystal system could not be determined, although the extinction in polarized light makes reference to the tetragonal, the hexagonal, or the rhombic system necessary. The index of refraction is high. Pleochroism distinct, the colors observed being for the thicker crystals, *a* (and *b*) sea green, *c* sky blue."

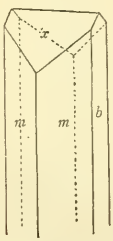
7. Pharmacosiderite.

No analyses were made for want of sufficient material.

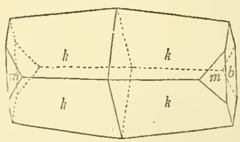
8. Brochantite.

This hydrous sulphate of copper occurs in two distinct types in the specimens examined. The first, or ordinary brochantite, is of a prismatic habit as is shown in fig 6. The crystals are dark green and transparent, but do not give good measurements, owing to the imperfection of the surface. The cleavage parallel to *b* (010, *i-ĭ*) is perfect. The measured angle of $m \wedge b$, $110 \wedge 010 = 51° 46'$, is only approximate, and differs con-

6.



7.



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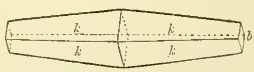


siderably from Miller, who gives 52° 5′, and Schrauf, who gives 52°.

* Proc. Colorado Sci. Soc., ii, 153.

The second type is like warringtonite from Cornwall, described by Maskelyne.* This variety was suspected by Mr. Pearce (loc. cit., p. 135). It is of a light green color and has a curved double wedge-shaped habit. The forms observed are shown in figs. 7 and 8. The crystals were poor for measuring, all the planes, with the exception of *b*, being curved to a great degree. The crystals were none of them more than 2 or 3^{mm} long, with the relative proportions of the figures. They were implanted by *b*; *m*, in fig. 7, was identified with certainty, the angle for $b \wedge m$ being 52° approximately. The plane lettered *k* was very much curved in all cases and its symbol, consequently, is not known with exactness. It corresponds in its angles very roughly, it is true, to the *k*, 12 . 1 . 4, of Schrauf; some of the angles obtained from these crystals and the corresponding ones of Schrauf's warringtonite being given here:

	Washington.	Schrauf.
$b \wedge k$, 010 ∧ 12 . 1 . 4 =	80°–82°	86° 43′
$m \wedge k$, 110 ∧ 12 . 1 . 4 =	45°	43° 11′
$k \wedge k'$, 12 . 1 . 4 : 12 . 1 . $\bar{4}$ =	75°–80°	

In most of the crystals of this type *b* was undulating parallel to $\dot{c}$.

Want of material forbade an analysis of this mineral, but blowpipe tests and the crystallographic examination establish its identity beyond doubt.

Art. XXVI.—*The Taconic System of Emmons, and the use of the name Taconic in Geologic nomenclature;* by Chas. D. Walcott, of the U. S. Geological Survey. With Plate III.

(Continued from page 242.)

Geology of the Taconic Area as known to Dr. Emmons.

(1). The strata referred to the "Taconic System;" (2). The stratigraphic position of the "Taconic System."

Dr. Emmons began the study of the Taconic area in Berkshire County, Mass., and from there extended his investigations, to the north, into Bennington County, Vt., and to the west, into Washington and Rensselaer counties, N. Y.† In 1842,‡

* Ch. News, x, 263, 1864. Phil. Mag., IV, xxix, 475.

† "My first business is to sketch a picture of the oldest of the sediments, as they are exhibited in a series which collectively constitute the Taconic System and as it is developed in the Taconic ranges of Berkshire and the adjacent country immediately north and south." (Am. Geol., pt. 2, p. 5, 1856).

‡ Geol. N. Y., pt. 2, p. 144, 1842.

he proposed the Taconic System, with the statement that it was composed of five different rocks, as follows:

"1. A coarse granular limestone of various colors which I have denominated *Stockbridge limestone*," etc.

"2. *Granular quartz* rock, generally fine-grained, in firm, tough, crystalline masses of a brown color, but sometimes white, granular and friable."

"3. *Slate*, which for distinction I have denominated *Magnesian slate*," etc.

"4. *Sparry limestone*, generally known as the sparry limerock."

"5. A slate, which I have named *Taconic Slate*, and which is found at the western base of the Taconic range. It lies adjacent to the Lorraine or Hudson River shales, some varieties of which it resembles," etc.

A section is given on page 145, fig. 46, to show that the "Taconic System" embraced all the strata between the gneiss on the east and the "shales of the Champlain group" on the west. The latter are represented as unconformably superjacent to the "Taconic slate."

His second memoir appeared in 1844* as a pamphlet, published in advance of vol. i, of the Agriculture of New York, in which, in 1847, the subject matter was reprinted without change. The changes from the stratigraphic scheme of 1842 consist in placing the granular quartz at the base of the system, with the Stockbridge limestone conformably resting upon it. A theoretical section† is given to show the relation of the various formations. The crystalline gneiss is represented with (1), the Granular Quartz or brown sandstone resting upon it; then, in turn (2), the Stockbridge limestone; (3), Magnesian slate; (4), Sparry limestone; (5), Roofing slate; (6), coarse brecciated bed; (7), Taconic slate, and (8), Black slate. On the following page, the section shown by fig. 7 represents these beds as all having a high and uniform dip to the eastward,‡ and with the Hudson river shales (9), unconformably superjacent to the Taconic slate (8).

When speaking of the lithologic characters of the system, Dr. Emmons says: "Taking one broad view of the whole system, it may be described as consisting of fine and coarse slates,

* Agric. N. Y., vol. i, pp. 45-112, 1847. The pamphlet of 1844 is very rare, as few copies were issued, and I shall make all references to its contents as reprinted in the volume of 1847, combining the dates as 1844–'47.

† Loc. cit., p. 62, fig. 6.

‡ This is corrected for the "Lower Taconic" rocks in the Section published in 1856 (Am. Geol., vol. i, pt. 2, p. 19), but all the strata of the "Upper Taconic" are considered superior to the Stockbridge limestone.

with subordinate beds of chert, fine and coarse limestone, and gray, brown and white sandstone.*

The geological map, prepared to accompany the memoir of 1844–'47, bears the date of 1844 and is a reprint of the Geological Map of New York, issued in 1842, with additional data on the geology east of the Hudson and Champlain valleys. The long, narrow range of the "Taconic System" is colored drab in its extension from Canada to Westchester County, N. Y. There is no reference to the "Taconic System" in the legend on the map, and the formations composing it are not distinguished by different colors, the reason for which is explained in the description of the map, published on page 361 of the Agriculture of New York, vol i, 1847.†

In 1856,‡ Dr. Emmons divided the "Taconic System" into an upper and a lower division: the upper division taking the formations 4 to 8 of the section of 1844–'47, and the lower division the formations 1 to 3; an arrangement that was repeated in 1859 (Manual of Geology), when the name "Magnesian slate" was replaced by that of "Talcose slate." In the diagram, fig. 10, the formations are represented in the order of succession given in 1856; and, on the map, the geographic area is given within which the typical localities of the various formations occur and also the extension of the latter to the north and south. This is the stratigraphic scheme of the "Taconic System" as arranged by its author from the results of his latest field observations.§

"*Granular Quartz*" (Terrane No. 1, of section on side of map and fig. 10).—Dr. Emmons calls the "Granular Quartz" the basal member of the "Taconic System," and, in his opinion, the base of the Paleozoic sediments on the North American continent. He describes its occurrence in Vermont and follows it, with interruptions, across Massachusetts into the northeastern part of Dutchess County, N. Y., and also south into Putnam and Westchester counties.‖ The stratigraphic

* Loc. cit., p. 61.

† The copy I have of this map was purchased by me from a second-hand book dealer, in 1876. I have reason to state that 3000 copies were originally delivered to the Secretary of State, of the State of New York, by the printers, and I think that copies can still be obtained from the said Secretary's office, despite the published statement that the edition was stolen or destroyed. (See letter of Dr. Emmons to Prof. Jules Marcou: Am. Acad. Arts and Sci., vol. xii, p. 188, 1885, also copied by Dr. Hunt, Am. Nat., vol. xxi, p. 122, foot note 3, 1887).

‡ The first part of this volume is dated 1855. The second part, containing the description of the "Taconic System," was issued in 1856.

§ I shall not comment on the so-called Taconic rocks, as identified by Dr. Emmons in Canada, Maine, Rhode Island, Michigan, and the southern Appalachian region. All those determinations rested on lithologic characters; and the strata referred by him to the "Taconic System" range from pre-Cambrian to the Niagara of the Silurian.

‖ Agric. N. Y., vol. i, p. 86, 1847.

position was determined by its relation to the crystalline rocks beneath and the superjacent strata, as no fossils were known by him from the formation. A talcose conglomerate that is treated as a subordinate member of the "Granular Quartz series" is described as occurring between the quartzite and Primary, in several localities.

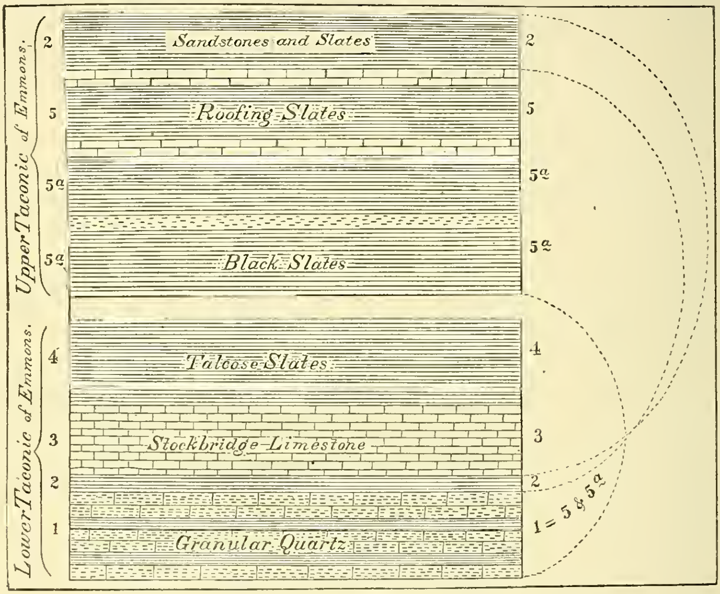


Fig. 10.—A tabular view of the strata as arranged by Dr. Emmons. The figures placed at the sides are equivalent to those used on the section on the side of the map. The dotted lines on the right side show the relation of the "Upper Taconic" to its geologic equivalent the "Granular Quartz."

Conformably resting on the "Granular Quartz," on the north side of Graylock Peak, at the Hopper, he found a bed of "talcose slate," 400 to 500 feet thick, which is represented in the table (fig. 10) by number 2. It appears to be the extension of a formation of more than 2,000 feet in thickness that occurs on the western side of the Taconic range. (See section on the map.)

Stockbridge limestone (Terr. No. 3 of Section and fig. 10).—Upon the slates of Terrane No. 2 a series of limestones and marbles are conformably superimposed that are called by Dr. Emmons the "Stockbridge limestone." This includes all the limestones, "good and bad, in connection with the bed known as marble." A good description of this terrane is given in the memoir of 1844–'47, and again in 1856. It is assigned a thickness of 500 feet, in Saddle Mountain, Mass.

Talcose Slates (Terr. No. 4 of Section and fig. 10).—These slates, which are called "Magnesian slates" in the reports of 1842–'44–'47, were given the name "Talcose slates" in 1856. A thickness of 2000 feet is assigned to them on the Taconic range and they are represented as conformably superimposed upon the Stockbridge limestone.

"*Upper Taconic.*"—In the scheme published in 1844–'47 the Magnesian slate is succeeded by the Sparry limestone, Roofing slate, a coarse brecciated bed, Taconic slate, and Black slate, and on p. 13, Am. Geol., pt. 2, 1856, this succession is recognized. On page 49 (loc. cit.), however, the entire scheme is changed; the Black slate is placed at the bottom of the series and then, in succession, siliceous slates: slates and sandstones, with thin-bedded blue limestones succeeded by thicker beds of sandstone; blue, green, purple and red roofing slates, coarse sandstone and shale passing into conglomerates and brecciated conglomerates. "The latter terminate the series eastward, and geographically near the Hoosick roofing slates. In the foregoing brief enumeration in the ascending order, the rocks follow each other in a conformable position, and beginning with the thin black slates, end in thick bedded sandstones and conglomerates," (loc. cit., p. 50).

In this re-definition of the "Upper Taconic," the Sparry limestone is no longer considered as belonging to it, and I have failed to find it mentioned subsequently as a distinct formation of the "Upper Taconic." The sparry limestone spoken of in describing the "Upper Taconic" section crossing Washington County, refers to the thin interbedded sparry limestones, in which I have found Olenellus and other Middle Cambrian fossils. The sparry limestones west of Hoosick Falls are referred to the Lower Silurian and removed entirely from the "Taconic System."

As is shown by Professor Dana, Dr. Emmons, in 1842, called the Sparry limestone the oldest of the Taconic limestones, and, in 1844, he placed it beneath the Taconic slate and above the Stockbridge limestone.* In 1856,† however, a section was published showing the Taconic Range by C and, at its western base, the limestone (2) is identified with the Stockbridge limestone (2), of B (Graylock Peak). What Dr. Emmons intended by this, and why he did not mention the change in the text, is not explained by him. Professor Dana called my attention to it by letter, and says that he accepts the evident meaning given by the section, which is, that Dr. Emmons identified the Sparry and Stockbridge limestones as one formation. With our present knowledge, this explanation is the only one open to us.

* This Journal, III, vol. xxxiii, pp. 415, 416, 1887.
† Am. Geol., vol. i, pt. 11, p. 19, fig. 2.

In 1859 the section is republished,* but the numbers are omitted from all the formations except those of Graylock Peak. Whether the omission was by design or accident is unknown.

In the black slates, at the summit of the "Taconic System" of 1844–'47 and at the base of the "Upper Taconic" of 1856, Dr. Asa Fitch found a few fossils which he gave to Dr. Emmons, who described two species in the memoir of 1844–'47, under the names of *Elliptocephala asaphoides* and *Atops trilineatus*. In 1859 Dr. Emmons compared these fossils with the Primordial fauna of Barrande, and established their position in the stratigraphic series on paleontologic evidence.† Their reference to a pre-Potsdam horizon, in 1844–'47 and 1856, was on the supposed stratigraphic position of the beds in which they occurred.

Résumé.—It is not necessary to repeat the full and accurate lithologic descriptions of the five terranes (fig. 10) mentioned by Dr. Emmons in 1844–'47 and 1856. They are grouped in fig. 10 to represent his view of their succession within the "Taconic System."

2. *Stratigraphic position of the "Taconic System."*—Dr. Emmons founded the "Taconic System" under the belief that it was composed of older formations than those of the New York Lower Silurian, the base of which was then the well-known Potsdam sandstone. In the memoir of 1842, he says: "But I have, at the head of this section, asserted that the slates and masses of the Taconic System are not related to, or connected with those of the Champlain group. By this I mean that they are not the same rocks in another condition." ‡ Again he says: "They are to be considered, however, as furnishing us with a knowledge of that state which immediately preceded the existence of organic beings." § After further field study his views became more positive in regard to the relation of the Taconic to the Lower Silurian rocks. He says: "I shall take the broad and distinct ground that the Taconic System occupies a position inferior to the Champlain division of the New York system, or the Lower division of the Silurian system of Mr. Murchison." ‖

"1. *Position.*—It rests unconformably upon primary schists, and passes beneath the New York system, the oldest and inferior members of the latter being superimposed unconformably upon the Taconic slate."¶ These views were sustained in his publications of 1856, 1859 and 1860.

On the section, accompanying the memoir of 1844–'47, pl. 18, Section I, the strata of the "Taconic System" all dip con-

* Manual of Geology, p. 85, fig. 60.
† Manual of Geology, p. 87, 1859.
‡ Geol. N. Y., pt. 2, p. 138, 1842.
§ Loc. cit., p. 164.
‖ Agric N. Y., vol. i, p. 55, 1847.
¶ Loc. cit., p. 108.

formably to the eastward. On the east they rest unconformably on the primary and, on the west, the Calciferous and Hudson terranes are represented as unconformably superjacent to the Taconic slates. Dr. Emmons says: "This section may be regarded as one of the best for exhibiting and proving the entire independence of the Taconic System from the Primary below and the New York system above." *

Two sections published in 1859 † may be taken as expressing his latest views of the relations of the different parts of the "Taconic System," in its typical area, with the exception of the "Upper Taconic" and the Lower Silurian (Ordovician), on the western side. In these sections, the "Lower Taconic" forms a synclinal with the "Granular Quartz" at the base and then the Stockbridge limestone and Talcose slates, respectively superjacent, the "Upper Taconic" being entirely disconnected from the latter. He held the view, from the first, that the eastward dip of the greater part of the strata of the "Taconic System" resulted from successive uplifts, "which, in consequence of the confined position of the rocks, have often produced local foldings and plications of the strata." ‡ His view of the extent and character of the uplifts was subsequently changed, as is shown by his representation of the position of the sparry limestone in 1842,§ 1844§ and 1855.

In the memoir of 1856 several sections were illustrated and described to show the unconformity between the Taconic slate and the Calciferous sandrock, and thus establish the inferior position of the "Taconic System" to the Lower Silurian (Ordovician) strata. These sections will be spoken of again, under the head of "Discussion and Comparison."

Dr. Emmons correlated the "Taconic System" with the Cambrian system of Sedgwick, in his first memoir of 1842, in the following words: ‖ "The Taconic rocks appear to be equivalent to the Lower Cambrian of Prof. Sedgwick, and are alone entitled to the consideration of belonging to this system, the upper portion [of the Cambrian—C. D. W.] being the lower part of the Silurian System." ¶

Again, in the memoir of 1844–'47, he says, when speaking of the proposed abandonment of the Cambrian System by English geologists: ". . . . were it not for a single fact, the

* Loc. cit., p. 366.

† Manual of Geology, p. 85, figs. 58 and 60.

‡ Geol. N. Y., pt. 2, p. 142, 1842.

§ See Professor Dana, this Journal, 3d Ser., vol. xxxiii, p. 415.

‖ Geol. N. Y., pt. 1, p. 163, 1842.

¶ Dr. T. S. Hunt (Am. Nat., vol. xxi, p. 124, 1887) interprets this passage to prove that Dr. Emmons in 1842 correlated the upper portion of the Taconic with the Lower Silurian of Murchison, but, as I read it, Dr. Emmons refers the Upper Cambrian, not his Taconic, to the Lower Silurian.

writer would freely acquiesce in the decision, so far as the British rocks are concerned. This fact is found in the existence of peculiar fossils on both sides of the Atlantic, which, so far as discoveries have been made, are confined to the slates of the Cambrian and Taconic systems; and now the great object of the writer is to show that the above question has not been settled right, or according to the facts; or, in other words that the Taconic rocks are not the Hudson River slates and shales in an altered state, or that all the Cambrian rocks are not Lower Silurian." *

In the following pages observations and deductions therefrom are given to support the above statement in relation to the "Taconic System," but nothing further is said of the fossils from the Cambrian system, and I am at a loss to know to what species the author referred. Reference is made to the Cambrian sections of Sedgwick, in 1856, to show that although the Cambrian slates are conformably beneath the Coniston limestone bearing Lower Silurian fossils, and hence may be referred to the Silurian, the Taconic rocks are unconformably beneath the equivalent Calciferous sandrock of the New York series and cannot be included with the Lower Silurian.†

Among the letters of Dr. Emmons, published by Prof. Jules Marcou,‡ is one, dated November 19, 1860, in which he says:§

". . . . I do not think him [referring to Barrande] right in maintaining that his Primordial group is a part or parcel of the Silurian: . . . . the Lower Silurian is strictly unconformable to every part of my Taconic series, and this series is . . . . separate and distinct from Silurian."

On the same page, in a letter dated November 20th, 1860, he says: "On reading his [Barrande's] papers, I found that, after all, his Primordial group is *only Lower Silurian*. I conceive we have exactly his *Primordial group* in the band of slates containing the *Paradoxides*. But this band is only a very narrow belt of beds."

In a letter dated December 28th, or 29th,‖ he says, when speaking of the announcement of the *Huronian* System by Logan: "I claimed that the *Huronian* was the *Taconic* System . . . Are you aware that most, if not all, of those beautiful graptolites Mr. Hall refers to the Hudson River group belong to the Taconic System?"

Again, in a letter dated January 23d, 1861:¶ "The acknowledgment of the *Primordial of Barrande in this country* is really one of the finest and best facts in geology, making a *coördination of American and European rocks so complete and harmonious*."

* Agric. N. Y., vol. i, p. 49, 1847.
† Am. Geol., vol. i, pt. 2, p. 90, 1856.
‡ Proc. Am. Acad. Arts and Sci., vol. xii, 1885.
§ Loc. cit., p. 186.
‖ Loc. cit., p. 188.
¶ Loc. cit., p. 190.

In commenting upon Professor Marcou's reference of the Potsdam sandstone to the "Taconic System," he objects to such references on stratigraphic grounds, as is shown by his letter of January 28th, 1861.

These later letters of Dr. Emmons prove that he considered the "Taconic System" to include the Huronian of Logan and the graptolite-bearing shales of the Hudson valley, from his letter of November 20th, 1860, he also included the Paradoxides beds of the "Upper Taconic" which equal the Primordial group of Barrande, which "is *only* Lower Silurian," and declared that "the Lower Silurian is strictly unconformable to every part of my Taconic series."

Despite the statements made in the preceding paragraph, I think we may say that Dr. Emmons regarded the original "Taconic System" as stratigraphically unconformable and subjacent to the Potsdam sandstone of the Lower Silurian of the New York section and believed it to rest unconformably upon the crystalline gneiss at its base and to form a great system of sedimentary rocks between the gneiss and Potsdam sandstone.

Comparison and Discussion.

Comparison.—A comparison of the geology of the Taconic area as known at the present time with the geology of the same area as known to Dr. Emmons develops several points of agreement. His lithologic descriptions are usually easily verified; and the general dip and arrangement of the strata within the "Taconic System" are the same with the exception of the relations of the strata referred to the "Lower" and "Upper Taconic."

The points of disagreement are: the identification of the geologic age of the formations of the "Lower Taconic;" the stratigraphic relations of the "Lower" and "Upper Taconic;" the stratigraphic relations of the "Upper Taconic" and the superjacent Silurian formations, and the value of the stratigraphic and paleontologic identifications of the age of the "Upper Taconic" slates.

1. Dr. Emmons considered the "Lower Taconic" to be composed of three non-fossiliferous pre-Silurian formations—"Granular quartz, Stockbridge limestone and Talcose slates" (see fig. 10) that were unconformably superjacent to the crystalline gneisses beneath and conformably subjacent to a great series of slates, forming the "Upper Taconic," that, in turn, were unconformably subjacent to the lowest of the Lower Silurian formations, the Potsdam sandstone.

We now know that the base of the "Taconic System," the "Granular Quartz," contains fossils that prove it to be the geologic equivalent of the greater portion of the "Upper Taconic;" also, that it is the arenaceous deposit that accumulated along the pre-Paleozoic shore while the siliceous, argillaceous and calcareous muds, now forming the "Upper Taconic," were being deposited to a greater depth off the immediate shore line. This entirely negatives the conclusion of Dr. Emmons, that the "Upper Taconic" slates were superjacent to the "Lower Taconic" rocks.

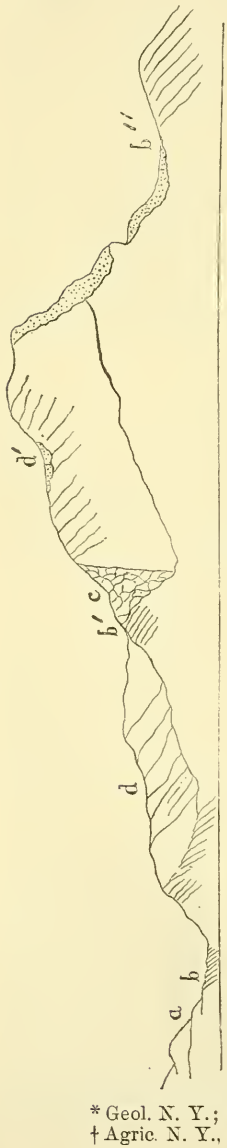


Fig. 11.

2. The second formation, the "Stockbridge limestone," has afforded fossils that prove it to be the equivalent of the Trenton, Chazy and Calciferous limestones of the Lower Silurian of the New York section, and it is not, as claimed by Dr. Emmons, a peculiar pre-Silurian deposit of limestone.

3. Conformably resting upon the "Stockbridge limestone" the "Talcose slates" (Terr. No. 4) occupy the stratigraphic position of the Hudson Terrane, in the New York section, and a species of graptolite, abundant in the Hudson Terrane, occurs in the "Talcose slates" near Hoosick, N. Y.

We have next to consider the relations of the "Upper Taconic" slates to the superjacent Silurian formations and the value of the stratigraphic and paleontologic identifications of the age of the "Upper Taconic."

In the first published section* of the "Taconic System," the "Shales of the Champlain Group" are represented as resting unconformably against, and on, the Taconic slates. This is repeated in the section published in 1844–47.† These two sections are largely theoretic, but, on page 89 (loc. cit.), Dr. Emmons gives a section of Bald Mountain, in the town of Greenwich, Washington County, N. Y., which is here reproduced (fig. 11).

This section is intended to show the unconformity between the Taconic slates, *b*, *b'*, *b''*, and the Calciferous formations, *d*, *c* and *d'*, it being assumed by Dr. Emmons that the slates, *b*, *b'* and *b''*,

* Geol. N. Y.; Rep. Second Geol. Dist., p. 145, fig. 46, 1842.
† Agric. N. Y., vol. i, p. 63, fig. 7, 1847.

were identical, and that d' was a mass of the Calciferous sandrock of the New York section, and, also, the mass represented by *c*. I began the investigation of this section, in 1887, by searching for fossils in the various formations, and then studied its stratigraphy. The result is given in the section represented by fig. 12. I found that the blue limestone, *c*, of figs. 11 and 12, extends beneath the shales and limestones capping the mountain and that it is interbedded in the shales and considerably broken and displaced on the south edge of the mountain, toward the fault line, as shown in fig. 12. *Leperditia fabulites* was found in it, on both the west and south side of the mountain. The true *Calciferous sandrock*, of the New York section, is shown at E, interbedded in the shales, S and X. In the limestones, *d*, forming the summit of the mountain, in fig. 11, I found *Lingulella cœlata*, *Linnarssonia Taconica*, *Obolella* sp. undet., *Hyolithellus micans*, *Microdiscus speciosus* and *Olenellus Thompsoni:* all of which are Middle Cambrian species and characteristic of the slates, b'', in fig. 11, east of the mountain. Dr. Emmons identified this mass of strata, d', with the Calciferous sandrock on lithologic characters, overlooking the fact that a similar rock might occur in his Taconic series. Two miles to the north, on the farm of D. Walker Reid, this belt of calciferous rock is over 600 feet thick, it contains a characteristic Middle Cambrian fossil, *Hyolithellus micans*, and is conformably subjacent and superjacent to shales and limestones, containing over fifteen characteristic species of Middle Cambrian fossils.

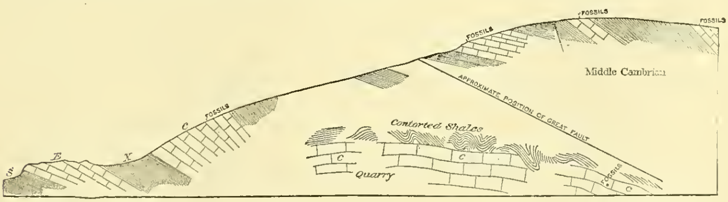


FIGURE 12.—Section of Bald Mountain from the south. The profile of the mountain and position of the Cambrian and Lower Silurian rocks are taken from a photograph. The "Upper Taconic"=Cambrian slate, sandrock and limestone are shown to the right of the fault, and *c*=Chazy limestone; *x*=dark shales, interbedded between *c* and the Calciferous sandrock, E; *s*=dark argillaceous shales beneath the Calciferous sandrock.

The section of Bald Mountain proves that the strata of the "Upper Taconic" are there pushed over on to the Chazy Terrane, and that the "Upper Taconic" is not unconformably subjacent to the latter or to the Calciferous sandrock.

To the north of Bald Mountain, about two miles, a somewhat similar mass of limestone to that of *c* is adjacent to the fault line and contains: *Orthis testudinaria*, *Strophodonta alternata*, Maclurea and other gasteropods, *Calymene senaria* and fragments of *Asaphus platycephalus*. Details of all the exposures observed where the "Upper Taconic" shales and the rocks of the Lower Silurian come in contact will be given in a report on the geology of Washington and Rensselaer counties.

Another section,* taken by Dr. Emmons just east of the village of Whitehall, is reproduced in fig. 13. The object of this is to show the presence of a mass of calcareous sandrock, *d'*, resting unconformably upon the Taconic slate, which Dr. Emmons identified as the Calciferous formation of the Lower Silurian. I studied the section in 1886, also in 1887, and found Cambrian fossils, represented by the heads of the Olenellus and fragments of Ptychoparia, imbedded in the sandrock, *d'*, and also found the strike and dip of the sandrock and shales to

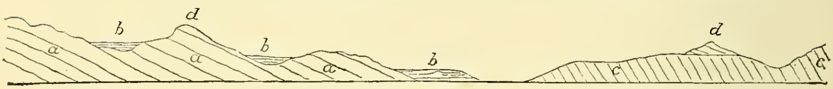


FIGURE 13, *a, a.*—Easterly prolongation of the mountain, which is surmounted by the Calciferous sandrock: *b b*, Tertiary clay; *c, c*, Taconic and black slate; *d, d*, Calciferous sandstone, unconformable to the Taconic slates, and dipping southeast at an angle of 40–45°. (After Emmons.)

be conformable. Another section on the same page† is entirely within the Champlain series on my map and west of the great fault line. It is 30 miles north of Bald Mountain and in the township of Whitehall. I found the Potsdam sandstone at its base, in the village of Whitehall, and then, superjacent to it, the Calciferous Terrane, with a band of dark argillaceous shale, lithologically similar to that of the Hudson Terrane, between it and the superjacent Chazy limestone. Resting on the Chazy limestone there is a second band of dark shales, 175 feet thick, that is subjacent to the Trenton limestone, and the latter is subjacent to the argillaceous and sandy shales of the Hudson Terrane. The strata of the entire section are conformable; and the limestones were identified by contained fossils. East of the shales of the Hudson Terrane, the existence of the great fault line is shown by the presence of strata, resting against, and on, the Hudson Terrane, that carry Middle Cambrian fossils. These interbedded shales, between the limestones, and, also, the Hudson shales, were considered, by Dr. Emmons, to be of Taconic age, and the limestone to lie unconformably above them.‡

* Agric. N. Y., vol i, p. 56. fig. 2, 1847. † Loc. cit., p. 56, fig. 3.

‡ One fact, not recognized by Dr. Emmons at Bald Mountain or along the great fault line, is that in many localities belts of dark argillaceous shale occur between the Calciferous, Chazy and Trenton limestones; that, in others, one or more of these formations is entirely a shale formation, and that the Potsdam Ter-

Another illustration of the supposed overlap of the Champlain upon the Taconic Terrane is given in the American Geology, pt. 2, p. 72, fig. 12. It is in the township of Greenbush, opposite Albany, N. Y , on Cantonment Hill. There a mass of the Trenton limestone is caught on the line of the great fault separating the Champlain and Cambrian strata, as at Bald Mountain and other places in Washington county, and, also, in Vermont. The strata of the Hudson and Trenton Terranes are broken and displaced, but there is no evidence that the Trenton was deposited upon the upturned edges of the Cambrian or "Upper Taconic" slate; and, on the line of the same fault, 20 miles to the south, in the township of Schodack, Mr. S. W. Ford discovered an unconformable contact between the dark-drab siliceous and micaceous shales of the Cambrian and the dark argillaceous shales of the Hudson Terrane.* Mr. Ford kindly took me to the locality which he has so well described, and I saw the "hade" of the fault, the slickensides on the opposing surfaces, and broke out graptolites from the Hudson shales beneath, and within six inches of, the fault line. A short distance south the limestones interbedded in the dark-drab shales gave us an abundance of characteristic Middle Cambrian fossils. For the details of this overthrust of the Cambrian upon the Hudson Terrane, see Mr. Ford's paper.

Dr. Emmons illustrates another section† that shows the same errors of observation as in the figure of the section at Cantonment Hill. Again, in fig. 22,‡ of the section at Snake Mountain, in Vermont, the error made at Bald Mountain is repeated, for it is now well known that the supposed overlying Calciferous (?) sandrock ("Red sandrock") is a stratum of the Cambrian pushed over on to the Lower Silurian Terrane,§ and not a Lower Silurian formation, unconformably superjacent to the "Upper Taconic" strata.

All the overlying limestones that he mentions as unconformably overlying the Taconic rocks, with the exceptions noted, where they contain Middle Cambrian fossils, are west of the

rane, off shore, was originally deposited either as a calcareous or argillaceous mud. It was owing to this oversight that he frequently identified the shales of the Champlain series as those of the Taconic. Another phenomena not understood by him, was the creeping or protruding of shales from beneath heavy masses of limestone, on account of the pressure squeezing the shales out and turning them up. In this way many of his non-conformities of dip appear to have been erroneously observed. In many instances he did not recognize the lithologic differences between the great mass of his Taconic slate and that of the Hudson Terrane. The black shale (marked "Taconic," in the Bald Mountain section, *b*, *b′*, fig. 11) is not similar to the shale containing the trilobites, east of the great fault, yet he identified them as lithologically the same formation.

* This Journal, vol. xxix, p. 16, 1885.

† Am. Geol., vol. i, pt. 2, p. 79, fig. 14, 1856.

‡ Loc. cit., p. 87.

§ This Journal, III, vol. xiii, p. 413, 1877.

fault line separating the Cambrian and Silurian Terranes; and the shales west of the fault belong to the Silurian, not to the "Upper Taconic" Terrane. The line of outcrop of the Cambrian Terrane is well marked, and I have endeavored to locate it accurately on the map. The great Appalachian fault separates the Potsdam and other Silurian rocks from the Cambrian; and nowhere on the western side of the Cambrian Terrane, to my knowledge, either in New York or Vermont, is there a deposition contact, either conformable or unconformable, between the rocks of the "Taconic System" and the Potsdam or other Silurian terranes. I have examined all the localities cited by Dr. Emmons and, later, by Professor Marcou and, in every case, the great fault separates the strata of the two systems. In fact, the Taconic usually rests on the Silurian strata as the result of the overthrust from the east; and, as will be shown in my report on Washington County, N. Y., the strongest proof of the presence of a fault line is shown by the mechanical disturbance of the Cambrian strata, on the eastern side of the fault.

That the Taconic slates are unconformably pre-Potsdam, is yet to be proven in any area known to Dr. Emmons, either in New York or Vermont. Where they pass beneath the shale representing the Potsdam horizon, beneath the Stockbridge limestone in the Taconic Range, they are conformably pre-Potsdam, but this fact was unknown to Dr. Emmons.*

Résumé.—As the result of these comparisons, we find that the "Lower Taconic" is essentially a repetition of the lower Silurian (Ordovician) section of the Champlain valley. It differs in lithologic details and in having a less abundant fauna in the typical Taconic area

The "Upper Taconic" is found to be conformably subjacent to the "Stockbridge" limestone of the "Lower Taconic," and to include the Potsdam horizon at or near its upper portion. Its base is not unconformably subjacent to the Lower Silurian Terrane, as maintained by Dr. Emmons and Professor Marcou.

The value of the paleontologic identification by Dr. Emmons of the "Upper Taconic" slate as a pre-Potsdam formation will now be considered.

* Professor Henry D. Rogers, in his address before the meeting of the Association of American Geologists and Naturalists, held at Washington, in May, 1844, said, when speaking of the unconformity claimed by Dr. Emmons between the Champlain and Taconic rocks: "I must take the liberty of expressing my disbelief of any such unconformity, and of observing that in the prolongation southwestward of this altered and plicated belt as far as the termination of the Blue Ridge in Georgia, a distance of 1000 miles, no interruption of the general conformity of strata has ever met the observation of my brother or myself."—(Amer. Jour. Sci., I, vol. xlvii, p. 152, 1844).

On page 63, of the Agriculture of New York (vol. i), under the heading "Black Slate," Dr. Emmons says: "I shall describe the rocks in the descending order: and by so doing, I commence with the mass of which there is some doubt whether it ought to be considered as a distinct rock or merely the upper portion of the Taconic slate; still I am disposed to regard it now as a separate and distinct rock, forming, so far as examinations have been made, the highest member of the Taconic system. Circumstances which have led to the separation of this from the rock referred to are of an interesting character; interesting particularly as being connected with the discovery of crustaceans where they were least expected."

Dr. Asa Fitch found the fossils from the "Black Slate," in 1843, and gave them to Dr. Emmons, who described two species of trilobites under the names of *Atops trilineatus* and *Elliptocephala asaphoides;* the first he thought to be an intermediate genus between the Calymene and Triarthrus; of the second, *Elliptocephala asaphoides*, he compared parts with similar parts of the *Asaphus tyrannus*, of the Lower Silurian of England.*

On page 68 of the same memoir, under the head of "Fossils peculiar to the Taconic Slate," he describes two species of Annelid trails: one from the Green Taconic slate, and the other from the sandstone in Washington County. He follows this with a description of nine species of what appeared to be trails from the slates of Waterville, Maine. It appears from this that Dr. Emmons considered these various trails to be "fossils peculiar to the Taconic slate," and that the trilobites which he described he did not consider, at that time, as typical of the "Taconic System," for he says (loc. cit., p. 64), in speaking of the "Black Slate:" "Assuming that its fossils are distinct from the fossils of this and other systems," etc.

In his conclusions, he says:† "The Nereites and other fossils of the Taconic slate are unknown in any of the members of the Champlain group. In addition to which, it is important to bear in mind the fact that in this group the Mollusca of the New York system are also wanting."

In 1856,‡ he referred the Black slates to a position above the Talcose slates of the "Lower Taconic," thus making them the base of the "Upper Taconic" series. On page 98, loc. cit., the argument is made that the "Taconic System" is peculiar in its contained organisms, and that he has the right to consider the absence of certain Silurian fossils as evidence that the Taconic was not of Silurian age. As has been shown in the first part of this paper, the limestones of the "Lower Ta-

* Loc. cit., pp. 64, 65.

† Loc. cit., p. 108.

‡ Am. Geol., pt. 2, p. 49, 1856.

conic" carry characteristic Lower Silurian (Ordovician) fossils, as, also, do the shales overlying the limestones.

In 1859 (Manual of Geology, p. 87), Dr. Emmons for the first time compared his *Elliptocephala asaphoides* with the genus Paradoxides, of Barrande's Primordial Zone, stating that the Taconic Paradoxides is also Silurian, and hence it is shown that the Primordial Zone, in Bohemia, is in coördination with the upper series of Taconic rocks. This statement is the first known to me upon which, either by paleontologic or stratigraphic evidence, Dr. Emmons could base his assertion that any portion of the "Taconic System" was of pre-Potsdam age.

The want of clearness in his views is well shown by the extract already quoted from his letter of Nov. 20, 1860, published by Prof. Marcou. "His [Barrande's] Primordial group is *only Lower Silurian.* I conceive we have exactly his *Primordial group* in the band of slates containing the Paradoxides."—What becomes of the stratigraphic break between the Lower Silurian and Taconic rocks if the "Black slates" are still retained in the "Taconic System," remains unexplained. If removed the fossils go into the Lower Silurian with it.

Dr. Emmons described several species of graptolites* from the "Taconic System," the majority of which are now known to also occur in the Hudson Terrane, in the valley of the Hudson. On the map, I have given the distribution of the Hudson Terrane in the Taconic area, as determined by stratigraphic and paleontologic evidence. It is in the central belt, carrying the red slates, that the graptolites occur which led Dr. Emmons to include, as a matter of necessity, if he put the red slates in the Taconic, the dark, argillaceous shales of Hudson Terrane at Troy, Albany, and Baker's Falls, in the Hudson Valley, for they contain the "beautiful graptolites"† referred to by him in 1860. At Albany, N. Y., however, the graptolite beds contain a characteristic Trenton-Hudson fauna.‡ This removes a considerable portion of the "Upper Taconic" strata from the "Taconic System."

* Am. Geol., vol. i, pt. 2, pp. 104–111, 1856.

† See letter to Prof. Jules Marcou; Proc. Am. Acad. Arts and Sci., vol. xii, p. 188, 1885.

‡ Mr. C. E. Beecher found three of the same species of graptolites (*Climacograptus bicornis*, *Dicranograptus ramosus* and *Diplograptus mucronatus*) as those found by me in the "Taconic Slates" of Washington and Rensselaer counties, associated with Brachiopoda, 5 species; Lamellibranchiata, 16 species; Pteropoda, 2 species; Gasteropoda, 3 species; Cephalopoda, 2 species; Annelid, 1 species; Crustacea, 1 species, and Trilobita, 2 species. For names of species, see Mr. Beecher's paper. (Thirty-sixth Ann. Rep. N. Y. State, Mus. Nat. Hist., p. 78, 1884).

Résumé of the Paleontologic Evidence.

(1.) The trilobites described in 1844–47, from the "Black Slate," were referred to the highest member of the "Taconic System," on stratigraphic evidence.

(2.) The same trilobites were referred to the lowest member of the "Upper Taconic," on stratigraphic evidence, in 1856.

(3.) In 1859 they were for the first time referred to a pre-Potsdam position by comparison with a fauna whose position had been stratigraphically determined in relation to the Silurian fauna.

(4.) The Nereites and other trails with the exception of the two from Washington County, N. Y., described as typical of the "Taconic System," have not yet been stratigraphically located in the geologic series.

(5.) The graptolites referred to the "Taconic System" form a portion of the fauna of the Hudson Terrane.

Discussion.—There is not much opportunity for a discussion of the geologic age and position of the "Lower Taconic" rocks. The thorough work of Professor Dana practically settled those points before I began my investigation. Dr. T. S. Hunt opposed Professor Dana's conclusions, basing his dissent on the result of his own studies of the geology of southeastern Pennsylvania and, on his acceptance of certain theoretic views in regard to the lithology of the "Lower Taconic" rocks. He argued that the "Lower Taconic" was the typical Taconic System and of Archean age,* and that Professor Dana's interpretation of the stratigraphy was not sufficient, without the aid of fossils, in the typical Taconic region, to establish the Lower Silurian age of the Stockbridge limestone or the crystalline marbles of the Lower Taconic. With the facts presented in this paper, however, I do not think that Dr. Hunt can claim support for his views without first substantiating them by researches in the Taconic area, a matter that he has apparently not given his attention,† heretofore.

*("Taconic Question in Geology;" Min. Physiology and Physiography, p. 582, paragraph 92, 1886). "92. Considering the pre-Cambrian age of the Lower Taconic to be established, as well as its distinctness alike from the older crystalline rocks below and from the Cambrian series above, to which Emmons had given the name of Upper Taconic—it was proposed by the writer, in 1878, to restrict the term Taconic—for which the alternative name of Taconian was then suggested,—to the Lower Taconic of Emmons." For other views held by Dr. Hunt, see Am. Jour. Sci., 3d ser., vol. xxxiii, pp. 417, 418, 1887.

†Some of Dr. Hunt's errors consist: 1. In relying upon a lithologic theory based upon observations made far distant from the Taconic area 2. His acceptance of Dr. Emmons's theory of the stratigraphic position of the "Lower Taconic" strata without personal investigation when it was well known that *all* of Dr. Emmons's contemporary geologists opposed the "Taconic" theory. 3. His assuming that it was largely personal opposition to Dr. Emmons that led all geologists who investigated the Taconic area to decide against the "Taconic" theory. 4. His ignoring all stratigraphic and paleontologic evidence published by Professor

Professor Dana was in accord with the opinion of Professors W. B. and H. D. Rogers, Edward and C. H. Hitchcock, W. W. Mather and James Hall, as well as with the results of his own field studies, when he called the "Granular Quartz" Potsdam, the "Stockbridge limestones, Lower Silurian (Calciferous-Chazy-Trenton) and the overlying "Talcose" shales the Hudson River formation. He held the opinion that the "Lower Taconic" was the typical "Taconic System," as first defined in 1842, but as that was proven to be Lower Silurian in age the "Taconic System" could not longer be recognized. In opposition to this Professors Marcou and Winchell argue that if the "Lower Taconic" was of Lower Silurian age the "Upper Taconic" contains Primordial fossils and is, therefore, equivalent to the Cambrian; and, as the discovery of fossils in the "Upper Taconic" was made before typical Primordial fossils were published from Sedgwick's Cambrian System, the name Taconic had priority over that of Cambrian and should be used in place of it to designate the strata containing the First or Primordial fauna of Barrande.

I was influenced by the statement made by Dr. Emmons that the slates of the "Upper Taconic" were unconformably beneath Lower Silurian strata, and, also, by the views of Professors Dana and Marcou when, in 1885, I wrote my observations, "On the Use of the Name Taconic," in the introduction to Bulletin 30, of the U. S. Geological Survey. I was satisfied from the evidence presented by Professor Dana, that the limestones of the "Lower Taconic" belonged to the Calciferous-Chazy-Trenton Terrane, and that the overlying schists were properly referred to the Hudson Terrane. The reference of the quartzite beneath the limestone to the Potsdam horizon, also appeared to be consistent with the data known to him. I was but partially convinced, however, from the evidence presented by Dr. Emmons and Professor Marcou that the "Upper Taconic" slates were stratigraphically pre-Potsdam, or that there was a valid claim for the substitution of the name Taconic for that of Cambrian.

Professor Jules Marcou, although a persistent advocate for the use of the name Taconic, did not go to the typical Taconic area to study the "Taconic System," but studied the extension of the "Upper Taconic" slate and shales in northern Vermont, and identified the "Upper Taconic" as the true "Taconic System." I have carefully examined the localities where he describes the occurrence of a non-conformity between the Georgia slates and the superjacent so-called Potsdam sandstone and at none of them

Dana and others within the past fifteen years on the ground that the writers were putting forth the "old metamorphic hypothesis" of Mather, Rogers, etc. (See Am. Nat., vol. xxi, pp. 114–320, 1887).

could I find a trace of the Potsdam sandstone. The sandstone referred to the Potsdam is of Middle Cambrian age and, at Parker's farm contains two of the same species of fossils that occur in the slates conformably subjacent to the sandstone. The only non-conformity found is formed by the overthrust of the Georgia or Cambrian strata upon the Lower Silurian Terrane, just as at Bald Mountain in Washington County, N. Y., Snake Mountain in Vermont and all along the line of the great fault, wherever outcrops of the two systems occur.

His extension* of the "Taconic System" to include the Potsdam sandstone is in opposition to all of Dr. Emmons's views of the relations of the Taconic and Potsdam strata, as Dr. Emmons founded the "Taconic System" largely on the belief that a great stratigraphic break existed between the Potsdam and Taconic, and that the fauna of the Taconic was unlike that of the "Champlain group," of which the Potsdam formed the base.

Dr. Emmons's errors are nearly all traceable to his trust in the lithologic characters of the various formations within the Taconic area. He established the "Taconic System" in 1842, on the differences in the lithologic characters of the Taconic rocks and those of the New York 'Lower Silurian.' The unconformity between the "Taconic System" and "Champlain" series, announced in 1844–'47, was primarily based on the similarity of the lithologic characters of the Calciferous sandrock of the Lower Silurian and the calciferous sandrock of what we now know to be, from its contained fossils, a part of his "Upper Taconic" series. Again, when the latter (calciferous sandrock of the Cambrian) was pushed over on to the dark shales of the 'Lower Silurian,' on the line of the great fault, he identified the latter shales with the "Upper Taconic" shales, and thus obtained an unconformity, as at Bald Mountain, between the Lower Silurian and Taconic strata. He failed to recognize the fact, shown along an outcrop of a hundred miles or more, that the Potsdam and, frequently, the Calciferous Terranes were represented in the geologic sections by a shale undistinguishable from the shale of the Hudson Terrane; also, that the same conditions occur in the Champlain valley, in the towns of Fort Ann, Kingsbury, and Hartford, Washington County, N. Y., and that, in several localities, the Trenton limestone is replaced by shale. This explains much of the confusion in his stratigraphy and, also, in that of Professor Jules Marcou, in northern Vermont, who was misled in the same manner. The shales containing the Primordial fauna are usually lithologically dissimilar from the dark argillaceous shales of the Lower Silurian,

* Proc. Bost. Soc. Nat. Hist., vol vii, p. 371, 381, 1860.

but, as Dr. Emmons included the dark graptolitic-bearing shales of the Hudson Terrane, within the Taconic area, in the "Upper Taconic," he necessarily compared and identified the black shales of the Lower Silurian with the "Black Slate" of the "Upper Taconic." He could scarcely do otherwise, when the stratigraphy along the western side of the "Taconic System" supported his theory, if such an identification of the shale was made.

The fact that the Potsdam sandstone, as a lithologic formation, is a local deposit in the immediate vicinity of the Adirondack mountains and that the sediments being deposited at the other localities at the same time, embedding similar organic remains, were argillaceous, siliceous and calcareous muds, does not seem to have impressed him, although he devotes many pages of his various memoirs to the description and discussion of the lithology of the Taconic and Lower Silurian rocks.

Dr. Emmons was not a collector of fossils, or he would have found them in nearly all the formations within the Taconic area; and I think that no student conversant with the faunas of the Lower Silurian and Cambrian terranes will long hesitate in concluding that he did not have sufficient critical knowledge of the faunas to which the fossils belonged that he did obtain, to identify the strata from which they came on paleontologic evidence otherwise he could not have so confused them.* When Dr. Fitch gave him the fossils that he had found in the "Black Slate," two miles north of Bald Mountain, in 1843, he at once referred them to a pre-Potsdam horizon, on *stratigraphic* evidence, without making any comparisons with a fauna which he knew to be pre-Potsdam at some other locality. In fact, no such data were at his command at that time, and the reference of the fossils to a pre-Potsdam horizon was based entirely upon the fact that they were in strata which he considered to be situated unconformably beneath the Potsdam sandstone or, in its absence, the Calciferous sandrock.

I wish to mention here that, in 1847, Dr. Emmons did not consider the two species of trilobites as characteristic of the true Taconic slate, but of the overlying "Black Slate," which he considered to be pre-Potsdam, from the evidence of the Bald Mountain section. I also call attention, again, to the fact that there was no valid stratigraphic evidence of the pre-Potsdam age of the "Black Slate;" moreover, as I have shown, the "Black Slate" is the lowest member of the "Taconic System" and not the highest, as stated by him, in 1847, or next above

* It is not practicable for me, owing to want of space, to give a full analysis of the paleontologic work done by Dr. Emmons in connection with his argument for the Taconic system. This will appear in my report on the geology of Washington County, N. Y.

the "Lower Taconic," as stated in the scheme of 1856. (See fig. 10.)

The comparisons made by Dr. Emmons between the fossils of the "Black Slate" and the Primordial fauna of Barrande, in 1859, came too late to anticipate the identification of the Primordial fauna in the Cambrian of Sedgwick, for the Cambrian System, as used by me, was correctly identified, paleontologically, by M. Barrande, in 1851.*

As I have repeatedly stated, Dr. Emmons assigned the two species of fossils described by him from the "Upper Taconic" slates to a pre-Potsdam horizon, on stratigraphic evidence that, on investigation, proves to have been based on errors of field observation. Such being the case, there was no proof of the position of the fauna, as he had no means for comparison with a similar fauna that had been stratigraphically located elsewhere in the geologic series. It was a *fortunate happening* that the "Upper Taconic" fossils proved to be of pre-Potsdam age, and not a scientific induction based on accurate observations or comparisons.

M. Barrande visited England in 1851 and determined the age of the Primordial fauna found in the typical Cambrian area of Wales before he knew of the existence of the vestige of the Primordial fauna published by Dr. Emmons. Subsequently, upon the evidence of Dr. Emmons's published stratigraphic sections, showing that he, Dr. Emmons, knew the fossils to be stratigraphically pre-Potsdam, M. Barrande was misled into crediting him with a discovery (in 1859) that was based on errors of field observation, and I did the same thing in the introduction to Bulletin 30, U. S. Geological Survey, in 1885.

* January 20th, 1851, M. J. Barrande read a paper before the Geological Society of France, upon the "Silurian Terrain of England." He presented a sketch of a section from Wales showing the Archean and, resting upon it, the stages corresponding to the stages C and D, of the Bohemian section, or the strata of the First or Primordial fauna and the Second or Lower Silurian fauna. Above the Lower Silurian the Upper Silurian is shown as resting unconformably upon the latter. In this paper the Lower Cambrian of Sedgwick is identified by organic remains, through comparison with the established succession of fossils in the Bohemian Basin. (Bull. Soc. Géol. de France, t. viii, pp. 207-212, 1851).

[To be continued.]

ART. XXVII.—*Three Formations of the Middle Atlantic Slope;* by W. J. McGEE.

(Continued from page 143.)

THE APPOMATTOX FORMATION.

Character and Distribution.—Near the summits of the bluffs overlooking the Rappahannock river from the southward a mile or two west of Fredericksburg, a distinctive, stratified, orange-colored sandy clay is found reposing upon Potomac sandstone, from which it is readily distinguishable by its greater homogeneity, the more complete intermingling of its arenaceous and argillaceous materials, its more regular stratification, and its more uniform and predominantly orange color. It is as readily distinguishable from the Columbia deposits, on the other hand, by its vertical homogeneity, its comparatively regular stratification, its distinctive color, and its greater range of altitude—extending as it does from tide-level to the highest eminences of the Piedmont escarpment between the Rappahannock and the Roanoke. At Fredericksburg the deposit is commonly thin and confined to limited isolated areas, especially at the higher levels, and it appears at but a single locality (Potomac creek) north of the immediate valley of the Rappahannock; but it rapidly increases in thickness and continuity to the southward. About the confluence of the Ni, Po, and Ta rivers it forms the surface over a meridional zone fully 10 miles wide; it is well exposed in the bluffs of the Taponi, along which it reposes upon the fossiliferous Eocene; and in the bluffs of the Mattaponi and the Anna rivers, as well as over the intervening divides, it is the prevalent surface formation, maintaining the characteristics exhibited at Fredericksburg save that it is frequently gravelly. In the vicinity of Richmond it is occasionally exposed toward the summits of the river bluffs, but is there less conspicuous than the subjacent Miocene, Eocene and Potomac deposits; while still further southward it continues to thicken and expand.

The distinctive orange-colored sands and clays of the formation are typically exposed on and near the Appomattox river from its mouth to some miles west of Petersburg. A mile below Petersburg they are found at tide-level in the river banks; in the eastern part of the city they appear overlying the fossiliferous Miocene beds mid-height of the bluffs; and at the "Crater" a mile and a half east, in the railway cuttings in the southwestern part, and on the upland two miles west of the city, they occupy the highest eminences. The zone of outcrop here is at least 30 or 40 miles wide. As at Fredericksburg, the deposit is a regularly but obscurely stratified orange-colored clay or sand, sometimes interbedded with gravel or interspersed with pebbles. Perhaps the best exposure is at the "Crater" (a pit formed by the explosion of 8,000 pounds of powder in a mine carried by Federal engineers beneath a Confederate fort, July 13, 1864). Here the principal material is a dense, tenacious clay, orange, gray, pink, reddish, and mottled in color, plastic yet firm when wet, and so hard and tough when dry that medalions stamped from it as souvenirs are as durable as rock—indeed the well known strategetic measure to which the "Crater" is due was rendered successful by the firmness and tenacity of the clay through which the entire mine was excavated save where it barely touched the subjacent fossiliferous glauconitic sands of the Miocene. At Butterfield's bridge in the southwestern part of Petersburg the railway cutting exposes some 20 feet of plastic clay (like that found at the "Crater"), pebbly and sandy clay, and cross-laminated clayey sand, all predominantly orange-colored, in alternating beds; and it is noteworthy that here, as at some other points, flakes and lines of white plastic clay similar to those of the Potomac arkose are occasionally included in the formation.

The formation continues to thicken and expand south of the Appomattox river, until it forms the surface everywhere in the vicinity of the fall-line save where it is cut away by erosion or concealed beneath the Columbia deposits. Typical exposures occur along the Atlantic Coast Line railway at several points, notably on the Roanoke opposite Weldon, N. C., where a few pebbly bands are intercalated within the regularly stratified orange-colored clays and sands.

In brief the inland margin of the Appomattox formation, as exposed north of Roanoke river, is a moderately regularly stratified sand or clay with occasional intercalations of fine gravel, generally of pronounced orange hue, and without fossils; it reaches a thickness of probably 50 to 100 feet and forms the predominant surface formation over a zone 40 or 50 miles wide on the Roanoke, but attenuates and narrows northward, finally disappearing at Potomac creek, 4 or 5 miles north of Fredericksburg; and although it appears to thicken seaward it soon disappears beneath tide level and newer deposits.

Stratigraphic Relations.—At Fredericksburg the formation reposes, sometimes unconformably and again without visible unconformity, upon the lower member of the Potomac, and like relations are frequently exhibited in the vicinity of Richmond and Petersburg; in the bluffs of the Taponi generally, and of the Pamunkey two or three miles north of Hanover Court House, it rests unconformably upon fossiliferous Eocene beds; at the "Crater" and at a number of other localities in the vicinity of Petersburg it rests without visible unconformity upon fossiliferous Miocene beds; in the western part of Petersburg it lies directly upon the Piedmont crystallines; two miles northeast of Bellfield it cannot be clearly demarked from the fossiliferous Miocene; and at Weldon it rests upon deeply ravined crystalline rocks save where inconspicuous remnants of Potomac arkose intervene. It therefore reposes upon a foundation made up alike of Piedmont crystallines, Potomac deposits, Eocene clays and greensands, and Miocene beds, all of which, with the possible exception of the last, were deeply degraded before its deposition.

The formation is overlain only by the alluvium of small streams, æolian sands, etc., on the broad plains between Petersburg and Weldon, by occasional accumulations of wave-washed debris derived from its own mass in the extensive Quaternary terraces prevailing in its area, and by the characteristic clays, sands, and gravels of the Columbia formation in the vicinity of the larger streams.

Taxonomy.—Since the formation has yielded no fossils, its age and relations can only be determined by stratigraphy, degree of alteration of materials, depth of erosion, etc. It is manifestly newer than the fossiliferous Miocene upon which it rests, and older than the Columbia formation by which it is overlain; and its fresh aspect and comparatively slight erosion indicate that its place is much nearer the later than the earlier of these formations.

The Appomattox formation is stratigraphically continuous with an extensive series of clays and sands investigated in North Carolina by Kerr, and referred by him first to the Quaternary and subsequently to the Eocene. Since the rôle played by these deposits is increasingly important southward, and since they have been casually recognized at many points in the Southern Atlantic slope, it is probable that they will be found to reach considerable volume in South Carolina, Georgia, and Alabama; and although precise relations have not yet been ascertained, it is indicated not only by physical considerations but by Fontaine's recent studies in Virginia and Alabama that at least a part of the Orange Sand of Hilgard and other southern geologists is equivalent to the Appomattox formation of the north rather than the Columbia, which is not known to extend much farther southward than North Carolina. (It should be noted that a part of the deposits designated "Orange Sand" by different geologists consist of re-arranged residuary debris of the Tuscaloosa and perhaps other formations.)

Too little is yet known of the Appomattox formation to warrant minute interpretation of its history or correlation of its record either with those of other deposits of the Atlantic Slope or with the degradation records of the Piedmont and Appalachian hills.

[To be continued.]

ART. XXVIII.—*A Diorite Dike at Forest of Dean, Orange County, N. Y.;* by J. F. KEMP.

RECENT workings in the Forest of Dean magnetite mine, in Orange Co., N. Y., prove it to be intersected diagonally by a dike of diorite. This rock was referred to in the Report of the New Jersey Survey for 1886, p. 107, but not until the last summer was the writer able to take the dimensions underground. The dike, about six feet in width, intersects the mine workings in the western branch at an angle of 30°, runs in unbroken width sixty feet across, and disappears in the footwall. Microscopic examination of a series of sections along its length proves it to be a very typical diorite quite similar to those described by Hawes* from Compton Falls and by Harrington† from the neighborhood of Montreal. The rock is dark gray in color, very fine grained, the component crystals being too small to be distinguished macroscopically. The spec. gravity varies from 2·925 to 2·974.

Under the microscope it is found to consist of crystals of plagioclase, hornblende and magnetite, together with certain alteration products of the first two. The hornblende is of the ordinary brown type, generally in well developed crystals showing the prism and pinacoidal faces. It is of rather light brown color, not remarkably pleochroic $c = b > a$. The individual crystals vary from $0·1^{mm}$ to $0·3^{mm}$. In the more altered portions of the dike the hornblende is changed to a greenish mineral resembling chlorite, with threads and fernlike aggregates of secondary magnetite penetrating it. These thread-like aggregates are exceedingly minute, not over $\frac{1}{250}^{mm}$ in breadth, whereas the original magnetite is in isolated angular masses, seldom showing octahedral outlines, $\frac{1}{10}$–$\frac{1}{50}^{mm}$ in diameter. The magnetite is free from indications of titanium. The plagioclase is in rod-shaped crystals averaging $0·1^{mm}$ by $0·3^{mm}$ of irregular outline. Acicular inclusions probably apatite are not infrequent. The extreme smallness of the feldspar crystals made any attempts at separation with the heavy solutions unsuccessful. Calcite and quartz appear as secondary products, corroborating Rosenbusch's general statement in regard to the Lamprophyr group of the dike rocks.

Compared with slides of the Campton Falls dike, the feldspar and magnetite are noticeably more abundant, the hornblende less so, at the same time the crystals of the last named mineral are less elongated and smaller but much better developed. Compared with the Montreal dike much the same may

* This Journal, III, vol. xvii, p. 147. † Geol. Survey Canada, 1877–78, 439.

be said, as the latter resembles the Campton rock very strongly in structure. Specimens of each were kindly given me for comparison by Professor Hitchcock and Dr. Harrington.

The following analysis by the writer shows higher silica, than the two dikes above referred to, also more alumina and iron, but less lime. Allowing some of the lime to the horn blende, the feldspar appears to be within the oligoclase limits of the plagioclase series. A number of extinctions on $\infty P \breve{\infty}$ of from 7°–9° indicated the same.

SiO_2	48·19
Al_2O_3	16·79
Fe_2O_3	18·37
CaO	6·85
MgO	1·32
K_2O	1·11
Na_3O	5·59
Loss on ignition	2·31
	100·53
Soluble in HCl before fusion	23·5
Of this Fe_2O_3	18·0

All the iron determined as sesquioxide.

Noticing in the Report on Mining Industry, 10th Census, p. 118, Pl. XXVIII, a trap dike figured as cutting the Palmer Ore Bed near Lake Champlain, I procured specimens of the dike, but on microscopic examination they proved to be diabase.

Stray bowlders of rock similar to the Forest of Dean dike are to be seen not unfrequently in field work in the region, but no other definite locality is as yet known to the writer.

Geological Laboratory, Cornell University.

ART. XXIX.—*New Lecture Apparatus for demonstration of Reflection and Refraction;* by W. LECONTE STEVENS.

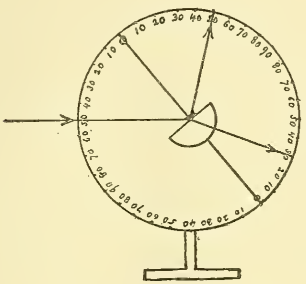
THE apparatus of which a brief description is here offered is so simple, and in every particular so much more convenient than any other designed for the same purpose, that the writer deems it worth bringing to the attention of his fellow-teachers in physics.

The refracting medium is a hemi-cylinder of crown glass, carefully polished, and mounted so as to turn on its axis horizontally. The radius is $2{\cdot}5^{cm}$, the length 5^{cm}. The axis passes through the center of a circle of white card-board, whose radius may be 20^{cm} or 30^{cm}. Each of its quadrants is graduated from

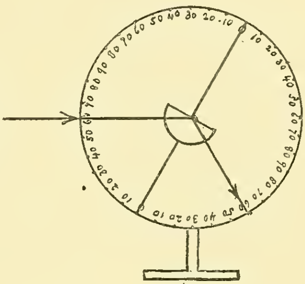
0° to 90°, as shown in the diagram, the diameter connecting the two zero points being perpendicular to the face of the hemi-cylinder. From a horizontal slit in front of the lantern a beam is sent through the middle of the glass and focussed on the zero-point at the further edge of the card-board, whose plane has been slightly inclined so that the path of the beam is sharply defined upon it. The incident, reflected, and transmitted beams are in the same line, the angle of incidence being zero.

The hemi-cylinder is now rotated through any desired angle, for example 50°, as shown in fig. 1. The card-board moves

1.



2.



with it. The room should be but slightly darkened, so that there may be no difficulty in reading the graduation on the circle. Part of the beam is reflected and part refracted. Both are plainly seen and the angles of reflection and refraction are measured. Varying the angle of incidence from 0° to 90°, one readily observes that the ratio of the reflected light to the refracted light decidedly increases. Turning still further, the beam from the lantern strikes normally on the curved surface and is totally reflected within the glass at its plane face (fig. 2). Rotating still further, the re-appearance of the refracted beam announces the critical angle, which is read upon the circle.

In the common form of apparatus where a beam is deflected by a mirror, then sent through smoky air and cloudy water, new adjustments are necessary for every variation of the angle of incidence, involving some trouble and loss of time. With the hemi-cylinder but one easy adjustment is needed for all. The higher refractive index of glass is an additional advantage, aside from the superior definition. The expense is scarcely more than that of having the hemi-cylinder made by a practical worker in glass. A small silvered mirror is substituted for the hemi-cylinder if the law of reflection alone is to be exhibited.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Spectrum of the Residual Glow.*—Crookes has examined the spectrum of the residual phosphorescent glow obtained when the rarer earths are illuminated by the electric spark in a modified form of Becquerel's phosphoroscope. The glow is observed through apertures in a revolving disk, twelve in number, symmetrically placed. On the axis of the disk is a brass cylinder, having twelve teeth at one end. An adjustable spring presses on the teeth, a second spring upon the smooth surface of the cylinder, these springs completing the battery circuit through the primary of an induction coil. By suitably adjusting the former, the spark may be made to take place at the instant when the substance under examination is visible through the aperture in the disk, or to precede it by a very short interval easily calculated. The relative length of the makes and breaks is adjusted by moving the spring to or from the bases of the teeth. Much lower vacua are necessary, since the residual gas has no phosphorescent spectrum. The phosphorescent bands in the spectrum of pure yttria do not appear at the same speed of rotation. The first to appear is the greenish-blue band $G\beta$, then the deep blue $G\alpha$, the citron $G\delta$ and the deep red $G\zeta$; the last at a duration of 0·00175 second. At 0·00125 second $G\delta$ and $G\beta$ are equally bright and $G\eta$ just visible; and at ·000875 second all the bands are seen of their usual brightness. The author has observed that on adding strontia to a mixture of yttria and samaria and on viewing it in the above phosphoroscope with the wheel rotating rapidly, the line $G\delta$ is completely suppressed and the spectrum is identical with that of Marignac's $Y\alpha$. Alumina, giving the crimson line has a very persistant residual glow. Antimony oxide mixed with lime in the proportion of five per cent phosphoresces white with a broad space in the yellow. In the phosphoroscope the glow is green and very strong, the red and orange being obliterated. Chromium oxide with lime in the same proportion, gives a pale red phosphorescence, the red and orange being cut off in the phosphoroscope. Diamonds glowing pale blue have the longest residual glow, those glowing yellow coming next; those phosphorescing red have no residual glow. Zinc sulphide (Sidot's hexagonal blende) phosphoresces brilliantly even in a very low vacuum, with a green light. As the exhaustion is increased the edges of the crystals become blue, the two colors finally being equally bright. In the phosphoroscope, however, the blue is visible only at a high speed while the green lasts for an hour or more. The curious fact is noted that the spark spectrum of old yttrium and of the higher and lower fractions obtained from it are perfectly identical, though the phosphorescent spectra and chemical properties of the three are markedly different; and the author

discusses his sub-molecule theory and his independent element theory in regard to them. On the latter theory the spark spectrum may belong to Gδ.—*Proc. Roy. Soc.*, xlii, 111; *J. Chem. Soc.*, li, 1066 (abstr.) Dec., 1887. G. F. B.

2. *On the presence of Chlorine in Oxygen prepared from Potassium chlorate.*—BELLAMY has observed that all of those substances which when mixed with potassium chlorate facilitate the evolution of oxygen give rise also to the production of chlorine, the greater amount being set free at the commencement of the decomposition. He also calls attention to the fact that all these substances which thus favor the decomposition of the chlorate are acidic in character, and by taking up oxygen form acid oxides or anhydrides; as for example the oxides of manganese, iron, cobalt and nickel. In some cases the activity is due to admixed acidic bodies, as colcothar, which contains generally basic sulphate. The peroxides give oxygen up and take it again alternately. In the formation, even transitorily, of chromates, permanganates, etc., chlorine or its compounds must be set free and the final residue of the operation must have an alkaline reaction. If, however, the chlorate is mixed with a basic oxide such as lime, magnesia or soda, no evolution of chlorine is observable; but neither is any acceleration of the decomposition of the chlorate produced. The author represents the decomposition in presence of manganese dioxide in three stages. (A) $KClO_3+MnO_2=KMnO_4+O+Cl$. (B) $(KMnO_4)_2=K_2MnO_4+MnO_2+O_2$. (C) $K_2MnO_4+MnO_2+KClO_3=(KMnO_4)_2+KCl+O$.—*Ber. Berl. Chem. Ges.*, xxi, (Ref.) 3, Jan., 1888. G. F. B.

3. *On the Interaction of zinc and Sulphuric acid.*—MUIR and ADIE have studied the interaction which takes place under various circumstances between zinc and sulphuric acid. Six different grades of zinc were used, and with acids varying in concentration from H_2SO_4 to $H_2SO_4\,(H_2O)_{100}$. About ten grams of zinc and 50^{cc} of the dilute acid were used in each experiment. The reactions were effected in small flasks each connected by means of a T tube first with a flask containing an ammoniacal solution of silver nitrate and then with another containing a solution of iodic acid mixed with a little starch paste. The experiments in many cases continued for long periods, sometimes three weeks, the flasks being heated when necessary in a zinc chloride bath. The results, which are given in tabular form, show the interaction to be one of great complexity. While the action is similar for commercial and for approximately pure zinc, the quantities of sulphur dioxide and hydrogen sulphide diminishing as the zinc becomes purer, pure hydrogen being almost the sole gaseous product when the acid is diluted with ten or twelve parts of water even at temperatures near the boiling point; yet it is observed that commercial zinc continued to give small quantities of hydrogen sulphide whatever the strength of the acid and whatever the temperature. When acid of the concentration $H_2SO_4(H_2O)_2$ acts on commercial zinc at 100° scarcely any sulphur dioxide or hydro-

gen sulphide is produced; but at 165° abundance of the latter gas is evolved, and torrents of it at 180°, with but little of the sulphur dioxide. Approximately pure zinc interacting with the same acid at 160° gives both gases in abundance. With regard to the appearance of sulphur, the authors are disposed to regard it neither as a product of the interaction of SO_2 and H_2S, nor as produced by the reducing action of the hydrogen upon the SO_2; but as rather due to the mutual action of hydrogen sulphide and hot concentrated sulphuric acid. In general it appears that the interaction between approximately pure zinc and acid is chiefly a direct chemical interaction and that the products of the reactions with the less pure zincs are largely due to the occurrence of secondary electrolytic changes.—*J. Chem. Soc.*, liii, 47–58, Jan., 1888. G. F. B.

4. ORGANIC ANALYSIS; *A Manual of the Descriptive and Analytical Chemistry of certain Carbon Compounds in common use.* By ALBERT B. PRESCOTT, Ph.D., M.D., Director of the Chemical Laboratory of the University of Michigan, etc. 8vo, pp. 533. New York, 1887 (D. Van Nostrand.)—This book appears to be a valuable addition to the literature of technical analysis. For the compounds of which it treats, it furnishes, first a systematic chemical description of these compounds, followed by the qualitative and quantitative methods to be pursued in their examination, together with tests for their purity. The titles are arranged alphabetically for convenience of reference. The references given are copious and reliable. Among the articles which seem to us especially valuable are those on the alkaloids, classified as the aconite, the cinchona, the cadaveric, the midriatic, the opium and the strychnos alkaloids; those on elementary analysis, on fats and oils, on coloring matters and on the tannins. Considerable care has evidently been exercised not only in selecting the titles so as to include substances likely to be offered for examination, but also in giving the results of the latest investigations. For clearness, completeness and accuracy, the book will add to the already excellent reputation of its author. It is provided with a full index and is printed and bound in a very satisfactory manner. G. F. B.

5. PRACTICAL PHYSICS *for Schools and the Junior Students of Colleges;* by BALFOUR STEWART and W. W. HALDANE GEE. Vol. I. Electricity and Magnetism. 16mo, pp. xviii, 221, London, 1888 (Macmillan & Co.)—This little book, though elementary, is one of the best of its kind in the language. The arrangement is excellent, the experiments well chosen, the descriptions and discussions clear, and the exercises admirably adapted to fix the text in the mind of the student. Morever the apparatus required is simple, much of it being constructed by the pupil himself. We commend the book to those teachers who are engaged in elementary physical laboratory instruction, as admirably suited to their needs. G. F. B.

6. *Spectrum of the oxyhydrogen flame.*—Professors G. D. Liveing and J. Dewar find that the spectrum of water extends with diminishing intensity, into the visible region on the one hand and far into the ultra-violet on the other. The latter portion they have photographed by means of a single calcite prism, using a long exposure. "The spectrum exhibits the appearance of a series of rhythmical groups more or less overlapping one another, and the arrangement of the lines in these groups is shown to follow, in many cases the law that the distances between the lines, as measured, in wave-lengths, are in arithmetical progression." Their researches apparently confirm the theoretical conclusions of Dr. Grünwald of Prague, for they discovered a number of lines which apparently occupy the positions which they should according to his hypothesis.—*Royal Society*, Feb. 2; *Nature*, Feb. 16, 1888, p. 383. J. T.

7. *Application of the Electrolysis of Copper to the Measurement of Electric Currents.*—In the process of standardizing Sir William Thomson's new electrical instruments, Mr. Gray has been led to examine the accuracy of the method by means of the deposition of copper, and concludes that the constant of an electric current instrument can be obtained with certainty, by this method, to one-twentieth of one per cent.—*Phil. Mag.*, March, 1888, p. 179. J. T.

8. *Influence of light upon electrical discharges.*—Hertz in a previous number of the *Annalen der Physik* having called attention to a remarkable influence of the ultra-violet rays upon electrical discharges, E. Wiedemann and H. Ebert repeated his researches and have confirmed his results. When a spark will no longer pass between the terminals of a Ruhmkorff coil, if a beam of ultra-violet light falls upon the electrodes the spark will traverse the interval between the electrodes. Wiedemann and Ebert show that the effect is also produced by the light of burning magnesium and that the effect is confined to the ultra-violet rays; red and green producing no effect. The effect is produced at the negative electrode and not at the positive. The authors studied the effect in various gases, and at different pressures. The phenomenon varied with the pressure and with the medium. The same number of the Annalen contains a paper by W. Hallwachs on the influence of light upon electrostatically charged bodies. He finds that the ultra-violet rays modify the charge and the insulating properties of bodies.—*Annalen der Physik und Chemie*, No. 2, 1888, pp. 241–264, 301–312. J. T.

9. *Wave-lengths of standard lines.*—In a long paper continued through two numbers of the Annalen der Physik, F. Kurlbaum discusses the various methods of measurement of wave-length, and gives the results of the most refined methods which his experience has led him to adopt. His measures of the wave-length of one of the components of the sodium line, D_1, compare as follows with those of previous observers :

D_1=589, 625, Müller, Kempf.
607, } Bell.
603, }
602, Peirce.
589, 590, Kurlbaum.
—*Annalen der Physik und Chemie*, No. 2,1888, pp. 381–412.

J. T.

II. Geology and Natural History.

1. *On the distribution of strain in the Earth's crust resulting from secular cooling, with special reference to the growth of continents and the formation of mountain chains;* by Charles Davison. With a Note by G. H. Darwin.—Starting from the results reached by Sir W. Thomson and independently by Prof. Darwin in regard to the rigidity of the earth, and from the conclusions of the former as to the secular cooling of the earth, Mr. Davison has gone forward and discussed the distribution of strain in a solid globe resulting from secular cooling with reference to the effect of this distribution on the great features of the earth's surface. His conclusions, as will be seen, throw much light upon what he terms "the beautiful contraction-theory of mountain evolution" to which the work of Thomson and Darwin leads up.

The author starts by supposing that the earth is bounded by a smooth, spherical surface and is made up of a great number of very thin concentric shells, each so thin that the loss of heat may be considered throughout as uniform. The first conclusions reached are:

1. "That the rate at which any shell parts with its heat increases to a certain depth below the earth's surface, where it is a maximum, after which it decreases toward the center, and the depth of the surface of greatest rate of cooling is continually increasing, and varies as the square root of the time that has elapsed since the consolidation of the globe." Also,

2. "Folding by lateral pressure takes place only to a certain depth below the earth's surface; at this depth it vanishes, and, passing through it downwards, folding gives place to stretching by lateral tension."

Accepting now, for the sake of simplicity, 174,240,000 years as the time that has elapsed since the consolidation of the earth, a period which lies well between the limits set by Sir W. Thomson and for which the depth at which the rate of cooling becomes practically insensible is 400 miles, the following conclusions are reached:

3. "(1) Folding by lateral pressure changes to stretching by lateral tension at a depth of about five miles. (2) Stretching by lateral tension, inappreciable below a depth of about 400 miles, increases from that depth toward the surface; it is greatest at a depth of 72 miles, that is, just below the surface of greatest rate of cooling; after this, it decreases, and vanishes at a depth of

about five miles. (3) Folding by lateral pressure commences at a depth of about five miles, and gradually increases, being greatest near the surface of the earth." Furthermore,

4. "Within certain limits, it is true that the depth of the unstrained surface increases as the square root of the time that has elapsed since the consolidation of the globe." Also,

5. "Folding by lateral pressure was effected most rapidly in the early epochs of the earth's history, and, since then, the total amount of rock folded in any given time decreases nearly in proportion as the square root of the time increases. The same law being approximately true of the total amount of rock stretched by lateral tension, it follows that the ratio of the amount of rock stretched to the amount folded in a given time is very nearly constant, but in reality slightly diminishing as the time increases."

While not claiming that great weight should be attached to the numerical results obtained, the author goes on to consider the effects of crust-stretching and folding on the evolution of the earth's surface features. Assuming that the formation of the great continental masses took place in the initial period of the earth's history, it follows that:

6. "Owing to the pressure of the continental wrinkles, the amount of stretching under them must have been very much less than under the great oceanic areas. Thenceforward, therefore, crust-stretching by lateral tension must have taken place chiefly beneath the ocean-basins, deepening them and intensifying their character. And, in leading to the continual subsidence of the ocean-bed, it is evidently a physical cause of the general permanence of oceanic areas; a cause, it is true, continually receding from the surface, and diminishing in intensity with the increase of time, but probably even now not quite ineffective.

"Again, the amount of crust-stretching by lateral tension being greatly in excess of the amount of crust-folding by lateral pressure due to secular cooling, it follows that folding beneath the ocean-bed will do little but diminish its rate of subsidence. The effects of folding in changing the form of the earth's surface features will therefore be most apparent in the continental areas, especially in those regions where the change of vertical pressure above the folded layers diminishes most rapidly, *i.e.*, near the coast-lines where the slope toward the ocean depths is greatest. It is perhaps worthy of remark that these are the districts where earthquake and volcanic action are now most prevalent. In the coast regions, moreover, the products of continental denudation are chiefly deposited, and the rock-folding due simply to secular cooling produces in vast masses of sediment still more crushing and folding. The direction of the folds will be perpendicular to the average slope of the surface above them, *i.e.*, they will generally be parallel to the coast-line. Hence the continents will grow by the formation of mountain chains along their borders.

"In a given time, the amount of rock-folding resulting from secular cooling was greatest in the first epochs of the earth's history, and diminished as the time increased. It does not necessarily follow that the early mountain ranges were the loftiest and most massive, but probably they were; and very possibly also, the displacement, by crushing and folding, of two neighboring portions of rock was greatest in early times. But, taking into consideration the whole surface of the globe, the process of mountain-making diminishes with the increase of the time, and so also does the rate of continental evolution.

"It cannot be said that the contraction theory on the hypothesis of solidity is entirely free from objections. Two very obvions ones have already been alluded to in the course of this paper, namely (1) The small calculated depth of the unstrained surface, especially in early geological periods; and (2) The small proportion of folded rock to stretched rock directly produced by secular cooling. But I do not think that these objections are by any means fatal to the theory. Assuming the earth to be practically solid, and to have been originally at a high temperature throughout, I believe it may be concluded that the peculiar distribution of strain in the earth's crust resulting from its secular cooling has contributed to the permanence of ocean-basins, and has been the main cause of the growth of continents and the formation of mountain chains."

In the course of his discussion the author takes up the argument of the Rev. O. Fisher on the insufficiency of the contraction theory, and gives several reasons why it should be regarded as inconclusive. The subject discussed by Mr. Davison is further considered by Prof. Darwin in a note appended to the paper of the former; he shows that some of the conclusions may be reached somewhat more simply, and furthermore makes some deductions as to the results of distortion and the magnitude of the effects accomplished. Prof. Darwin calls attention to the fact that the stretching of the earth's crust which is of importance from a geological point of view is the excess of the actual stretching above that due to rise of temperature—this if negative is a contraction and is shown by a crumpling of strata.

Assuming the time elapsed since consolidation to be 100 million years, the present depth of the stratum of no strain is two miles, and the depth is proportional to the time since consolidation. For the upper layers of the earth it is found that the integral effect is always a stretching, and this is negative; that is, it is a crumpling, as was to be expected. As to the amount of the crumpling, it is found that in ten million years 228,000 square miles of rock will be crumpled up and piled on the top of subjacent rocks. Prof. Darwin concludes:

7. "The numerical data with which we have to deal are all of them subject to wide limits of uncertainty, but the result just found, although rather small in amount, is such as to appear of the same order of magnitude as the crumpling observed geologically.

"The stretching and probable fracture of the strata at some miles below the surface will have allowed the injection of the lower rocks amongst the upper ones, and the phenomena which we should expect to find according to Mr. Davison's theory are eminently in accordance with observation. It therefore appears to me that his view has a strong claim to acceptance."

2. *Lavas of Krakatoa.*—Prof. Judd reviews the analyses of these lavas (Geol. Mag., vol. i, 1888), and shows that they are essentially andesyte, in which enstatite predominates over the pyroxene, and that much glass is present. Yet they vary greatly in the proportions of the constituent minerals and hence widely in ultimate composition. There is a large difference also in the condition of the glassy base as to its microlites, their number, grouping, and other peculiarities. A fragment of the obsidian, on approaching a white heat, swells up as it melts into a cauliflower-like mass five or six times the size of the original, proving the presence of some volatile material which is given off at a high temperature. The amount of distension undergone was found to be 3½ to 7, 8 or even 9 times that of the glass. The obsidian sometimes contains knots of pitchstone, the feldspar crystals of which show the effects of a large amount of corrosion, and sometimes of re-solution. Dr. Judd observes also that the stony lavas sometimes have the feldspar, pyroxenes and magnetite aggregated in little knots, producing a kind of structure which he calls glomero-porphyritic.

3. *Geologie von Bayern*, von Dr. K. WILLHELM VON GUMBEL. First Part, *Elements of Geology.* Lieferung 5, in continuation of volume I, pp. 961 to 1088 8vo, with numerous illustrations.—Although entitled Geology of Bavaria, this work by Dr. von Gumbel so far as published is essentially a comprehensive treatise on the science. The sheets here issued treat of the Pliocene, Quaternary, and Recent periods, and then commences, on p. 1020, a new division of the work, on Geogeny or the development of the Earth.

4. *Recent contributions to our knowledge of the vegetable cell.*—Die Morphologie und Physiologie der Pflanzenzelle, von Dr. A. Zimmermann. 8vo, 223 pp. (From Schenk's Handbuch der Botanik.) Die morphologische und chemische Zusammensetzung des Protoplasmas, von Dr. F. Schwarz. 1887. 8vo, 244 pp. (In Cohn's Beiträge zur Biologie der Pflanzen. Bd. V.) Articles in current Journals, cited in the text.

The progress which modern methods of research have permitted Vegetable Physiology to make is shown by even a superficial comparison of the classical treatises of Mohl (1851) and Hofmeister (1867) with any of the recent publications on the same subject, for example, with that placed at the head of the list given above. It will be remembered that Mohl described protoplasm and first gave it its name in 1846, and therefore, at the time of the publication of his "Vegetable Cell," his attention was directed largely to the examination of the cell-contents; whereas, up to that time, a great part of the study in this field had been devoted to the forms, markings and distribution of the structural elements. In Hofmeister's voluminous work, protoplasm and the other cell-contents receive the larger share of space, and are treated of as fully as the limitations of the methods then in use allowed.

By the application of improved processes of staining the contents of cells, and especially by the employment of the newer objectives, recent investigators have been encouraged to attack problems which it would have been thought hopeless even to approach twenty years ago. It is needless to dwell upon the fact that many of these problems have not yet been satisfactorily solved, and that not a few of them are still unanswered.

The present sketch will allude to a few of the contributions published during the last year or two, and an attempt will be made to indicate some of the relations to what has been previously known.

In extended studies by Reinke and Rodewald (1881) on the chemical character of protoplasm, it was stated that the reaction is alkaline. By careful microchemical studies of cell-contents, Schwarz (1887) has ascertained by the use of an infusion of red-cabbage that the reaction of cell-sap is sometimes acid and sometimes alkaline, but that of the protoplasmic mass is always alkaline. This alkalinity he ascribes to the presence of potassium compounds, presumably proteid combinations. The acid reaction detected in the case of old cells when all the contents are placed in contact with test paper is due to the considerable excess of acid cell-sap.

Schwarz has extended his studies to certain points regarding the structure and chemical constitution of protoplasmic contents of the cell. Recent writers have distinguished more or less completely and with considerable diversity of nomenclature, between the general protoplasmic mass of the vegetable cell and its differentiated protoplasmic contents. The latter, which are always imbedded in the former, are known as the nucleus and the chromatophores: the mass in which they are held is termed the cytoplasm. The chromatophores are three, namely, starch-accumulators, color-granules, and chlorophyll-granules. It is with the characters of the cytoplasm, nucleus and chlorophyll-granules that Schwarz has been specially engaged. Concerning the former, he says that in Cytoplasm there exists no normal network, but that a part of the mass can under certain circumstances become transformed into threads and constitute the well-known fibrillæ. Cytoplasm is to be regarded as a mixture in which under certain conditions there can be a separation of its solid, viscid and fluid substances. The microsomata (the very minute granules which occur in the cytoplasm) are sometimes of the nature of precipitates.

In the nucleus, Schwarz discriminates between (1) a fibrillar framework, (2) a basic substance, (3) nucleoli, and (4) an enveloping membrane. The chemical constituent of the framework is termed by him linin; that of the basic substance, paralinin; that of the nucleoli, pyrenin; that of the peripheral envelope, amphipyrenin: while in the fibrillar framework is distributed chromatin. The chlorophyll granule is believed by him to possess numerous fibrillæ imbedded in a basic substance and surrounded by a plasma-membrane, but the fibrillar character is detected only when the granules are swollen by immersion in water, and a portion of the basic substance is dissolved. Schwarz distinguishes two proteids in the above, chloroplastin and metaxin. The author's earlier studies under Pfeffer naturally led him to experiment upon the subject of precipitation-membranes and the allied one of vacuolation. He holds that when there is a mixture of two substances, one of which is soluble and the other insoluble but capable of limited enlargement by imbibition, there can be vacuolation; but in a mass of homogeneous substance there can be no vacuolation. The author has conducted many interesting experiments relative to the behavior of the different proteids with regard to digestive ferments, and also with regard to the action of various metallic compounds.

E. Belzung (Ann. Sc. nat. bot. iv, 179, 1887) has criticised Schimper's views relative to the formation of starch-grains through the agency of the starch-accumulators (leucoplasts). He states that in many instances the bodies described by Schimper could not be found, and that in many of the cases where they were seen they did not bear out Schimper's theory. In a rejoinder (ibid. VI, v, p. 77) Schimper demonstrates defects in Belzung's observations and shows that he has no reason to modify his original conclusions.

Heinricher (Mitth. bot. Inst. zu Graz, 1) has pointed out the occurrence in the tissues of certain Cruciferæ of idioblasts which he terms albuminoid-sacs. They are best seen in sections parallel to the plane of the leaf, in alcoholic material treated with Millon's reagent or in material which has been acted on by boiling water. The sacs or vesicles are more or less curved and are generally simple.

It has been known from researches by Hanstein and DeVries that when certain fresh-water Algæ are placed in a nutrient plasmolytic solution, for instance, a ten per cent solution of glucose or a twenty per cent solution of cane-sugar, the shrunken protoplasmic mass still remains living and even manifests some phenomena of growth. At this point Klebs (Ber. deutschen bot. Gesellsch., 1887, p. 189) takes up the subject, showing that it is possible to examine in this manner the mode of growth of the cell-wall. He concludes from his observations that in the case of Vaucheria the growth is by apposition in the newer walls and by stretching in the enlargement of the older walls. He examined also the relations of growth under these conditions to the surroundings, but of these results he has given only a general outline. The following statement relative to the nucleus is of considerable interest. From experiments on the cells of Zygnema and of Funaria, in which the protoplasm was by means of plasmolysis severed into parts, it was only the segment which retained the nucleus which was capable of completely restoring the cell: the other fraction remains living for weeks, but although such segments of Zygnema form no new cell-wall and do not grow in length, they are nevertheless assimilative and accumulate much starch. He states that the physiological rôle of the nucleus is as yet wholly unknown. It is well to note that in cultures like those detailed by Klebs it is advantageous to add to the liquid one-tenth of one per cent of potassium chromate in order to prevent the appearance of destructive fungi in the nutrient solution.

Janse of Leyden has published interesting studies made at the Zoological Station at Naples, in much the same field, the difference being chiefly that he employed salt-water algæ. (Botan. Centralbl., xxxii, p. 21.)

Haberlandt (Ber. deutsch. botan. Gesellsch., v, 205) has examined the position of the nucleus in certain vegetable cells, and concludes that in most cells whose walls show a localized thickening or an increase of surface, the nucleus is in close proximity to the active portion. He finds further, that from any given wood-parenchyma cell only one thylle developes, and this on the side where the nucleus lies and where a duct is in contact: the nucleus is transferred to the thylle. The author has also studied to some extent the behavior of the nucleus in severed threads of Vaucheria. His observations, made independently of those of Klebs, have led him to about the same conclusions.

Zacharias (Botan. Centralbl., xxxii, 59) has re-examined the relations of the nucleus to its surrounding protoplasm, and finds that the latter does not enter the nucleus when division is taking place, but that there is always a distinct demarcation between the two.

Zopf has detected in the spores (conidia) of *Podosphæra oxyacanthæ*, granules hitherto undescribed. For them he proposes the name of Fibrosin-granules, and states that they probably constitute a portion of the reserve matters. G. L. G.

III. Miscellaneous Scientific Intelligence.

1. *Beiträge zur Geophysik: Abhandlungen aus dem geographischen Seminar der Universität Strassburg*, herausgegeben von Prof. Dr. Georg Gerland. 1 Band. 373 pp., 8vo. Stuttgart, 1887. (E. Schweizerbart'sche Verlagshandlung, E. Koch.)—This volume forms the first of a series to be published at intervals, perhaps yearly, as the material accumulates. It contains papers by the members of the geographical Seminar of the Strassburg University, and speaks well for the activity of a teacher who can inspire his pupils to accomplish such results. The introduction by the editor is an interesting and comprehensive discussion of the scientific scope of Geography, its various departments, and its relation to the kindred sciences of geology, anthropology, etc.

The memoirs forming the bulk of the volume are four in number. The first by H. Blink is on the winds and sea currents in the region of the small Sunda islands; a second by H. Hergesell on the change in the planes of equilibrium of the earth caused by the formation of the polar ice masses and the resulting changes in sea level; a third by the same author on the influence which a change in the geoid can have upon the relative heights of a plateau and on the fall in a stream bed; a fourth by E. Rudolph discusses submarine earthquakes and eruptions, as to their phenomena, distribution and cause, with a catalogue of observed occurrences of this kind.

2. *Klima und Gestaltung der Erdoberfläche in ihrer Wechselwirkung dargestellt* von Dr. J. Probst. 173 pp. 8vo. Stuttgart, 1887, (E. Schweizerbart'sche Verlagshandlung, E. Koch.)—The author's discussion of this subject falls into two parts. The first embraces the consideration of the climatic conditions of the successive geological periods, and the second takes up the modifications and mutual relations between the climatic development and the form of the earth's surface. The peculiar features of the climate of the early geological periods are discussed with their causes, and a close similarity traced between this and the true ocean climate of the present day in its greater uniformity, greater warmth and peculiar distribution. The consideration of the later periods follows with an attempt at an explanation of their climatic conditions. This portion of the work offers a number of points of interest with less that admits of criticism than the following part. It is hardly possible to accept the author's estimate of the effects upon the fundamental development of the earth's features of the contraction caused by the unequal cooling of portions of the underlying earth's crust by the cold currents which form part of the sea's circulation.

3. *Beobachtungs-Ergebnisse der Norwegischen Polarstation Bossekop in Alten* von Aksel S. Steen. I Theil, Historische Einleitung, Astronomie, Meteorologie, 100 pp. with 4 plates. Christiana, 1887. (Die Internationale Polarforschung 1882–83).—This volume is one of numerous contributions made to science as the result of the labors at the International Polar Stations established in 1882. The Norwegian station was at Bossekop at the end of the Altenfjord, 69° 28′ N. lat. and 23° 15′ E. long. The observations made extend over the subjects of astronomy and meteorology and are given in full detail in a series of tables; the daily cause of the air-pressure, temperature, moisture, wind velocity, and cloudiness are given on the closing plates.

4. *The Asteroids, or Minor Planets between Mars and Jupiter;* by Daniel Kirkwood. Lippincott & Co., Philad. 1888. 12°, pp. 60.—A very convenient summary of facts and a collection of tables of the small planets. These are followed by a discussion of the various facts shown by the tables.

5. *A Manual of Descriptive Geometry;* by C. A. Waldo. Heath & Co., Boston. 8°, pp. 77.—A book of suggestions, defi-

nitions, problems, etc., whose scope is by no means to be measured by the number of pages.

6. *Annals of the Astronomical Observatory of Harvard College;* Vol. XIII, p. ii. Cambridge, 1888. E. C. PICKERING, Director. The zone observations made, principally by Professor Searle, in the years 1882–6 with the transit wedge photometer attached to the large equatorial are here published. The stars measured are largely from the zones observed by Bond.

7. *The Movements of the Earth;* by J. NORMAN LOCKYER. Macmillan & Co. 1887, 8°, pp. 130.—A small volume, the first of a series promised by Mr. Lockyer, to give the *Outlines of Physiography.* This volume explains the various motions of the earth, and the first principles of the measurement of space and time in Astronomy.

8. *Publications of the Lick Observatory of the University of California;* E. S. HOLDEN, Director. Vol. I. Sacramento, 1887. —This volume contains a history of the institution, an account of various observations made during the progress of construction; a description of part of the instrumental equipment; and a series of reduction tables.

9. *Cordoba Observations.*—The ninth volume of the *Resultados del Observatorio Nacional Argentine,* containing the observations made under Dr. Gould's direction in 1876 has been received.

10. *Elementary Treatise on Analytical Mechanics;* by W. G. PECK. 319 pp., 8vo. New York and Chicago, 1887 (A. S. Barnes & Co.).—The important principles of analytical mechanics are presented in this volume systematically and with a good deal of clearness of arrangement though without much claim to originality.

OBITUARY.

JAMES C. BOOTH died March 21, at Philadelphia, at the age of seventy-eight. He was the author, with M. H. Boyé, of the Encyclopedia of Chemistry, published in 1844, and also of a report on the Geology of Delaware, with chemical notes. He contributed a considerable number of papers on chemical subjects, several of them in analytical mineralogy. He was for many years on the staff of the U. S. Mint at Philadelphia.

Geologie des Münsterthals, von Dr. A. Schmidt, A.O., Prof. Univ. Heidelberg. 2d part. Porphyry. 172 pp. 8vo. Heidelberg, 1887 (Carl Winter's Universitätsbuchhandlung).

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[THIRD SERIES.]

ART. XXX.—*The Absolute Wave-length of Light;* by LOUIS BELL. Part II.

[Continued from page 282.]

THIS continuation of my previous paper contains the angular measurements and the details of the measurement and calibration of the gratings, together with the final results. In addition I have endeavored to point out the probable sources of error in some recent determinations of absolute wave-length.

Angular Measurements.

In my former paper (this Journal, March, 1887) the work with glass gratings was described in detail, so that it will only be necessary to summarize it here.

Grating I was used during October and November, 1886, and forty-eight series of observations were obtained as follows, each series consisting of three to seven observations.

Date.	Number of series.	Angle.
Oct. 19,	1	45° 1′ 47″·2
20,	1	45 1 48 ·4
22,	2	45 1 48 ·2
23,	1	45 1 49 ·8
26,	4	45 1 49 ·3
27,	3	45 1 48 ·2
31,	1	45 1 50 ·1

Date.	Number of series.	Angle.
Nov. 3,	1	45° 1′ 48″·6
4,	3	45 1 47 ·4
5,	2	45 1 47 ·9
10,	4	45 1 47 ·8
11,	6	45 1 49 ·7
16,	8	45 1 48 ·2
17,	5	45 1 47 ·5
20,	6	45 1 47 ·5

Grating I was used at an average temperature of very nearly 20°, to which all observations were reduced. The average barometric height was 761^{mm}, so that no correction was required for this cause. Weighting and combining the above observations the final value is

$$\varphi = 45^\circ\ 1'\ 48''\cdot24 \pm 0''\cdot11,$$

corresponding to the spectrum of the third order.

The resulting probable error in wave-length is about one part in a million.

Grating II was used in March, 1887, at an average temperature of very nearly 20° and an average pressure of 760^{mm}. Thirty-six series of observations were obtained in the fourth order, as follows:

Date.	Number of series.	Angle.
Mar. 6,	2	42° 5′ 1″·2
10,	1	42 4 58 ·6
11,	7	42 5 1 ·4
15,	1	42 5 4 ·0
16,	6	42 4 57 ·8
17,	6	42 4 58 ·5
18,	7	42 4 59 ·1
23,	6	42 4 58 ·3

Combining and weighting, the mean value is:

$$\varphi = 42^\circ\ 4'\ 59''\cdot28 \pm 0''\cdot2.$$

The probable error is equivalent to about one part in six hundred thousand in the wave-length.

Both the glass gratings were used exclusively for the line D_1, which was on the whole most convenient for measurement, D_2 being rejected by reason of the troublesome atmospheric lines. The relative wave-lengths of a very large number of lines have been so exactly determined by Prof. Rowland that any one of them would have given results equally valuable, and in the subsequent work with gratings III and IV, two of these standard lines were employed.

In this second part of the investigation, the gratings as before mentioned were used on the large spectrometer in which the telescopes were kept at a fixed angle and the grating was turned. This method is, of course, applicable only to very solid instruments in which the angle can readily be kept constant, and it should be further noted that it also requires the use of very perfect gratings, since the grating is used asymmetrically. As a result of this the spectra on the two sides differ in dispersion, and if the ruling is irregular either in spacing or in contour of the individual lines, may differ quite widely in focal length, definition and illumination. After critical examination gratings III and IV appeared to be so nearly perfect in ruling, as to be quite secure from the dangers of the method. The method has moreover the distinct advantage of enabling the angle of deviation to be varied within certain narrow limits. Hence it becomes possible so to arrange the apparatus as to give to some convenient line a double reflection that shall be an exact submultiple of 360°. This once accomplished it becomes an easy matter completely to eliminate the errors of the divided circle and obtain a value of $n\varphi$, dependent only on the micrometer constants, which in turn may be themselves almost eliminated. To be sure, this method practically confined observations to the spectra of a given order and limits the choice of lines for measurement, but the first objection does not apply to gratings of which the ruling is very nearly perfect, and since the relative wave-lengths of a large number of lines are known with very great exactness, measurements of the absolute wave-length are quite comparable even if made on different lines.

As regards the constancy of the angle between the collimator and observing telescope there was every reason to expect entire permanence throughout the experiments, and observation soon justified this expectation. The telescopes were firmly secured at both ends to one and the same casting, which in turn was firmly bedded in a brick pier. In addition the size of the apparatus was such that a variation of even 1″ in the angle was quite improbable. The angle measured in the ordinary way with a collimating eye-piece could be determined to 1″ of arc, exclusive of errors of graduation in the circle. At first there appeared to be distinct variations in the angle as determined at the beginning of each series of observations, reaching sometimes more than 10″. It soon appeared however that when the same part of the circle was used the angle between the telescope was sensibly the same and the apparent variations were then traced to a periodic error in the divided circle, which by the method of repetition was completely eliminated from the measurements of angles of deviation and only appeared in the determinations of θ. This error was finally eliminated by measuring θ in various portions of the circle.

The method of determining φ was as follows: The instrument being adjusted by the ordinary methods, a suitable line was selected for measurement and then the angle θ was slightly increased or diminished until by measurement of a double deflection $n\varphi$ was found to be very close indeed to 360°. Then a double deflection was carefully measured and if time permitted several times repeated, an observer always being at the eye-piece to see that the line should not move from the cross hairs while the micrometers were being read. Then, clamping the main circle, the grating holder was turned through 2φ until the line was very closely upon the cross hairs, any slight readjustments made necessary by this disturbance of the instrument were made, and the process was repeated. In this way the initial line of the circle was finally reached and a value of $n\varphi$ obtained which depended only on the algebraical sum of the micrometer readings, always a small quantity.

The determination of the temperature, a very difficult and uncertain matter in the case of glass gratings, is here comparatively simple. A sensitive thermometer (Baudin 6156) was kept in contact with the grating, its bulb being carefully shielded by cotton. The construction of the spectrometer made it impracticable effectively to shield the grating from radiation from the observer's body; but the thermometer apparently proved effective in giving the real temperature since no discrepancies in the results could be traced to thermal causes. The thermometer readings were made to 0°·05, and the temperature of observation rarely varied more than two or three degrees from 20° C.

The temperature being thus obtained, the necessary correction was introduced directly into the angle of deviation. Writing the formula for wave-length in the form

$$\lambda = C\, s \sin \varphi,$$

where C is a factor depending on the method in which the grating is used, and differentiating we obtain

$$\frac{\delta s}{s} = -\cot \varphi \delta \varphi,$$

where if we take 1° for the temperature variation $\frac{\delta s}{s}$ is the coefficient of expansion. Whence

$$\delta \varphi = -\frac{\frac{\delta s}{s}}{\cot \varphi} =$$

correction for 1° variation in temperature. For grating III for instance $\delta\varphi = 2''{\cdot}688$ and by this means all the deviations were reduced to 20°. Writing again the equation for wave-length in the form for the method here used,

$$c = \sin\varphi\cos\theta.$$

Now to obtain the variation in φ due to a change in the angle between the telescopes,

$$\delta\varphi = \tan\varphi\tan\theta\delta\theta.$$

Taking now $\delta\theta = 1''$ and φ as found in these experiments

$$\delta\varphi = 0''{\cdot}089.$$

By this means the necessary correction could be introduced in the angle of deviation, but the angle between the telescopes was so nearly constant as to render this correction needless.

The line selected for measurement with III was a sharp one in the green at 5133·95 of Rowland's map. The angle θ between the telescopes was adjusted so that in the eighth order the double deflection was 72°. Eighteen complete series of observations were then obtained, each giving a value of 10φ from which the errors of the circle were completely eliminated. The results in detail were as follows, corrected to 20° on thermometer used,

Date.			ϕ.			
1887.	Nov.	2,	36°	0′	27″	·19
	"	3,	36	0	25	·87
	"	4,	36	0	24	·40
	"	5,	36	0	24	·95
	"	5,	36	0	26	·83
	"	9,	36	0	26	·14
	"	16,	36	0	27	·40
	"	16,	36	0	27	·37
	"	17,	36	0	27	·57
	"	22,	36	0	25	·16
	"	29,	36	0	25	·69
	"	29,	36	0	25	·99
	"	29,	36	0	25	·91
	"	30,	36	0	26	·10
	"	30,	36	0	25	·86
	"	30,	36	0	25	·81
	Dec.	1,	36	0	25	·68
	"	1,	36	0	25	·80

The last decimal place is retained simply for convenience in averaging. The mean value of φ is 36° 0′ 26″·07 which reduced for the error of thermometer at 20° gives finally,

$$\varphi = 36° \ 0' \ 25''{\cdot}17.$$

The probable error of this value is 0″·14. The effect of a small error in φ on the resulting wave-length is given at once by

$$\delta\lambda = \cos\varphi\delta\varphi.$$

In this case the error introduced by an error of 1″ in φ is a little less than 1 part in 250000.

The mean value of θ during these measurements was

$$\theta = 6° \ 59' \ 58''\cdot 6.$$

In case of grating IV the line selected for observation was one of Rowland's standards at w.l. 5914·319 of his preliminary list. It is a very close double, the components being distant from each other something like $\frac{1}{75,000}$ of their wave-length. The double deflection was as before 72° but in the fifth order. As with grating III eighteen series of observations were obtained, with the following resulting values of φ

Date.			ϕ.
1887.	Dec.	16,	36° 0′ +1″·16
	"	16,	36 0 +0 ·66
	"	16,	36 0 +0 ·67
	"	19,	36 0 +0 ·64
	"	19,	36 0 +1 ·56
	"	19,	36 0 +0 ·85
1888.	Jan.	12,	36 0 −1 ·19
	"	12,	36 0 −1 ·61
	"	12,	36 0 −1 ·79
	"	14,	36 0 −1 ·09
	"	14,	36 0 −0 ·95
	"	14,	36 0 −0 ·89
	"	19,	36 0 −0 ·48
	"	19,	36 0 −0 ·59
	"	19,	36 0 −0 ·49
	"	20,	36 0 +0 ·51
	"	20,	36 0 −0 ·11
	"	20,	36 0 +0 ·55

The mean value, corrected as before for error of thermometer, is:

$$\varphi = 35° \ 59' \ 59''\cdot 06 + 0''\cdot 15$$

The effect of this probable error is obviously the same as in case of grating III. The mean value of the semiangle between the telescopes was

$$\theta = 6° \ 58' \ 31''.$$

During the observations with grating III the barometric height reduced to the place of observation was very nearly 762^{mm}, but during the work with grating IV it was phenomenally high, reaching an average value of 766^{mm}, an amount so far from normal pressure as to render a small correction necessary.

The mean temperature during the observations with III was about 21° C., but in case of IV it averaged almost exactly 20° C. varying at most only two or three degrees from that figure.

Measurement of the Gratings.

The comparator on which this, the most important portion of the research, was accomplished was the same one described in my previous paper. It had however been improved in several particulars. The platform carrying the standards had been fitted with smooth rack and screw adjustments, and the microscopes and micrometers were new. The illumination of a grating under the power used,—two hundred and fifty diameters—is by no means an easy matter, and at the same time a powerful and symmetrical illumination is absolutely necessary for the most accurate work, particularly in case of rather small grating spaces. I had been thoroughly dissatisfied with the illumination previously used—a lamp at a suitable distance—and now made a radical change. A three candle-power electric lamp was attached directly to the microscope just below the eyepiece and about a foot above the objects measured. A small mirror carried by an arm screwed to the objective reflected the beam into the Tolles illuminator. A glass bulb filled with water surrounded the light and served the double purpose of stopping radiation and partially condensing the beam upon the mirror above mentioned.

I am aware that such an arrangement is somewhat revolutionary, and it was only after a careful trial that I convinced myself that the heat from so near a source was not injurious.

In the first place it should be noted that the lamp is only used for a few moments at a time and at intervals long compared with the time of observation. Thus the very minute heat wave that reaches the bar through the bulb of water cannot possibly produce a perceptible rise of temperature during the time of an observation, while during the intervals it is completely dissipated.

As an experimental fact, no heating effect whatever is sensible even after a whole day's observations. To show at once this fact, and the general character of an average series of comparisons I subjoin ten comparisons of $Dm_1S^a_2$ with a certain decimeter on glass, made at intervals of about three-quarters of an hour on two successive days. The figures are taken directly from my note book.

Date.		T=
June 1, 1887	$Dm_1S^a_2 = G + 21^\delta{\cdot}3$	17°·4
"	" " + 21·6	17 ·4
"	" " + 22·1	17 ·5
"	" " + 22·1	17 ·5
"	" " + 20·8	17 ·5
"	" " + 20·1	17 ·5
June 2,	" " + 21·4	17 ·0
"	" " + 21·0	17 ·0
"	" " + 21·0	17 ·0
"	" " + 21·0	17 ·1

The temperature was given by a thermometer in contact with S^a_2 and 1δ of the micrometer equalled $0^\mu{\cdot}28$. In a comparison of two standards with such unequal coefficients of expansion as glass and speculum metal, the evil effects of radiation should be at their maximum, but the preceding series, including as it does all the experimental errors and showing an extreme variation of but $0^\mu{\cdot}5$, leaves, I think, little to be desired.

The comparator was placed in a vault some six feet below the level of the street, which was provided with thick double walls with an air space between. This observing room enabled the temperature to be kept down to a daily variation of less than half a degree, the extreme range for several days being frequently less than that amount. Before this vault in the new Physical Laboratory was completed the comparator had been placed in an upper room of one of the old buildings, where it was well nigh impossible to keep anything like a constant temperature, particularly since the heat was unavoidably partially shut off during the night. Owing to this state of affairs the measurement of the gratings on which my preliminary wave-length was based, was made under difficulties and in most of the series necessarily under a rising temperature. Now when a glass standard is measured against a metal one, glass being a notoriously bad conductor, and having a very small coefficient of expansion, if any rise of temperature takes place the length found for the glass will be too small, for responding less readily to a change it will be actually measured at a lower temperature.

It therefore became necessary to re-measure the glass gratings Nos. I and II, to eliminate this source of error, which was done before the results for III and IV were obtained. These gratings are very nearly 3^{cm} long and they were therefore compared with successive triple centimeters of S^a_2 until the fifteen centimeter mark was reached. Grating I was first taken in hand and six complete series of observations were obtained, each micrometer reading being the mean of several, and the extreme limits of temperature variation during the two days occupied by the comparisons being 0°·3 C. The following gives a summary of the results.

$$\left.\begin{array}{l} 5G = 15^{cm}S^a_2 + 19^\delta{\cdot}0 \\ 5G = 15^{cm}S^a_2 + 21{\cdot}5 \\ 5G = 15^{cm}S^a_2 + 18{\cdot}1 \\ 5G = 15^{cm}S^a_2 + 23{\cdot}9 \\ 5G = 15^{cm}S^a_2 + 22{\cdot}6 \\ 5G = 15^{cm}S^a_2 + 18{\cdot}3 \end{array}\right\} \text{At } 19^\circ{\cdot}9 \text{ C.}$$

Hence combining these and reducing them to the standard temperature of 20° we have:

$$60000 \text{ spaces} = 5G = 15^{cm}S^a_2 + 5^{\mu}\cdot 2 \text{ at } 20°$$

The micrometer constant here used was that of the new micrometer where $1\delta = 0^{\mu}\cdot 257$.

In precisely the same way Grating II was remeasured, the six series giving the following relations

$$\left.\begin{array}{l} 5G = 15^{cm}S^a_2 + 157^{\delta}\cdot 4 \\ 5G = 15^{cm}S^a_2 + 154\cdot 9 \\ 5G = 15^{cm}S^a_2 + 154\cdot 5 \\ 5G = 15^{cm}S^a_2 + 152\cdot 4 \\ 5G = 15^{cm}S^a_2 + 154\cdot 9 \\ 5G = 15^{cm}S^a_2 + 162\cdot 4 \end{array}\right\} \text{At } 19°\cdot 8 \text{ C.}$$

Combining and reducing these results as before we have the equation

$$42640 \text{ spaces} = 5G = 15^{cm}S^a_2 + 39^{\mu}\cdot 9 \text{ at } 20°$$

The temperature variation in the two days of observation was only 0°·2.

Gratings III and IV were then measured. In this case a large number of comparisons were obtained at both high and low temperatures with the object of detecting any differences which might exist between the coefficients of expansion of the gratings and those of the speculum metal standards. III and IV being a little over a decimeter in length were very easy to measure, particularly since the lines were very sharp and of approximately the same width as those on the standards.

III proved to have sensibly the same coefficient as the standards. I subjoin the comparisons made at or very near 20°.

$$\begin{array}{lll} G = & Dm_1S^a_2 & + 32^{\delta}\cdot 9 \\ G = & \text{"} & + 33\cdot 0 \\ G = & \text{"} & + 32\cdot 7 \\ G = & \text{"} & + 33\cdot 2 \\ G = & \text{"} & + 32\cdot 3 \\ G = & \text{"} & + 32\cdot 6 \\ G = & \text{"} & + 34\cdot 5 \\ G = & \text{"} & + 33\cdot 4 \\ G = & \text{"} & + 34\cdot 2 \\ G = & \text{"} & + 32\cdot 6 \end{array}$$

Combining these and other series of observations gives finally

$$28418 \text{ spaces} = G = Dm_1S^a_2 + 8^{\mu}\cdot 5 \text{ at } 20°$$

It should be noted that the extreme variation in the above series is $2^{\delta}\cdot 2$, very nearly $0^{\mu}\cdot 5$, or one part in two hundred thousand.

In the case of IV the coefficient appeared to be somewhat smaller than that of S^a_2. The range of temperature secured was not large but as nearly as could be ascertained the coefficient is about $16^{\mu}\cdot 1$ per meter per degree, while that of the standards is $17^{\mu}\cdot 9$ per meter per degree. However, since the measurements of φ made with IV were distributed with a tolerable degree of symmetry on both sides of 20°, any error due to an inexact value of the coefficient of expansion would appear mainly in the probable error in φ The variation found would, as a matter of fact have changed the final value of φ by less than $0''\cdot 2$.

The comparisons of IV made near 20° were as follows:

$$G = Dm_1S^a_2 + 35^{\delta}\cdot 8$$
$$G = \text{"} + 35\cdot 5$$
$$G = \text{"} + 35\cdot 6$$
$$G = \text{"} + 36\cdot 0$$
$$G = \text{"} + 34\cdot 0$$
$$G = \text{"} + 35\cdot 8$$
$$G = \text{"} + 34\cdot 6$$
$$G = \text{"} + 36\cdot 3$$
$$G = \text{"} + 33\cdot 3$$
$$G = \text{"} + 36\cdot 7$$

Combining these and the other observations,

$$39465 \text{ spaces} = G = Dm_1S^a_2 + 9^{\mu}\cdot 1 \text{ at } 20°.$$

The probable error of the relations found for III and IV can hardly exceed one part in a million so far as the distance between the terminal lines selected is concerned. These terminal lines were varied at each comparison so that while each of the above relations represents 39,465 spaces, the lines measured between, though in the same vicinity, are seldom or never identical.

In gratings I, II, III the number of spaces was very easily counted as the dividing engine automatically rules every hundredth line longer, and every fiftieth line shorter, than the others. In grating IV the number of spaces was found readily enough by ruling at a known temperature the terminal lines of a test plate almost exactly a decimeter long, and containing a known number of lines. A comparison of this with the grating gave the quantity required.

Calibration of the Gratings.

In my previous paper the need and method of determining the errors of ruling in a grating were briefly noticed. It is fitting here to enter somewhat more into detail.

The grating space is never perfectly uniform throughout the whole extent of the ruled surface. The variations may be in general classed as regular and irregular. In the first class we put variations in the grating space which are purely periodic or purely linear. These produce respectively "ghosts," and difference in focus of the spectra on opposite sides of the normal. Either fault might be large enough to unfit the grating for wave length determination, and would be always undesirable, but nevertheless would introduce no gross errors into the result. Variations of the second class include the displacement, omission or exaggeration of a line or lines, and what is of great importance, a more or less sudden change in the grating space producing a section of the grating having a grating space peculiar to itself. The former types of accidental error, unless extensive are harmless, and are present in most gratings usually showing as faint streaks in the ruling. It is with the last mentioned error that we mainly have to do.

Consider a grating the space of which is sensibly uniform except throughout a certain portion. Let that portion have a grating space distinctly larger or smaller than that of the remainder of the grating. If the abnormal portion is a considerable fractional part of the whole grating it will, in general, produce false lines and injure or ruin the definition of the grating. Such a grating we should nowadays throw aside as useless, although many of the older gratings are thus affected. Suppose however that the abnormal portion is confined to a few hundred lines. Such a series of lines will have little briliancy and less defining power and consequently will simply diffuse a certain amount of light without either producing false lines or, in general, injuring the definition. In short, when the full aperture of the grating is used, the spectra produced will be due only to the normal grating space, the abnormal portion having little or no visible effect. If however we attempt to evaluate the grating space by measuring the total length of the ruled surface and dividing it by the number of spaces therein contained, we shall obtain an incorrect result, since this average grating space, including, as it does, the abnormal portion, will be necessarily different from the normal grating space which produces the spectra observed.

In general if n be the total number of spaces and s the normal grating, space the length of the ruled surface will be $ns+A$, where A is a quantity depending on the magnitude and nature of the abnormal portion. It will have for its maximum value $\Sigma(s-s')$, where s' is the varying grating space, in the case when the change in the space is so local and sudden as to produce no effect at all on the spectrum; and will be variously modified by the considerations now to be mentioned. If we could always assume that the abnormal portion of the grating produced no effect on the spectrum the elimination of errors of ruling would thus become comparatively simple. But in practice it is not very uncommon to find gratings in which there are several portions where the spacing is abnormal, in one case perhaps producing no effect, in a second producing false lines and in a third causing a faint shading off of the lines. For an abnormal portion will produce no effect, a slight shading or reduplicated lines, according to its extent and the amount of its variation from the normal.

The following experiment will readily show the laws which govern these errors of ruling. Place a rather bad grating—unfortunately only too easily obtained—on the spectrometer, and setting the cross-hairs carefully on a prominent line, gradually cover the grating with a bit of paper, slowly moving it along from one end. In very few cases will the line stay upon the cross-hairs. A typical succession of changes in the spectrum is as follows: Perhaps no change is observed until two-thirds of the grating has been covered. Then a faint shading appears on one side of the line, grows stronger as more and more of the grating is covered, and finally is terminated by a faint line. Then this line grows stronger till the original line appears double and finally disappears leaving the displaced line due to the abnormal grating space. This description, I regret to say, is from the examination of a grating which had been used for the determination of absolute wave-length.* This case is exceptionally complete, but even with a very good grating minute displacements can usually be noticed.

When the abnormal portion is sufficiently extensive to produce a faint shading along one side of the lines when the full aperture of the grating is used, the effect of the error on the resulting wave-length may be in part eliminated by the fact that the shading would displace the apparent center of the line and hence slightly change the observed angle of deviation. For this reason a grating so affected would be likely to give results varying with the order of spectrum used, since the appearance of the line would vary somewhat with the illumination. It is at once apparent, however, that no combination of the results from different orders of spectra can possibly eliminate the class of errors we are discussing, since the alge-

* Not by the author it is almost needless to add.

braic sign of the error will be the same for all orders and it will be in every case a nearly constant fraction of the wave length.

The problem before the experimenter is then the following: To detect the existence and position of any abnormal portion of the grating in use, to separate as far as possible such portions as produce a visible effect from those which do not, and thus finally to determine the proper value to be assigned to the quantity A.

The investigation is somewhat simplified by the fact that, for the most part, abnormal spacing occurs at an end of the ruled surface, generally at the end where the ruling was begun, since, when the engine is started it is likely to run for some little time before it settles down to a uniform state. Then, too, one is able to disregard the slight and gradual variations in the grating space which appear in every grating, since their effects will in general be integrated in the spectrum produced.

It only remains therefore to study those larger and more sudden changes which can produce a sensible error in the result. It is evident that the process of examination indicated above will serve to detect the more extensive faults, together with any errors of figure in the surface, but an abnormal portion consisting of only a few hundred lines will not have resolving power enough to produce a marked effect. Making then a slit in a card just wide enough to expose a sufficient number of lines to give tolerable definition, one can examine the grating section by section, and still further discriminate between the normal and abnormal spacing, errors of figure being included as before. But as the number of abnormal spaces decreases a point will be reached when this method breaks down completely, and since the error in the resulting wave-length may be as large in this case as when the fault is more extended, another method must be sought. So far as I know the only method which will detect and evaluate all these errors is that which I have called calibration, measuring the relative lengths of n grating spaces taken successively along the ruled surface. The process employed was as follows. The stops of the comparator were set as close together as practicable, limiting the run of the carriage to a distance which varied in different cases from 4 to 10^{mm}. Then the grating to be examined was brought under the microscope and micrometer readings were taken on the lines just within the run of the carriage; the grating was then moved along about the length of the run and the process repeated till the whole grating had been gone over. The variations in the micrometer readings then gave the variations in the length of n spaces in different parts of the grating. The only assumption involved was that the variation in the different sections did not amount to an entire space, an hypothesis quite secure in gratings with spaces as large as those employed. It was thus possible to determine quite accurately the variations in the grating space throughout the whole grating.

It should be noted that since these variations may be of almost any kind and magnitude the errors produced by them will not in general be eliminated by combining the results obtained from several gratings. It may happen that the gratings used by one experimenter will have errors that will counterbalance each other, while those used by another will all have errors of the same sign. For instance, by the merest accident the gratings used by the writer gave nearly identical results corrected and uncorrected, while those used by Peirce uniformly required a reduction in the resulting wave-length. The number of gratings used by a given investigator is however so small that the errors will very seldom be eliminated, while no combination of the results obtained from different orders of the same grating can produce any useful effect whatever.

Each of the gratings used in this research was examined minutely by the above methods and in each was found an abnormal portion of one sort or another. Of eight gratings which I have calibrated all have shown a similar error and of more than twenty which I have examined in the spectrometer only one (grating III) failed to show an abnormal section at one end. Since this is the commonest form of the error in question, it is but natural to inquire why it cannot be avoided by covering the defective end. The reason is simple enough. By stopping out the defective portion the grating is reduced to an incommensurable length which enormously increases the difficulty of measuring it. A grating which is in length some convenient submultiple of a meter is easy to measure with a comparatively high degree of exactness, but one which is, say, twenty seven millimeters long, is exceedingly difficult to measure accurately since it involves a long micrometer run or the errors of subdivision down to single millimeters. It is therefore better to use the full aperture of the grating and find A by calibration.

In calibrating the gratings used, I divided I and II, which were thirty millimeters long, into six sections of 5^{mm}, and the large gratings III and IV into centimeters. Each grating was carefully gone over five times and the mean result taken. The following corrections were found.

The actual variations found in each grating are given below, the figures given being the difference of *n* lines from the distance between the stops, the lines being taken in the consecutive sections of the gratings.

Grating I.

Sections	1	2	3	4	5	6
Residuals,	0^{μ}·78	0·98	0·81	1·03	0·86	1·24

Grating II.

Sections	1	2	3	4	5	6
Residuals,	2^{μ}·07	1·93	1·52	1·68	1·31	0·45

Grating III.

Sections	1	2	3	4	5	6	7	8	9	10
Residuals,	2^{μ}·80	2·85	1·77	2·77	2·70	2·77	2·67	2·64	2·73	2·77

Grating IV.

Sections	1	2	3	4	5	6	7	8	9	10
Residuals,	0^{μ}·31	0·28	0·35	0·43	0·40	0·43	0·31	0·35	0·28	0·82

The calibration of III is worth describing in detail. Centimeter 3 was evidently too long. I therefore measured the centimeters from 15 to 25^{mm} and from 25 to 35^{mm}. The former was quite normal but the latter showed an increase almost identical with that of the whole third centimeter. I then examined the grating in a strong light and detected at 27^{mm} from the end, a faint line, such as usually indicates a few wavering lines caused perhaps by dust under the diamond point. Placing, however, this line under the microscope a band of perhaps twenty lines appeared with spacing noticeably wider than usual. Here was a very serious flaw in a grating to all appearance absolutely perfect. A most critical examination in the spectrometer of course failed to detect it, but it was both detected and located with unerring certainty by the process of calibration. Micrometrical measurements on this group showed an excess of about 2^{μ}·5 over an equal number of spaces elsewhere on the grating. This quantity of course had to be taken account of in connection with the previous calibration.

The deduction of the necessary corrections from the data given by calibration requires no little care and judgment, and can be properly done only in connection with a detailed study of the spectra given by various portions of the gratings concerned. For the four gratings used by the author, these corrections, applied directly to the lengths of the gratings in the form of the quantity A before mentioned, are very nearly as follows:

Grating.	A
I	-0^{μ}·10
II	+ 0·40
III	− 2·00
IV	+ 0·45

It should be distinctly understood that the corrections deduced from the calibration are necessarily only approximate. A very minute examination of a grating on the spectrometer is impossible, since a small section of the ruled surface has not sufficient resolving power to give measurable spectra. On the other hand, while calibration gives the variations of the grating space with a high degree of exactness, it obviously cannot definitely decide how far these variations are integrated in the spectrum measured. Consequently while calibration will in every case give a valuable approximation, it must necessarily leave residual errors.

In these experiments the gratings were always measured parallel to the terminations of the lines. Consequently the length of each grating as found directly must be multiplied by cos $(90^\circ - \alpha)$, where α is the angle made by an individual line with the line formed by the locus of the terminations. In case of gratings I, II, III this angle was found by measuring a test plate as described in my previous paper and was found to be within a very few seconds of 89° 56′.

Grating IV ruled on the new engine was tested by measuring the sides and diagonals of the ruled surface and gave an almost exactly identical value of α. No correction therefore need be introduced for this cause, since cos $(90^\circ - \alpha)$ does not differ sensibly from unity.

Final result for Absolute Wave-length.

Only one equation needs to be added to those already given for S^a_2. This is the one for the third 5^{cm} space, necessary to determine the absolute length of the first 15^{cm}. 5^{cm}, (3) and (4) were compared and the following relation was found between them: $(4) = (3) + 0^{\mu}\cdot 4$. The relation found in 1885 was $(4) = (3) + 1^{\mu}\cdot 1$. Consequently (3) has not sensibly shortened and nearly the whole change found in S^a_2 has taken place in the last five centimeters. Writing now the absolute lengths of

$$Dm_1\ S^a_2 \text{ and } 15cm.\ S^a_2,$$

$$Dm_1\ S^a_2 = 100\cdot 00666^{mm} \text{ at } 20^\circ.$$
$$15cm\ S^a_2 = 150\cdot 00897 \text{ at } 20^\circ.$$

Applying now the relations found for grating I in the foregoing section,

$$s = 0\cdot 002500226^{mm}$$

And since $\varphi = 45^\circ\ 1'\ 48''\cdot 24$

$$\lambda = 5896\cdot 18$$

Similarly for grating II,

$$s = 0\cdot 003519041^{mm}$$
$$\varphi = 42^\circ\ 4'\ 59''\cdot 28$$
$$\lambda = 5896\cdot 23$$

Computing the similar quantities for the speculum metal gratings III and IV, for grating III,

$$s = 0{\cdot}003519358^{mm}$$
$$\varphi = 36° \ 0' \ 25''{\cdot}17$$
$$\theta = 6° \ 59' \ 58''{\cdot}56$$
$$\lambda = 5133{\cdot}89$$

and for grating IV,

$$s = 0{\cdot}002534306^{mm}$$
$$\varphi = 35° \ 59' \ 59''{\cdot}06$$
$$\theta = 6° \ 58' \ 31''$$
$$\lambda = 5914{\cdot}37$$

Reducing now these latter wave lengths to the corresponding values of D_1, introducing the barometric corrections and combining, the final results for that line are

Grating	W. L.
I	5896·18
II	5896·23
III	5896·15
IV	5896·17

Finally, then, the mean value of the absolute wave-length of D_1 in terms of the mean value assigned to $S^a{}_2$ is

5896·18

in air at 760^{mm} pressure and 20° C. temperature, or *in vacuo*,

5897·90

It is no easy matter to form an estimate of the probable error of this final result. So far as errors of observation go, the result should be correct to within one part in half a million, but there are so many complex sources of constant errors in this problem that such a statement means little. My present result exceeds the estimated probable error of my former result considerably, though it falls within the limit set by Prof. Rowland and myself for the possible error and noted in his paper on "Relative Wave-length" of the same date as my own. The cause of this discrepancy is partly due to the varying temperature under which the glass gratings were first measured, and partly to the change in the value assigned to the standard of length.*

Then too, the corrections applied to gratings II and III may be slightly in error. Taking into account all these sources of uncertainty it is my opinion that the above final result is not likely to be in error by an amount as great as one part in two hundred thousand.

* In terms of the length I originally assigned to $S^a{}_2$ the wave-length of D_1 would be 5896·14, while if the value deduced from the Berlin comparison were taken it would be 5896·22. The wave-length quite certainly lies between these values, but the proper weight to be given to the Berlin comparison relatively to the others is rather uncertain.

Taking the above value of the absolute wave-length and applying the appropriate corrections to some of the fundamental lines given in Prof. Rowland's paper (this Journal, March, 1886) the wave-lengths of the principal Fraunhofer lines in air at 20° and 760^{mm} are,

A (line between "head" and "tail" of group)	7621·31
B "	6884·11
C	6563·07
D_1	5896·18
D_2	5890·22
E_1	5270·52
E_2	5269·84
b_1	5183·82
F	4861·51

Comparisons between these wave-lengths and the older ones become somewhat uncertain toward the ends of the spectrum since the appearance of lines like A, B, G and H vary so much with the dispersion employed. The relative wave-lengths above given are certainly exact to within one part in half a million.

It may not be out of place here to discuss the most recent work on this problem. Just before the publication of my first paper the very elaborate paper of Müller and Kempf appeared. Their work is a monument of laborious research and it is unfortunate that so much time should have been spent in experiments conducted with glass gratings of small size and inferior quality. Since the invention of the concave grating, it is a waste of energy to make micrometric measurements with plane ones, and this statement could hardly be corroborated more strongly than by the relative wave-lengths given by Müller and Kempf. The probable error of their wave-lengths is in general not less than one part in two hundred thousand. That the value assigned by them to the absolute wave-length is as near the truth as it probably is, is due to no lack of faults in the gratings. Their results for the line D_1 were as follows:

Grating.	W. L.
"2151"	5896·46
"5001"	5896·14
"8001"	5895·97
"8001L"	5896·33

A discussion of these errors as exemplified in the paper under consideration would take up too much space to be inserted here, but one or two points are worthy of notice. When a grating gives different results in the different orders, it is evident that there are in it serious errors of ruling, and the maximum amount of the variation will give a rough estimate of their size as compared with those of other gratings. Applying this test, the four gratings rank as follows: "5001," "8001 L," ".2151," "8001," where the first which gave for the w. l. 5896·14, had no sensible variation in the different orders and the last, which gave 5895·97, varied in the most erratic fashion. It by no means follows, however, that because a grating gives identical results in the various orders, it is therefore free from errors of ruling. Witness Grating III of this paper in which the error was of a kind which could not be detected at all in the spectrometer. Yet it was large enough to give, if neglected, 5896·28 for the wave-length of D_1.* Speaking of errors in gratings a case in point is the work of Peirce. On account of the reasons heretofore noted Peirce's standards of length are somewhat uncertain in value so that no definite correction can be as yet applied to his wave-length from this cause. Three of his gratings, however, I have calibrated, and each of them showed an error tending to diminish the wave-length. If the mean result obtained from these had been assumed to be correct it would have been equivalent to the introduction of a constant error. Peirce's preliminary result is for this reason too large by more than one part in a hundred thousand; how much more, it is impossible to say without knowing the results obtained from each grating and so being able to apply the corrections found. Peirce's method was such as should have secured very excellent results and such will undoubtedly follow a further investigation of the standards and gratings. Still another recent determination is that by Kurlbaum, who used two good sized speculum metal gratings and measured them with particular care. Like the previous experimenters he neglected, although he did not ignore, the errors of ruling and consequently the results he obtained are somewhat in doubt. A serious objection, moreover, to his work is the very small spectrometer he used. To undertake a determination of absolute wave-length with a spectrometer reading by verniers to 10″ only, and furnished with telescopes of only one inch aperture is simply courting constant errors. More especially is this true since it would be hard to devise a method more effective in introducing the errors of ruling, than to use a grating with telescopes too small to utilize its full aperture, and then determine the grating space by measuring the total length of the ruled surface. Kurlbaum's gratings, too, were of an unfortunate size, 42 and 43^{mm} broad respectively, and consequently by no means easy to measure. On the whole his result, 5895·90 is not surprising.

* The results given by the gratings used by the author, neglecting the correction A would be as follows:

I, 5896·20; II, 5896·14; III, 5896·28; IV, 5896·12

Curiously enough the mean would be practically unchanged.

The agreement of relative wave-lengths as determined by different experimenters unfortunately gives no measure as to the accuracy of the work. The relative wave-lengths as determined by Müller and Kempf and by Kurlbaum agree in general to within 1 part in 100,000: the absolute wave-lengths assigned by these experimenters vary by more than 1 part in 30,000.

A very ingenious flank movement on the problem of absolute wave-length has been made by Macé de Lépinay. His plan was to use interference fringes in getting the dimensions of a block of quartz in terms of the wave-length, and then to avoid the difficulties of the linear measurement by obtaining the volume through a specific gravity determination. His results do not indicate, however, experimental accuracy as great as can be obtained by the usual method, and the final reduction unfortunately involves a quantity even more uncertain than the average standard of length, i. e., the ratio between the meter (?) and the liter.

It may be interesting here to collect the various values which have been given for the absolute wave-length within recent years. Results are for the line D_1.

Mascart	5894·3
Van der Willigen	5898·6
Ångström	5895·13
Ditscheiner	5897·4
Peirce	5896·27
Ångström corrected by Thalen	5895·89
Müller and Kempf	5896·25
Macé de Lépinay	5896·04
Kurlbaum	5895·90
Bell	5896·18

These figures are discordant enough. When beginning the present work, I had hoped that it would prove possible to make a determination of absolute wave-length commensurate in accuracy with the relative wave-lengths as measured by Prof. Rowland. This hope has proved in a measure illusory, by reason of the small residual errors of the gratings and the greater uncertainty involving the standards of length. I feel convinced, however, that the result reached is quite near the limit of accuracy of the method. It should be remembered that any and every method involves the uncertainty of the standards of length, an uncertainty not to be removed until a normal standard is finally adopted and exact copies of it distributed. And as far as experimental difficulties are concerned, the next order of approximation will involve a large number of small but troublesome corrections, such as the effect of aqueous vapor on atmospheric refraction, varying barometric height, the minute variations in the grating space, failure of thermometer to give temperature of grating exactly, and countless others which will suggest themselves only too readily.

Aside from the use of gratings, decidedly the most hopeful method as yet suggested is that due to Michelson and Morley.* Theoretically the plan is particularly simple and beautiful, consisting merely in counting off a definite number of interference fringes by moving one of the interfering mirrors and measuring, or laying off upon a bar, the resulting distance. The mechanical difficulties in the way, are however formidable, and whether or no they can be surmounted only persistent trial can show. The possible sources of error are of much the same type and magnitude as those involved in the comparison of standards of length, and if these errors are avoided, the uncertainty concerning the standards still remains. Whether or no the practical errors of the method are greater or less than with gratings only experience can prove. Certainly if the method is capable of giving exact results it is in the hands of one able to obtain them from it.

In closing this paper I can only express my sincerest gratitude to the various friends who have done all in their power to facilitate my work, and especially to Professor W. A. Rogers who has been tireless in his endeavors to determine the true value of the standards of length; to Mr. J. S. Ames, Fellow in this University, who has given me invaluable aid in the work with metal gratings; and to Professor Rowland who has furnished all possible facilities and under whose guidance the entire work has been carried out.

Physical Laboratory, Johns Hopkins University, March, 1888.

Art. XXXI.—*Three Formations of the Middle Atlantic Slope*; by W. J. McGee. (With Plates VI and VII.)

(Continued from page 330.)

The Columbia Formation.

General Characters.—The Columbia formation exhibits two phases which, although distinct where typically developed, intergraduate. The thicker and more conspicuous phase occurs commonly along the great rivers at and for some miles below the fall line, and may be designated the *fluvial* phase; while the thinner generally forms the surface over the remainder of the Coastal plain, and may be designated the *interfluvial* phase.

* This Journal, III, xxxiv, 427.

The first phase is bipartite, the upper division consisting of massive or obscurely stratified brick clay, loam, and fine sand, and the lower of stratified and cross laminated gravel and coarse sand, containing abundant erratic bowlders; while the second consists of an indivisible bed of gravel, sand, clay, etc., chiefly of local origin and thus varying from place to place though tolerably homogeneous in each exposure. The first phase, too, is confined to limited altitudes, approximately constant on each river but rising northward, while the second occurs indiscriminately at the highest and lowest altitudes within the Coastal plain, its thickness culminating at the lower levels and along the coast.

The Fluvial Phase.—The bipartite phase of the formation is well developed along all of the larger rivers of the Middle Atlantic slope, but most characteristically and extensively on the Potomac, the Susquehanna, and the Delaware.

The deposits on the Potomac.—Washington lies within a rudely triangular amphitheater opening southward, into which the Potomac falls from the northwest and the Anacostia from the northeast, the former passing from torrential to estuarine condition and turning southward within the limits of the city. The western side of the amphitheater is the Piedmont escarpment, which south of the city is a terraced or irregular slope rising to a somewhat undulating plain 200 to 425 feet in altitude; the eastern side is the line of bluffs overlooking the Anacostia and rising into two broad terrace plains 175 and 275 feet in height respectively; and the northern confine is the deeply ravined margin of a terrace 200 feet in altitude stretching from the breach made by the Potomac in the Piedmont escarpment directly eastward to the broader valley of the Anacostia three or four miles above the confluence. The floor of the amphitheater is a series of low terraces rising from a few feet below to about 100 feet above tide, the most conspicuous two being about 40 and 80 feet in altitude respectively. To the southward the amphitheater opens into a broad valley occupied partly by the Potomac estuary and partly by a low but extended series of terraces, of which the best developed members are about 20 and 40 feet above tide respectively.

Throughout this amphitheater the fluvial phase of the Columbia formation is the prevailing superficial deposit up to 150 feet above tide; except where manifestly eroded or buried beneath modern alluvium, it is everywhere exposed; all of the lower and many of the higher terraces are built of it; and it unquestionably lines the estuaries of both the Potomac and the Anacostia beneath the recent alluvium. The relation between the deposit and the topographic configuration is striking, and too intimate to be fortuitous. Everywhere west of the Anacostia-Potomac channel (the deposit does not occur east of the rivers) the limiting boundary of the fluvial phase of the formation is the 150 foot contour; and the limit within which it exhibits a certain notable and well defined type is the 90 foot contour.

Within the amphitheater the formation varies considerably in structure and composition and in the relative thickness of the two members—the basal member being best developed centrally and near the entrance to the Potomac gorge, and the superior and finer member reaching the best development and greatest volume peripherally and at points distant from the gorge. The section in the central part of the city of Washington is, however, typical; and two exposures so located, which together form a general section of the fluvial phase of the formation, are shown in the accompanying plates.

Plate VI is reproduced mechanically (by the Moss process) from a photograph of the exposure on the north side of E street between 1 and 2 southeast. The upper member is homogeneous loam, rather too sandy for use as a brick clay, either massive or obscurely stratified, containing a few small pebbles irregularly disseminated or arranged in layers. On mechanical analysis the loam is found to consist of (1) fine silty or clayey particles of impalpable fineness, intimately mingled with (2) sand grains of variable size, form and composition, and with (3) gravel of all sizes from that of coarse sand to that of the pebbles shown in the plate; the relative proportions being perhaps 50 per cent of impalpable clay and silt, 35 or 40 per cent of sand grains up to $\frac{1}{8}$ inch in diameter, and the balance gravel grains and larger pebbles. The homogeneous loam graduates downward imperceptibly into obscurely stratified sandy and gravelly loam in which sand from $\frac{1}{8}$ inch downward constitute some 40 per cent, gravel from $\frac{1}{8}$ inch upward about 30 per cent, pebbles from an inch upward perhaps 20 per cent, and impalpable silt not more than 10 per cent of the volume—the structure remaining unchanged save that the stratification becomes more and more distinct toward the base. The gravelly loam graduates in turn into a bed of stratified sand and fine gravel, sometimes cross-laminated, with occasional pebbles up to 3 or 4 inches disseminated through it. This bed is practically destitute of impalpable silt, and is screened for building sand. The stratified sand passes rather abruptly, but with some interstratification, into a heterogeneous mass of coarse sand, gravel, pebbles and bowlders up to a foot in diameter.

Plate VII, also reproduced mechanically from a photograph, supplements Plate VI. The exposure occurs on the opposite side of the street and, extending nearly to the base of the Columbia formation, exhibits the typical aspect of the lower member—the greater part of the superior loam having been artificially removed long before the recent excavation was made. The uppermost stratum consists of pebbly and sandy loam corresponding to but somewhat coarser than the basal portion of the upper member in Plate VI; and in this section, too, the stratum graduates insensibly into stratified sand, which in turn passes imperceptibly into the gravel bed at the summit of the lower member.

The gravel deposit constituting the lower member is distinctly but irregularly stratified and rather indefinitely tripartite. The uppermost stratum is a bed of gravel and sand similar to but thinner than that above the stratified sand, containing rounded and sub-angular bowlders up to over a foot in diameter (commonly arranged in beds), lenticular layers and pockets of sand, etc.; the next stratum is a regularly bedded mass of clay and loam, evidently derived largely from the Potomac formation, which is locally inclined; and finally at the base there is another bed of gravel (imperfectly shown in the plate) resting on an irregular surface of purple-brown Potomac clays. Combining the three strata and analyzing their constituents, it is found that perhaps 20 per cent consist of pebbles and bowlders from an inch to a foot or more in diameter, some 25 per cent of gravel and pebbles from $\frac{1}{8}$ inch to one inch in diameter, about 30 per cent of finer sand, and the remainder (including the redeposited Potomac clay) of impalpable silt or clay; and examination of the pebbles and bowlders shows that nearly all of the larger are angular or sub-angular and either of Piedmont gneiss or of quartz undistinguishable from the vein quartz of the Piedmont zone, while 75 or 80 per cent of the smaller are well rounded and of quartz and quartzite similar to those of the lower member of the Potomac formation.

These sections occur about three miles southeast of the gap cut by the Potomac river in the Piedmont escarpment, and in the line of the old outer gorge. Nearer the gap the superior member attenuates, and the gravel bed thickens and becomes coarser until in some sections fully one-half of the formation is made up of pebbles and bowlders up to four or five feet in diameter; to the eastward the loam increases in thickness and homogeneity, its pebbles disappear, and the stratification becomes more regular, while the basal member attenuates and the pebbles and bowlders of which it is composed diminish gradually both in size and abundance; to the southward and further from the gap the upper portion of the loam is a homogeneous brick clay, its lower portion is a stratified sand, and the lower member of the formation is represented only by a thin bed of gravel and small bowlders; and still further southward, as at Alexandria, the superior loam becomes fine and silty, and there is but an inconspicuous bed of pebbles, with no large bowlders, at the base.

Most of the materials composing the formation in the Washington amphitheater may be readily traced to their sources: nine tenths of the larger angular and sub-angular bowlders are either (1) gneiss identical with that exposed in the gorge of the Potomac river within a few miles to the westward, or (2) quartz undistinguishable from that of the veins intersecting the gneiss; the well rounded quartz and quartzite pebbles are indistinguishable from those of the Potomac formation, and indeed in some cases Potomac outliers unquestionably *in situ* graduate insensibly into taluses which descend the slopes and in turn graduate into the Columbia gravels; the intercalated layers of plastic clay and accumulations of arkose are lithologically identical with certain characteristic phases of the Potomac formation; the sand, clay and loam sometimes resemble the residuary products formed by the disintegration of the adjacent Piedmont gneisses *in situ* so closely as to be distinguished only by structural features; and in all cases the petrographic identity is unquestionably indicative of the source of the material.

The Genesis of the Deposits.—An essential element in any philosophic classification of the rocks of the earth is genesis, and geologic science has now reached a stage in which processes and products, agencies and results, are commonly correlated, and in which at least the broader classifications are genetic.

There are recognized five principal categories of agencies by which the various superficial deposits of the earth are produced, viz: chemic, igneous, glacial, aerial and aqueous.

Now on comparing the upper member of the fluvial phase of the Columbia formation with the known products of each of these categories of agencies, it becomes evident that the deposits were not produced by either of the first two classes of agencies, since they have no distinctive features in common with chemic and igneous deposits; that they are not glacial, since they are too regularly and continuously stratified, since the two members are distinct in structure and composition and yet intergraduate, and since the pebbles and bowlders are neither striated nor polished; that they are not aerial since the materials are coarser and more continuously bedded than those transported by winds; and hence that the deposits are aqueous in origin. By legitimately extending the same process of reasoning it might equally be shown that they are not fluviatile, torrential, lacustral, nor marine, and indeed that they can only be a sub-estuarine delta of the river on which they occur.

The same conclusion is reached by the converse process of reasoning. At Washington the Potomac river passes from fluviatic to estuarine condition, and the materials transported by the river proper are precipitated in the estuary. The opportunities for examination of these sediments are limited, because they are seldom exposed above tide level (subaerial alluvium being significantly absent along the fall line margin of the Coastal plain); but the numerous borings made in engineering operations indicate that the sub-estuarine deposits opposite Washington consist predominantly of fine silt or clay, and subordinately of sand and gravel, with occasional pebbles and bowlders of considerable dimensions either scattered or in beds. In brief, the deposits of the Potomac estuary of the present at Washington differ from the upper division of the fluvial phase of the Columbia formation only in the larger proportion of silt and the smaller size of interspersed bowlders; and below Washington the modern estuarine deposits become progressively finer to and beyond Alexandria, just as do the deposits of the Columbia formation. Now the precise conditions of genesis of the modern sub-estuarine deposits are known: the silt is carried down the river and into the estuary at all stages but most abundantly during freshets to either settle immediately in the slack water or sweep back and forth with the tide until flocculation and more gradual deposition finally take place; the fine sand is similarly transported into the estuary and dropped toward its head; most of the coarse sand, gravel and pebbles are swept over the falls or collected in the gorge of the Potomac by the raging torrent which the river becomes during its freshet stages, and are quickly deposited in the upper part of the estuary; while the larger pebbles and bowlders, together with some of the smaller, are gathered along the river and floated into the estuary by the ice floes with which the torrent is laden during spring freshets; and the distribution of the various materials, fine and coarse, is affected by the strength of the currents, by local eddies and basins, and by distance below the mouth of the gorge, while the area of deposition is determined by present tide level. Were the land in the vicinity of Washington to be elevated 150 feet, and were this level to be maintained until the sub-estuarine deposits now in process of formation were dissected by erosion, desiccated by draining, and decolored by oxidization, they would unquestionably form a homologue of the upper member of the Columbia formation, differing from it only in coarseness of materials and in geographic extent; and the modern deposit, like the older, would rise upon the valley sides to the shore line contour, and its surface would similarly form a broad terrace plain.

The altitude of the old delta now exposed as the Columbia formation indicates submergence of about 150 feet during the period of its deposition; and such submergence is attested not only by the deposits but by an extensive system of terraces. The Columbia formation itself forms, within the Washington amphitheater, two distinct terrace plains, modified by erosion and culture yet each miles in extent, together with several others of less area; the upper level of the deposit is marked by broad shore lines on both sides of the head of the estuary and by a rock shelf in the gorge of the Potomac half a mile in average width and fifteen miles long; southwest of Washington there is a wave-fashioned plain, 220 feet above tide, which is more than twenty-five square miles in area and so little modified by erosion that considerable tracts are imperfectly drained; a more deeply ravined plain of like altitude five square miles in area forms the marginal portion of the Piedmont plateau to the northward of Washington; beyond the Anacostia there are equally distinct terrace plains, that of 175 feet above tide at St. Elizabeth's Insane Asylum being so imperfectly invaded by erosion and so level to the very verge of the river bluffs that drainage is imperfect over fully a square mile of its area; and in many other localities, and at all altitudes up to 250 feet or more, broad terraces abound. The extensive terracing of the tract gives origin to a striking topography of plains and scarps, through which profiles, drawn in any direction, exhibit characteristic combinations of horizontal lines and steep slopes. Independently of the deposits, the terraces and shore lines in the Washington amphitheater prove submergence of the land to a depth of over 250 feet—the deposits at the highest levels representing rather the interfluvial than the fluvial phase of the Columbia formation.

While nothing more than comparatively brief submergence of 150 or more feet was required to produce the upper member of the Columbia formation, other conditions were required to produce the coarse lower division, which differs materially in composition from the sediments now laid down in the Potomac estuary; but since the abundance and size of the pebbles and bowlders now swept into the estuary are determined by the amount and thickness of the ice floated into it during the spring freshets, it is evident that the chief additional condition required for the deposition of the coarse materials of the older formation was diminution of temperature and consequent increase in floe transportation with, perhaps, concurrent strengthening of fluvial currents. It might accordingly be safely inferred from the phenomena of this tract alone that the lower member of the formation was deposited during a period of low temperature. The refrigeration thus suggested by the deposits of the Potomac river is proved by those of the Susquehanna and Delaware; and since the bowlders of the lower Columbia at Washington are fully twenty times as large and abundant as those brought down in the spring freshets of to-day, the diminution in temperature must have been considerable.

In brief, it is evident that the Columbia formation within the Washington amphitheater is a sub-estuarine delta deposited when the sea rose at least 150 feet higher, and the temperature was considerably lower, than to-day.

The Deposits on the Susquehanna.—About its locus of transition from fluvial to estuarine condition (for Chesapeake bay is simply the estuarine portion of the river), the Susquehanna is flanked by an extensive bipartite deposit, the upper member of which consists of loam with occasional disseminated pebbles and small bowlders, while the lower is a great mass of coarse sand and gravel interspersed with large bowlders. The distribution of the deposit, vertical and horizontal, is limited by the 240-foot contour, and it is typically developed only below the 120-foot contour; the most abundant materials of determinate source are bowlders from the Piedmont and Appalachian regions, and well-worn quartzite pebbles from the subjacent Potomac formation; the entire area is extensively terraced; and in general the phenomena duplicate those of the Potomac river. They are described in detail and fully illustrated elsewhere.*

Certain minor differences between the Susquehanna and Potomac deposits are noteworthy. The former reach far the greater volume, the thickness being thrice and the area twice as great as on the Potomac; the bowlders of the lower member are much larger—the largest being from 100 to 200 cubic feet in dimensions, or fully three times as large as those found on the Potomac and 50 times as large as those now transported into the bay in vernal ice-floes; the materials of the upper member are finer than on the Potomac, and consist in part of mechanically divided but undecomposed carbonate of lime, which either forms a calcareous cement or segregates into calcareous nodules resembling loess-kindchen; indications of iceberg action are found in the deposits; and a much larger proportion of the pebbles and bowlders of friable rock are sharply angular and evidently ice-transported. The resemblances between the deposits on the two rivers in structure and composition, in geographic and hypsographic distribution, and in all other distinctive characters, indeed, prove that they are homogenetic—i. e., that the Columbia formation on the Susquehanna

* "Notes on the Geology of the head of Chesapeake Bay," 7th An. Rep. U. S. Geol. Survey (in press).

as on the Potomac is a sub-estuarine delta laid down during a period of cold and submergence; and the differences prove that the submergence and the refrigeration were both the greater on the former river.

Above the fall-line the Susquehanna, unlike the Potomac, is flanked by deposits corresponding to the sub-estuarine delta. Between Columbia and its mouth, it is true, the river flows rapidly through a steep-sided gorge of considerable depth, the tributaries have high declivity, and superficial deposits are not preserved; but above Columbia the valley widens, its slope diminishes, and remnants of slack water deposits appear. Four miles above Harrisburg the river breaks through Kittatinny mountain in a widely-known water-gap, and embouches upon a slightly undulating terraced plain 100 to 200 feet above its level; and the prevailing superficial deposit over this plain is loam or brick clay passing down into a gravel or bowlder bed. A representative section of the prominent terrace half a mile northeast of Harrisburg is as follows:

1. Fine loam, massive above and horizontally laminated below, with a few disseminated pebbles and layers of sand toward the base, largely used as a brick clay.............. 7 feet.
2. Irregularly stratified gravel, comprising pebbles (commonly rounded) from 3 inches downward, imbedded in a matrix of coarse brown sand, the shale deeply ferruginated and sometimes cemented............................ 4 feet.
3. Stratified coarse brown sand abounding in pebbles and bowlders.. 3 feet.

The three members are here sharply demarked, but elsewhere intergraduate.

Save that these deposits at Harrisburg are somewhat thinner, that the bowlders are smaller, and that they are without Piedmont crystallines, they are scarcely distinguishable from those about the head of Chesapeake bay. There is the same brick-red color, the same degree of ferrugination, the same bipartition and the same structure in each member, the same black ferruginous cement uniting and staining the pebbles, the same intergraduation of the members, and indeed so close similarity in all essential respects that either deposit might be accepted as the type of the other. And the deposits at Harrisburg are representative of those of a considerable area: the tract mantled with brick clay and gravel on the north side of the river below the Kittatinny water gap is 10 miles long and 5 miles wide, and the area of the deposits on the south side of the river is nearly as great. Above the water gap the deposits are still more largely developed; mile after mile the Susquehanna is flanked by gently sloping plains descending nearly to the river and then dropping suddenly to its flat bottomed gorge, and everywhere except in the sharper ravines and larger tributary valleys the deposits prevail, and the altitude to which they rise progressively increases up the river; within its hypsographic limit the formation in the Susquehanna valley is nearly as continuous and distinctive as the glacial drift of the northern part of the state, and its influence upon the industries of its area is equally important.

The relations of these deposits to the terminal moraine and the relations of both to the topography are significant, and are well exhibited in the Susquehanna valley about Berwick and Bloomsburg. The broad features of the region, like those of the inter-montane Appalachian valleys generally, comprise old base level plains of considerable uniformity, bounded by mountain ranges, sharply incised by waterways cut down to a newer base-level. The principal waterway is the broad, steeply bluffed outer gorge of the pre-morainal Susquehanna. This gorge is partly filled with the overwash gravels from the moraine; and in these gravels the narrow inner gorge of the present river is excavated.

Three miles above Bloomsburg the old base-level plain is 5 or 6 miles wide, gently undulating, and 200 to 300 feet above the river, which follows its southern side (fig. 1). The entire plain is covered with a sheet of fine loam or brick clay similar to that of Harrisburg, and like it graduating downward into stratified sand or gravel containing well rounded bowlders of quartzite and other sub-local rocks up to a foot or more in diameter. On approaching the river this plain breaks down sharply in an abrupt escarpment, 75 to 100 feet high, overlooking the pre-morainal valley, the loam and gravel extending to the verge of the escarpment but failing below. This outer

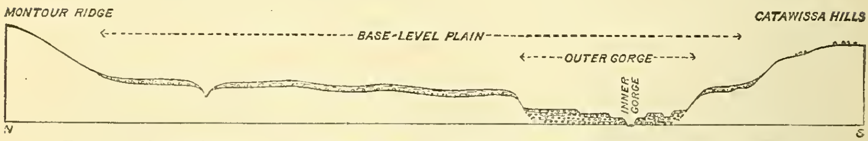

FIG. 1.—Cross-Section of Susquehanna Valley between Bloomsburg and Berwick.

valley of the Susquehanna is perhaps one and a half miles wide, and is lined to an undetermined but considerable depth with rounded pebbles and cobbles, sometimes interstratified with or overlain by fine gravel, sand or loam—the whole representing the overwash materials from the terminal moraine; and the valley bottom descends by step-like terraces of wonderfully sharp contour and fresh aspect to the narrow inner gorge within which the river tumbles and dashes over a bed of similar pebbles and cobbles. South of the river the surface rises rapidly to the plateau-like summit of the Catawissa hills; and patches of loam similar to that forming the surface north of the river occasionally appear on the slope from 100 to 250 feet above the channel, and the hill-tops, 500 feet and less above the river, are dotted here and there with well rounded quartzite pebbles and bowlders two feet or more in maximum dimensions; the isolated loam patches and scattered bowlders alike representing residuary traces of a once continuous formation now largely removed.

The overwash gravels are stratigraphically continuous with and graduate imperceptibly into the terminal moraine, and are manifestly the product of a rapid glacier-born stream with considerable declivity. The loam of the base-level plain, on the other hand, is unquestionably a deposit of slack waters; but it contains a notable element of partly oxidized rock-flour (like that found at the head of Chesapeake bay), evidently of glacial origin. Moreover, the high-level bowlders at the base of, or incorporated within, the loam are much larger than those transported by the present river, and were evidently distributed by floating ice of greater thickness than that now formed in the same region. Both members of the formation thus attest contemporary climatal refrigeration.

As already indicated the high-level loam of the Bloomsburg-Berwick section is continuous—save where locally cut off by mountain ranges rising above its altitude—down the river to Harrisburg, and the residuary cobbles and bowlders occur at intervals over the slopes and within the inter-montane valleys from which the loam has disappeared; while the newer overwash gravels attenuate, their altitude diminishes, the materials become finer, the terraces merge and finally disappear, and the entire deposit fails above river level and the inner gorge is completely lost, about the confluence of the Western Branch at Northumberland. Traced up stream the loam and the residuary bowlders of the Columbia formation persist to the terminal moraine where the soft contours of the loam-mantled plain disappear beneath the knobby-surfaced moraine, and both loam and bowlders are incorporated in the moraine material; while the overwash gravels lining the outer valleys lose their distinct terracing, the cobbles increase in size and become less and less perfectly rounded, the materials become more and more heterogeneous until they too merge into the terminal moraine, and the entire valley is finally filled with aqueo-glacial gravels to a height of 250 or 275 feet above the present level of the river and to an unknown depth below.

While the gravel and cobble deposit is simply the overwash from the terminal moraine, the loam and high level residuary gravels evidently represent a distinct and far older formation:

the older deposit is bipartite, while the newer is indivisible; the loam of the older is unquestionably a slack water deposit, while the well rounded pebbles and cobbles of the newer were just as unquestionably assorted and deposited by rapid currents; the older deposit rises to altitudes of 500 feet above the level of the river, while the lower attains a maximum altitude of only 275 feet; the outer gorge of the Susquehanna has evidently been excavated in obdurate paleozoic rocks since the older deposit was laid down, while the work of the river since the deposition of the newer has been limited to the excavation of the far smaller inner gorge in unconsolidated gravels; the older deposit has been deeply dissected by the tributary waterways, and its slopes are softened and its escarpments rounded by weathering, while the same tributaries, despite their high declivity, have cut but trifling channels in the newer deposits, and the terrace scarps yet remain sharp-cut; the older deposit is everywhere deeply oxidized and ferruginated and its exposed bowlders of obdurate quartzite decolored and sometimes disintegrated, while the materials of the newer deposit are fresh and bright; and the older deposit everywhere passes beneath the terminal moraine into which the newer merges.

The relation of the loam and high level bowlders to the valley of the Susquehanna is significant. The river of the present is commonly unnavigable, and flows in a succession of rapids and intervening pools in a broad, shallow, rock-bottomed channel, with an average declivity of over two and one-half feet per mile: it is preëminently a transporting and corrading stream; and its local and temporary deposits are coarse. Yet the loam by which the valley sides are lined is evidently a deposit of slack waters, and the associated cobbles and bowlders appear to have been dropped from floes floating upon comparatively still waters; and the altitude of the deposits progressively increases northward. To produce such a change in the regimen of the Susquehanna as the Columbia phenomena indicate would require submergence of 240 feet at its mouth and fully 500 feet at the terminal moraine, and the transformation of its rock-bound gorge into an estuary, tidal to the Kittatinny water-gap at least.

The testimony of the Susquehanna phenomena corrborates and supplements that recorded in the Washington deposits, in that they are not only indicative of land submergence and coeval cold but prove (1) that the period of submergence was one of northern glaciation, (2) that this glacial epoch was long anterior to the one during which the terminal moraine was formed, and (3) that the submergence increased northward.

The Deposits on the Delaware.—As shown by the researches of Lewis and Chester, at Philadelphia and in northern Delaware respectively, Delaware river and bay are flanked on the west from Philadelphia to Dover by a deposit of brick-clay or loam passing into gravel below—the Philadelphia Brick Clay and Red Gravel of the former author, and the Delaware Gravels of the latter. The deposits have been described in detail by these authors, and it will suffice to add that not only in general characters but in the less conspicuous features detectable on minute examination they are undistinguishable from their homologues in corresponding position on the Susquehanna and Potomac; the structure and composition are similar, the geographic and hypsographic distribution are alike, there is equal lixiviation and ferrugination, like ravining by erosion, the same extensive terracing, etc.; the only noteworthy difference being the somewhat greater altitude of the Delaware deposits, and the occasional presence of far transported northern pebbles and bowlders in their lower portion.

North of Philadelphia the Delaware deposits exhibit certain noteworthy characteristics allying them with those of the upper Susquehanna. Over the gentle river-ward slopes of eastern Montgomery and Bucks counties, Pennsylvania, more or less conspicuous accumulations of loam or brick clay occur up to altitudes of 250 feet or more; and well rounded bowlders occasionally appear at even greater altitudes. Within 100 feet above tide the deposits are practically continuous and extensively terraced—*e. g.*, there is at Trenton a sharply defined terrace 80 feet in altitude composed of homogeneous brick clay passing downward into a bowlder-bed, through which the Delaware has cut its modern gorge; and the celt-yielding Trenton gravels fill a basin lined with these older Quaternary deposits. Still farther northward the brick-clay or loam, with associated cobbles and bowlders, are found at progressively increasing altitudes; they occur in every inter-montane valley on the Delaware to the terminal moraine at Belvidere; and they are found on both sides of the Lehigh from its mouth to the water-gap, the loam being largely utilized in brick manufacture at Allentown and elsewhere.

The cross-section of the Delaware valley five miles below Belvidere is in all essential respects a duplicate of the Bloomsburg-Berwick cross-section of the Susquehanna shown in fig. 1: there is the same loam-lined base-level valley 200 to 300 feet above the river, with scattered quartzite bowlders up to at least 400 feet; within this valley there is excavated, through loam and subjacent rock, an outer gorge at least a mile and a half wide; this outer gorge is bottomed with well rounded and current-sorted overwash gravels from the terminal moraine; and the sharply cut inner gorge of the present river, quarter of a mile wide and 50 feet deep, has been carved in the newer gravels. To the northward the high level loam and bowlders pass beneath the terminal moraine, and the overwash gravels graduate into the hillocky debris of the drift-lined valley as on the Susquehanna; and as on that river too the overwash gravels rapidly diminish in size and abundance down stream, the terraces meantime merging and decreasing in height, until both practically disappear above water level 10 miles below Belvidere. Local accumulations of the overwash gravels occur, however, at various lower points on the river, the last and most conspicuous being at Trenton, where the later-glacial Delaware river opened into a broad estuary in which the vernal ice-floes dropped their debris gathered at the ice front.

On the Delaware, as on the Susquehanna, the two series of superficial deposits—the moraine with its derivatives and the terraced brick clay with its gravels—are perfectly distinct and widely diverse in age; and here, too, the deposition of the loam and high level gravels must have been accompanied by transformation of the Delaware river from a rapid unnavigable stream abounding in cascades and rapids, to a tidal estuary miles in width within which fine silt and clay were dropped, and upon which bowlder-bearing ice-blocks floated—the land-submergence reaching fully 400 feet in the latitude of the terminal moraine.

The Deposits on other Rivers.—Every considerable stream of the Middle Atlantic slope has at the fall-line a conspicuous deposit analogous to those of the Potomac, Susquehanna, and Delaware; and while the deposits vary in volume with the streams, the structure, the composition, the geographic and hypsographic relations, etc., remain constant or change slowly with latitude. The Schuylkill and Brandywine deposits merge into those of the Delaware, but in their up-stream extension are distinguishable therefrom by the abundance of local and the sparseness of northern materials; the deposits of Elk and Northeast rivers are distinguishable from those of the Delaware on the one hand and of the Susquehanna on the other by the preponderance of local materials, and at low levels by their independent terrace systems; the Patapsco deposits merge into those of the Susquehanna at Baltimore, but local pebbles in the lower member and the preponderance of local residuary debris in the upper give individuality to the Patapsco delta, which in structure, composition, and general aspect, is undistinguishable from that of the Potomac river at Washington; the two branches of the Patuxent have beautifully terraced deltas exhibiting characteristic bipartition and all of the diagnostic features of the fluvial phase of the Columbia formation; and the Anacostia has an independent but homologous system of deposits and terraces made up predominantly of materials derived from the marginal portion of the Piedmont area.

South of the Potomac river the deposits and terraces remain conspicuous, though their maximum altitudes diminish: Occoquan river, Acquia creek, and neighboring streams have well-marked terrace-systems built of deposits of uniform structure, though each deposit is made up of the materials traversed by the individual stream; the Rappahannock valley is fashioned into terraces miles in extent and flanked by brick clays passing into gravel and bowlder beds made up of the Piedmont rocks and well-rounded gravel derived from the adjacent Potomac beds, the whole resembling the delta of the Potomac river so closely that a typical section in one would equally represent the other; the Taponi and the Mat have corresponding deltas which unite and flank the Mattaponi for miles, and the two Anna rivers exhibit similar deposits of greater volume merging along the Pamunkey; the superficial deposits about the head of tide in James river are so similar to those of the Potomac that Plates VI and VII could be almost exactly duplicated there, though the area of the delta is somewhat greater and its altitude somewhat less than that of the latter river; the Appomattox has its elevated delta which merges into that of the James, but is distinguished in the vicinity of Petersburg by an independent system of terraces and by the preponderance of local rocks; the Nottoway and Meherrin also exhibit well-developed deposits of the usual bipartite structure, as do the smaller streams, Rowanty, Stony, and Fontaine; and finally the Roanoke embouches from its narrow Piedmont gorge into a tidal estuary flanked by low bluffs built of or capped by the prevalent brick clay and gravel with local bowlders.

The maximum altitude of the deposits, which is 500 feet on the Susquehanna and 400 feet or more on the Delaware, diminishes southward to perhaps 275 on the Schuylkill, 245 at the mouth of the Susquehanna, 145 feet (with inconspicuous deposits somewhat higher) on the Potomac, 125 feet on the Rappahannock, 100 feet on the James, and 75 feet on the Roanoke; and as already pointed out,* the maximum size of the bowlders in the lower member, as compared with those now transported by the rivers, diminishes from 50:1 on the Susquehanna to 20:1 on the Potomac, 10:1 on the Rappahannock, 5:1 on the James, and 2 or 3 times the present volume on the Roanoke.

Recapitulation.—Briefly, the deposits along the Middle Atlantic slope rivers about their loci of transition from fluvial to estuarine condition are so closely similar that not only will the description of a typical section on one waterway apply to those of all the others, but it would in most cases be difficult to determine from the most minute examination which stream

*This Journal, III, xxxiv, 219, 1887.

a particular specimen or section represents; the differences are limited to systematic variation in altitude and coarseness, to variation in volume (which is proportional to that of the streams on which the deposits occur), and to inconspicuous variation in composition resulting from the incorporation of (1) local materials on each river, and (2) rock-flour and other glacial debris on the more northerly rivers. The deposits are evidently contemporaneous and homogenetic; the structure, composition, geographic and hypsographic distribution, terracing, and other features of each independently proves that it is a sub-estuarine delta formed during a brief period of land-submergence and refrigeration, increasing northward; and the relations of the various deltas to the terminal moraine and other deposits prove that this period was long anterior to that of the last ice-invasion.

The Interfluvial Phase.—Character and Distribution.—The fan-shaped deltas flanking the Middle Atlantic slope rivers at the fall-line attenuate down stream and toward their peripheries, and either disappear in feather edges along ascending slopes, or merge into a distinctive deposit by which the interfluvial portion of the Coastal plain is generally mantled. This deposit, unlike the complementary and more conspicuous one developed only along the rivers, is variable in composition and inconstant in structure, and has a wide range in hypsographic distribution. Four leading structural types, ranging in altitude from 100 feet in the south to 400 feet in the north down to tide level, may be discriminated.

1. As exposed in the terraces and shore lines in the vicinity of the fall-line, the deposit consists of a heterogeneous and irregularly bedded mass of sand, gravel and bowlders fringing the terrace, and increasing in thickness from perhaps a foot or two upon the terrace plain to five, ten, or fifteen feet along the scarp; the materials being predominantly local, and evidently derived largely from contiguous portions of the terrace-plain but intermingled with loam, pebbles and bowlders similar to those of neighboring deltas. Similar accumulations occasionally fill old ravines and other depressions in the formerly irregular surfaces now smoothed into terrace-plains. This type of the deposit is well exhibited in the scarp of an extensive terrace near Washington (in a cutting on the Falls Church road), and in the cuttings in the northeastern part of the same city on Benning's road; but such exposures are common, and those observed and noted between the Roanoke and the Delaware are numbered by scores. They frequently occur above the maximum altitude of the fluvial phase of the formation in the same latitude.

2. A second type is exhibited only in northern New Jersey

and on the marginal portion of the Piedmont zone at altitudes reaching 250 feet or more. It consists of great beds of well rounded quartzite cobbles a foot or less in diameter, together with many smaller pebbles, generally imbedded in reddish loam. A representative locality is the plateau (100 to 150 feet above tide) between Harlingen and Rocky Hill and five or six miles north of Princeton, where, over an area of several square miles, well rounded quartzite cobbles cumber the fields and are heaped up along the lanes in great winrows sufficient to fence the farms and pave the roads.

3. The type of the deposit into which the deltas commonly merge is a confused and heterogeneous mass of sand, gravel, and pebbles of obscure or inconstant structure, the materials evidently derived in larger part from the sub-terrane and in smaller part from the contiguous deltas, and the thickness ranging from a foot or two to perhaps fifteen or twenty feet. In the south the materials are predominently fine, comprising sand, clay and silt interspersed with occasional pebbles up to three or four inches in diameter, with a few intercalated sheets of gravel; while in the north the deposit is predominently coarse and gravelly, especially toward the northern extremity of the Coastal plain where it has been recognized by Cook, Lewis and Chester as "Southern Drift," "Yellow Gravel," "Delaware Gravels," etc.; and in a general way it varies in coarseness and in thickness from the fall-line to the coast, the thickness increasing and the coarseness diminishing seaward. This is by far the most extensive type of the deposit; it covers perhaps three-fourths of the area of the Coastal plain; but despite its vast extent, good exposures are uncommon. Those at Ordinary Point on Sassafras river, in northern New Jersey, and on Long Island (described elsewhere by the writer, Cook and Merrill, respectively), are, however, representative of the latitudes in which and the altitudes at which they occur.

4. At low levels, especially along the coast, the deposit becomes fine, assumes moderately regular stratification, attains considerable thickness, and yields recent fossils. This type has been described by W. B. Rogers in eastern Virginia, Tyson in peninsular Maryland, Booth and Chester in southern Delaware, Conrad in New Jersey and southern Maryland, Merrill on Long Island, and others in different localities, and does not require extended notice here.

Summarily, the interfluvial phase of the formation consists of a mantle of either heterogeneous or definitely assorted and deposited material, largely local but partly erratic, overspreading the Coastal plain (except along the water ways), from the Roanoke to the Raritan, and encroaching upon the Piedmont region in the north; this general mantle merges into the elevated deltas of the fluvial phase on the one hand, and into the modern alluvial, estuarine and marine deposits on the other; and it is either buried beneath or broken up and incorporated within the terminal moraine in its northward extension.

Sources of Materials.—The prevailing materials of the deposit may be roughly classed as (1) well rounded cobbles and pebbles, such as those of northern New Jersey; (2) well rounded quartz and quartzite gravel, such as overspreads peninsular New Jersey; (3) fine gravel and sand, clean or intermixed with clay or silt, forming a matrix in which the coarser materials are imbedded, and constituting the great bulk of the deposit, particularly in the south; (4) loam, resembling that of the upper division of the fluvial phase, and exemplified by the high level red loams of northern New Jersey and southeastern Pennsylvania; and (5) clay and silt, generally stratified and limited to low altitudes. The sources of the first two of these classes are precisely, and those of the next two proximately, determinate.

1. The cobbles of northern New Jersey are in form and material identical with, and in size generally smaller in a graduating series than, the high level bowlders of the fluvial phase along the Delaware; both are identical lithologically with the axial quartzites of the southeasternmost Appalachian ranges; and both cobbles and bowlders not infrequently contain fossils identical with those of the quartzite ridges. The erratics, it is true, are commonly more profoundly metamorphosed than the parent ledges; but they obviously represent the most obdurate portions of these ledges, and moreover examination shows that in many cases the metamorphism is superficial and produced by interstitial growth after the manner described by Irving, while the interior remains in the same condition as the quartzites now found *in situ*. Some of these cobbles doubtless formed originally a part of the Potomac formation, and were removed from it and redeposited during the Columbia epoch; but others appear to have been derived directly from the quartzite ranges whose bases were washed by the floe-bearing Columbia waters, and whose ledges were shattered by the Columbia cold. Certainly the angular blocks now cumbering the upper mountain slopes, and the smaller and well-rounded cobbles imbedded in the Columbia formation, are but the extremes of a graduated series whose continuity can be readily traced along either the Delaware or the Lehigh.

2. Save that its average size is slightly smaller, the well-rounded gravel of peninsular New Jersey and the Maryland-Delaware peninsula is identical in all physical characters with that of the Potomac outliers skirting the Piedmont escarp-

ment from the James to beyond the Schuylkill; there is not a fossil nor a rock-variety in one that cannot be duplicated in the other; the materials are sometimes absolutely undistinguishable in hand-specimens or in extensive sections except by general structural features; and in some cases the high-level gravels of the Potomac outliers may be traced continuously into the low-level gravels of the Columbia. The lower member of the Potomac formation is the great gravel source of the Middle Atlantic slope, and has furnished materials for upper Potomac, Cretaceous, Eocene, and Miocene gravel beds; but during the Columbia period of delta-deposition the waves of the ocean beat upon its unprotected outliers between the Rappahannock and the Raritan, and especially between the Susquehanna and the Delaware, and its contributions were larger than ever before. By petrography, by paleontology, by structural continuity, and by physiographic relations, it is proved that the source of the mysterious gravels of the northern Coastal plain are derived from the Mesozoic gravel-heaps of the adjacent Piedmont margin.

3. In a general way the fine gravel and sand may be traced by petrographic similarity to the immediate sub-terrane and to the terranes traversed by the nearest great water-ways; and in some cases—*e. g.*, where they consist of redeposited Potomac arkose with little admixture of foreign matter—the exact source may be ascertained.

4. The amount of loam found in any part of the formation is roughly proportional to the proximity of deltas; and its origin is evidently the same as that of the predominant element in the upper division of the fluvial phase of the formation, *i. e.*, it is redeposited residuary debris from the Piedmont region.

5. The clays and silts appear to be made up of the finest and farthest-transported debris from rocks *in situ* and from the coarser materials, both local and erratic.

Genesis.—It is impossible to convey definite conceptions of geologic structure or topographic configuration by verbal description; and it is impracticable to prove the sub-aqueous origin of the interfluvial phase of the Columbia formation by mechanical reproduction of structural aspect, as in the fluvial phase; but neither is necessary (1) since the sub-aqueous deltas of the fluvial phase graduate into and are stratigraphically continuous with the interfluvial phase, (2) since marine fossils have been found within it by a dozen eminent geologists and paleontologists (enumerated later), (3) since no other agency or agencies known to geologic science are competent to produce such deposits, (4) since its margin is marked by unmistakable shore-lines and beaches, and (5) since every geologist who has ever investigated any considerable part of the formation, including

Lyell, Mather, the Rogers brothers, Tuomey, Desor, Conrad, Booth, Tyson, Kerr, Fontaine, Cook, Lewis, Chester, Merrill, Britton, and others, has recorded the conviction that such part at least was waterlaid. The physiographic relations of the phenomena and the area over which they prevail are such that the evidence of sub-aqueous origin is cumulative, and now that definite observations have been extended over the greater part of the area it can only be regarded as decisive ; the coarseness of the northern deposits as compared with the southern, and the occasional presence of evidently ice-dropped bowlders indicates that the period of submergence was one of refrigeration ; and the limited volume of the formation indicates that the period of deposition was short.

So the interfluvial deposits corroborate and extend the testimony of the deltas; and the phenomena conjointly record a brief period of submergence of the entire Coastal plain in the Middle Atlantic slope reaching 100 feet in the south and over 400 feet in the north, with coëval cold, long anterior to the terminal moraine period.

The Terraces and Shore Lines—Every Middle Atlantic slope river embouches through a narrow gorge in the Piedmont escarpment into a widely flaring shallow valley partly occupied by the estuarine portion of the river; and each of these valleys is notably terraced. The city of Weldon is located on a broad terrace of the Roanoke sixty feet above its tidal waters; Petersburg is built upon two or three distinct terraces flanking the Appomattox, of which one is 110 feet in altitude and many miles in extent; the higher portions of Richmond, including the public park, are located upon an extensive terrace overlooking James river from a height of 180 feet above tide on the north, while another terrace eighty feet in altitude has an area of at least twenty-five square miles on the south side of the river; the terraces on the Rappahannock at Fredericksburg are as distinctive and more extensive than those of the lacustral basins of Bonneville and Lahontan, as are also those about Washington ; the valleys of the Patuxent and Patapsco, of the Susquehanna, and of the Brandywine and Schuylkill, exhibit wide reaching series of terraces of progressively increasing altitude; at Trenton the Delaware has cut a narrow gap in an otherwise continuous terrace of brick clay and gravel of great extent and uniformity, and through that gap the Trenton gravels have been swept; and at Metuchen, N. J., wonderfully broad terraces extend to the very base of the hillocky terminal moraine, which has evidently been pushed out upon their plains.

While the best developed terraces about the mouths of the rivers form independent systems, the higher members frequently extend across the divides from river to river. Thus between the Roanoke and the Appomattox the highways traverse sensibly horizontal plains, only broken at long intervals by the low steep scarps of terraces, or by the narrow steep-sided ravines incised within them, the plains being of such extent as to yet remain imperfectly drained. The same is true of the low plateau between the Appomattox and the James, and of the greater part of the country between the James and Rappahannock. North of the Rappahannock the high level terrace-plains become less conspicuous as the shore line rises from the friable clastics to the firm crystalline terranes, but considerable plains occasionally occur; and between the Schuylkill and the terminal moraine beautiful terrace-plains of wide extent are carved out of the Triassic sandstones up to altitudes of nearly 200 feet. The terraces are best developed along the inland margin of the Columbia formation, but reach somewhat greater altitudes, ranging from about 100 feet in the south to more than 400 feet in New Jersey.

Though most prominent along the fall-line, the terraces are not confined to it, but occur at intervals over the entire Coastal plain, their extent and perfection depending upon the materials in which they are carved or from which they are built, and upon the erosion they have suffered. Thus in eastern Maryland it is possible to approximately map the western boundary of the greensands by the perfection of the terraces—the firm clays to the westward being everywhere distinctly terraced, while the more friable sands have assumed the characteristic undulating surface happily designated "topographic old age" by Chamberlin.

In brief, there is a practically continuous series of terraces and beach marks along the fall line from the Roanoke to the terminal moraine—a series of shore lines as distinctive and unmistakable as those circumscribing the valleys of the extinct lakes of the Great Basin, of India, of northern Arabia, or of the partially ice-bound basins of Minnesota, Michigan, Ohio and New York, though they are generally more profoundly modified by erosion and are frequently concealed by forests. These shore lines embody an easily interpreted record of geologic vicissitude which coincides in every detail with that of the Columbia deposits. They are sometimes carved out of the sub-terrane but are generally built of the loam, sand, and gravel of which the Columbia formation consists, and are evidently coëval therewith. Now it is manifest that these terraces are water fashioned; but they are not fluvial. There is always a vertical component in fluvial action, and the energy of the action varies with the value of this component; every alteration in the course of a wandering stream means change in declivity, and every change in declivity means modification in competence and variation in deposits. So fluvial deposits are heterogeneous. Moreover rivers take the paths of least resistance and flow freely in deep channels, and in selecting their courses they avoid the higher levels and seek depressions which they continually deepen; the deeper the initial depression the more rapidly is it deepened; and thus fluvial action ever accentuates irregularity of surface. So fluvial plains are multiform. But the forces concerned in the formation of the Middle Atlantic slope terraces acted horizontally over great distances and with uniform energy for a considerable period, filling depressions, softening contours, and obliterating relief, yet so gently that essential homogeneity of deposit in the horizontal direction and essential uniformity in surface prevails for miles. Only the undulatory and horizontally acting force of waves appears competent to produce so great expanses of uniform surface and constant structure as are exhibited in this region.

By the testimony of terraces and shore-lines the existence of inland seas and lakes of Quaternary age in many portions of the world has been proved to the satisfaction of geologists; yet although the middle Atlantic slope terraces have been more deeply graven by erosion and reduced by weathering, they are more extensive than those of any of the extinct or shrunken Quaternary lakes in the country; and their testimony is equally decisive.

[To be continued.]

Art. XXXII.—*On some peculiarly spotted Rocks from Pigeon Point, Minnesota;* by W. S. Bayley.

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The northeastern extremity of Minnesota is known on the charts as Pigeon Point.* This point extends in an easterly direction into Lake Superior. It is separated from Canada by the waters of Pigeon Bay and Pigeon River. Its length is about three and a half miles. Its width varies from a few hundred feet to a little less than half a mile. The greater portion of its mass consists of a great dyke of coarse olivine gabbro† or diabase. Associated with this is a large quantity of

* The exact location of the point is T. 64 N., R. 7 E. of the 4th principal meridian, Sections 25, 26, 27, 28, 29, 30, 31 and 32.

† Cf. Irving: Copper-Bearing Rocks of Lake Superior, Monograph V, U. S. G. S. Washington, 1883, p. 369 et seq.

bright red drusy granite, whose relations to the gabbro have not yet been satisfactorily determined. To the south of these eruptive rocks, on the Lake Superior side of the point, is a narrow strip of slates and quartzites, which dip to the southeast at an angle of 15°–20°, and are cut by numerous diabase dykes. According to Irving* these slates and quartzites belong to Hunt's Animiké series and are Huronian in age. Upon their contact with the eruptives these fragmental rocks lose all traces of sedimentary origin. Under the microscope they are seen to have undergone extreme metamorphism. Whether this consists in a mere recrystallization of the material already existing in them, or in a recrystallization with the addition of new substance derived from the eruptive rocks, or in a complete solution of their fragments in the latter must be left for further study to decide.

The object of the present paper is to describe certain peculiar spots noted on the quartzites in a few localities and to discuss briefly their origin

The quartzites in their unaltered forms comprise evenly bedded light gray, pinkish and black varieties. These are all very compact and hard, and have the vitreous appearance characteristic of indurated quartzites. They are cut by joint cracks running in a north and south direction and standing nearly vertical. The sides of these cracks are usually covered with little quartz crystals. Under the microscope the darker varieties are seen to consist mainly of round and angular pieces of quartz, in a groundmass of interlocking silica, which under crossed nicols is resolved into small areas optically continuous with the original grains to which they are attached.† Decomposed orthoclase, colored red by minute plates of hematite and iron hydroxide, a very little plagioclase, sometimes fresh but more frequently much altered, little flakes of brown biotite, chlorite, and grains of magnetite and earthy iron minerals constitute the balance of the rock. In the lighter varieties the plagioclase is more abundant and the chlorite much less so. In the pinkish varieties reddened orthoclase and plagioclase make up about half of the entire rock.

In certain restricted areas on the south shore of the point, notably in the western half of section 25 and in the southeast quarter of section 32, curious circular spots are developed on the surface of the quartzite. These spots vary in size from less than a quarter of an inch to over two inches in diameter. On a weathered surface they appear as slight depressions surrounded by a raised rim of a lightish brick-red color. Their distribution

* This Journal, xxxiv, 1887, p. 262.

† Cf. Irving and Van Hise: Bulletin of the U. S. Geol. Survey, No. 8, Washington, 1884.

is very irregular. Frequently a single spot stands alone. Sometimes two or more spots are united, and when this is the case one rim encloses the group. Figure 1 represents the shape and general appearance of some of these groups as seen on a smooth weathered surface.

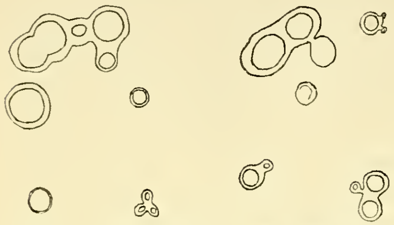

Fig. 1. About one-third actual diameters.

When the rock bearing such spots is broken it is observed that the bodies producing them are themselves either lenticular in shape or spherical. They possess a sugary texture and are of a pistachio green color. When moistened with hydrochloric acid they effervesce with a slight evolution of gas. Like the circles on a weathered surface these spheroidal bodies are also surrounded by a narrow brick-red rim. The rims are here fairly well defined against the substance which they enclose, but on their outer edges gradually shade off into the body of the rock.

Associated with these spotted rocks, but at a greater distance from the eruptives, are other quartzites which show no spots on a weathered surface, but which contain little concavities with diameters of about the same magnitude as those of the spots mentioned above. On a fresh fracture of these, instead of the green spheroidal bodies, are circular and oval areas, which reflect the light evenly, as from a smooth cleavage surface, and show a silvery luster. When treated with acids they effervesce very briskly. They are nothing more than concretions of calcium carbonate so often met with in the slates and sandstones of many regions.*

Under the microscope the body of a specimen of one of these rocks (No. 11,461 of the collection of the Lake Superior Division U. S. Geological Survey) is seen to be composed of an aggregate of quartz, feldspar and green mica. The quartz is in rounded grains, which everywhere show secondary enlargement. Much of the feldspar is triclinic. The green mica is slightly pleochroic and seems to have crystallized in position. A few grains of magnetite are scattered through the section, and small areas of calcite are occasionally found enclosing the other constituents. The silvery spots consist of perfectly transparent calcite. This encloses all the other constituents, which are the same as those found in the main portion of the section. It polarizes in large areas, although several of these are seen in a single spot.

* Cf. Tschermak: Lehrbuch der Mineralogie, Auf. II, p. 117.

The rocks immediately associated with the spotted rocks in the same beds, but which themselves are free from spots, differ but slightly from the last described rock in structure. They contain, however, quite a large quantity of chlorite, which has clearly been derived from biotite on the one hand, and from feldspar on the other. Closely intermingled with this, but more particularly in the neighborhood of little calcite nests numerous irregularly shaped plates of a light green, strongly pleochroic and brightly polarizing epidote are frequent. In most cases however the epidote occurs in tiny rounded grains and rudely outlined crystals scattered everywhere throughout the feldspathic and chloritic groundmass in which the enlarged quartzes are imbedded. These little particles are sometimes crossed by cleavage cracks parallel to which extinction takes place. They have a faint greenish tinge and a very high refractive index. In addition to chlorite and epidote the rocks of this class sometimes contain flakes of brown biotite, magnetite and calcite.

The groundmass of the spotted rocks when examined under the microscope, presents the same features as are observed in the epidote-bearing rocks just described, except that the epidote grains are much less abundant and in some cases are almost entirely lacking.

The spots, on the contrary, are usually very rich in epidote. They consist of enlarged quartz grains, a little feldspar and occasionally a small quantity of chlorite, all imbedded in a mass of calcite and epidote. The amount of calcite present varies within wide limits. It sometimes occupies nearly the entire space between the quartz, feldspar and chlorite to the almost complete exclusion of the epidote. In other cases it occurs only sparingly, while the epidote is massed in little plates, grains and crystals. Only rarely were well terminated crystals observed (No. 11,463). These average $\frac{1}{25}$ of a millimeter in length. A few forms are represented in figure 2. Although but very slightly pleochroic, the true nature of the crystals cannot be doubted. In color they are of such a very pale green tint as to be almost colorless. They possess a cleavage and an extinction parallel to their long axes, have a high index of refraction and are usually free from inclusions. They are distinguished from sahlite, which they closely resemble, by the fact that the plane of their optical axes is at right angles to their cleavage.

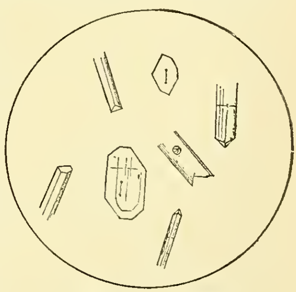
Fig. 2. × 200.

Around the spots are clear zones corresponding to the raised rims, mentioned as surrounding the hollow interiors of spots on a weathered surface. These zones are sometimes composed of grains and plates of epidote larger than those found in the interior of the spots, either with or without calcite. When epidote is present in the rims there is a scarcity of this mineral in the interior of the spots. This is the rule in those rocks which contain a large amount of altered feldspar and chlorite. In these feldspar, quartz, chlorite, a little bleached biotite, little plates of hematite and grains of magnetite constitute both the interior of the spot and the body of the rock. In the spot the chlorite is better crystallized than elsewhere. The rim contains only quartz, calcite and epidote, except on its outer edge, where there is an accumulation of red oxide of iron. In those cases in which the interior of the spots contains a large amount of epidote, the exterior zone is comparatively free from this mineral, consisting essentially of quartz and feldspar stained red by iron oxides. In both cases chlorite is absent from the rim.

Although each specimen of these spotted rocks, when examined under the microscope, presents features peculiar to itself, it is unnecessary to describe them all. It is sufficient to have called attention to their most striking characteristics, and to have mentioned merely those features common to the class. The incidental peculiarities due most probably to slight differences in the original composition of different parts of the beds have been neglected.

The occurrence of the spots in well defined beds lying between those which contain no spots, would at once lead to the supposition that they owe their origin to the existence in these beds of some substance, which was absent from those containing no spots. The shape of the spots and their groupings suggest concretions. Epidote is not known to occur in such forms in fragmental rocks, while concretions of calcite are common. The existence of such calcite concretions in the unaltered rocks of Pigeon Point is clearly established in the one instance mentioned above (No. 11,461). Here we have a quartzite differing in no wise from similar quartzites occurring at a distance from the eruptive rocks, except in the possession of calcite concretions. Nearer the eruptives, whether these be granite or diabase, are other quartzites containing a little more well individualized chlorite and large quantities of epidote. This epidote is closely associated with calcite, the latter increasing with the decrease of the former, and the two being always bounded by the outlines common to concretionary bodies in sedimentary rocks. As the result of a large number of studies upon limestones which have been altered in the neighborhood of eruptive masses it has been found that epidote* is one of the most common of the new minerals produced. Moreover it is known that in these cases of limestone metamorphism the eruptive rocks have added but little, if any, of their substance to the intruded rock, except perhaps silica. Their principal agency in the production of contact phenomena has been heat. The percolation of silica-bearing solutions through calcite-bearing sedimentaries was alone not sufficient to produce the crystallized epidote described above. This is evident from the existence of epidote-free calcite concretions in rocks occurring at some distance from any eruptive mass, while at the same time these rocks are typical indurated quartzites in which all the quartz grains have been enlarged by the deposition of secondary silica around them (No. 11,461). There was no necessity for the addition to these concretions of any material from the eruptive rocks in order to change them into epidote. They already contained the elements essential to the formation of this mineral. These merely needed an opportunity to arrange themselves in the form of epidote—a very stable compound under the conditions prevailing during contact metamorphism, as so many investigations have shown. This opportunity, it is believed, was afforded by the appearance of the eruptive masses. The epidotic rocks and spotted quartzites are always found in close proximity to masses of eruptive origin. They moreover contain large amounts of newly developed chlorite, a result which may likewise be ascribed to contact action. It would seem, then, that we are justified in regarding these epidotic rocks, particularly the spotted varieties, as the result of the action of the intrusive rocks, upon the sedimentary beds through which they forced their way from beneath.

Where calcite was scattered in little nests through the mass of the fragmental rocks, epidote is now found in similar relations to the other constituents. Where the calcite was present in spheroidal concretions enclosing quartz grains, feldspar, chlorite, etc., there now occur little spheroidal bodies consisting in large part of crystals of epidote. The hard envelopes around these spheroids appear to owe their power to resist weathering principally to the lack of chlorite in their composition.

In closing I would acknowledge my obligations to Dr. Geo. H. Williams of the Johns Hopkins University for valuable suggestions offered during the earlier portion of this study.

January 19, 1888.

* Cf. J. Roth: Allgemeine und chemische Geologie, Bd. i, p. 428 et seq.; and Rosenbusch: Mikroskopische Physiographie, 1885, Bd. i, p. 498.

Art. XXXIII.—*The Taconic System of Emmons, and the use of the name Taconic in Geologic nomenclature;* by Chas. D. Walcott, of the U. S. Geological Survey. With Plate III.

(Continued from page 327.)

Nomenclature.

I. Use of the name Taconic. II. Use of the name Cambrian. III. Classification of North American Cambrian rocks.

Use of the name Taconic.—To the writer the evidence presented and referred to in the preceding pages proves that the "Taconic System" was founded on errors of stratigraphy of such character and magnitude that the name Taconic has no claim upon the geologist for recognition in geologic nomenclature.

I endeavored to make, in 1886, an argument for the use of the name Taconic for the Middle division of the Cambrian System, but it failed in the light of later results of field work; and now I think that geologic nomenclature will be benefited by dropping the name entirely. Based on error and misconception originally, and used in an erroneous manner since, it serves only to confuse the mind of the student, when applied to any formation or terrane. There are several reasons for the foregoing conclusions that perhaps it is best to here state:

1st.—The name is not applicable. The Taconic range, from which the "Taconic System" was named, is not known to contain a fossil of the First fauna or a formation that contains one elsewhere. The "Upper Taconic" slates lie west of the range, and the "Granular Quartz" series east of it; and the range is formed of strata of the Trenton-Hudson Terrane.

2d.—The "Taconic System" was considered pre-Potsdam, on two suppositions: (*a*) that the Calciferous sandrock of the Lower Silurian is unconformably superjacent to the Taconic slates, on the west; (*b*) that the variation of the lithologic characters of the Lower Taconic rocks, from the New York Lower Silurian, indicates a distinct system of rocks. We find that the unconformity (*a*) was based on errors of field observation, and (*b*), that the "Lower Taconic" rocks are of Lower Silurian age, with the exception of the lower quartzite, which is Cambrian and *conformably* subjacent to the Lower Silurian.

3d.—The claim of priority of discovery of the Primordial fauna is invalidated by the fact that the fossils found in the Taconic slate were referred to a pre-Potsdam horizon on an erroneous interpretation of the stratigraphy and not from comparison with a known fauna that had been stratigraphically located in any clearly defined geologic section.

4th.—It is only a fortunate happening, and not a scientific induction based on accurate stratigraphic or paleontologic work, that any portion of the "Taconic System" is found to be where Dr. Emmons placed it.

5th.—The application of the principles stated at the beginning of this paper rules out the name Taconic from geologic nomenclature.

6th.—The term Cambrian antedates Taconic for a stratigraphic system and, also, as a correctly-defined faunal definition.

It was stated under "Discussion" that Professor Dana held the opinion that the "Lower Taconic" was the typical "Taconic System," as first defined in 1842, but as that was proven to be Lower Silurian in age, the "Taconic System" could not longer be recognized.* For a time I was inclined to disagree with this view, but as I approach the end of this investigation I am convinced, after a full consideration of all the circumstances, that the position taken by Professor Dana is the correct one.

The first published section of the "Taconic System" gives *all* the rocks included within it in 1842.† The gneiss is represented on the extreme east and the "Taconic slate" on the extreme west and the "shales of the Champlain group" as resting unconformably on the "Taconic slate." This section includes *all* the strata of the "Taconic System," as then known to Dr. Emmons, and agrees with the description, in the accompanying text, of the rocks of the System.‡

Five additional sections are given on Plate XI, four of which are in the typical area and agree with the section in the text (loc. cit., p. 145, fig. 46). The latter section and the first four sections of Plate XI do not extend west of the area of Hudson slate on the line of Hoosick Falls in Rensselaer Co., N. Y. (see map). They all limit the "Taconic System" at this belt of the Hudson Terrane, and the accompanying text corroborates the view expressed in the sections. A glance at the map shows that not one single outcrop of rock of the "Upper Taconic" was included in the "Taconic System," as originally proposed, with the exception to be noted of Section 5, Plate XI, and not until 1887 was it proven that any portion of the original Taconic System was older or subjacent to the horizon of the Potsdam sandstone. As is mentioned in the 1st reason given for rejecting the name Taconic, there is not a known stratum of rock in the Taconic range that is of the geologic

* This Journal, III, vol. xxxi, pp. 241–244, 1886.

† Geol. N. Y., pt. 2, p. 145, fig. 46, 1842.

‡ Loc. cit., pp. 144, 145.

age assigned to it by Dr. Emmons. In 1844 he incorporated a great series of slates and shales belonging to another geologic system by extending his sections across the western belt of the Hudson Terrane, that limited the section of 1842, and on west to the next line of outcrop of Lower Silurian rocks. This addition gave the opportunity to separate off the "Upper Taconic" in 1856. I have shown that all his reasons for calling this series pre-Potsdam were based on errors of stratigraphy; and that it was a fortunate happening that any portion of the "Upper Taconic" rocks occur where he placed them in his stratigraphic scheme. Even if there were no errors to vitiate Dr. Emmons's argument for the pre-Potsdam position of the "Upper Taconic," that portion of his system could not retain the name "Taconic;" for it belongs to a different stratigraphic system from that to which the strata of the Taconic range belong and to which he gave the name "Taconic."

Section V, of Plate XI, represents a section of strata a few miles south of Burlington, Vt., and includes, not the "Taconic System" of the first five sections and the text by Dr. Emmons in 1842, but strata entirely disconnected from the original Taconic, which, nineteen years later, was proven to belong in part to the "Upper Taconic." This section is not mentioned in the text, but it is evidently considered as exhibiting the same relative geologic section as the other sections, a view that is substantiated by the name "Taconic slate" being given to the strata referred to the "Taconic System." There is not any stratigraphic connection between the Vermont section (No. 5) and the sections in the Taconic area (see map), and until 1859 there was not any paleontologic evidence that the slates of section 5 were or were not of the same geologic age as the "Taconic slates" of the five other sections and the text. In 1859 the publication of the Olenellus fauna by Professor Hall, proved that Dr. Emmons was mistaken in referring the Vermont slates, of section 5, to his Taconic System of 1842. I do not think that we can admit as evidence in favor of the strata of the "Upper Taconic" having been described in the original work of 1842, such an erroneous identification of a section that had at the time no stratigraphic or paleontologic connection with the original Taconic System.

It was not until the field work, in the fall of 1887, was concluded that I arrived at the above conclusions. Professor Dana reached it long before, and Dr. T. S. Hunt holds that the "Lower Taconic" is the typical Taconic. It matters not whether geologists agree to restrict the test of what the original Taconic was to the original Taconic of 1842 or hold that Dr. Emmons had the right to add the strata separated off into the "Upper Taconic" in 1856, the name Taconic does not appear to have any place in the geologic nomenclature of to-day.

The following tabulation of the successive phases of the Taconic system viewed in the light of present facts is instructive. It was proposed in a letter from Professor Dana to the writer:

PHASE I, 1842.

*		"Taconic System"	True order begins.	
*	6.	Stockbridge limestone	II.	Lower Silurian limestone.
*	5.	Magnesian slate of Graylock	III.	Hudson slate.
*	5.	Granular quartz	I.	Cambrian.
*	4.	Limestone	II.	Lower Silurian limestone.
*	3.	Magnesian slate of Taconic mountains	III.	Hudson slates.
*	2.	Sparry limestone	II.	Lower Silurian limestone.
*	1.	Taconic slate	III.	Hudson slates.

PHASE II, 1844.

5.	*a.* Black slate. Fossiliferous	I.	Cambrian.
	b. Taconic slate "		Mostly Hudson slate.
4.	Sparry limestone	II.	Lower Silurian limestone.
3.	Magnesian slates	III.	Hudson slates.
2.	Stockbridge limestone	II.	Lower Silurian limestone.
1.	Granular quartz	I.	Cambrian.

PHASE III, 1855.

I. *Upper Taconic.*

2.	Black slate	I.	Cambrian.
1.	Taconic slate	III.	Mostly Hudson slate.

II. *Lower Taconic.*

3.	Magnesian slate	III.	Hudson slate.
2.	Stockbridge limestone and Sparry limestone	II.	Lower Silurian limestone.
1.	Granular quartz	I.	Cambrian.

Use of the name Cambrian.—There is no necessity for reviewing the Silurian-Cambrian controversy. All the facts, as understood by many writers, are accessible to the student of English geologic literature. It is my opinion that the name Cambrian should be used for the system of strata characterized by the "First Fauna."

The Cambrian System was correctly established on a stratigraphic basis in 1835, and included the same relative geologic terranes as the "Taconic System," with the exception of going a little lower in the section containing the Primordial fauna. Like the Taconic, it included the Lower Silurian (Ordovician) System, a fact noted and corrected by Dr. Emmons, *for the Cambrian*, in 1842. The Cambrian section stands intact to-day, and, on faunal evidence, separates into two great divisions, the lower of which is the Cambrian System, as used by many

* Made equivalent to the lower unfossiliferous part of Sedgwick's Cambrian as known to Dr. Emmons at that time.

writers for the system of strata characterized by the "First Fauna," and the upper the Champlain of Emmons, the Lower Silurian of Murchison, or the Ordovician of some more recent authors.

Classification of North American Cambrian Rocks.

In the classification of the fossiliferous sedimentary rocks of all countries it becomes more and more evident that the great systems—Cambrian, Silurian, Devonian, etc.—must rest on the broad zoologic characters of their included faunas and not on stratigraphic breaks between the systems, and that geologists will need to recognize the fact so well stated by Lapworth, that "we have no reliable chronological scale in geology but such as is afforded by the relative magnitude of zoological change—in other words, that the geological duration and importance of any system is in strict proportion to the comparative magnitude and distinctness of its collective fauna."* In pursuance of the above principle I have separated the Cambrian System in North America from the Lower Silurian. In the magnitude of sedimentation and extent of the fauna it ranks with the other great geologic systems, and we cannot unite it with the Lower Silurian except from reasons that, if followed out, will unite all the systems from the Cambrian to the Quaternary.

In arranging the different strata composing the Cambrian System three primary divisions are distinguished by the predominence in each of a fauna that, in assemblage of genera and species, may be separated from others whenever two or more of them occur in the same stratigraphic section. This extends to the identification of the relative geologic horizon by the fauna when its vertical or geographic connection with other faunas is not preserved. The three divisions of the table have been recognized to a greater or less extent in all the sections of Cambrian strata studied in North America, and all the observed Cambrian faunas come within their limits.

The second column in the table gives local names that have been applied within certain geologic provinces, where the fauna and the sedimentation indicate a greater uniformity of conditions than existed throughout the larger areas outlined by the first three divisions. The right-hand column gives the names of local subdivisions where the conditions of sedimentation and of life were still more restricted.

The table is a correlation of the various sections described in the introduction to U. S. Geological Survey Bulletin No. 30, and hence is tentative. It is the expression of my present knowledge and opinion. All who use it in geologic work

* Geol. Mag., vol. vi, p. 3, 1879.

should refer to the data given in that Bulletin, and decide individually upon the value of the correlations made in the table.

UPPER CAMBRIAN.	Lower Calciferous.	Lower portion of the Calciferous formation of New York and Canada. Lower Magnesian of Wisconsin, Missouri, etc.
	Potsdam. Knox. Tonto.	Potsdam of New York, Canada, Wisconsin, Texas, Wyoming, Montana and Nevada; Tonto of Arizona; Knox Shales of Tennessee, Georgia and Alabama. The Alabama section may extend down into the Middle Cambrian.
MIDDLE CAMBRIAN.	Georgia. L'Anse au Loup. Prospect.	Georgia and "Granular Quartz" formations of Vermont, Canada, New York and Massachusetts. Limestones of L'Anse au Loup, Labrador. Lower part of Cambrian section of Eureka and Highland Range. Nevada. Upper portion of Big Cottonwood Cañon Cambrian section. Utah.
LOWER CAMBRIAN.	St. John. Braintree. Newfoundland. Uinta?	Paradoxides beds of Braintree, Mass., St. John, New Brunswick. St. John's area of Newfoundland; Lower portion of Big Cottonwood Cañon Cambrian section, Utah. Uinta? (The Ocoee conglomerate and slates of East Tennessee are doubtfully included.)

Description of the Map and Section.

The map shows the geographic distribution of the strata referred to the "Taconic System" in eastern New York and western Vermont, Massachusetts and Connecticut. The data for it are taken from the Geological map of Vermont and New Hampshire, by Professor C. H. Hitchcock, 1877 (Geol. Northern New England); the maps published by Professor Dana, on the geology of the region studied by him in western Massachusetts and Connecticut, and eastern New York; and the map of southwestern Vermont, published by Professor Dana on the result of Rev. A. Wing's field studies (Am. Jour. Sci., 3d ser., vol. xiii, 1877); and for Washington and Rensselaer Counties, N. Y., as mapped from field work done by myself in 1886–87.

The line of contact of the Cambrian and pre-Cambrian rocks on the east, in Vermont, is tentative, as it is known to be incorrect in details; the data for correcting it have not been obtained.

Certain changes in the identification of the strata, as compared with the older maps, have been rendered necessary by the correlations made in this paper; and the shales, in the vicinity of the limestones south of the Rensselaer county line, have not been colored, as it is yet undetermined whether they belong to the Hudson or Cambrian Terrane. The shales immediately beneath the limestone (3) are shown as a distinct terrane (2) in the section but on the map they are merged with the Georgia terrane (5).

The exact localities of fossils within the typical Taconic area are shown by the letter F. Many localities to the north and south are not indicated.

Section.—The geologic section crosses the Taconic area on the line marked A, B, on the map, which is very near the line of the original section published by Dr. Emmons in 1847 (Geol. N. Y., pt. 1, pl. xviii, Sec. 1). On the line C, D fossils have been found more abundantly on the eastern side, and the structure is found as in Dr. Emmons's section of 1856.

1. Cambrian quartzite—Terrane No. 1.
2. Hydromica (Potsdam ?) shales—Terrane No. 2.
3. Trenton, Chazy and other limestones of the Lower Silurian —Terrane No. 3.
4. Hudson (hydromica) shales of the Taconic range and, in the Hudson valley, the Hudson terrane—Terrane No. 4.

4*a*. A belt of strata of the Hudson terrane, faulted in between Cambrian rocks—Terrane No. 6 of text.

5, 5*a*. Slates, with interbedded limestones and sandstones of the Georgia Terrane, of the Cambrian—Terrane No. 5.

6. Pre-Cambrian (Agnotozoic) or Archean rocks. *a*, *b*, *c*, *d*, fault lines, known to the writer, in Washington County, N. Y. The hade of the Ball Mountain fault (*a*) is approximately correct (see fig. 12) while that of the other faults is probably much more oblique or inclined to horizontal than as represented. They are drawn to show where they occur and not to indicate the hade or angle of the faults. The minor undulations, faults and displacements that occur on the east side, between 3 and the gneiss are not represented.

Comparing this with Dr. Emmons's sections, we find a difference in the arrangement of the strata in the eastern half. The "Lower Taconic" embraced the strata from Terrane No. 1, on the east, to Terrane No. 3, on the west side of the Taconic range, and included *all* the strata of the original "Taconic System" as known and defined by Dr. Emmons in 1842. The "Upper Taconic" included the strata of terranes Nos. 2, 4, 4*a*, 5, and 5*a*, west of the Taconic Range, which was added to the original "Taconic System" in 1844.

I have not attempted to show that the quartzite contains interbedded limestones and schists in some localities, nor that the limestone series (3) is broken by interbedded schists or arenaceous beds; nor that, as at Graylock, the quartzite (1) extends completely beneath the synclinal of the limestone (3) and appears on the western side. It is only the illustration of the general relations of the quartzite, limestone and schists to each other that is attempted.

To the west of the Taconic Range the section passes down through the limestone (3) to the hydromica schists (2), and thence to the great development of slates and shales with their interbedded sparry limestones, calciferous and arenaceous strata, all of which contain more or less of the Olenellus or Middle Cambrian fauna.*

No. 2 occupies the stratigraphic position of the Potsdam formation elsewhere; and 5 and 5*a* by contained fauna and stratigraphic relations, are correlated with the Granular Quartz series (1) and referred to the horizon of the Middle Cambrian, as the latter is defined in Bulletin 30, U. S. Geological Survey, and in the table of classification (*ante*).

Between the limestone (3) and the slates (5) there are several displacements, but none to displace the strata sufficiently to bring rocks of other formations in sight, and so break the section that the general relations of 3, 2 and 5 can be interpreted by me in a different manner from that given in the section.

Art. XXXIV.—*Terminal Moraines in North Germany*; by Professor R. D. Salisbury, of Beloit, Wisconsin.

During the past summer some observations have been made upon the drift formations of northern Germany which may not be without interest to the students of Quaternary Geology in America. It is the writer's expectation to continue the same line of study next season. It is due toPresident T. C. Chamberlin, who has done so much for Quaternary Geology in America, to say that the study of the drift phenomena of the above specified region was undertaken at his suggestion, and that he had forecast with surprising accuracy, the results which observation has confirmed.

So far as the work has been prosecuted, attention has been mainly directed to a terminal moraine, or, more exactly, to a terminal morainic belt, which crosses Germany, and which has been traced in more or less detail from Denmark to the Russian border. In the tracing of this belt, the main reliance has been upon topography, which here, as in America, affords the most reliable and the most available single criterion for the determination of the formation.

So striking is the topography throughout the greater part of the course of the moraine in Germany, that it could not fail to

* Thirty-five species in Washington County, N. Y., as known to date. (See this Journal for September, 1887).

attract the attention of one familiar with the surface expression of terminal moraines. The determination of the general course of this belt is, therefore, attended with no difficulty, and its surface deportment, taken together with other characteristic accompaniments, is such as to leave no possible doubt as to the genuineness of its morainic character. The other features of terminal moraines upon which, in the absence of decisive topography, reliance must be placed, are never wanting where the topography is strongly marked. This is as true of the formation in Germany as in America, but the necessity of resorting to these less decisive characteristics as a prime means of determination, is here less frequent.

In some portions of its course, the morainic belt is single and strongly developed, and its limits sharply defined. In others it is composed of more or less distinct members, sometimes weak and unobtrusive, and often assuming complex relationships. The number of these constituent belts, as they now appear is not constant. In certain meridians, four have been recognized, more or less distinctly separated from each other, while in other parts, through the union of two or more of these members, the number is reduced to three, two or even one.

No attempt will be made at this time to indicate the position of these individual belts, though through considerable portions of the course of the moraines, this might be done. Detailed study will make it possible to map these constituent belts, and to determine with some degree of precision, their relationships in time.

It is to be borne in mind, therefore, that although the belt is here outlined in its entirety, and as if it were a unit, it is not to be regarded as a single moraine, or even as a belt of moraines necessarily closely connected in origin, or *in point of time.* The belt, as here outlined, embraces a broad tract, within which morainic developments are a general—a dominant fact. Occasionally the belt is seriously interrupted, in some or all its parts by broad gaps, some of which represent the drainage avenues of the ice-period, and some of which appear to be the beds of lakes which occupied reëntrant areas within the margin of the ice itself. In a general statement of the course of the moraine, and only a general statement is here admissible, these details cannot find place. Within the belt too as here outlined, there are numerous inter-morainic tracts, which are now and then of considerable proportions.

The width of the morainic belt is so great that the position of the outer and inner borders will be separately indicated. Leaving out of consideration for the moment certain subordinate, but very significant phenomena which will be adverted to later, the course of the moraine-belt, commencing at the west, is essentially as follows:

Through the northern part of the province of Schleswig, it lies near the eastern coast of the peninsula, having a nearly north-and-south course. It passes through Flensburg at the head of Flensburg Fjord, and beyond this point assumes a course bearing slightly more to the east, but still nearly corresponding to the coast-line. Its outermost (southwestern) border lies a little southwest of the city of Schleswig, and a few miles north of Rendsburg (province Holstein), on the Eider. Continuing in the same general direction, the outer border lies a few miles north of a line connecting Rendsburg with Neu Münster. Its limit is here sharply defined, and easily recognized. Beyond Neu Münster it bears more to the south, and passes near Segeberg, Oldesloe and Mölln. Here it curves more to the eastward, and passes near Zarrentin, on Schall lake and near Boddin.

Eastward from this point (lat. 53° 35′, lon. 28° 45′), the belt is, for some distance, very complex and discontinuous, at least in its outer portions. The individual moraines are widely separated, and the area here outlined is therefore proportionally wide, and embraces much territory which is not morainic. The general course of the belt however is continuous in a direction south of east. Its southern border lies south of Pritzwalk and Wittstock (province Brandenburg), in the vicinity of Neu Ruppin, and a little north of Eberswalde (lat. 52° 45′, lon. 31° 30′). In the longitude of Pritzwalk and Wittstock, the main developments are much farther north, although reasonably strong moraines lie as here indicated. East of this point the moraines reach their southernmost extension. For some distance east of Eberswalde their course is easterly and then bears to the northward. The main developments lie north of a line passing near Soldin, Friedeberg, Woldenberg, south of Neu Stettin, and north of Konitz, from which point the outer border follows a generally northeasterly course to the longitude of Danzig.

The northern border of the moraine-belt to this point, commencing with Schleswig, follows approximately the coast line as far as Rostock. Its width is therefore very great. East of Rostock, the northern border lies north of Teterow, near Neu Brandenburg, a little south of Pasewalk and north of Stettin. Eastward from Stettin, its course is more or less direct to a point a few miles north of Danzig.

From the meridian of Danzig a moraine of huge proportions swings to the southeast, thus exhibiting on German soil, the phenomenon of morainic looping so abundantly represented in the United States. The southern border of this eastern loop lies south of Stargard, near Jablonowo and Mantowo (lat. 53° 20′, lon. 37° 20′). Here its course becomes more easterly, and finally north of east, passing near Ortelsburg (lat. 53° 30′, lon. 38° 30′), and thence extending in a generally direct course to Lyck, near the Russian frontier (lat. 53° 45′, lon. 40°). The corresponding northern border lies north of Riesenberg (province Ost Preussen), a little north of Morungen, near Bischoffstein and Rastenburg (lat. 54°, lon. 39°).

In cases in which the individual members of the morainic series are not united with each other, they are sometimes distinctly traceable individually, and sometimes so connected by cross ranges, as to form a sort of morainic complex or network. The separate ranges are individually strong at certain places and weak at others. They are sometimes all strong on a given meridian, sometimes all weak, and again some are massive while others are feeble. The moraines or the morainic belt, therefore, considered as a unit, constitutes a very different topographic feature in different regions, and is generally much more conspicuous when the moraines are united, than when they are separated.

Apart from the relief produced by the formation itself, the country traversed by the moraine is generally level. It is therefore often a conspicuous feature, rising 200 feet or 300 feet, and even 400 feet above the surrounding country. With a given elevation it is conspicuous or unobtrusive, according as its rise from the bordering lowlands is prompt or gradual. It is sometimes so prominent as to have received the local appellation of mountain range, and numerous points are, in this level country, designated mountains. It is possible that in such cases the total elevation is not always entirely due to drift accumulation, although no evidence to the contrary is at hand. Throughout most of its course, the belt constitutes so prominent a relief feature as to have been a potent factor in determining drainage.

The topography of the moraine distinguished from the moraine as a topographic feature—is exceedingly varied. For the most part it is characterized by the knob and basin topography which is so generally characteristic of terminal moraines in similar situations. This topography finds expressions in all degrees of strength. Even when of the sag and swell, or knob and basin type, there may be, with a given altitudinal variation, wide variations of topography limited on the one hand by the nature of the material, which limits the maximum gradient of slopes, and on the other by the width of the moraine, which fixes the minor limit possible within the same. These extremes, as well as all gradations between them, find place in the moraine in question. The topography is now rough, now gentle, according as the elevations and depressions have steep or gentle slopes. Throughout wide stretches of the moraine, the altitudinal variations, within narrow areal limits are fully 100 feet. Not infrequently, isolated basins, "kettles," no more than 10 or 12 rods in diameter, have a depth of 50 feet below the lowest points of their borders, while pointed knolls rise 100 feet or more in their immediate vicinity. Commonly the topography is less strongly marked, the undulations assuming gentler, flowing contours, with variations much less than those indicated.

More broadly considered, the relief of the moraine is not confined to so narrow limits. At many points there are variations of 200 feet or 250 feet within the moraine. These however are not commonly so closely associated as are those of smaller proportions, so that even with the greater range, the surface may appear less rough. Occasionally the moraine surface is wanting in knolls and basins, but this is rarely the case for any considerable distance.

The topography and the complexity of the moraine, together with its great width, afford abundant opportunity for the formation of lakes, which are accordingly an almost constant concomitant of the moraine. Their number is exceedingly great. So characteristic are they, and so nearly restricted to the moraine, that a tracing of the lake belt would be almost identical with a tracing of the moraine itself.

In constitution, the moraine presents all the diversities common to such formations. Sand, gravel and clay predominate each in turn, and the ratio between coarse and fine material is an ever-varying one. In general, it may be said that the moraine is predominantly sandy, at least superficially, and that the proportion of stony material is great.

Scarcely less characteristic than the features of the moraine itself, are certain deposits of drift, widely associated with it. Among these are the extensive plains of sand and gravel, particularly the former, which skirt the outer face of the moraine. In scores of localities which have fallen under notice, approach to the moraine from the south is over a wide belt of sand, which has a distinct though gradual upward incline toward the moraine. The material of these border plains becomes coarser as the moraine is neared, and contains bowlderets and even bowlders in the immediate vicinity of the range.

It is to be observed that the moraine lies far north of the southern limit of drift, just as the main moraines of America lie, throughout the larger part of their course, far north of the southern drift limit.

In all these characteristics, viz: in its composition from several members, in its variety of development, in its topographic relations, in its topography, in its constitution, in its associated deposits, and in its wide separation from the outermost drift limit, this morainic belt corresponds to the extensive morainic belt of America which extends from Dakota to the Atlantic Ocean. That the one formation corresponds to the other does not admit of doubt. In all essential characteristics they are identical in character. What may be their relations in time remains to be determined.

It is not improbable that the outer and inner members of this series, where widely separated geographically, are also somewhat widely separated in time. The former frequently show unmistakable signs of greater age. Where the geographical separation does not obtain, this difference is also wanting. This relationship would be easily explained by supposing that, where the range is single, the margin of the ice was as far advanced at the time of the formation of the subsequent moraines (or at least at the time of the last), as at the time of the formation of the first, and that, where the moraine is two-fold or more, the ice failed at a corresponding number of moraine-forming periods, to reach its earlier position. Analogous relationships were long since recognized in America.

It may be fitting to mention a few localities where the moraine may be seen in strongly typical development. Such are (1) in province Holstein, the region about (especially north of) Eutin; (2) province Mecklenburg north of Crivitz and between Butow and Kröpelin; (3) province Brandenburg, south of Reckatel, between Strassen and Bärenbusch, south of Fürstenberg and north of Eberswalde, and between Pyritz and Soldin; (4) province Posen, east of Locknitz, and at numerous points to the south, and especially about Falkenburg, and between Lompelburg and Bärwalde. This is one of the best localities; (5) province West Preussen, east of Bütow; (6) province Ost Preussen, between Horn and Windikin.

The drift-covered area south of the indicated belt is not altogether without moraines, and in this respect also the German and American fields are similar. Furthermore, in Germany as in America, these outer developments are less continuous, partly because of subsequent erosion and partly because of their originally weaker and more discontinuous character. Detailed work will doubtless make it possible to show the connections of these local (as they now appear) fragments, some of which have but a limited development, while others may be traced for considerable distances.

Without mentioning more isolated occurrences of this kind, reference may be made to certain morainic phenomena south of Berlin, and which, though not consecutively traced, appear to constitute for some distance a traceable, though quite unobtrusive belt. At several points both east and west there are fragments of moraines of undoubted character. These outer occurrences are significant, but their full meaning will only be understood when detailed work shall have shown their relationships. It is not impossible that a chain of such isolated formations may be found to be so situated with reference to each other, as to indicate an outer moraine of greater age than the northern group. It is possible that some of the accumulations there included, belong rather with these outer fragments, in time of origin, though not widely separated geographically from the later formations to the north. In this case, the variation in the position of the ice-front at different epochs must have been great.

The failure to bring the drift formations of the continent of Europe into closer correspondence with those of our own country, is to be attributed, in part at least, to the absence of a common basis of study. The terminal moraines are unquestionably the most conspicuous, and by means of their topography the most easily recognized of the drift formations. They are therefore especially adapted to serve as common centers of study, and with this one common phase of the drift formations, which may be in some sense a standard of comparison the work of geologists on opposite sides of the water may, more readily than heretofore be correlated, and such correlation cannot fail to facilitate the solution of the many yet unsolved problems in glacial geology.

Heidelberg, Nov. 15, 1887.

Art. XXXV.—*Note on the Viscosity of Gases at High Temperatures and on the Pyrometric use of the principle of Viscosity;* by Carl Barus.*

By passing gases under known conditions through capillary tubes of platinum, kept at measured temperatures between 5° and 1400°, I have found a series of data for the relation be-

* The forthcoming Bulletin of the U. S. Geological Survey to which the present note refers, is a first contribution to a research on the physical constants of rocks, the experiments of which are to follow a general plan devised by Mr. Clarence King. The Bulletin in question is restricted to methods of high temperature measurement and will be in six parts, of which the first is a brief historical introduction. Chapter I of the work discusses experiments which Dr. William Hallock and I made in New Haven with a very large high temperature apparatus. In Chapter II (which with the following chapters is my contribution) I investigate apparatus and methods for the practical calibration of electrical pyrometers by aid of fixed thermal data. In Chapter III I discuss certain pyrometric qualities of the alloys of platinum generically, and the data lead to curious electrical results. In Chapter IV I describe methods for the calibration of electrical pyrometers

tween viscosity and temperature of which the following little table is a good exhibit. Air and hydrogen are the gases chosen. In the table θ'', η'', ζ'', respectively denote the temperature, the viscosity and the coëfficient of external slip of the gas, R'' the radius of the capillary tube at θ''; and η, ζ, R, have the corresponding signification at 0° C. The measurements were made absolutely. The time of efflux (t) for a known volume of gas $V_0=50^{cc}$ nearly, varied in round numbers from $t=160^{sec}$ at 0° C. to $t=2350^{sec}$ at 1200° for air, and from $t=85^{sec}$ at 0° C. to $t=900^{sec}$ at $\theta''=1000°$ for hydrogen. R in these experiments is about $0{\cdot}0079^{cm}$. The capillary platinum tubes were used in fascicles of two, side by side, and wound together in form of a nearly compact helix, at the internal and external surfaces of which temperature was measured. From the absolute values of $\eta'' : \left(1+4\frac{\zeta''}{R''}\right)$, the quotients in the third column of the table are computed, which quotients in proportion as ζ'' approaches zero reduce to $\eta'' : \eta$. With this value I have compared $(1+\alpha\,\theta'')^{\frac{2}{3}}$ where $\alpha=0{\cdot}003665$. This compari-

	θ''	$\dfrac{\eta''}{1+4\zeta''/R''} \Big/ \dfrac{\eta}{1+4\zeta/R}$	$\sqrt[3]{(1+\alpha\theta'')^2}$	Diff.
Air (Table XXV)	565°	2·083	2·113	—·030
	592	2·117	2·158	—·041
	995	2·693	2·785	—·092
	1216	3·147	3·099	+·048
Air (Table XXVIII)	442	1·991	1·900	+·091
	569	2.149	2·119	+·030
	982	2·711	2·766	—·055
	1210	3·214	3·092	+·122
Hydrogen (Table XXVI)	961	2·772	2·734	+·038
	1212	3·581	3·095	+·486*
Hydrogen (Table XXVII)	418	1·935	1·858	+·077
	512	2·098	2·023	+·075
	520	2·113	2·036	+·077
	952	2·760	2·721	+·039

* Platinum pervious to hydrogen.

(notably the thermo-element) by direct comparison with the air-thermometer. I have given the porcelain bulb a *re-entrant* form, the bottom folding inward in such a way as to form a narrow cylindrical tube, the closed end of which is at the center of figure of the bulb. Into this central tube the junction of the thermocouple to be calibrated is inserted. To further insure identity in the environments of the two pyrometers to be compared, the air thermometer bulb is snugly surrounded by a spherical muffle revolving around a horizontal axis. This muffle is in its turn surrounded by the walls of a nearly spherical furnace, the burners of which are set something like a force-couple and blow into the furnace a cyclone of flame revolving around the vertical. Chapter V concludes with a full experimental discussion of the subject set forth in the above text.

son is made in the fourth column and the residual errors inserted in the final column. The data given are typical values. ζ symbolizes Helmholtz's "Gleitungs-coefficient."

From the table it follows that for the range of temperatures within which I have observed the *mean* increase of gaseous viscosity takes place proportionally to the two-thirds power of absolute temperature. Interpreted by aid of the well-known Clausius-Maxwell relations, the results of the table may be stated succinctly thus: The mean free path of the molecule of a perfect gas varies directly as the sixth root of its absolute temperature. I had hoped to find that at temperatures sufficiently high the mean free path would be independent of temperature, a law to be regarded as a criterion of a perfect gas and for which the experiments of E. Wiedemann when used to interpret the low-temperature results of O. E. Meyer, Puluj, Warburg, Obermayer, and particularly the admirable researches of Holman* seemed to contain suggestive evidence. But after applying many devices for the removal of errors, I found that my original results were not essentially changed. Accepting the law of sixth roots as indicating perfect gaseity (i. e. the non-occurrence of ephemeral mechanically cohering molecular aggregates) it appears that the *linear* magnitude, mean free path, is proportional to the cube root of the velocity of the mean square,—a singularly suggestive result.

The chief discrepancy of my work is this, that the temperature measured externally is not identical with the temperature at which transpiration actually occurs. Taking the transpiration data alone they show a surprising degree of accordance even above 1300°. If $[\theta'']$ be the temperature computed from transpiration data under assumption of the above law, I found in successive measurements, for instance:

θ''	$[\theta'']$	θ''	$[\theta'']$	θ''	$[\theta'']$	θ''	$[\theta'']$
436°	450°	568°	575°	975°	971°	1210°	1245°
446	459	570	577	981	972	1210	1247
455	469	575	581	990	982	1209	1245

If the law governing the thermal variations of the viscosity of a gas were rigorously known, Poiseuille-Meyer's equation applied to transpiration data would enable us to measure tem-

* After a careful consideration of his own results and those of all earlier observers, Mr. Holman has discarded exponential relations altogether. For my own part, I believe that at the present stage of research a conservative policy is the wiser. In chemistry the hypothesis of residual affinity is fast gaining ground. Hence before final decision can be made, it will be necessary to have exhausted data for an interval of temperature (say 500° to 1000°) within which the ephemeral molecular aggregates in question may reasonably be assumed to be absent. Discussion must be reserved for the Bulletin.

perature absolutely, over a wider thermal range and with a degree of precision and convenience unapproached by any other known method.

The present method lends itself easily for the study of dissociation phenomena in gases. I hope to be able to show that in the case of imbedded capillaries, the method may be used for the high temperature study of vapor tensions and phenomena near the critical temperature. From such points of view I am justified in believing that the favorable character of my experiments introduces a new instrument of pyro chemic research; an instrument which in addition to the special work to which it may be applied, always subserves the purpose of a pyrometer, and which is particularly available for the coördination of values within a field of high temperature where absolute data are either isolated or wanting.

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SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Boiling-point and molecular formula of Stannous chloride.*—Biltz and Victor Meyer have determined the boiling point of stannous chloride, the temperatures being estimated by the air thermometer. The first series of experiments gave the value 604·5°, the second series 607·7°; the mean being 606·1°. Since this substance is easily procured and is non-volatile, it may serve a useful purpose for vapor density determinations, for which we now have sulphur, boiling at 448° and phosphorus sulphide boiling at 518°. Experiments on the vapor density of stannous chloride show that this constant lessens very slowly with rise of temperature. But they do not confirm the formula Sn_2Cl_4, originally given by V. and C. Meyer. The results obtained are considerably greater than the formula $SnCl_2$ requires, but the authors have not obtained a constant value corresponding to the doubled formula. The details of the method will be given shortly.—*Ber. Berl. Chem. Ges.*, xxi, 22, Jan. 1888. G. F. B.

2. *On the occurrence of Germanium in Euxenite.*—Krüss has discovered the existence of germanium in the acid oxides obtained from euxenite. The mixed oxides were boiled with hydrogen chloride to extract the iron, washed and digested for eight days with ammonium sulphide in a closed vessel. Though all sulphides soluble in ammonium sulphide must have been thus taken up, analysis showed no arsenic, antimony, tin, molybdenum, tungsten, etc. in the solution; and yet on evaporation and ignition, the solution left a fixed white residue, soluble in ammonium sulphide. The white sulphide obtained by Winkler's method mixed with sulphur, was heated in a current of carbon dioxide and left a

crystalline mass of dark red sulphide showing a metallic luster. In a current of hydrogen, the sulphide yielded pure germanium having all the properties of the metal obtained from argyrodite. The amount present in euxenite is about one-tenth of one per cent. —*Ber. Berl. Chem. Ges.*, xxi, 131, Jan., 1888. G. F. B.

3. *On the Double Acetate of calcium and copper.*—RÜDORFF has prepared and analyzed anew the large quadratic crystals described first by Brewster. They were prepared by dissolving 25 grams copper acetate and 66 grams calcium acetate in 350 c.c. of water, moderately heated. On cooling the crystals separated. Upon analysis they gave the formula $CaCu(C_2H_3O_2)_4 . (H_2O)_6$; and not $(H_2O)_8$ as determined by Ettling.—*Ber. Berl. Chem. Ges.*, xxi, 279, Feb. 1888. G. F. B.

4. *Ueber die Reaktionsgeschwindigkeit zwischen islandischem Doppelspat und einigen Säuren.*—A recent number of that excellent new journal, the *Zeitschrift für physkalische Chemie* (vol. ii, p. 13), contains an interesting article by W. SPRING on the rapidity with which Iceland Spar is attacked by certain acids, in continuation of an earlier article in which marble was the substance investigated. The surfaces exposed to the acid were the cleavage planes, and also planes cut parallel and perpendicular to the vertical axis. At a temperature of 15° it was found that the surfaces parallel to the axis dissolved with sensibly the same velocity as the cleavage planes, but this equality disappeared as the temperature rose and at 35° and 55° the reaction was 1·23, 1·28 times more rapid. In the case of the surfaces normal to the axis at 15° the rapidity of solution was greater but did not increase so rapidly with increase of temperature. In taking the ratio of the velocity of solution for the vertical and transverse surfaces at the different temperatures the number 1·14 is obtained as the mean, which, it is interesting to note, is not far from the relation of the two refractive indices to each other (viz: 1·115). In other words the author establishes a relation between chemical activity and optical elasticity.

5. *The Integral Weight of Water;* T. STERRY HUNT.—In a paper on Chemical Integration published in this Journal for August, 1887, and reprinted in the *Chemical News*, Sept. 23d and 30th, it was said that in comparing the densities of liquid and solid bodies with those of known gaseous species, such as water-vapor and carbon dioxyd, "or in the last analysis with the density of the hydrogen unit, . . . we get the specific gravity of these bodies, the dyad integer of hydrogen at 0° and 760^{mm} ($H_2=2·0$) being unity." Subsequently, in a paper on Integral Weights in Chemistry, in the *L., E. and D. Philosophical Magazine* for October, 1887, it was stated that a litre of hydrogen gas "at 0° and 760^{mm} being assumed as the unit of volume for all species, the weight of a litre of any other vapor or gas *at the standard temperature and pressure is its integral weight.* In like manner, the integral weight of a liquid species is the weight of the same volume at its boiling point under a pressure of 760^{mm}. . . . The

weights thus obtained for equal volumes of the various liquid and solid species are evidently the specific gravities of these species; that of hydrogen at the standard temperature and pressure being unity ($H_2=2·0$). They are at the same time the integral weights of the species compared." Notwithstanding this clear statement in both papers that it is hydrogen at 0° and 760^{mm} which is to serve as the unit of specific gravity alike for gaseous, liquid and solid species, the reader will find in these papers, and also in the first edition of the author's *New Basis for Chemistry* (1887), an error in the subsequent calculation. The problem having been approached from the comparison of the weights of equal volumes of liquid water at 0° and 100°, and of water-vapor at 100° and 760^{mm}, by an inadvertence (until now unperceived) the weights alike of hydrogen gas and of water-vapor at the latter temperature were substituted for their weights at 0° and 760^{mm}; thus leading to a grave error in the figure given for the integral weight of liquid water, and of bodies for which it serves as the unit of specific gravity, and making it equal 29244. In fact, however, taking as the unit of weight that of the litre of hydrogen gas at standard temperature and pressure (0° and 760^{mm}) and comparing it with that of liquid water at 100° (its temperature of formation at 760^{mm}), when a litre of it weighs 958·78 grams, we have:

$$0·0896 : 958·78 :: 2 : x = 21400·3.$$

This value is thus alike the specific gravity of the liquid on the hydrogen basis and its integral weight, which, if we take $H_2O=$ 17·96, corresponds very closely to $1192(H_2O)=21408$; ice being probably $1094(H_2O)$, calcite, $584(CCaO_3)$ and aragonite, 630 $(CCaO_3)$. While the writer regrets this error in calculation, made in direct contradiction to the principles laid down by him in both of the papers cited, it will be seen that its correction in no way affects their argument, which he hopes to develop further at an early day.

Washington, D. C., February 22, 1888.

6. *Absorption Spectra.*—The relation of absorption spectra to the various physical constants of the substances which afford the spectra has not been fully made out. Fr. Stenger's experiments conduct him to the conclusion that the absorption of light by various substances depends primarily upon the size of the physical molecule. Changes in the state of aggregation, or changes produced by different media in which a substance is dissolved produce absorption spectra of different character only when the state of the physical molecule is also altered. The author discusses, from this point of view, the law of Kundt connecting the index of refraction and the dispersive power of a medium in which a substance is dissolved with the displacement of absorption bands toward the red end of the spectrum. Vogel's researches upon the absorption of dyes in the solid state, obtained by staining gelatine films, and their absorption in the liquid state is also adduced as an evidence of the truth of the author's

hypothesis that the physical molecule in concentrated solutions is more complicated than in diluted solutions.—*Ann. der Physik und Chemie*, No. 4, 1888, p. 577. J. T.

7. *Wave-length of the two red lines of potassium.*—A determination by M. H. Deslandres gives for the stronger line 766·30, for the weaker 769·63. As a measure of comparison the wave-length of D_2 was taken as 588·89.—*Compte Rendus*, March 12, 1888. J. T.

8. *Explosion of gases.*—A. von ŒTTINGEN and A. von GERNET have repeated the work of Bunsen, Berthelot and Vieille, and also that of Mallard and Le Chatelier upon this subject making use however of instantaneous photography to study the phenomena. A rotating mirror was employed with a metallic pointer to which an electrical spark passed when the mirror was in the right position to reflect an image of the eudiometer tube, in which the explosion took place, into a photographic camera. The same spark served to explode the gases. The most sensitive Beernaert plate gave no trace of an image. No results could be obtained by staining the plates with cyanine or with azaline. Eastman's negative film paper, however, gave a faint image. The authors were compelled to sprinkle certain powders in the eudiometer tube. Chloride of copper gave the best results. Plates of the phases of the explosions accompany the paper. The experiments show that the explosion of hydrogen is not accompanied by light. The resulting high temperature, however, produces a disintegration of the glass of the eudiometer tube and produces a certain illumination. Three species of wave motion are observed: first, a fundamental wave, which is entitled Berthelot's wave; second, more or less parallel secondary waves; third, polygonal waves of smaller amplitude. The photographic image of the electric spark which was received upon the same plate as that of the explosion, enabled the authors to estimate the velocity of the explosion. The result obtained, 2800 meters per second, is of the same order of magnitude as that obtained by Berthelot. The authors agree, in the main, with Berthelot's conclusions, differing only in reference to the beginning and the end of the explosion. They explain the secondary waves on Bunsen's hypothesis of the reflex action of waves due to successive explosions produced by the electrical spark. They, therefore, term these Bunsen's waves.—*Ann. der Physik und Chemie*, No. 4, 1888, pp. 586–609. J. T.

9. *Dust particles in the Atmosphere.*—JOHN AITKIN in an article read to the Royal Society of Edinburgh, gives a method of estimating the number of these particles in the air. The method is based upon the hypothesis that in a receiver filled with super-saturated air when there are few dust particles present the fog particles are large and are seen to fall like rain inside the receiver. A small glass receiver was connected with an air pump and with a cotton wool filter. Inside the receiver was placed a small stage with a silvered mirror ruled with fine lines which

served to enumerate the fine drops. The latter, under a microscope, appear brilliant, upon a dark suface. The following are some of the results obtained by this method :

Source of the air.	Number per c. c.
Outside air, raining	32,000
Outside air, fair	130,000
Room	1,860,000
Room, near ceiling	5,420,000
Bunsen Flame	30,000,000

—*Nature*, March 1, 1888, p. 428. J. T.

10. *Magnesium and Zinc.*—Hirn has investigated the electropositive character of magnesium with the view of replacing zinc in certain batteries. In the Daniell cell its E. M. F. is 2 volts; in a Grove 2·9 volts; in a Leclanché, 2·2 volts, and in a bichromate-cell, it gives as much as 3 volts. The local action, however, is considerable and its constancy uncertain.—*Nature*, March 22, 1888, p. 497. J. T.

11. *Gravity.*—In a discussion upon gravitation at a meeting of the Physical Society of Berlin, Helmholtz explained his conception of the action of gravitation. He considers gravitation as being the law of nature, established by experience, that every body, when, in the neighborhood of another body is subject to an acceleration which is proportional to its mass and diminishes in the ratio of the inverse square of the distance between them. Such a law of nature as this, established as it is on the basis of experience, is on the whole not unsatisfactory.—*Nature*, March 8, 1888, p. 455. J. T.

II. Geology and Mineralogy.

1. *Geology: Chemical, Physical and Stratigraphical;* by Joseph Prestwich. In two vols. Vol. II, pp. 606. 8vo, *Stratigraphical and Physical.* Oxford, 1888. (Clarendon Press.)—The first volume of Prof. Prestwich's valuable work was issued in 1886. This second volume commences with the oldest formations, and closes with the Quaternary. Its first chapter gives a very convenient table of the geological series of England with their equivalents in the different countries of Europe, and follows this with a corresponding table of the rocks of India, with an enumeration of their prominent genera of fossils; and the same for North America, Australia, New Zealand and South Africa. The author makes the Cambrian end with the Tremadoc slates, and divides the Silurian (or the remainder of it) into Upper and Lower. The volume is full in its accounts of the several formations and their distribution in Great Britain and other countries, and in illustrating figures; and its plates of fossils are particularly fine. A handsome folded plate represents "the probable extent of land covered by ice and snow during the Glacial period, their extent now and the present boundaries of floating ice," and its importance is doubled by being also a good bathymetric map of the oceans from recent data. An excellent colored geological

map of Europe and Great Britain, folded and on cloth, makes a frontispiece to the volume and gives great value to the work. The map is by Wm. Topley, F.G.S., and J. G. Goodchild, F.G.S. It is the only map of the kind in any treatise on geology in the English language.

2. *On the level-of-no-strain and mountain making.*—The memoir by Mr. Davison and Prof. Darwin on the contraction-theory of mountain-making was noticed in the last number of this Journal. The same subject has been further discussed by the Rev. O. Fisher and Mr. T. Mellard Reade (Phil. Mag. for January and March.) All of these authors agree in the existence of the level-of-no-strain in the earth, first announced by Mr. Reade, and their estimates of its depth do not vary very widely, all agreeing that it must be within a few miles (2 to 5) of the surface. As regards the amount of crumpling of strata on this basis Mr. Darwin (as noted before) makes it small and yet not entirely insignificant (228,000 sq. miles in 10 million years). Mr. Fisher's conclusions upon the supposition of a temperature of solidification of respectively 7000° and 4000° are contained in the following table:

Temperature of solidification.	7000°	4000°
Depth of level of greatest cooling	54 miles	31 miles
Depth of level of no strain	2 miles	0·7 miles
Temperature of level of no strain	358° F.	124° F.
Mean height of elevations	19 feet	2 feet
Total contraction of radius	6 miles	2 miles

Mr. Reade discusses some of the geological consequences of the level-of-no-strain and concludes that it is "plain to demonstration that the lateral pressure that forced up the mountains could not reside in a shell of compression only 5 miles thick having a zero strain in the under side."

3. *Geology of Rhode Island; Franklin Society Report.* 130 pp., 8vo., 1887. Providence, R. I.—This report is largely bibliographic, but is very full in notes that review well what is known on the geology of the State and show who have been the observers. They also make it apparent that no thorough study of the geology of the State has been undertaken. The State contains the coal formation among metamorphic rocks, and this alone makes it one of the three or four best centres to start from for the study of New England geology.

4. *Annual Report for* 1886 *of the Geological Survey of Pennsylvania.* 8vo.—This part of the Report of 1886 contains Part II, on the Oil and Gas Region, by J. F. Carll; a chapter on the Chemical composition of Natural Gas, by F. C. Phillips, and a Bibliography of Petroleum.

5. *Annuaire Géologique universel, Revue de Géologie et Paléontologie;* dirigée par Dr. L. Carez and H. Douvillé, avec le concours de nombreux Géologues Français et étrangers; publié par Le. Dr. Dagincourt. Tome III. Paris, 1887.—The former volumes of this Annual contained, besides lists and abstracts of geological papers of the year, a catalogue of geologists of different countries, with their places of residence. The present is con-

fined wholly to the former purpose, and in it 777 pages are devoted to the Geology and 235 to the Paleontology of 1886. It is a work that geologists, whatever their special department, will find very useful if not indispensable.

6. *The Geological Record for* 1879. An account of works on Geology, Mineralogy, and Palæontology published during the year with supplements for 1874–78. Edited by W. Whitaker and W. H. Dalton. 418 pp. 8vo, London, 1887, (Taylor and Francis.)—This comprehensive volume, like its predecessors in scope, will be thoroughly welcome although it is somewhat late in appearing. For the future it is announced that the editorship has passed into the hands of Mr. Topley and the work is to be brought up to date by publishing the titles only of papers from 1880–87. The portion from 1880–1884 is finished and in great part printed, making two volumes. That for 1885–87 is in hand though not yet in type. Subscribers will be quite ready to respond to the suggestion of the editor-in-chief, that the delay should be pardoned in view of the fact that the board of workers labor without pecuniary return.

7. *A Manual of the Geology of India. Part IV: Mineralogy* (mainly non-economic), by F. R. Mallet. 179 pp. 8vo, with 4 plates. Calcutta and London, (Trübner & Co.) 1887.—The economic side of the mineralogy of India has already been discussed in Part III of this work by Mr. V. Ball. The scientific treatment of the same subject has now been taken up by Mr. F. R. Mallet, and this important contribution to mineralogical literature is the result. It is a subject about which our knowledge has been in the past vague and scanty, and although much remains to be done in the way of investigating the mineral treasures of India, this complete and accurate presentation of what is now known about them is of great value.

8. *Brief notes on recently described minerals.*—Arseniopléite.—Occurs in reddish brown cleavable masses forming small veins or nodules with rhodonite and hausmannite in a crystalline limestone from the Sjö mine, Gryhyttan, Sweden. It is shown optically (Bertrand) to be uniaxial and negative, probably rhombohedral. Analysis gave:

As_2O_5	Sb_2O_5	MnO	Fe_2O_3	PbO	CaO	MgO	H_2O	Cl	
44·98	*tr.*	28·25	3·68	4·48	8·11	3·10	5·67	*tr.*	= 98·27

This is corrected to give Mn_2O_3 7·80, MnO_2 21·25, H_2O 4·54, final sum 97·94. It is closely related to the large group of manganese arseniates from Sweden.—*L. J. Igelström* in *Bull. Soc. Min.*, vol. xi, 39, 1888.

Barkevikite, Calciothorite, Melanocerite, Nordenskiöldine, Rosenbuschite.—In a preliminary paper giving an outline of results obtained in a study of the augite- and elæolite-syenite veins of southern Norway, Brögger has briefly described several new species and given new facts about many others, as låvenite, gibbsite, homilite, natrolite, leucophanite, meliphanite, etc.

Barkevikite is a hornblende mineral near arfvedsonite, but distinct from that in optical characters. Calciothorite is a hydrous mineral consisting of thorium and calcium silicate and probably (like thorite, orangite, eucrasite, frejalite) an alteration product of an original thorium silicate near zircon in form and composition ($ThSiO_4$).

Melanocerite is a complex silicate of the cerium metals, yttrium and calcium, with other substances in small amount including 3·19 p. c. B_2O_3; it is found in tabular rhombohedral crystals of a dark brown color. Nordenskiöldine is a mineral having the remarkable composition $CaO . SnO_2 . B_2O_3$. It occurs in tabular crystals belonging to the rhombohedral system. Color sulphur yellow. Hardness = 5·5–6; sp. gravity = 4·20. Rosenbuschite is a silicate of calcium and sodium with zirconium, titanium and also lanthanum in small amount. It occurs in orange-gray monoclinic crystals near wollastonite and pectolite in angle, and is characterized as a zirconium-pectolite. Hardness = 5–6; sp. gravity, 3·30.—*W. C. Brögger in Geol. För. Förh.*, vol. ix, 247, 1887.

Barysil.—A new lead silicate from the Harstig mine, Pajsberg, Sweden. It occurs in iron ore with calcite, yellow garnet, tephroite and galena. Crystallization hexagonal with basal cleavage. Color white. Hardness = 3; sp. gravity, 6·11–6·55. Analysis gave:

SiO_2	PbO	MnO	FeO	CaO	MgO	ign.
16·98	77·84	3·49	0·16	0·41	0·58	0·66 = 100·12

This corresponds to $3PbO . 2SiO_2$.—*A. Sjögren and Lundström in Œfv. Vet.-Akad. Förh.*, xlv, 7, 1888.

Belonesite (Belonesia), Cryphiolite (Crifiolite).—Two species described by A. Scacchi in a memoir upon a fragment of an old volcanic rock enveloped in the Vesuvian lava of 1872. Belonesite occurs in minute acicular crystals referred to the tetragonal system; they are white and transparent. Qualitative tests lead to the conclusion that in composition it is a molybdate of magnesium, $MgO . MoO_3$.

Cryphiolite occurs in small tabular monoclinic crystals covered and concealed (as the name suggests) by apatite. The color is honey-yellow; sp. gravity = 2·674. An analysis gave:

P_2O_5 48·91	MgO 33·58	CaO 14·60	Loss 2·91 = 100

The presence of fluorine is suggested and the possible amount estimated as 6·93 p. c., which brings the mineral near wagnerite in composition.—*Mem. Accad. Napoli*, II, i, No. 5.

Bementite.—Occurs in stellate aggregations with foliated structure, resembling pyrophyllite. Friable. Sp. gravity, 2·981. Color pale grayish yellow. An analysis yielded:

SiO_2	MnO	FeO	ZnO	MgO	H_2O
39·00	42·12	[3·75]	2·86	3·83	8·44 = 100

This corresponds approximately to $2(H_2,Mn)O . SiO_2$; the water goes off above 200°. Occurs embedded in calcite at Franklin

Furnace, N. J. Named after Mr. C. S. Bement, of Philadelphia. —*G. A. König in Proc. Acad. Nat. Sci., Philad.*, 1887, 311.

DIHYDRO-THENARDITE.—A sodium sulphate containing two molecules of water. It forms a thin bed on the shores of Lake Gori, Tiflis, Russia, and crystallizes in the monoclinic system.—*Markownikow in Ber. Chem. Ges.*, 1887, 546 (J. Russ. phys. ch., Ges.).

FIEDLERITE, LAURIONITE.—Two related minerals found in the old lead slags of Laurion, Greece, and produced by the action of the sea-water upon them during the past 2,000 years. Laurionite occurs in white prismatic crystals (orthorhombic) not far from mendipite in angle. Hardness, =3·5. Composition, $Pb(OH)_2.PbCl_2$; an analysis by Bodewig yielding:

Pb 79·38 O 3·17 Cl 13·77 H_2O 3·68 = 100

Fiedlerite is related in composition, but no analysis has been given. It occurs in minute tabular monoclinic crystals, in part twins.—*G. vom Rath in Sitzungsber. Nied. Ges. Bonn*, June 6, 1887; *Köchlin in Ann. Mus. Wien*, vol. 2, 185, 1887.

LAUBANITE.—A zeolite resembling stilbite from the basalt near Lauban, Silesia. Occurs in fine fibrous radiated aggregates, sometimes spherical, of a snow-white color. Hardness, 4·5–5; sp. gravity = 2·23. Analysis gave:

SiO_2 47·84, Al_2O_3 16·74, FeO 0·56, CaO 16·17, MgO 1·35, H_2O 17·08=99·76

This corresponds to $2CaSiO_3+Al_2(SiO_3)_3+6H_2O$, which is not far from laumontite.—*H. Traube in Jahrb. Min.*, 1887, vol. ii, 64.

MARTINITE.—Occurs as a pseudomorph having the form of gypsum in the guano on the island Curaçoa. In white or yellowish aggregates of colorless microscopic rhombohedrons. Sp. gravity, 2·894. Analysis gave:

P_2O_5 47·67 CaO 46·78 H_2O 4·52 Organic 0·75 Insol. 0·20=99·92

The formula suggested is $2Ca_3(PO_4)_2+4CaHPO_4+H_2O$.—*J. H. Kloos, Jahrb. Min.*, 1888, vol. i, 41 ref.

METALONCHIDITE.—A mineral from the St. Bernhard mine near Hausach in Baden. It is essentially a variety of marcasite, agreeing with it in form and characterized by the presence of 2·7 p. c. of arsenic with some nickel and lead, thus approximating closely to Breithaupt's lonchidite.—*Sandberger in Œst. Zeitschr. Berg-Hütt.*, xxxv, 1887.

9. *Note on Xanthitane;* by L. G. EAKINS (communicated.)—Through the kindness of Mr. Wm. Earl Hidden, Prof. Clarke has lately received some fine specimens of Xanthitane, first described by C. U. Shepard, this Journal, 1856, vol. xxii, p. 96, which were turned over to me for examination. The material is from Green river, Henderson Co., N. C., and is undoubtedly an alteration product of sphene—following the form very closely. It is light yellow, friable and mixed with impurities which cannot be removed, preventing the determination of whether or not it is a definite mineral, but it is interesting from the fact that it apparently represents a clay with the silica replaced by titanic oxide.

Specific gravity 2·941 at 24°. The air dried material loses 6·02 per cent of water at 100°. The following analysis is on material dried at 100°.

SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	P_2O_5	H_2O
1·76	61·54	17·59	4·46	0·90	*tr.*	4·17	9·92=100·34

Laboratory, U. S. Geol. Survey, Washington, D. C.

III. Botany and Zoology.

1. *Recent contributions to our knowledge of the vegetable cell.* (Second paper, continued from page 344.)—Loew and Bokorky distinguish between active and passive albumin in vegetable cells. The former is characterized by its great chemical instability, and especially by its property of reducing silver solutions even when they are very dilute: the latter, on the other hand, is relatively stable and is not readily changed or oxidized. These distinctions have been pointed out by the authors in various communications, more recently in a treatise on certain relations of protoplasm. According to them, active albumin, in combination with water, forms all living protoplasts, and, at the death of the cell, passes over into "common" or passive albumin. The authors (Bot. Zeit., Dec. 30, 1887) announce that they have detected active albumin also in cell-sap in many species of Spirogyra. From its solution in cell-sap it is precipitated whenever a dilute solution of ammonic carbonate is allowed to act on the cells. A granular precipitate appears not only in the plasma-membrane where the granules are confined within or are attached to the membrane, but in the cell-sap as well, the latter granules settling, after a time, to the lower part of the cell. *These granules do not occur in either the membrane or the cell-sap if the cell has been previously killed by pressure, cutting, or by chemical means.*

It is interesting to compare these statements with those made by Charles Darwin and others. The views of Mr. Darwin are well known by readers of his Insectivorous Plants (see page 39), and need not be further alluded to here. Pfeffer explains the appearance of aggregation in a different way: he regards the precipitate as consisting of tannate of albumin, which forms on account of the neutralization of the cell-sap by means of the ammonic carbonate. Pfeffer calls attention to the fact that the precipitate re-dissolves when an organic acid, for instance, citric, is added, and falls again when the sap becomes again alkaline. He has shown that the precipitation is effected by the addition of a tenth per cent solution of ammonic carbonate, and that re-solution occurs when a two-hundredth of one per cent solution of citric acid is employed. Loew and Bokorky state, however, that the cell-sap of Spirogyra is not acid in reaction, and that it contains no free acid. Therefore, according to them, Pfeffer's explanation of the phenomena is not satisfactory. The so-called "aggregation" is, as Francis Darwin and others have pointed out, a common occurrence in many cells. It appears to demand further investigation.

It is a familiar fact that the crystalline forms of calcium oxalate which occur in plants are referable to two crystalline types: (1) tetragonal or quadratic, when they have six equivalents of water; (2) monoclinic or clinorhombic, when they have two equivalents of water. Souchay and Lenssen attributed the difference to difference in the rate of crystallization, the first type resulting from rapid precipitation, the latter from a slower reaction. That the two types can occur in the same liquid is proved by a simple experiment suggested by Kny: on a glass slide is placed a drop of gelatin with a crystal of oxalic acid on one edge, at the opposite edge of the drop is placed a fragment of calcium chlorid. The two substances soon begin to form at their point or line of contact a white precipitate, first of octahedra, and later of a few monoclinic crystals intermingled with them. Haushofer has stated that the character of the mother liquor exerts a controlling influence on the shape of the crystals and their content of water; according to him the tetragonal crystals are formed from dilute neutral or alkaline calcium solutions at the ordinary temperature of the room. The other type is produced when there is a slight excess of oxalic acid or when the temperature is much higher. At this point Kny has undertaken a re-investigation of the subject (Ber. Deutsch. Bot. Gesellschaft, 8, 1887). He concludes that the relative concentration of the solutions in question has a great, even if not controlling, influence in determining the form of the crystals. In the course of his experiments he made some interesting observations regarding the inclusion of coloring matters in the crystalline structure. Certain aniline and other coal-tar dyes tinged some of the crystals while other dyes were without any effect. Thus in the dialyzer, crystals of the monoclinic type were tinged by eosin while the octahedra remained colorless; on the other hand, by aniline-blue both were distinctly colored. But in both cases the larger crystals remained without color. Fuchsin failed to color any of the crystals. G. L. G.

2. *Garden and Forest.* A weekly Journal of Horticulture and Arboriculture, conducted by Professor C. S. SARGENT, of Harvard University. It is pleasant to note that this periodical fully meets the expectations which were formed when the announcement of its publication was first made. Aside from matters of general and public interest, like the subjects of forest preservation, the care of plants, and the like, each number thus far has been enriched by a description of some plant of botanical (and often horticultural) interest, by Dr. Sereno Watson. These articles by Dr. Watson have been illustrated by Mr. Faxon's excellent drawings. The journal promises to be a substantial addition to the list of scientific periodicals, while, at the same time, it preserves to a large degree elements of general popularity. G. L. G.

3. BIBLIOTHECA ZOOLOGICA.—The first number* of this im-

* Bibliotheca Zoologica—Original-Abhandlungen aus dem Gesammtgebiete der Zoologie. Herausgegeben von Dr. Rud. Leuckart in Leipzig und Dr. Carl Chun in Königsberg. Heft 1, Die Pelagische Thierwelt in grösseren Meerestiefen und ihre Beziehungen zu der Oberflächenfauna. Geschildert von Prof. Dr. Carl Chun in Königsberg. Mit 5 Tafeln.

portant zoological periodical is published. It is edited by Professors Leuckart and Chun and they propose to devote this new serial to more elaborate monographs than can from their size or the number of their illustrations easily find a place in zoological periodicals. The Bibliotheca Zoologica will hold in zoology very much the same place which Palæontographica and similar publications hold in palæontology. The first number contains a most interesting monograph on the existence of a pelagic fauna at great depth and its relation to the surface pelagic fauna. Dr. Chun was engaged upon a monograph of so-called deep-sea Siphonophoræ collected by Chierchia during the voyage of the "Vettor Pisani." Though collected on the sounding line they were labelled with the utmost precision as living below 1000 meters. Chun who was also preparing a monograph of the Mediterranean Siphonophores came to the conclusion that the collection of Chierchia supported the views of Studer that peculiar Siphonophores formed an important part of a pelagic deep-sea fauna. Under the auspices of the Zoological Station at Naples he carried on most successful deep-sea tow net experiments from August to October, 1866. Unfortunately this expedition, interesting as its results are, does little toward settling the subjects under discussion because neither the distance from shore nor the depths investigated were great enough to eliminate the disturbing effects of close proximity to land; as it was near the continental slope, on the very edge of which Dr. Chun trawled with the tow net. The results are further vitiated from the fact that they have been carried on in a closed sea where the conditions of temperature are strikingly different from those of the Atlantic, and where at a depth of about 500 fathoms we find already the lowest temperatures of the deepest part of the Mediterranean. The minimum seasonal differences of temperature between that and the surface cannot be contrasted to oceanic conditions.

Dr. Chun made use for his investigations of an ingenious self-closing tow net invented by Captain Palumbo of the "Vettor Pisani." It may be closed at any given point by means of a propellor working in a rectangular frame attached to the tow net on the same principle as the propellor for upsetting the Negretti Zambra deep-sea thermometer and the Sigsbee water bottle. The little steamer "Johannes Müller" of the Naples Zoological Station made an excursion to the Ponza Islands as well as expeditions to the Gulf of Salerno, to Ischia and Ventotene.

The contents of the deep-sea tow nets used by the Challenger could not be assigned to any definite depth as the nets were not closed either on the descent or the ascent. Neither can the method adopted on the "Blake" of collecting at intermediate depths by means of the Sigsbee collecting cylinder be considered decisive. It had not been tried long enough or frequently enough at great depths (it was not carried beyond 150 fathoms) to decide the depth to which the surface pelagic fauna might sink or to prove the existence of an intermediate deep-sea fauna in the depths between the surface fauna and the deep-sea fauna.

From the depth of 1300 meters Dr. Chun brought up a large pelagic fauna. Small Craspedote Medusæ, Ctenophores, Dyphiæ, Tomopteridæ, Sagittæ, Alciopidæ and numberless Copepods, Stylocheiræ, larvæ of Decapods, Appendiculariæ, Pteropods and small transparent Cephalopods. Dr. Chun assumes that where he found this mass of Invertebrates there were no currents and that so rich a booty brought up by a hap-hazard cast of the net indicates a wonderful richness of the deep-sea pelagic fauna, especially when we remember that surface pelagic fishing is only successful in the wake of tide currents, calm streaks and the like. But there is nothing to show that so close in shore there is not a more or less active interchange of the fauna from the shore slopes to that of the greater depths. Should the observations of Dr. Chun be repeated off shore in the deep water of oceanic basins and the existence of this deep-sea pelagic fauna proved beyond a doubt, it will help to explain the manner in which the deep-sea fauna obtains its food; nor will it be necessary to suppose, as he seems inclined to do, that these deep-sea animals are wholly dependent on the broth concocted at the surface and passing down in a ceaseless rain upon the bottom. Surely no one who has trawled and dredged in the deep-sea can have failed to note the large number of free-swimming animals such as Crustacea, Cephalopods, Annelids and fishes of which only an occasional specimen could be caught by the slow moving dredge or trawl, while a faster trawl brought up the more nimble deep-sea types. It seems to us that the results of Chun merely prove that in a close sea, near shore, even at considerable depth there is a great mixture of true deep-sea types and surface pelagic animals which sink at certain times far beyond the limits usually assigned to them. Certainly no one who has engaged in deep-sea work has ever supposed that there were not at the bottom or near the bottom free-swimming animals which occasionally found their way to the surface while many of the so-called surface pelagic types have been proved by deep-sea expeditions to be the young of abyssal species. Chun has however clearly proved that many embryonic stages of surface pelagic animals are only found at considerable depths. Deep-sea fishing with a properly closing net promises to be a material help to embryological investigations.

Chun looks upon the slight changes of temperature as the important factors in determining the periodic rising and sinking of the surface pelagic fauna. He thinks the great increase of temperature at the surface compels surface pelagic animals to seek cooler depths. While this is undoubtedly true for some groups it does not hold good for the larger number and we are more inclined to consider the condition of the surface, whether calm or ruffled by waves and winds, as a more powerful influence. Thus while there is always a richer pelagic fauna to be collected at night it is only on calm nights that a good harvest will be obtained. Yet in all my experience of surface collecting I have never met with such prodigious masses of surface pelagic animals as on the hottest days of our dredging expeditions. When the sea happened to be smooth as glass under a blazing tropical sun it seemed as if the water was nearly solid as far as the eye could reach with countless surface animals of all sorts. It is true that such remarkable collections were only seen in the track of the Gulf Stream when at a distance from shore, or when we were in the track of currents due to the influence of neighboring islands or continents.

We have a considerable number of deep-sea sedentary types which have an extraordinary bathymetrical range. There is no reason therefore why pelagic animals which are more or less helpless and drift at the mercy of the waves and winds and currents, should not be able to flourish under similar extremes of pressure and temperature. The more so as the majority belong to groups of Invertebrates, on which the effects of pressure would be far less perceptible. The tow-net trawling of Murray in some of the deeper lochs of the western part of Scotland indicates that the range of this deep-sea pelagic fauna does not extend far from the bottom, although specimens of nearly all the species occasionally find their way to the surface. There is nothing to show that the more active deep-sea Crustacea, Fishes, Cephalopods, Pteropods, Annelids, Acalephs, Polyps, Rhizopods have not a considerable range and may pass rapidly either vertically or near the bottom through layers of water of very considerable differences of temperature and pressure. That this movement takes place through all intermediate layers of water near the shores within moderate depths seems conclusively proved by Chun's investigations. That it takes place far from the continental slopes in the oceanic areas is altogether another question. Chun has also come to the conclusion that the surface pelagic fauna does not extend to any great depth, but he has undoubtedly shown that within a short distance from the shore there are a large number of deep-sea pelagic animals living within a moderate range from the bottom, and that they occasionally come to the surface. These deep-sea pelagic types become mixed with the surface pelagic fauna much as many of the abyssal types which have a great bathymetrical range are dredged within the hundred-fathom line or near it, and constitute a part of our shallow-water fauna.

We must remember that nearly all of the Radiolarians which Chun mentions as having been taken with the tow net at a depth of 300 fathoms have also been collected at the surface. The species enumerated of Tomopteris of the Phronimidæ are more common in deeper water than at the surface. The same is true of Stylocheiron, of the species of Spirialis, and of the two species of Cephalopods. But there are several species of large Appendiculariæ, which have thus far escaped the surface tow net of all the naturalists who have explored the Bay of Naples. Chun seems to have demonstrated for surface pelagic animals a far greater bathymetrical range than they were known to have, and one which, perhaps, corresponds to the wide bathymetrical range of many so-called deep-sea types which extend from the greatest depths at which animals have been dredged almost to the regions of the littoral belt.

An interesting chapter on the "Dissogonie" of Ctenophores concludes this capital memoir. Chun has suggested the term Dissogonie to indicate the peculiar reproduction and development of embryo Ctenophoræ. He has observed that the *Cydippe* form of Bolina, after the degeneration of the genital organs (which are fully developed soon after leaving the egg envelope), is developed into the Bolina form. This monograph is illustrated by five excellent plates from the pencil of Dr. Chun. One of the plates gives a sketch of the deep-sea tow net, as well as of the photographic apparatus used by Dr. Chun. A. AG.

6. *Report on the Annelids, of the Dredging Expedition of the U. S. Coast Survey Steamer "Blake;"* by E. EHLERS. 336 pp., 4to, with 60 plates.—Memoirs of the Mus. Comp. Zool. vol. XV. Cambridge, 1887.—An admirable volume. Some of the plates are colored; all engraved in the best style of the art.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *National Academy of Sciences.*—The following is a list of the papers entered to be read at the April meeting of the Academy in Washington:

J. E. OLIVER: The Rotation of the Sun.

T. STERRY HUNT: The Foundations of Chemistry.

T. C. MENDENHALL: On an Improved Form of Quadrant Electrometer, with Remarks upon its use.

E. D. COPE: On the Vertebrate Fauna of the Puerco Series. On the Auditory Bones of the Batrachia.

ORMOND STONE: The Orbit of Hyperion.

B. K. EMERSON: Map of Connecticut River Region in Massachusetts.

A. HYATT: Parallel Series in the Evolution of Cephalopoda. Evolution of Cephalopoda in the Fauna of the Lias.

L. F. WARD: The Evidence of the Fossil Plants as to the Age of the Potomac Formation.

S. P. LANGLEY: Vision and Energy.

H. A. ROWLAND: Report of Progress in Spectrum Photography. Note on the Spectrum of Carbon and its Existence in the Sun.

H. P. BOWDITCH: Reinforcement and Inhibition.

A. GRAHAM BELL: On Apparent Elasticity produced in an Apparatus by the Pressure of the Atmosphere; and the Bearing of the Phenomenon upon the Hypothesis of Potential Energy.

H. A. NEWTON: The Orbits of Aerolites.

E. C. PICKERING: A Large Photographic Telescope.

W. T. SEDGWICK and G. R. TUCKER: A New Method for the Biological Examination of Air; with a description of an Aerobioscope.

WOLCOTT GIBBS and HOBART AMORY HARE: Preliminary Notice of the Object, Methods and Results of a Systematic Study of the Action of Definitely Related Chemical Compounds upon Animals.

IRA REMSEN: On the Constitution of the so-called Double Halogen Salts. Studies on the Rate of Decomposition of the Bromides of the Saturated Alcohol Radicals.

THEO. GILL: The Characteristics of the Order and Sub-orders of Fishes.
F. W. PUTNAM: The Serpent Mound and its Surroundings.
C. V. RILEY: The Systematic Relations of Platypsyllus as determined by the Larva.
C. H. F. PETERS: On the Position of the Nova of 1572, as determined by Tycho Brahe.
J. S. NEWBERRY: Some Notes on the Laramie Group. On the Structure and Relations of Placoderm Fishes.

At the meeting the Draper Astronomical Medal was presented to Professor E. C. Pickering, of Cambridge, and the Lawrence Smith Medal, for original work upon the subject of Meteorites, to Professor H. A. Newton, of New Haven.

The American Anthropologist, published under the auspices of the Anthropological Society of Washington, vol. i, No. 1, January, 1888, 96 pp. 8vo. Washington, D. C., 1888.—This new Quarterly Journal, which has all the commendation it needs in the fact of its being the continuation of the Transactions of the Anthropological Society of Washington, comprises in its editorial Committee: Prof. J. HOWARD GORE, Mr. THOMAS HAMPSON, Mr. H. W. HENSHAW, Prof. O. T. MASON, Dr. WASHINGTON MATTHEWS, S. V. PROUDFIT and Col. F. A. SEELY. It desires to extend the range of its contributions and of the usefulness of the Washington Society. The present number contains papers by Dr. J. C. WELLING on the Law of Malthus; Col. SEELY on the development of time-keeping in Greece and Rome; Dr. FRANK BAKER, anthropological notes on the human hand; and Dr. D. G. BRINTON, on the Chane-abai (four-language) tribe and dialect of Chiapas. Other papers are to appear on the nephrite question, by Dr. A. B. MEYER of Dresden; on the subject "From barbarism to civilization," by Major POWELL; on Discontinuities in Nature's methods, by H. H. BATES of the U. S. Patent Office. The subscription price of the Journal is three dollars a year. Communications should be addressed to Mr. Thomas Hampson, Washington, D. C.

OBITUARY.

OSCAR HARGER, whose death was announced in the December number, was born in Oxford, Conn., January 12, 1843. From his father, a farmer and land surveyor, he inherited great physical endurance, remarkable mathematical talents and the salient points of his strong character. By almost unaided exertions he prepared himself for college, and, entering Yale, maintained himself during the four years of undergraduate study by teaching and mathematical work, and was graduated with high standing in the Class of 1868. During his college course he developed great mathematical capacity and ever after took special delight in abstruse mathematical work, often resorting to it for recreation. It is probable that the bent of his mind was mathematical but, while a boy, he had studied botany and become familiar with the native plants about his home, although his time was so occupied with farm labor during the proper time for botanizing that he commenced the study of grasses and sedges in winter, collecting and identifying many species from the hay stored in barns. His success in botany undoubtedly led him to turn his attention to other departments of natural history, and after graduation from college he abandoned the mathematical career open to him and began the study of zoology with Professor Verrill. In his zoological studies he at once showed special aptitude for original work and had begun important investigations when, in 1870, he accepted the position of Assistant in Paleontology under Professor Marsh, which he held uninterruptedly until his death.

Although the greater part of his time and energy was given to work in vertebrate paleontology, he continued his investigations in invertebrate zoology as long as his health permitted and published papers on myriapods, a fossil arachnid, isopods, and, jointly with the present writer, a report on a dredging expedition to the region of St. George's Banks. His last and most important published works are a report on the Marine Isopoda of New England and the adjacent waters, and on the Isopoda of the Blake dredgings on the eastern coast of the United States. The former, his only completed work, is a systematic and accurate monograph, one of the most important contributions to our knowledge of the Isopoda, and will long remain a standard authority and a manual for the study of that group on our coast.

These publications establish his reputation as a zoologist, but his best work and highest attainments were in the department of vertebrate paleontology. Remarkable logical powers, an unbiased mind, and years of accurate observation, had given him a truly wonderful knowledge of vertebrate osteology. Under his hand the broken and disarranged bones of an unknown carpus or tarsus seemed to fall into their proper places by magic. But his knowledge was not one of details alone; he had a truly philosophical grasp of the bearing of facts on evolution and classification; and only the few who knew his attainments can appreciate how much paleontological science would have been advanced had he been able to publish his observations and conclusions. He was not a scientific specialist only, but took a deep and practical interest in politics and other questions of the day, and his peculiarly open mind, wholly untrammeled by bias or preconception, gave his views and arguments on any subject originality and value.

Mr. Harger never enjoyed robust health, and in 1879 he was attacked by a cardiac trouble which increased from year to year. Though knowing that his life was despaired of by his physicians and friends, he never spoke of his illness but, with silent courage and indomitable will, worked on cheerfully, attending to his regular duties until prostrated by cerebral hemorrhage a week before his death.

In 1875 he married Miss Jessie Craig of New Haven, who, in the highest sense, was his helpful and sympathizing companion. Only those can fully appreciate his loss whose privilege it was to belong to the little circle enjoying his every day companionship and who feel that they are better for the example of his pure and inflexibly truthful life. S. I. S.

Professor Jules-Émile Planchon, of Montpellier, died April 1st, at the age of 65 years.

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[THIRD SERIES.]

ART. XXXVI.—*Note on Earthquake-Intensity in San Francisco;* by EDWARD S. HOLDEN, LL.D., Director of the Lick Observatory.

TOWARD the end of 1887, the Regents of the University of California published a pamphlet prepared by me bearing the title "List of Recorded Earthquakes in California, etc.;" 1887; 8vo, pp. 78. This work contained all the information regarding California earthquakes which I have been able to collect. The information is presented in a popular rather than a scientific form, though the Introduction contains statistics, more or less valuable, relating to the distribution of the shocks by years, months and seasons.

It is the object of the present note to obtain an estimate of the absolute value of the earthquake-intensity developed at San Francisco during our historic period. I am obliged to confine myself to San Francisco, whose records are very complete, owing to the conscientious care of Mr. Thomas Tennant.

With this end in view I have gone over the printed pamphlet and wherever the data were sufficiently exact, I have assigned the intensity of each separate shock on the arbitrary scale of Rossi and Forel, omitting every doubtful case. The later papers of Professor Rockwood already contained this datum. Omitting all doubtful cases, I found 948 shocks at 214 different stations in California which had been so well reported as to allow an intensity on the scale, to be assigned with certainty. In San Francisco, 417 shocks in all have been recorded. Of these, 200 were accurately described.

The Rossi-Forel Scale.

I. Microseismic shock—recorded by a single seismograph, or by seismographs of the same model, but not putting seismographs of different patterns in motion; reported by experienced observers only.

II. Shock recorded by several seismographs of different patterns; reported by a small number of persons at rest.

III. Shock reported by a number of persons at rest; duration or direction noted.

IV. Shock reported by persons in motion; shaking of movable objects, doors and windows, cracking of ceilings.

V. Shock felt generally by every one; furniture shaken; some bells rung.

VI. General awakening of sleepers; general ringing of bells; swinging of chandeliers; stopping of clocks; visible swaying of trees; some persons run out of buildings.

VII. Overturning of loose objects; fall of plaster; striking of church bells; general fright, without damage to buildings.

VIII. Fall of chimneys; cracks in the walls of buildings.

IX. Partial or total destruction of some buildings.

X. Great disasters; overturning of rocks; fissures in the surface of the earth; mountain slides.

Determination of the mechanical equivalent of each degree on the Rossi-Forel scale.

It is necessary to determine the value of each degree on the Rossi-Forel scale in terms of some natural units. This it is impossible to do with exactness, owing to the nature of the subject, and it is somewhat difficult to get results sufficiently exact to be used in practice.

Referring to the Rossi-Forel scale, we find that degrees I, II, III correspond to the *feelings* of the observer—to his sensations. The rest of the scale (IV–X) refers chiefly to the effects of the shock in producing motion upon inanimate matter. The problem is to get some kind of a common unit of a mechanical sort, and to express the various degrees of the scale in terms of this unit. There is no question as to what unit to employ. The researches of the Japanese seismologists have abundantly shown that the destruction of buildings, etc., is proportional to the acceleration produced by the earthquake shock itself in a mass connected with the earth's surface.

The earthquake motion is a wave-motion, and although it is not simple harmonic, it is necessary to assume it to be such to obtain a basis for computation. We assume then a = amplitude of the largest wave; T = period of the largest wave; $V = \frac{2\pi a}{T}$ = velocity of the impulse given by the shock; $I = \frac{V^2}{a} = 4\pi^2 . \frac{a}{T^2}$ = intensity of the shock, defined mechanically

= destructive effect = the maximum acceleration due to the impulse.

It would be logical to express I in fractions of the acceleration due to gravity, *i. e.*, 9810^{mm} per 1^s. As these fractions are usually small, it is convenient to give the values of I in terms of millimeters per 1^s.

The observations of Ewing, Milne and Sekiya on Japanese earthquakes give for each shock a and T, from which V and I can be computed. Very frequently a description of the effects of the shock on buildings, etc., is given by them, which description is often sufficiently minute to justify the characterization of the shock by one of the degrees of the Rossi-Forel scale.

I have carefully examined all the writings of the three gentlemen named, accessible to me, and after rejecting all doubtful cases, I have found twenty-one shocks ranging in intensity from I to IX, in which the a and T were determined by instruments and in which I could assign the Rossi-Forel intensity with confidence. The following table is the result:

*Equivalents of the degrees of intensity of Earthquake shocks on the Rossi-Forel scale, in terms of the acceleration due to the velocity of the shock itself.**

$$I = \frac{V^2}{a} = \frac{2\pi a}{T^2}$$

Rossi-Forel Scale.	Intensity.			Diff.
I	corresponds to	20^{mm}	per 1^s	----
II	"	40	"	(20)
III	"	60	"	(20)
IV	"	80	"	(20)
V	"	110	"	(30)
VI	"	150	"	(40)
VII	"	300	"	(150)
VIII	"	500	"	(200)
IX	"	1200	"	(700)

So far as I know, this is the best determination possible from the meager data now available.

The observations at Berkeley and Mt. Hamilton are especially directed toward obtaining better values of these relations. A few years of observations will determine them, at least for the lighter shocks (I–VI).

* It is interesting to observe the influence of long period in diminishing the destructive effect of a shock of given amplitude. Thus a shock of intensity VIII has $I = \frac{4\pi^2 a}{T^2} = 500^{mm}$ per 1^s by observation. If $T = 0{\cdot}1^s$, $a = 0{\cdot}1^{mm}$, while if $T = 1^s$, $a = 13^{mm}$, and so for other cases.

Absolute intensity of Earthquake action at San Francisco.

417 shocks of all intensities have been recorded at San Francisco in the years 1808–1888. Of these, 200 were described so definitely that their intensities could be assigned on the Rossi-Forel scale with tolerable certainty. This work has been done with great care and is summarized in the following table :

No. of shocks actually recorded at San Francisco (1808–1888) *for which the intensity is known.*

Intensity on Rossi-Forel Scale.	Number of Shocks.
I	8
II	4
III	55
IV	50
V	58
VI	12
VII	4
VIII	7
IX	2
Total,	200

Beside the 200 shocks of known intensity, there are 217 shocks printed in my catalogue. No doubt a great number of the lighter shocks (I, II, III,) are not recorded at all.

Earthquake action is so irregular and lawless, that it is not possible to make any estimate however rough of the number of these lighter shocks. Experience has amply proved that the average intensity of San Francisco shocks is not above IV on the Rossi-Forel scale. The vast majority of our shocks are II and III and the average is certainly below IV. I shall, therefore, assume this fact as a basis for computation.

The 200 shocks of known intensity are evaluated and summed up in the following table:

						Units of Acceleration.
8	shocks of intensity	I	correspond to	8 × 20	=	160
4	" "	II	" "	4 × 40	=	160
55	" "	III	" "	55 × 60	=	3300
50	" "	IV	" "	50 × 80	=	4000
58	" "	V	" "	58 × 110	=	6380
12	" "	VI	" "	12 × 150	=	1800
4	" "	VII	" "	4 × 300	=	1200
7	" "	VIII	" "	7 × 500	=	3500
2	" "	IX	" "	2 × 1200	=	2400
200	recorded shocks of known intensities correspond to					22900 units.

The *average recorded* shock corresponds to I = 114 units or approximately to V on the scale. This simply proves that all, or nearly all, the shocks of intensity V and more severe have been recorded and that the lighter shocks have been neglected.

As has been said 417 shocks in all have been noted (of which only 200 are accurately described). I assume the 217 shocks of unknown intensities to have had between 48 and 49 units of intensity each, or 10460 units in all. This amounts to supposing our average shock to be of intensity IV.

In this way the table will stand:

	Units of Acceleration.
217 shocks of unknown intensity give	10460
200 " " known intensity give	22900
417 shocks recorded (1808–1888) give	33360

The average shock is of intensity IV corresponding to 80 units or to $\frac{1}{123}$d-part of the acceleration due to gravity. The total intensity of 33360 units has been experienced in 80 years and corresponds to 3·4 the acceleration due to gravity. That is if all the earthquake force which has been expended in San Francisco during the past 80 years were concentrated so as to act at a single instant, it would be capable of producing an acceleration of 3·4 times that of gravity or about 109 feet per second.

The total earthquake intensity during the 80 years is nearly equal to the intensity of 28 separate shocks as severe as that of 1868, but it has been doled out so gently and gradually that we have scarcely known of it.

On the average 392 units of intensity have been developed during each one of the 80 years (1808–88). This will allow for six shocks of intensity III per year or one every two months. In fact 417 shocks have been recorded in the 960 months.

I believe that my earthquake catalogue as printed and the present note, contain nearly all the precise information which can be extracted from our past records, at this time.

The automatic earthquake registers now in use at the University of California, Berkeley (under the care of Professors Le Conte and Soulé) and at the Lick Observatory, Mount Hamilton, will afford valuable data after a few years.

I am greatly in hopes that the chiefs of the U. S. Geological Survey and of the U. S. Signal Bureau may find it practicable to establish and care for seismometric stations in the state. The cost of such stations is small. I find that the excellent duplex-pendulum instrument of Professor Ewing can be satisfactorily duplicated for $15. The California Electric Works, 35 Market street, San Francisco, is now prepared to furnish such instruments at that price. If a sufficient number of stations can be established in California, it seems to me that we may look forward to the collection of data of real theoretical and of some practical importance within comparatively few years.

ART. XXXVII.—*On the relation of the Laramie Group to earlier and later Formations;* by CHARLES A. WHITE.

[Published by permission of the Director of the U. S. Geological Survey.]

WHILE some geologists and paleontologists have claimed the Laramie Group as belonging to the Tertiary, others have as earnestly asserted its Cretaceous age. In the course of my own investigations I have found so many of the paleontological characteristics of that formation to be of little or no value as indicating its age, and other evidence to be so conflicting in character,* that, in my somewhat numerous writings concerning that group, I have hitherto treated it as representing a gradual transition from the Cretaceous to the Tertiary. Investigations concerning the physical conditions which attended the deposition of that great group of strata, and the biological conditions which prevailed during its accumulation are certainly of far more importance than the mere question of its contemporaneity with other formations, which, as regards any formation, can at best be learned only approximately. Still this latter question is by no means a trifling one, and any facts bearing upon it ought to receive due consideration. The object of this article is to record certain lately acquired facts relating to this question, and to present the bearing upon it of others which have before been published.

During the twelve years preceding the autumn of 1887, in which I had made extensive studies and observations concerning the Laramie Group, I was never able to obtain any personal knowledge of the actual stratigraphical relation of that group to any of the marine Tertiary groups which border various portions of North America. I had studied the Laramie in numerous districts from the State of Nuevo Leon, Mexico, on the south to northern Montana on the north; and wherever the base of the formation was observable it was found to rest directly and conformably upon the uppermost of the marine Cretaceous formations.† Furthermore, wherever any strata were found resting upon the Laramie they were always those of the great fresh-water Tertiary series; but I had not then traced the Laramie into a district within which marine Tertiary strata were known to exist. That is, in tra-

* See White, C. A., On the commingling of ancient faunal and modern floral types in the Laramie Group. This Journal, III, vol. xxvi, pp. 120–123.

† For an account of the intimate stratigraphical relation of the Laramie to the marine Cretaceous formation next beneath it; and of a partial faunal connection of the Laramie with freshwater Tertiary formation next above it, see this Journal, III, vol. xxxiii, pp. 364–374.

cing the Laramie into Mexico I had followed the trend of that formation from the north, and thus passed to the westward of the outcrops of the Gulf Tertiaries.

In 1884, Professor E. D. Cope announced that he had found "the Claiborne beds resting immediately upon the Laramie at Laredo,"* Texas; but he then mentioned no correlated facts in support of this important announcement and, so far as I am aware, none have since been published. The known southeastward trend of the Laramie, and the circling, and therefore converging, trend of the Gulf series of formations made it evident that the district traversed by the lower Rio Grande would be found to be the most promising field in which to search for the stratigraphical relation between the Laramie and the Eocene Tertiary. With this object in view, I last autumn visited that region and had the satisfaction of confirming the observation previously made by Professor Cope.

Starting at Eagle Pass, Texas, I proceeded down upon the Texan side of the valley of the Rio Grande to Laredo, making observations by the way. The strata representing the Fox Hills Group of the western section and the Ripley Group of the eastern, were found to dip gradually in the direction of the course of the river, and to receive those of the Laramie Group upon them, the older strata passing finally from view in that direction.

The strata which are exposed in the bluffs along the left bank of the Rio Grande from twenty-five to thirty miles above Laredo, and which bear one or more workable beds of coal there, are referred confidently to the Laramie, although they afforded me only a few imperfect fossils. These strata dip gradually to the southeastward or approximately in the direction of the river's course, and disappear beneath the sandy strata of the Eocene Tertiary some ten or twelve miles above Laredo. Below this, and all around Laredo, the strata which I found exposed are of Eocene age; and in many places they bear an abundance of characteristic fossils.

Going westward from Laredo to Lampazos in Mexico, I was able to recognize the Eocene strata for a distance of about twenty miles, beyond which the underlying rocks are so fully obscured by the debris of the plain that no exposures were observed until the neighborhood of Lampazos was reached. The known presence of Laramie strata, a few miles to the northward of Lampazos, which bear characteristic molluscan fossils of that formation, however, leaves no room for doubt that the Laramie is overlaid by the Eocene upon the Mexican side of the Rio Grande, just as it is upon the Texan side.

*Proc. Am. Philos. Soc., vol. xxi, p. 615.

While I have no doubt as to the Laramie age of the strata referred to, which I observed on both sides of the Rio Grande, and none as to the Eocene age of the strata which I found overlying them, I am by no means certain that the lowermost strata which I found resting upon the Laramie near Laredo represent the lowermost strata of the Eocene division of the Gulf series. Indeed, so far as I could discover, no equivalent of the "Northern Lignite" the lowermost member of the Eocene of Hilgard's Mississippi section, exists in the region round about Laredo, unless the coal-bearing strata of the upper portion of the Laramie are really its equivalent. I am disposed to accept this view of the case, and to regard the Northern Lignite of the Mississippi section and its equivalents elsewhere, including the uppermost strata of the Laramie, as really of Eocene age.

Those lignitic beds in the State of Mississippi and in eastern Texas rest directly upon the Ripley Group, the uppermost of the marine Cretaceous series of the Gulf region, just as the Laramie rests upon the equivalent of the Fox Hills and Ripley Groups in western Texas. But the faunal hiatus between the Ripley and marine Eocene beds in those eastern regions is so great that one may reasonably suppose it to represent sufficient time for the deposition of a larger and more important formation than the lignitic beds alone constitute there; such a formation, for example, as is the Laramie Group. Still, the fact remains that the Laramie Group as a whole is, in the valley of the lower Rio Grande, overlaid by strata which all agree to be of Eocene age. This fact makes it certain that the Laramie Group as a whole is older than certain well marked Eocene strata; and it is also presumptive evidence of the Cretaceous age of at least the greater part of the Laramie. There are also other facts pointing to the same conclusion which will be discussed in the following paragraphs.

Several years ago, Dr. G. M. Dawson announced the existence, in that portion of British America which is in large part drained by the Saskatchewan River and its tributaries, of a formation in the Cretaceous series which had not before been recognized, and to which he gave the name of "Belly River series." Since then both he and other members of the Canadian Geological Survey have from time to time published accounts of the same formation.* They report this formation as resting upon the equivalent of the combined Benton and Niobrara groups of Meek & Hayden's section of the Upper

* See Dawson, Geo. M., Geol. and Nat. Hist. Survey Canada for 1882–83–84. C. pp. 1–169. Dawson, Geo. M., ib. for 1885, B. p. 166. McConnell, R. G., ib. for 1885, C. pp. 1–85. Whiteaves, J. F., Contributions to Canadian Paleontology, vol. i, Part I, 1885.

Missouri Cretaceous, and as underlying strata which bear molluscan forms such as characterize the Pierre and Fox Hills groups of the same section.

The fossils which they report as coming from the Belly River formation are wholly different from those that characterize the formations which underlie it, as well as the one which immediately overlies it. Their collections not only indicate the absence of true marine forms from the Belly River formation, and the presence in it of remains of both vertebrate* and invertebrate† faunas which are similar to those of the Laramie, but they contain a considerable number of molluscan forms which are specifically identical with a part of those which characterize the Laramie Group.

Those geologists furthermore report that the marine Cretaceous strata which overlie the Belly River formation are, in turn overlaid by true Laramie strata, bearing the characteristic fossils of that formation. The following table shows the relation of the forementioned formations, with one another; and also the relation of Dr. Dawson's section with the Upper Missouri section of Meek & Hayden.

Meek and Hayden.	Dawson.‡
Judith River beds [Laramie]	Laramie.
No. 5. Fox Hills Group No. 4. Fort Pierre Group	Fox Hills and Pierre.§
Wanting	Belly River beds.
No. 3. Niobrara Group No. 2. Ft. Benton Group	Benton and (Niobrara) ?
No. 1. Dakota Group	Dakota; and upper part of Kootanie.

Considerable paleontological difference between the combined Benton and Niobrara groups beneath, and the Pierre and Fox Hills groups above, has long been known to exist. In recognition of this difference Meek designated the two divisions respectively, as the "upper" and "lower series"; and as "Earlier and Later Cretaceous." Still, those formations have been generally regarded by geologists as forming a continuous series of marine deposits which was unbroken as such until the

* Professor E. D. Cope has examined collections of vertebrate remains from the Belly River formations, and has personally informed me that they consist wholly of Laramie types.

† See Cont. Canadian Paleontology, vol. i, Part I, pp. 55–77; and plates IX and X.

‡ See Ann. Rep. Geol. and Nat. Hist. Surv. Canada for 1885, p. 166, B.

§ It will be seen that Dr. Dawson combines together the Fox Hills and Pierre, and also the Benton and Niobrara divisions, recognizing only a single formation in each of the two cases. This combination has also long been adopted by members of the U. S. Geological Survey, on the ground that there is no sufficient reason for separating them except for occasional local study.

uppermost one received upon it the great brackish- and-fresh-water Laramie formation. Therefore the first announcement of Dr. Dawson's discovery was received with not a little surprise by the geologists who had studied the formations referred to in more southern regions.

I have never visited the Saskatchewan region and cannot therefore speak of the formations there from personal observation. But after carefully reading the accounts which have been published by the Canadian geologists, and having had gratifying personal interviews upon the subject with both Dr. Dawson and Mr. Whiteaves, I can now see no good reason to doubt the correctness of their observations. Accepting their conclusions, it appears that in the region referred to, the deposition of marine Cretaceous strata was interrupted at the close of the Niobrara epoch by such a change in physical conditions as caused the introduction upon the area which had been occupied by marine waters of a brackish- and fresh-water formation similar to the Laramie. It also appears that upon the completion of that brackish- and fresh-water formation, marine conditions, similar to the first, were resumed; and the Pierre-Fox Hills formation was then deposited. Furthermore, upon the completion of the last named formation, brackish- and fresh-water conditions were resumed, over the same area, when the Laramie Group was deposited.

The specific identity of a considerable part of the molluscan fauna of the Belly River formation with Laramie forms makes it necessary to assume that both faunas had a common origin. This proposition being accepted, the stratigraphical relation of the Belly River formation with the Laramie makes it further necessary to assume that at least a large part of the fauna of the Laramie was derived directly from that of the Belly River formation.

The introduction of a true marine formation between the two which are of brackish and-fresh-water origin precludes the supposition that the earlier fauna prevailed over the same area which it first occupied during the deposition of that marine formation. The presence of certain identical species in both the Belly River and Laramie formations is presumptive proof that those species somehow and somewhere survived during the time that the Pierre-Fox Hills formation was in course of deposition. The absence of any equivalent of the Belly River formation from the marine Cretaceous series which so extensively prevails to the southward of the Missouri river seems to indicate that the molluscan fauna of that formation originated in that northern region, and that it did not then extend far to the southward.

The species referred to were gill-bearing mollusca, and to have survived they must have had a continuously congenial habitat. That is, they were in part fresh-water and in part brackish-water forms, and those respective conditions of the waters in which they lived must have been somewhere continuous to have made the survival of those species possible. It is therefore probable that the Belly River and Laramie faunas somewhere became blended together as one, upon the final retirement of the marine Cretaceous waters; although no such blending of the strata of those formations has yet been discovered. Whatever may have been the facts in the case, the specific identity of those Belly River and Laramie mollusca makes it necessary to assume that at least a considerable part of the Laramie molluscan fauna began its existence long before the close of the Cretaceous period as it is represented by marine formations. This faunal relationship between the Belly River and Laramie formations also strongly connects the latter formation with the Cretaceous.

The two categories of facts relating to stratigraphical relations of the Laramie which have been presented in the preceding paragraphs of this article, and which are strongly suggestive of its Cretaceous age, have not before been publicly discussed in that connection. There are however two other categories, one relating to physical, and the other to paleontological phenomena which have been much discussed, both of which have been held by many persons to prove conclusively the Cretaceous age of the Laramie. The paleontological fact which has most influenced the views referred to, and the only one that need be mentioned here, is the occurrence of dinosaurian remains in the Laramie, extending even to some of its uppermost strata.

The physical phenomena referred to pertain to certain of the orogenic and epirogenic* movements which have taken place within the great region occupied by the Laramie Group. The movements referred to are those which on the one hand have resulted in the present elevation of that great western portion of North America, and on the other, in such great folds, for example, as those out of which the Uinta, and Rocky Mountains have been carved. In at least the greater part, and apparently all, of those movements the Laramie Group is found to have been fully involved together with all the formations beneath it; while the later formations were not so fully involved. Thus there appears to have been within that region no physical break in the continuous accumulation of material composing the true marine Cretaceous formations, and none of importance until the close of the Laramie period, if we ex-

* Etym. Ηπειρος; mainland, or continent.

cept the great hiatus which probably exists between the Carboniferous, and the Uinta Sandstone. The sedimentation also seems to have been continuous from the uppermost of the marine Cretaceous formations into the Laramie, although the faunas of these respective groups are widely different. Consequently field geologists have always experienced great difficulty, in the frequent absence of distinguishing fossils, in separating that marine Cretaceous formation from the Laramie; and they have therefore been disposed to regard the latter as a Cretaceous formation.

While I still believe that at least the upper strata of the Laramie Group represents a gradual transition from the Cretaceous to the Tertiary period, the facts which have been presented in the preceding paragraphs certainly constitute strong presumptive evidence of the Cretaceous age of the greater part of it. Judging from my own investigations, it is regarded as impossible to draw either a paleontological or a stratigraphical dividing line between the Cretaceous and Tertiary portions of the Laramie Group. Therefore the established custom of geologists in formulating a scheme of classification of the formations, seems to require that the whole group should be classed either as Cretaceous or Tertiary. It is not only conceivable, but it is natural to suppose, that a transitional formation might possess characteristics which, so far as evidence of age is concerned, would be nearly equally balanced between two periods. I believe the Chico-Téjon series of California, for example, actually presents just such a case. The evidence, as a whole in the case of the Laramie however does not appear to be so well balanced, and in my future writings I shall probably class the Laramie as a Cretaceous formation; although I shall regard this practice as little more than a matter of conventional convenience.

ART. XXXVIII.—*The Gabbros and Diorites of the "Cortlandt Series" on the Hudson River near Peekskill, N. Y.;* by GEORGE H. WILLIAMS.

IN two former papers* I have described two types—peridotites and norites—which form members of that complex group of massive rocks occurring in the northwestern corner of Westchester County, N. Y., and designated by Prof. J. D. Dana as the "Cortlandt Series." The area occupied by these rocks—about twenty-five square miles in extent and nearly coincident

* This Journal, III, xxxi, Jan. 1886, p. 26; ib., xxxiii, Feb. and March, 1887, p. 135 and p. 191.

with Cortlandt township—is mainly composed of norite, the many varieties of which were described in my last paper. In the southeastern and southwestern corners of the township, as well as on Stony Point on the opposite side of the Hudson River, olivine-norites and peridotites are found, while at other localities, mostly in the southwestern portion of the area, still different but closely allied types of massive rocks occur. These, which form the subject of the present communication, are :—

Class III, Gabbro,
Class IV, Diorite,
Class V, Mica-Diorite.

These rocks are everywhere connected so closely by intermediate forms that they may, to a certain extent, be regarded as facies of the norite. Indeed, even in the types most widely removed from the prevailing rock hypersthene is very liable to recur. There are enough general resemblances and connecting links to join all the rocks of this series into a geological unit ; and at the same time there are differences sufficient to show that many types were successively produced from the same igneous focus.

Class III. Gabbro (*von Buch.*)

1. *Gabbro proper.*—This rock is to be found at only a few isolated localities, of which the most representative is "Munger's Corners," a short distance west of Montrose Station on the N. Y. C. & H. R. R. Prof. Dana has designated this place as "*g*" on his map, and describes the occurrence as "a grayish white augitic rock."* It is represented by several slides in both Prof. Dana's and the Johns Hopkins University collection. (No. 42 and K, Mt. 13 (D)).

Under the microscope this rock appears as an aggregate of allotriomorphous plagioclase and augite grains. The latter mineral is of a reddish or grayish color, both often appearing in the same crystal individual. It is without pleochroism and frequently shows a pronounced orthopinacoidal parting. The substance of the augite or diallage is for the most part unaltered, although a little green uralite is occasionally developed. Accessory constituents in this rock are biotite, apatite, ilmenite and sphene. The last named mineral is quite abundantly represented in all sections and appears to have resulted from the alteration of the titanic iron.

The gabbro shows evidence of great dynamic action. The twinning lamellæ of the plagioclase are much curved and both

* This Journal, III, xx, p. 195, and p. 211, Sept. 1880.

the feldspar and the augite are often peripherally granulated by crushing and rubbing.

Another rock (No. 44) occurring at Centerville on the south side of Prof. Dana's limestone 4,* is in all respects identical with the gabbro at Munger's Corners.

The eruptive dykes which occur in such intimate association with the limestone at the southern end of Verplanck Point, are in part gabbros; in part mica- or hornblende diorites. No. 111, from one of the narrowest of these dikes, is quite like the gabbros last described, except that it is finer grained. Its augite also is more extensively changed to uralite. The thin section of this specimen includes some of the limestone in contact with the eruptive rock. This is altered by the metamorphic action into a granular aggregate of pale green pyroxene together with some pale hornblende and pleonaste.

2. *Mica-Gabbro.*—The presence of accessory biotite in the gabbros has been mentioned above; in some cases this mineral becomes so largely developed as to equal or even exceed the amount of augite present. Thus No. 109 and VK 5, of Prof. Dana's collection, both from dikes at Verplanck Point, differ only from the normal gabbro of this locality in the increased amount of biotite present. No. 45 also is only a biotite modification of the Centerville gabbro above mentioned.

The most interesting point in regard to the gabbros of the Cortlandt Area is that they always (so far as observations yet extend), *occur immediately beside limestone.* They seem to represent a local modification of the norite produced by an increase of lime, for this, as is well known, would change the orthorhombic magnesian hypersthene to a monoclinic pyroxene.

Class IV. Diorite. (*Haüy.*)

The hornblende, which imparts the essential character to this class of rocks, is compact and homogeneous in structure, possessing every appearance of a primary constituent. It occurs in allotriomorphous individuals which vary in size according to the coarseness of the rock-grain. In the main this hornblende is identical with that already described at length from the hornblende-peridotite of Stony Point.† In some instances this hornblende contains the same delicate inclusions, while in others these are totally wanting. Its pleochroism is always strong, and its color either a deep chestnut brown or a bright green. More rarely it shows by transmitted light a color intermediate between these two.

* Vid. the map in Prof. Dana's article. This Journal, III, xx, p. 195, Sept., 1880.

† This Journal, III, xxxi, p. 31, Jan. 1886.

The two types of diorite produced by the presence of brown or of green hornblende are quite distinct both in their occurrence and relationships. The former is always associated with pyroxene rocks and tends to pass gradually into norite, gabbro, or pyroxenite; by a total loss of feldspar these diorites may also develop into massive hornblendites. The diorites composed of green hornblende, on the other hand, show their closest relationship to the mica-bearing rocks.

The grain of these diorites varies extremely, from aphanitic varieties to such as have hornblende individuals over six inches in length.

1. *Brown-hornblende-Diorite.*—This type is best developed in the wonderfully complicated net-work of massive rocks exposed on the river bank along the northern portion of Montrose Point. The brown diorite is most intimately associated with norite, and grades, on the one hand into this, and on the other into a massive brown hornblendite. The other constituents are triclinic feldspar (presumably the same *andesine* as occurs in the norites),* apatite and magnetite. Accessory hypersthene is common by which the diorite shows its tendency to grade into the norite.

The brown diorites extend, with exactly the same associations, eastward from Montrose Point nearly as far as Montrose Station, as is shown by a large number of sections in both the University and in Prof. Dana's collection. They were, however, not encountered in other parts of the Cortlandt Area.

2. *Hornblendite.*—Both coarse- and fine-grained aggregates of compact brown hornblende occur abundantly along the northern portion of Montrose Point. These rocks have a glistening black color and are most intimately associated with the norites, hyperites, diorites, and pyroxenites which also occur there. No more complicated interpenetration of eruptive rock-types could possibly be imagined than is displayed at this locality—every rock includes and forms dykes in every other; and at the same time every type passes by gradual changes in its mineralogical composition into every other one!

The striking examples of the passage by paramorphism of pyroxene into compact brown hornblende described some time since by the writer,† occur in rocks from Montrose Point intermediate between pyroxenite and hornblendite. The origin of the brown hornblende from both the diallage and the hypersthene is so apparent as to suggest the derivation of all the hornblendites by paramorphism from preëxistent pyroxenites.

* This Journal, III, xxxiii, p. 140, Feb., 1886.

† This Journal, III, xxviii, p. 261, et seq., Oct., 1884.

Specimen Mt. 7 of Prof. Dana's collection is interesting as illustrating the alterations which one of the coarser hornblendites from Montrose Point has undergone. The change of the brown hornblende is to serpentine and talc.

Hornblendite composed entirely of green hornblende is rare within the Cortlandt Area. It does, however, occur among the dykes intersecting the limestone at Verplanck Point, as shown in section VK.1. of Prof. Dana's collection.

3. *Green-hornblende-Diorite.*—Typical diorites of this class are not common in the Cortlandt Area. Those observed occur in narrow dykes on Montrose or Verplanck Points. These diorites which are wholly free from biotite always contain a hornblende, which, though it may properly be called green, has nevertheless a decidedly brownish tinge. On the whole the relationship of these rocks with the brown hornblende diorites is much closer than it is to those of the following class.

By far the most typical development of the green-hornblende diorites belonging to the "Cortlandt Series," occurs along the edge of the steep rock wall which extends westward from Cruger's Station, toward Montrose Point. This abrupt ascent marks the contact between the massive rocks and the softer, though much metamorphosed schists. These diorites, however, always carry a large amount of biotite and therefore are more properly classed as

4. *Mica-hornblende-Diorites.*—The association between this type and the pure mica-diorite (class V) is extremely intimate and there is everywhere observable a tendency toward the development of the latter rock by the total replacement of the hornblende by the biotite.

The most prominent microscopical peculiarity of these green diorites is their sudden and extreme alterations of grain; very coarse and fine varieties occurring side by side in the same exposure, in a manner unequalled in any other part of the entire Cortlandt Area. The best locality to observe this structure is just above the brick-sheds near Cruger's Station, at a point marked "*p*" on Professor Dana's map.*

The constant mineral constituents of these diorites are a finely striated plagioclase, green compact hornblende, biotite, magnetite, epidote and apatite. Less abundant are an unstriated feldspar (orthoclase) and quartz. Garnet is a frequent endo-metamorphic product near the contact of the diorite with the schists. The hornblende differs only in its color from the compact brown hornblende already described in other members of the "Cortlandt Series." It occurs in irregular individuals which are filled with magnetite inclusions. The color is a deep green, often inclining to bluish-green, and the pleochroism is very intense.

* Loc. cit.

All the other constituents of the coarse hornblende-mica-diorites of Cruger's Point are identical with those of the typical and more abundant mica-diorite. They may therefore best be described in connection with this rock (class V), of which indeed the type now under consideration is only a particular facies.

A very fine-grained variety of the hornblende-mica-diorite is quite common as a dike rock on both Montrose and Stony Points. In many respects this presents a resemblance to Rosenbusch's group of *dioritic lamprophyres* or *kersantites*, and yet its extreme freshness and freedom from calcite, the frequently granular form of the feldspar, and the association in nearly equal proportions of biotite and green hornblende while augite is wholly wanting, separate this rock from any of the many varieties of kersantite described in Rosenbusch's recent work. The fine-grained, dark-gray dikes of this rock may be most advantageously seen in the cuttings on the West Shore Railroad through and near Stony Point. Here they intersect the much contorted schists, the peridotite and the mica-diorite and afford the evidence upon which Professor Dana admitted the truly eruptive nature of at least the more basic members of the "Cortlandt Series." * These dikes are, however, shown by the microscope to belong to the more acid rather than to the more basic of the massive rocks.

Class V. Mica-Diorite.

This rock is more uniform in its character than any other of the important members of the Cortlandt Series. It is in all cases essentially a rather coarse-grained aggregate of plagioclase and biotite, with accessory epidote, apatite and magnetite; often a little orthoclase and quartz; and sometimes garnet. The latter mineral is an endo-metamorphic product, and is to be found only near the contact with the schists.

The mica-diorite occurs only in the south-western part of the Cortlandt area; on the east side of the Hudson River west of Cruger's station, and on the west side at Stony Point (see map in my paper on the Cortlandt Peridotite, this Journal, Jan., 1886, p. 29).

No such pure type of mica-diorite† has ever, to my knowledge, been described from any locality.

* This Journal, III, xxviii, p. 384, Nov., 1884.

† Professor J. D. Dana called this rock *soda-granite*, (this Journal, III, xx, p. 198), and later *hemi-dioryte*, (ib., xxv, p. 478). The first name was proposed by Haughton in 1856 to designate, as it still does, a true granite in which the soda is in excess of the potash, (cf. A. Gerhard, Neues Jahrb. für Min., etc., 1887, II,

I have as yet been unable to secure a complete analysis of this rock, but an average of four determinations of its silica gives 53·94 per cent. This is sufficient of itself to establish the dioritic nature of the rock.

The feldspathic constituent varies considerably in composition as may be seen from the different extinction-angles occurring even in the same individual; nevertheless a number of specific gravity determinations, lying between 2·67 and 2·648, show that the mineral belongs to the oligoclase-andesine series. Some of this plagioclase is notable for being almost free from twinning striation. This is especially true for section No. 87, from Stony Point, whose feldspar was particularly studied. In other cases the striation is finely displayed, not infrequently according to both the albite and pericline laws. A zonal structure is common, and the delicate inclusions described in detail in the feldspars of the norites,* are sometimes abundant and sometimes absent.

The mica, which constitutes the only other essential constituent of these rocks, is a biotite very rich in iron. Its absorption is intense and basal sections are only translucent when very thin. Their color is then a greenish-brown. The optical angle is so small that it is impossible to determine whether the mineral is anomite or meroxene. The mica contains no other inclusions than magnetite grains and apatite needles. None of the pleochroic aureoles so common in the granites were observed.

The presence of orthoclase was not positively substantiated in these rocks. An unstriated plagioclase might easily be mistaken for orthoclase.

Quartz occurs sparingly in grains, which, from their allotriomorphous character, were evidently the last product of crystallization. These are frequently penetrated in every direction by the minute and indeterminate black needles mentioned by Hawes, Rosenbusch and others.

Magnetite is universally distributed. Apatite occurs in rare abundance, size and perfection. Sphene and zircon are often present, and epidote of somewhat exceptional character is very common, especially in the mica-diorite from Stony Point. This mineral is of a pale green color, without pleochroism and its

p. 267). Prof. Dana objects to the term mica-diorite, because (1) the original diorite was a hornblende rock and (2) because hornblende and mica are widely different minerals. It must, however, be remembered that, although these two minerals are so different, they play a very similar *rôle* in rock-composition. The name mica-diorite is here retained because, in spite of all objections to it, it has the very great advantage of being readily intelligible to students of petrography the world over,—something that cannot be said of any other term which might be proposed in its place.

* This Journal, III, xxxiii, p. 141, Feb., 1887.

source cannot be traced in the alteration of any older constituent. It is generally without terminations but is most remarkable for the peculiar eaten or corroded aspect presented by the crystals, (see fig.) These are often divided into the most complicated fret-work of interlocking tongues. The cleavage is parallel to the long direction of the crystal, and the extinction is parallel to the cleavage lines. The mineral is shown to be epidote and not a pale pyroxene, by the fact that the plane of the optic axes is perpendicular to the cleavage lines. Twin crystals of this epidote occur as shown in the figure.

Epidote in Mica-Diorite (No. 28.)

The bright red garnet crystals which are so often found in this rock are most frequent near the edge of its mass and are doubtless an endo-metamorphic product.

The structure of the mica-diorite is hyp-idiomorphous in the sense of Rosenbusch. It is most closely connected with the diorite proper, into which it grades through the mica-hornblende-diorites as explained above. On the other hand, it passes into the norites through the group of the mica-norites.* Some of these rocks contain much more biotite than hypersthene, closely resembling the hypersthene-bearing mica-diorite from Campo Major in Portugal described by Merian† and the norite facies of the Klausen diorite mass described by Teller and von John.‡ In the latter rock the feldspar has also been shown to belong to the andesine series.

Quartz-Mica-Diorite.—A quite exceptional member of the massive rocks of the "Cortlandt Series" occurs a short distance eastward of Montrose Station. This has a very light color with only comparatively rare and small flakes of biotite scattered through it. It forms a bed of moderate thickness within the dark massive norite against which it is sharply defined, i. e., there is here nothing like a gradual transition from the one rock to the other.

Professor Dana has described this rock as a granitoid mica-

* This Journal, III, xxxiii, p. 191, March, 1887.
† Neues Jahrbuch für Min., etc., Beil. Bd. III, p. 292, 1885.
‡ Jahrb. k. k. geol. Reichsanst., xxxii, p. 589, 1882.

ceous quartzite,* but a careful petrographical study of it shows that it is a massive rock, best to be designated as a *porphyritic quartz-mica-diorite.*

Under the microscope well-formed crystals of feldspar are seen imbedded in a rather coarse-grained groundmass composed mostly of quartz and feldspar. The porphyritic crystals possess a beautiful zonal structure and sometimes, though not commonly, polysynthetic twinning striation. No porphyritic quartz occurs.

The groundmass is a mosaic of interlocking grains unlike the structure of a quartzite. It contains biotite and epidote exactly like that characteristic of the mica-diorite proper, except that their amount is here much less. The feldspar of the groundmass is sometimes striated, sometimes not. Specific gravity determinations made with the Thoulet solution show all the feldspar of this rock to be plagioclase, varying between 2·63 and 2·67. This renders its separation from the quartz and the quantitative determination of the latter impossible.

This rock differs from the mica-diorite proper only in its greater amount of quartz and the proportionately smaller amount of biotite and epidote. It may be regarded as a variety of the former rock and as the most acid type of the whole "Series," which is throughout essentially a plagioclastic one.

We have now, within the limits of this and of my two former papers traced out the following types of basic and ultrabasic rock which form members of the group called by Professor Dana the "Cortlandt Series."

Class I. Peridotite.
1. Hornblende - Peridotite (Cortlandtite).
2. Augite-Peridotite (Pikrite).

Class II. Norite.
1. Norite proper.
2. Hornblende-Norite.
3. Mica-Norite.
4. Augite-Norite (Hyperite).
5. Pyroxenite.

Class III. Gabbro.
1. Gabbro proper.
2. Mica-Gabbro.

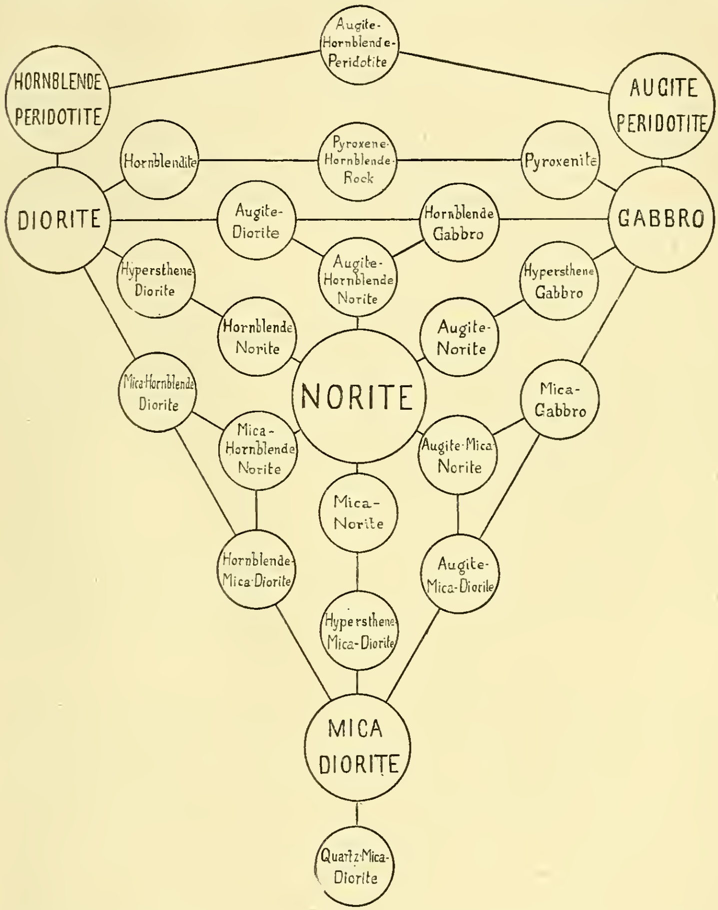
Class IV. Diorite.
1. Brown-hornblende-Diorite.
2. Hornblendite.
3. Green-hornblende-Diorite.
4. Mica-Hornblende-Diorite.

Class V. Mica-Diorite. ("Soda-granite," "Hemidioryte," Dana.)
1. Mica-Diorite proper.
2. Hornblendic Mica-Diorite.
3. Hypersthenic Mica-Diorite.
4. Quartz-Mica-Diorite.

In spite of the extent to which the subdivision of the various types has been carried in the descriptions, the actual variety of intermediate or transitional forms has not been adequately represented. In order to show more completely the

* This Journal, III, xx, p. 218, Sept., 1880.

number and relationships of these intermediate members and to connect all the various types together in one geological unit or "*Series*," the following diagram has been constructed. All



varieties represented in the circles correspond to actual specimens collected within the Cortlandt Area and many others might have justified a still more minute differentiation. The lines connecting the circles indicate the directions in which the best marked transitions take place.

These rocks present an admirable example of what are called *facies* of a geological unit mass. In spite of their great petrographical variety, they are everywhere connected by transitional forms into the closest relationship. And yet we need not regard all the rocks as having been formed simultaneously. The region was probably for a long time the scene of eruptive activity. At different periods different types may have been produced which broke through these already solidified. The quartz-mica-diorite near Montrose Station seems to be a later intrusion into the older and more basic norite.

This will conclude what the writer has to say on the massive rocks of the "Cortlandt Series." These are however so extremely varied that their study can hardly be said to be more than begun. It is earnestly hoped that some one may in future work out all their manifold variations and relationships more completely than the writer, at such a distance from the field, has been able to do.

Enough perhaps has already been said regarding the nature and mode of occurrence of these rocks to place their truly eruptive nature beyond all question; nevertheless all the evidence bearing on this point may be more advantageously summarized at the conclusion of the next and final paper, which will deal with the phenomena of contact metamorphism produced by the massive rocks in the adjoining schists.

Petrographical Laboratory, Johns Hopkins University,
Baltimore, Jan. 27, 1888.

Art. XXXIX.—*Three Formations of the Middle Atlantic Slope*; by W. J. McGee.*

(Continued from page 388.)

Résumé.—The Columbia formation consists of a series of subestuarine and submarine deltas and associated littoral deposits, occupying the entire Coastal plain of the Middle Atlantic slope up to altitudes ranging from about 100 feet in the south to over 400 feet in the north; the delta phase found at the mouths of the great rivers is bipartite, but the littoral phase overspreading the rest of the area is indivisible; its materials—which are derived largely from the Potomac formation and other local terranes and partly from the Piedmont and Appalachian regions—increase in coarseness northward, and are (in part) evidently ice-borne; it reaches greatest volume along the principal waterways and near the present coast; it is destitute of fossils at high levels and in its lower (and ice-borne) portion, but at lower levels and higher horizons yields remains of marine animals of recent and local species; it is connected with an extensive series of shore-lines and terraces;

* Plates VI and VII are issued with this number. The parenthetical clause in the second line of page 137 of this series should read *which he is disposed to refer to the Jurassic.*

and the deposits and shore-lines alike pass beneath, and are manifestly far older than, the terminal moraine.

The predominant and most significant phenomena of the formation are widespread stratified deposits and associated terraces; and if deposits are ever proof of deposition, and if shore lines ever tell of shores, the Coastal plain of the Middle Atlantic slope was submerged beneath floe-bearing oceanic waters during the Columbia period.

Synopsis of Earlier Studies.—While the isolated deposits representing it have not been correlated hitherto, and while the chronologic and taxonomic relations of its parts were never elucidated by local observers, the formation has been defined, and its genesis recognized, by every geologist who has studied its area.

W. B. Rogers was one of the first to locally discriminate the formation, and was also one of the last to discuss its relations: he recognized it in eastern Virginia in 1835,* and in 1839 accurately diagnosed its principal characters and inferred that it was formed in an ocean subjected to strong tides and currents;† and in 1875 he described it as developed about Washington, discriminated it from the newer Mesozoic (Potomac) gravels, indicated the sources of the coarser materials, noted its increasing coarseness northward, reiterated his inference that it represents a period of submergence sufficient to fill the valleys and perhaps flood the divides of the Coastal plain, and inferred further that it was formed during a period of cold and floating ice probably coeval with the ice period of the north.‡

H. D. Rogers recognized the formation in New Jersey in 1836, and inferred that the "sand and gravel" of which it consists was of sub-aqueous origin;§ and he maintained the same inference in 1840.‖

In 1841 Booth discriminated the formation in southern Delaware, enumerated its fossils, recognized its marine origin, and referred it to the "after-Tertiary age."¶

About the same time Conrad classified the later Tertiary deposits of the Middle Atlantic slope,** described various exposures of the stratified beds of the Columbia formation and enumerated their marine fossils (which are all of recent and local species), and referred them to the "Pleistocene or post-Pliocene."

* Geology of the Virginias, 1884. 29–30.
† Ibid., 253, 264, 275.
‡ Ibid., 709–13.
§ Report Geol. Survey of N. J., 2d ed., 1836, 17.
‖ Description of the Geology of N. J., 1840, 176.
¶ Mem. Geol. Survey Del., 1841, 94, 97.
** Bull. of Proceedings of Nat. Inst. for Promotion of Sci., 1841, 177, et seq.

Mather recognized the formation on Long Island in 1843, enumerated its fossils, referred it to the "Long Island division" of the "upper secondary system,"* attributed it to a marine current flowing northward "along the eastern coast," and inferred from the paucity of organic remains and the presence of ice-borne blocks that the temperature was low during its deposition.

The formation attracted Lyell's attention during his two visits to this country: During the earlier he referred to the "post-Pliocene" "the marine shells" of eastern Georgia and South Carolina, which "differ in no way from those of the adjoining sea," "contained in deposits of clay and sand" overlain in some places by dark colored clays yielding "remains of quadrupeds of extinct species;" and concluded that at the time of deposition the land stood lower than now, while the temperature of atmosphere and ocean were little different from to-day.† During the later he discriminated the "low region bordering the Atlantic" from southern Georgia to the Neuse River in North Carolina, and made up of stratified sands and clays yielding recent marine shells from the terraces of Eocene deposits by which it is overlooked—the low plain rising but ten to forty feet above tide and extending only twenty miles inland.‡

A few years later Tuomey described the same deposit in South Carolina as "sand, clay and mud, containing fossils, some sixty feet thick," rising eight feet above tide and extending only eight or nine miles inland,§ enumerated its fossils—which are all marine and nearly all recent and local,‖—and referred it to the post-Pliocene.

The observations of Lyell and Tuomey are significant in that they indicate narrowing and lowering of the formation southward.

In 1852 Desor reviewed the paleontology of the formation as developed from South Carolina to Sancoty Head and Point Shirley, noted that the fossils are "nearly all referable to living species" and that the deposit occupies only a narrow zone rising eighteen feet above tide in the south but widening greatly and reaching an altitude of 100 feet northward,¶ and inferred not only that it is marine, but that the climate was warmer than now when it was deposited. He classed the formation as post-Pliocene, and correlated it with the "Laurentian" of Canada and New England.

* Geology of N. Y., Part I, 1843, 246, 261–8, 274–5.

† Quart. Jour. Geol. Soc., vol. ii, 1846, 405–6.

‡ Second Visit to the U. S., N. Y. 1855, vol. i, 256–61; vol. ii, 197.

§ Geology of South Carolina, 1848, 186, 188, 212.

‖ Ibid., 203–5.

¶ This Journal, II, 1852. 50–3; c. f., Proc. Boston Soc. Nat. Hist., III, 1851, 79; Mem. Boston Soc. Nat. Hist., 1866–9, 252.

In 1860 Tyson described the formation as "beds of loamy clays and sands" (supposed to rise only thirty feet above tide, but represented on the map over areas of much greater altitude) containing a few marine fossils and covering a considerable portion of peninsular Maryland, concluded that "it consists of sediments derived from" the adjacent Piedmont and Appalachian regions, and referred it to the post-Tertiary.*

In 1867 Sanderson Smith pointed out that the gravel and sand beds rising fifteen or twenty feet above tide on Gardiner's Island contain twenty-five species of fossils, of which all but two now inhabit the Atlantic waters south of Cape Cod—the general facies of the fauna indicating a lower temperature than the present, and thus disproving Desor's hasty inference of warmer climate.† Verrill more recently enumerated about sixty marine species (of which nearly all are recent and found in the immediate vicinity) from the petrographically similar and paleontologically equivalent deposits of Sancoty Head, of which those from the lower strata indicate warmer and those from the upper strata colder climate than the present—the difference being attributed to local geographic changes.‡

In 1868 Cook described the formation as clean quartz pebbles and sand, covering the whole of peninsular New Jersey up to altitudes of 300 or 400 feet,§ designated it "Drift Gravel," mentioned the "deltas" and "terraces" of which it is in part composed, and inferred not only that it is subaqueous but also, from walrus remains within it, that the period of deposition was cold.‖ Ten years later he designated it "Yellow Sand and Gravel,"¶ pointed out that it is overlain by, and distinct in material and structure from, the modified and unmodified drift connected with the terminal moraine, and (finding difficulty in ascertaining the source of the materials) suggested that "it is a wash or drift from lands now under the waves of the Atlantic."** In 1880 he described the deposit in detail, designated it "Preglacial Drift," showed that it is unconformable to the glacial drift above and the Cretaceous below,†† and repeated his inference (but only as a "possible hypothesis") that it "was the wash from land to the southeast and now buried beneath the ocean, and took place in the later Tertiary age;"‡‡ and in 1884 he figured a bowlder of it, ten tons or more in weight, imbedded in the glacial drift.§§

In 1868 Cope recorded reindeer antlers from the gravels of

* First Rep. State Ag'l Chemist of Md., 1860, 44.
† Ann. Lyc. Nat. Hist., N. Y., viii, 1867, 149–51.
‡ This Journal, III, x, 1875, 364–9.
§ Geology of New Jersey, 227, 298, 242.
‖ Ibid., 285–342.
¶ Report on Clays, 1878, 17.
** Ibid., 20.
†† Report Geol. Survey of N. J., 1880, 87.
‡‡ Ibid., 95, 96.
§§ Report Geol. Survey of N. J., 1884, 16–17.

the formation in New Jersey, and enumerated other mammalia of the "terrace epoch" apparently from the same deposit (at least in part), including *Elephas primigenius*, *Mastodon giganteus*, *Equus fraternus*, *E. complicatus*, *Dicotyles nasutus*, *Cervus Virginiana* and *C. canadensis*.*

In 1875 Kerr combined and referred to the Quaternary or post-Pliocene a succession of clays, sands, gravels, etc., covering the Coastal plain in North Carolina up to 500 feet above tide, and classified them as "Glacial," "Champlain" and "Terrace,"† finding evidence of sub-aqueous deposition (1) in structure, (2) in "littoral and estuary shells undistinguishable specifically from those now living along the shore,"‡ and (3) in terraces,§ and of coeval refrigeration (1) in bowlders and (2) in indications of soil-cap movement.‖ Further investigation led him to divide the deposits into Eocene¶ and undoubted Quaternary, the latter rising about 100 feet above tide at Weldon and elsewhere in the northern part of the State, but inclining southward nearly to sea level on Cape Fear River; and he inferred from the presence of the deposits, their structure, and their fossils of recent marine species, as well as the terraces, that the formation was laid down during a Quaternary submergence "to the extent of probably 200 feet" on the Roanoke, but diminishing to only a few feet in the southern part of the State.**

Kerr's later work is important in that it harmonizes and extends that of W. B. Rogers and others in Virginia, and that of Lyell and Tuomey in South Carolina.

In 1879 Fontaine incidentally noted certain characters of the formation, mentioned its unconformity to the Mesozoic and Tertiary deposits, recorded its presence along the Potomac, James, and Roanoke rivers up to altitudes of 60 feet, and concluded that at least a part of it was deposited during the Glacial period by aqueo-glacial agencies.††

In 1880 Lewis separated the superficial deposits of Philadelphia into (1) Brick Clay, (2) Red Gravel, (3) Black Gravel, (4) Yellow Gravel or Philadelphia Gravel, (5) Micaceous Sand, and (6) Bowlders;‡‡ and later in the same year he combined the second and third, and apparently the fifth and sixth, of these divisions under the name of "Philadelphia Red Gravel," which he referred to the Champlain, and identified the "Yellow Gravel" of New Jersey with the fourth division (then

* Geology of New Jersey, 1868, 740.

† Report Geol. Survey of North Carolina, i, 1875, 154.

‡ Ibid., 155. § Ibid., 195 [misprint for 159.] ‖ Ibid., 158.

¶ The Appomattox formation was not discriminated by Kerr, though it comprises the greater part of the deposits described.

** Jour. Elisha Mitchell Scientific Society, 1884–5, Raleigh, 1885, 83–84.

†† This Journal, III, xvii, 1879, 42–3, 50, 54.

‡‡ Proc. Acad. Nat. Sci., Philad., vol xxxii, 1880, 262.

designated "Glassboro Gravel"), which he referred to the Pliocene.* The next year he concluded more specifically (1) that the Yellow Gravel of New Jersey "is an ancient deposit of aqueous origin, made at a time of submergence in pre-glacial times";† (2) that the Red Gravel was deposited by "an ancient flood of the [Delaware] river of great volume, at a time when it rose 100 or more feet higher than at present," while the bowlders, the absence of life traces, and the altitude of the deposit "point to the melting of a great glacier as the origin of the flood;" and (3) that the brick clay with its contained bowlders represents the closing episode of the same submergence when quiet conditions prevailed;—low temperature being again inferred from the absence of fossils and the presence of ice-borne bowlders.‡ Still more recently the same author pointed out that the Brick Clay and Red Gravel rise to the northward in the Delaware and Lehigh valleys, maintaining a height of 180 to 200 feet above the rivers;§ and, assigning the Yellow Gravel to the newer Pliocene, supposed it to have furnished most of the pebbles of the Red Gravel.‖

In northern Delaware the Philadelphia Brick Clay and Red Gravel of Lewis were found by Chester to merge southward, and he combined them under the name "Delaware Gravels,"¶ and inferred that they represent an epoch of land-submergence and melting glaciers. Subsequently he described the gravels, sands, clays, etc., of the same formation in southern Delaware, identified them with those mentioned by Booth, noted the occurrence of recent marine shells within them, designated the deposit "Estuary Sands,"** and demonstrated from stratigraphic continuity, from petrography, and from paleontology, that it is simply the peripheral extension of that which toward its center is divisible into Brick Clay and Red Gravel.

Merrill has recently described and correlated the formation as found in peninsular New Jersey and on Long Island. He regards the New Jersey deposit as post Pliocene (since it overlies unconformably "all the Mesozoic and known Tertiary beds, and is immediately overlain in turn by the glacial drift where it occurs south of the moraine"),†† and identifies it with the stratified deposits of Gardiner's and Long Islands; and on Long Island he discriminates (1) the Till or Drift proper and (2) the Gravel Drift—identifying the latter with the Yellow Drift or Pre-glacial drift of southern New Jersey‡‡ and noting

* Proc. Acad. Nat. Sci. Philad., vol. xxxii, 1880, 296–7.

† Antiquity and Origin of the Trenton Gravels, appended to "Primitive Industry" by Abbott, 1881, 524.

‡ Ibid., 525, 527.

§ Journal Franklin Institute, xcv, 1883. 369.

‖ Ibid., 371.

¶ This Journal, III, vol. xxvii, 1884, 190–2, 199.

** This Journal, III, vol. xxix, 1885, 40.

†† Official Report Geol. Survey of N. J., 1886, 133.

‡‡ Annals N. Y. Acad. of Sci., iii, 1886, 343.

the unconformable superposition of the former upon it,—enumerates the fossils from the older deposits, and on their testimony refers it to the post-Pliocene and correlates it with the fossiliferous beds of Sancoty Head, and concludes that it was "formed by swift currents which carried along fine and coarse deposits together."*

In 1884 Britton pointed out (1) that the Yellow Gravel of Staten Island and adjacent New Jersey is "a water deposit known to underlie the glacial drift," masses of it being "imbedded in the moraine," and (2) that it reaches altitudes of 200 feet,† while the terraces connected with the terminal moraine rise only 25 or 30 feet above tide.‡. He subsequently followed Cook in designating the formation "Pre-Glacial Drift," noted that it "is distributed along the Atlantic Border, from the coasts of the Southern States northward to the moraine, which it underlies unconformably," mentioned its unconformity to the Miocene, enumerated the fossil plants (mostly recent and local) obtained from it at Bridgeton, N. J., and inferred (1) that it is "later Pliocene or Pleistocene" in age, and (2) that "a considerable amount if not the greater part" of the deposits "may well have come from the erosion of the Cretaceous gravel beds" along the Piedmont margin§—his enumeration and interpretation of the local phenomena being alike eminently satisfactory.

Reviewing the observations of these geologists, it appears (1) that the Rogers brothers, Booth, Conrad, Mather, Lyell, Tuomey, and Desor found a series of stratified sands and clays, containing recent marine shells, rising and expanding from a few feet above tide and a few miles in width in South Carolina, to over 100 feet in altitude, and scores of miles in width in the northern Coastal plain, the fauna being closely related to or identical with that of Gardiner's Island, Sancoty Head, Shirley Point, and other obscure infra-moraine deposits along the New England coast; (2) that these deposits have been shown by W. B. Rogers, Tyson, Kerr and Chester, on the evidence of stratigraphic continuity, unity of structure, and identity of terraces, to extend to the inland margin of the Coastal plain; (3) that Chester has identified the phenomena and in some cases the localities described by Tyson and Booth, and shown that the brick clays and red gravels of the Delaware fall-line are stratigraphically continuous and homogenetic with the fossiliferous marine deposits recognized along the coast by the older geologists; (4) that Lewis has established the identity (in part) of the Philadelphia deposits with the gravels shown

* Annals N. Y. Acad. Sci., iii, 1886, 354–8.
† Proc. Nat. Sci. Assn. of Staten Island, Nov. 8, 1884.
‡ Ibid., April 10, 1886.
§ Trans. N. Y. Acad. Sci., iv, 1884–5 (1887), 26–33.

by H. D. Rogers and Cook, to overspread peninsular New Jersey; (5) that the identity of the New Jersey gravels with the stratified deposits of Gardiner's Island, Long Island, Sancoty Head and Shirley Point has been satisfactorily shown upon paleontologic grounds by Desor, Sanderson Smith, Verrill, Merrill and Britton; and (6) that the series of deposits has been shown by Cook, Merrill, Britton and others, to pass beneath the terminal moraine and its derivatives. In short, colligation of all recorded observations indicates that the entire Coastal plain of the Middle Atlantic slope is occupied by a series of stratified deposits, abounding in bowlders and coarse gravel along the fall-line and bearing recent marine fossils toward the coast, which are overlain unconformably by the terminal moraine in the north.

Reviewing the inferences of the same students as to the genesis and age of the formation it appears (1) that all consider it subaqueous; (2) that the Rogers brothers, Booth, Conrad, Mather, Lyell, Tuomey, Desor, Tyson, Sanderson Smith, Verrill, Cook, Kerr, Chester, Merrill, Britton, and perhaps others hold it to be marine; (3) that W. B. Rogers, Sanderson Smith, Cook, Cope, Kerr, Fontaine, Lewis, Chester, and others believe it was deposited during a period of low temperature; (4) that all refer it, wholly or in part, to the later Tertiary or Quaternary; and (5) that Cook, Merrill and Britton regard it as pre-glacial.

The several observations and inferences are in accord with those recorded above, and are here generalized only to corroborate conclusions reached independently after personal study (chiefly along the inland margin of the formation) in North Carolina, Virginia, the District of Columbia, Maryland, Delaware, Pennsylvania, New Jersey and New York.

Taxonomy.—The local relations.—By stratigraphic position and paleontology the Columbia formation is proved to be newer than any of the recognized Tertiaries of the Middle Atlantic slope, and its fauna is of modern facies. It therefore appears to be Quaternary or Pleistocene in age.

By (1) stratigraphic relations, (2) amount of erosion, and (3) degree of alteration, the formation is proved to be much older than the terminal moraine or the drift sheet whose margin it marks:

1. In the valleys of the Susquehanna and Delaware the terminal moraine is superimposed upon Columbia terraces and in part composed of Columbia materials; and similar relations have been repeatedly observed in New Jersey by Cook, on Staten Island by Britton, and on Long Island by Merrill.

2. A rough quantitative measure of the relative antiquity of the two deposits is found in the erosion they have suffered.

On the upper Susquehanna the post-Columbia and pre-moraine erosion sufficed to excavate a valley from one to two miles wide and 200 feet deep, while the post-moraine erosion has scooped out a valley only a quarter of a mile wide and less than 100 feet in average depth; and similar relations obtain on the upper Delaware. Along the fall-line the post-Columbia erosion is measured by the gorges of the rivers between their falls and their embouchures into estuaries, just as the post-moraine erosion is measured by the gorges of the drift-covered area; and the Potomac and the Niagara are among the most satisfactory of these chronometers. Now since the emergence of the land from the Columbia ocean, the falls of the Potomac have receded through an obdurate terrane from West Washington to Great Falls, a distance of fifteen miles, while the Niagara, under conditions favoring gorge excavations, has receded only seven miles since the last ice-sheet withdrew beyond its latitude; and the contrast is still more striking in scores of other cases. The difference is exemplified by the smaller streams as well as by the larger, and equally by the minor topographic configuration—the hydrography of the Columbia being mature, while that of the superimposed drift is nascent, and the Columbia surfaces being everywhere deeply furrowed and of ancient aspect, while the drift and Champlain surfaces are relatively little touched by time. In short, when post-moraine erosion is measured in yards, post-Columbia erosion must be measured in rods.

3. The moraine is seldom completely oxidized and lixiviated, and its rocks are seldom disintegrated; but where equally exposed the Columbia deposits are profoundly oxidized, lixiviated and ferruginated, and most of its non-siliceous rocks are disintegrated, while the materials are frequently cemented not only by ferruginous but also by siliceous and calcareous matter. The widely diverse degrees of alteration in the two deposits everywhere serves as a criterion by which they may be distinguished.

In brief, the various phenomena of the Columbia formation proves that while it represents an epoch of cold and submergence, it is many times as old as the moraine-fringed drift by which it is unconformably overlain. It is noteworthy, too, that the volume of Columbia deposits is several times greater than the volume of corresponding deposits of the later ice-epoch, indicating that the earlier refrigeration was much the longer; and it is equally noteworthy that the later drift overlaps far upon the earlier aqueo-glacial deposits, indicating that the later cold was the more intense.

The general relations.—A presumably complete sequence of Quaternary deposits and of the events they represent has been made out in the Great Basin. In 1878 Gilbert described the sediments of the extinct lake Bonneville, recorded the inference that the prevailing arid climate of the Great Basin was interrupted by a period of humid climate during which its mountain-enclosed basins were flooded and the lacustral sediments of Bonneville deposited, and correlated the humid epoch with that of northern glaciation;* and he subsequently pointed out that the humid epoch was brief and apparently "an episode occurring in the later part of a long period of aridity."† In 1878, King called attention to the sediments and chemical precipitates of the ancient lake Lahontan, and, avoiding detailed discussion of the former, conceived the latter phenomena to record (1) flooded and free-drained condition of the lake-basin, (2) shrinking and concentration of the waters and final desiccation of the basin with formation of the precipitate gaylussite, (3) re-flooding of the basin for a long period during which the soluble salts were washed away and the gaylussite changed into thinolite by pseudomorphosis, and (4) partial desiccation producing present conditions. This sequence was regarded as partly coincident with and partly supplementary to that deduced by Gilbert from the Bonneville phenomena; it was inferred that there was "a period of humidity anterior to Gilbert's earliest age of dryness" which was "enormously longer than [the period of humidity] in the second age of desiccation;" and the first of these humid periods was correlated with "the earliest and greatest Glacier period," and the second with "the later Reindeer Glacier period."‡ Gilbert later found evidence in the sediments of the Bonneville basin not only of a long humid period antedating that previously recognized but also of a much longer arid period preceding it, and concluded that the sequence of deposits represents a climatic sequence of "two humid maxima separated by an interval of extreme aridity," the second humid maximum being the more pronounced and the first the longer.§ Still later and after extended investigation, Russell found the sediments and precipitates of lake Lahontan to yield alike a record coincident with that of the Bonneville deposits,‖ save that the intermediate epoch of aridity was lengthened and some minor vicissitudes were introduced. He ascertained from the continuity of shore-lines and other evidence, however, that Lahontan did not overflow during

* Bull. Philos. Soc. of Wash., vol. i, 1874, 84–85; Progress Rep. Geog. and Geol. Surveys West of 100th Merid., for 1872, 1874, 49–50.

† Rep. Geog. and Geol. Surveys West of 100th Merid., vol. iii, Geology, 1875, 96–97.

‡ U. S. Geol. Expl. 40th Parallel, vol. i, Systematic Geology, 1878, 522–4.

§ Second Annual Rep. U. S. Geol. Survey, 1880–1, 1882, 186–200.

‖ Third Ann. Rep. U. S. Geol. Survey, 1881–2, 1883, 221–231; and Monograph U. S. Geol Survey, vol. x, Geol. History of Lake Lahontan, 1885, 261–263.

either flood stage, and read from the precipitates a record of (1) flooded condition of the basin without free drainage, (2) shrinking and concentration of the waters and precipitation of lithoid tufa (which was overlooked by King), (3) spasmodic reflooding of the basin and successive precipitation of (*a*) the mineral now pseudomorphosed into thinolite and (*b*) dendritic tufa (also overlooked by King), and (4) shrinking of the waters to below present level, followed by a slight re-advance.* This sequence of events is quite inconsistent with that deduced by King, and it thus appears that the coincidence in interpretation of the Lahontan precipitates by King and Russell respectively is no more than curiously fortuitous, and adds nothing to the weight of opinion of either investigator nor to the reliability of the history inferred from other phenomena. But there is a definite sequence of deposits in the Great Basin indicating a definite sequence of events (and the testimony of these deposits is corroborated by the shore-lines and by the precipitate as interpreted by Russell), viz: (1) basal gravels, representing long-continued arid climate; (2) lower lacustral beds; (3) medial gravels; (4) upper lacustral beds; and (5) recent gravels, etc.; and the two lacustral periods are correlated by Gilbert and Russell with two vaguely defined periods of northern glaciation.†

A fairly complete sequence of glacial and aqueo-glacial deposits in Iowa and northern Missouri affords a record of the early Quaternary history of the central Mississippi valley. It was pointed out by the writer in 1878, and again in 1879, that the bipartition of the glacial deposits and the intercalation of a forest bed within them in Iowa indicate two ice invasions separated by a long interglacial period;‡ in 1880 it was made known that the lower glacial deposit (or till) graduates upward into a series of stratified clays and extends much farther southward than the upper, which is associated with or graduates upward into loess;§ in 1882 it was shown that the loess is overlain by a third drift sheet, probably connected with the terminal moraine;‖ and recent investigations have shown that the stratified upper member of the lower till (locally known as "gumbo") not only bears unmistakable structural evidence of aqueous deposition but exhibits in its topographic configuration evidence of submergence of an extended area in Nebraska,

* Op. cit. (2), 236.

† While the lacustral deposits of the Great Basin are regarded as Quaternary by every stratigraphist and physical geologist who has investigated the subject, they have been referred to the Tertiary upon paleontologic grounds by Cope (Am. Naturalist, vol. xxi, 1887, 458–9) and perhaps others.

‡ This Jour., III, vol. xv, 1878, 339–41; Proc. Am. Ass'n for Adv. of Sci., vol. xxvii, 1878, 198–231; Geol. Magazine, N. S., vol. vi, 1879, 353–361, 412–420.

§ Trans. Iowa Hort. Society, 1880.

‖ This Journal, III, vol. xxiv, 1882, 222.

Kansas, Missouri, southern Iowa, Illinois, Indiana and southwestern Ohio, and indeed appears to be a continuation of the Port Hudson formation of the lower Mississippi as defined by Hilgard, thus indicating that during the earlier period of cold the central Mississippi valley was submerged—the far greater antiquity of the earlier till and "gumbo" than of their later homologues (the upper till and loess) being indicated by the intervening forest bed, by the greater disintegration and ferrugination of the older materials and by the far greater degradation beyond the limits of the newer deposits,* while there is much less indication of considerable lapse of time after the deposition of the loess and before the deposition of the superjacent moraine-fringed drift-sheet. So the Iowa-Missouri sequence in historic order is, (1) first glacial drift (basal till) passing upward into waterlaid clays with erratics ("gumbo"), (2) great unconformity and forest bed, (3) second till passing upward into or overlain by loess, (4) inconspicuous unconformity, and (5) third till apparently connected with the terminal moraine.

The glacial phenomena of Northern United States have been elaborately investigated by Chamberlin and found to contain a definite record of the events constituting the glacial history of the continent. His allocation of leading episodes in the historic order is as follows:

Epochs.	Subepochs or episodes.	Attendant or characteristic phenomena.
I. Transition epoch.	Not yet satisfactorily distinguished from the Pliocene.	
II. Earlier glacial epoch.	First subepoch or episode.	Drift sheet with attenuated border; absence or meagerness of coarse ultra-marginal drainage drift.
	Interglacial subepoch or episode of glaciation.	Decomposition, oxidation, ferrugination; vegetal accumulation.
	Second subepoch or episode.	Drift sheet with attenuated border; loess contemporaneous with closing stage.
III. Chief interglacial epoch		Elevation of the Upper Mississippi region 1,000 ± feet. Erosion of old drift, decomposition, oxidation, ferrugination, vegetal accumulations
IV. Later glacial epoch.	First episode or subepoch.	Till sheet bordered by the Kettle or Altamont moraine.
	Episode of deglaciation.	Vegetal deposits
	Second stage or subepoch.	Till sheet bordered by the Gary moraine.
	Episode of deglaciation.	
	Third episode	Till bordered by the Antelope moraine.
	Later stages	Marked by terminal moraines of undetermined importance.

* Trans. St. Louis Academy of Sciences (in press).

Epochs.	Attendant or characteristic phenomena.
V. Champlain epoch	Marine deposition in the Champlain and Saint Lawrence valleys and on Atlantic border; lacustrine deposits about the Great Lakes.
VI. Terrace epoch	Marked by fluvial excavation, notably of the flood plains of second glacial epoch.

When juxtaposed, the Middle Atlantic slope and Great Basin sections are exactly coincident, save (1) that the Champlain clays of the east are unrepresented in the west, and (2) that the duration of the interglacial epoch appears the greater in the east; there is not only the same general succession of events (cold-wet, warm-dry, cold-wet, the whole preceded and followed by warm-dry), but in each case the earlier period of cold and wet was the longer and the cold and wet of the later the more intense; and since the climatic episodes attested by the phenomena in either case were so extreme as to indicate that they were continental in extent, the two series of deposits may safely be correlated. The discrepancies are insignificant, (1) because it is evident that the Champlain epoch of the east must have been represented in the west by simple continuation of preceding conditions, and (2) because the testimony as to the duration of the interglacial epoch is much more complete and satisfactory in the east than in the west.

Difficulty is encountered in juxtaposing the Mississippi Valley section with the foregoing, since Chamberlin's fruitful investigations have convinced him that the longer interglacial epoch occurred posterior to the deposition of the loess and the till with which it is associated; while the writer's observations in Iowa, Missouri, and neighboring states indicate that the a-glacial epoch following the loess period was of limited length and represents only a temporary oscillation in the ice sheet, and that the interglacial period proper occurred anterior to the deposition of the second till and its associated loess. Under either interpretation, however, the section is fairly consistent with those of the Great Basin and Middle Atlantic slope; as interpreted by Chamberlin the short a-glacial epoch of the earlier period of refrigeration might well be regarded as indicating but a temporary oscillation of the ice sheet unaccompanied by appreciable change in altitude or in conditions of aqueo-glacial deposition; while under the writer's interpretation the complexity of the later record is attributable chiefly to its accessibility and to the care with which it has been deciphered, for, despite the greater number of divisions recognized in the later series, it is less important than the earlier as measured either by volume of derived aqueo-glacial deposits or by contemporaneous erosion. Space would not permit discussion of the data upon which the conflicting opinions rest, even if discussion were desirable; but the difference of view is simply an effect of intellectual perspective which shows to each investigator in exaggerated proportion the phenomena which he has most closely scrutinized, and will disappear with continued observation.

The juxtaposed sections are exhibited in the accompanying table.

It may be pointed out that the succession of deposit in the Mississippi Valley, as interpreted in the third column of the table coincides almost exactly with the sequence recognized by Penck in the German Alps, where the succession in historic order is (1) glacial drift, (2) an enormous accumulation of torrential gravels, now commonly ferruginated, cemented and deeply eroded, (3) a second glacial deposit, (4) a less accumulation of torrential gravels, with alluvium, laminated clays, lignite, etc., and (5) a third glacial deposit, found only at considerable altitudes in the mountains.*

Recapitulation.—In short the Columbia formation underlies and is several times older than the moraine-fringed drift-sheet of northeastern United States; it is apparently the aqueo-glacial margin of a drift-sheet largely concealed or obliterated in the northern Atlantic slope; it appears to be equivalent to the lower lake beds of the Great Basin, to the basal till and "gumbo" of Missouri, to (probably) the Port Hudson of Mississippi, and to (perhaps) the lowest glacial deposits of the Alps; and while the vertebrates of its correlatives suggest that it is Pliocene, both stratigraphy and invertebrate fossils prove that it is Quaternary.

It should be added that the conjoined phenomena of the Middle Atlantic slope and the Mississippi Valley indicate the respective areas of the earlier and later ice sheets: In the east the earlier extended the farther as shown by the superposition of the newer moraine upon the older aqueo-glacial deposits; but whether the earlier glacier formed no moraine, whether there was an earlier moraine perhaps coincident with the drumlin zone passing through central Massachusetts and New York, or whether the earlier drift was obliterated by the later glaciation, remains to be determined. In Iowa, Missouri and southern Illinois, on the other hand, the earlier ice sheet extended fully one hundred miles farther southward than the later, and, having evidently terminated in the waters of the expanded Gulf or of an inland lake, its limit is not marked by a terminal moraine. A hypothetic explanation of this discrepance, based

* Die Vergletscherung der Deutschen Alpen, 1882, 239, Tabelle II, etc.

Conspectus of American Quaternary Phenomena.

Epoch.	Middle Atlantic Slope.	Great Basin.	Mississippi Valley. Interpreted by McGee.	Mississippi Valley. Interpreted by Chamberlin.
Second glacial.	Champlain clays. Terminal moraine and upper till.	Upper lake beds.	Lake Agassiz clays. Terminal moraine and 3d till. (*Short a-glacial epoch?*) Loess (passing into) 2d till.	Terminal moraine and 3d till.
Inter-glacial.	(*Long a-glacial epoch.*)	Media gravels. (*Dry epoch.*)	Forest bed. (*Long a-glacial epoch.*)	(*Long a-glacial epoch.*)
First glacial.	Columbia formation (? passing northward into lower till.)	Lower lake beds.	"Gumbo" (passing into) 1st till.	Loess (passing into) 2d till. Forest bed. (*Short a-glacial epoch.*) 1st till.
		Basal gravels.		

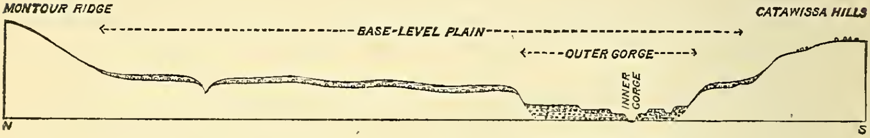
on well-known phenomena of the respective regions, is not far to seek: In the east the ice was thick and moved energetically, ploughing up subjacent deposits and scoring subjacent rocks, and quickly reached the line of equilibrium between growth and waste corresponding to given temperature; while in the Mississippi Valley the ice was but a third or a quarter so thick and moved sluggishly, passing over hundreds of square miles without removing the subjacent deposits or touching the subjacent rocks, probably failed to reach its line of equilibrium during the earlier, and certainly fell far short of it during the later and briefer refrigeration. The two ice-boundaries cross somewhere in Ohio.

The History Recorded in the Columbia Formation.—The geologic history recorded in the Columbia deposits and terraces and in the erosion and alteration which both have suffered is almost wholly supplementary to that read by most geologists in the later glacial deposits, and multiplies many times the length of the Quaternary as commonly conceived. Collectively the two series of deposits indicate that the Quaternary consisted of two and only two great epochs of cold (the later comprising two or more sub-epochs); that these epochs were separated by an interval three, five, or ten times as long as the post-glacial interval; that the earlier cold endured much the longer; that the earlier cold was the less intense and the resulting ice sheet stopped short (in the Atlantic slope) of the limit reached by the later; that the earlier glaciation was accompanied by much the greater submergence, exceeding 400 feet at the mouth of the Hudson and extending 500 miles southward, while that of the later reached but a tithe of that depth or southing; and that during the long interglacial interval the condition of land and sea was much as at present.

Moreover, as in the Potomac formation, geologic history is recorded not only in the formation itself but in its relation to the floor upon which it rests; and the history read from the deposits is thus materially supplemented.

A remarkable topographic characteristic is displayed by the Piedmont and Appalachian regions in the middle Atlantic slope, which has only been interpreted—or indeed recognized—within the decade. The entire area is but a gently undulating plain, diversified throughout by deeply incised waterways and, in the Appalachian zone, by bosses and ridges of obdurate strata which are narrowed and truncated by erosion but not planed off. The cross-section of the Susquehanna (fig. 1), with its gently undulating plain bounded by mountains and dissected by a steep bluffed gorge, is representative of the entire Appalachian zone; it is constantly repeated along each principal waterway of that zone, and—save that the bounding mountains are absent—throughout the Piedmont region; and lines drawn in any direction through the area give ever-varying but harmonious combinations of this profile. During recent years this peculiar configuration has attracted the attention of nearly all geologists who have worked in the area. Stevenson has attributed the broad intermontane plains of the Pennsylvania Appalachians to wave-action during, and their minor irregularities

1.



Cross-Section of Susquehanna Valley between Bloomsburg and Rerwick.

to spasmodic elevation following, a general submergence, and ascribed the incised valleys to the action of the streams now occupying them during a recent epoch of high land;* Kerr attributed the corresponding plains of the Piedmont region in North Carolina to glacial action during a remote epoch;† G. F. Wright ascribes certain of the plains along the western slope of the Appalachians to a temporary ice-dam in the Ohio Valley;‡ I. C. White recently referred the deposits upon these plains, if not the plains themselves, as exhibited along the Appalachian rivers, to submergence probably coeval with northern glaciation;§ but Gilbert has pointed out (orally) that in Virginia and North Carolina, at least, the system of intermontane plains represents an old base-level of erosion. The composite Appalachian profile indeed indicates clearly that at some period of the past the Piedmont-Appalachian area stood low until the rivers, their affluents, the rivulets leading into these, and even the minutest rain-born rills, cut their channels to base level and planed all the rocks except the obdurate quartzites and sandstones to the same level; and that afterward the land was lifted until the waters attacked their channels, cut out the labyrinth of recent gorges, and reduced the valleys, but not the hills, to a new base-level This degradation-record is as definite and reliable as any found within deposits; and while so little is known of the physical relations of the clastic deposits of the Coastal plain (though they have been systematically classified repeatedly upon other bases) that they tell us less than the Piedmont hills of the evolution of the continent,

* Proc. Am. Philos. Soc., vol. xviii, 1879, 315–316.
† This Journal, III. vol. xxi. 1881, 216–19.
‡ Am. Nat., xviii, 1884, 563–7.
§ This Journal, III, xxxiv, 1887, 374–81.

and while it is yet impossible for that reason to correlate the records of land and sea, it will eventually be shown that the broad base-level plain corresponds to an important marine formation somewhere in the Coastal plain series. The unconformity in deposits corresponding to the rise of land closing the base-level period has not been certainly identified, but it seems probable that the deep and broad estuaries of the Coastal plain were then excavated, or at least deepened; and their depth suggests that for a time the land stood higher than now.*

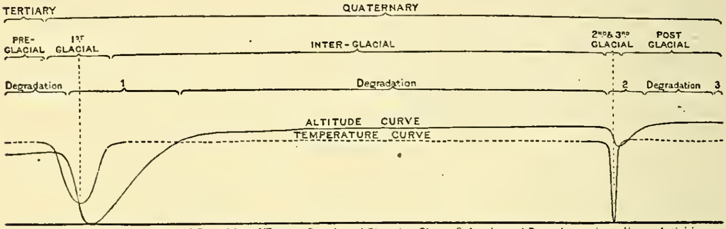
The Columbia formation reposes upon the less elevated portion of the Piedmont-Appalachian base-level plain and within the newer gorges dissecting it, as well as upon the Coastal plain and within its estuaries to considerable depths (generally undetermined but known to exceed 140 feet in Chesapeake Bay). It is evident from the relations of deposit to subterrane in the Piedmont region that the deposition of the formation occurred long posterior to the rise of the land by which the old base-level was disturbed; for despite the high declivity of the stream post-Columbia erosion has not sufficed to lay bare the bottom of the pre-Columbia gorge or to remove more than half or two-thirds of the Columbia deposits in the Susquehanna and Delaware Valleys; and the post-Columbia erosion of the Potomac is measured by a gorge but 15 miles long, half a mile wide, and 75 feet in average depth, while the post-base-level erosion is represented by an outer gorge more than 200 miles long, over a mile in width, and fully 200 feet in average depth, and by corresponding gorges extending to the very sources of all its tributaries. Indeed, when post-glacial erosion is measured in yards and post-Columbia erosion in rods, post-baselevel erosion must be measured in furlongs if not in miles.

So the direct record of the Columbia formation goes back to an era 3, 5, or 10 times as remote as that to which the Quaternary has commonly been carried, while its indirect record extends far into the Tertiary and affords part of the data required for equilibrating Tertiary and Quaternary time—the data from the deposits being yet lacking.

* It should be noted that, as indicated by rapid corrasion on the one hand and the failure of equally rapid deposition to fill the estuaries on the other hand, the Piedmont region is now rising, while the Coastal plain is sinking—the displacement coinciding with the fall line; that this movement has been in progress since the Columbia period at least; and that in consequence the records of continental oscillation found on opposite sides of the fall line are inconsistent. There is evidence, too, that the hydrography of the Coastal Plain, and especially the deflection of the rivers at the fall line, was determined during the Columbia period; and hence that the estuaries were cut not by the rivers which occupy them but by those which more nearly coincide with their courses.

The vicissitudes recorded in the Columbia formation and associated phenomena may be graphically represented as in the accompanying diagrams. It should be pointed out that the earlier part of the record is shadowy, that the quantitative estimates are but roughly approximate, and that the later part of the record is obscured by the fall-line displacement (which cannot be here discussed); yet the graphic interpretation of the

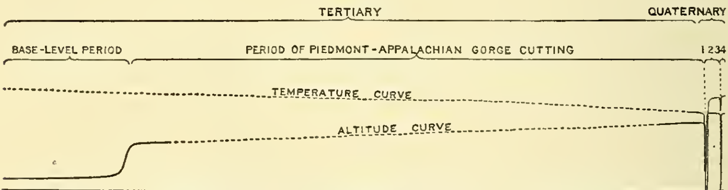
2.



1 Deposition of Columbia Formation. 2 Deposition of Trenton Gravels and Champlain Clays. 3 Accelerated Degradation due to Human Activities

later episodes (fig. 2) is reliable qualitatively, though the relations between these episodes and the more important antecedent vicissitudes is only represented provisionally (fig. 3).

3.



1 1ST Glacial Period 2 Inter-glacial Period 3 2ND and 3RD Glacial Periods 4 Post-Glacial Period

There is a break in geologic history, as commonly interpreted, between the Tertiary and the Quaternary—a hiatus partly natural and partly taxonomic, and exceedingly difficult to close by reason of diverse methods of classification as well as by reason of the dearth of common phenomena. But the formation under consideration is a superficial deposit of known genesis, intimately connected with the other Quaternary deposits of the country; it is at the same time a fossiliferous sedimentary deposit as intimately connected with the Tertiary formations of the middle Atlantic slope as these are connected among themselves; and thus the formation not only covers the natural discontinuity between the Tertiary and Quaternary, but, since it is susceptible of classification with either, closes the taxonomic hiatus as well. So the Columbia formation not only enlarges current conceptions of Quaternary time, and opens a hitherto sealed chapter in geology, but at the same time bridges an important break in geologic history.

ART. XXXIV.—*A Comparison of the Elastic and the Electrical Theories of Light with respect to the Law of Double Refraction and the Dispersion of Colors;* by J. WILLARD GIBBS.

IT is claimed for the electrical* theory of light that it is free from serious difficulties, which beset the explanation of the phenomena of light by the dynamics of elastic solids. Just what these difficulties are, and why they do not occur in the explanation of the same phenomena by the dynamics of electricity, has not perhaps been shown with all the simplicity and generality which might be desired. Such a treatment of the subject is however the more necessary on account of the ever-increasing bulk of the literature on either side, and the confusing multiplicity of the elastic theories. It is the object of this paper to supply this want, so far as respects the propagation of plane waves in transparent and sensibly homogeneous media. The simplicity of this part of the subject renders it appropriate for the first test of any optical theory, while the precision of which the experimental determinations are capable, renders the test extremely rigorous.

It is moreover, as the writer believes, an appropriate time for the discussion proposed, since on one hand the experimental verification of Fresnel's Law has recently been carried to a degree of precision far exceeding anything which we have had before,† and on the other, the discovery of a remarkable theorem relating to the vibrations of a strained solid‡ has given a new impulse to the study of the elastic theory of light.

* The term *electrical* seems the most simple and appropriate to describe that theory of light which makes it consist in electrical motions. The cases in which any distinctively magnetic action is involved in the phenomena of light are so exceptional. that it is difficult to see any sufficient reason why the general theory should be called *electro-magnetic*, unless we are to call all phenomena electro-magnetic which depend on the motions of electricity.

† In the recent experiments of Professor Hastings relating to the index of refraction of the extraordinary ray in Iceland spar for the spectral line D_2 and a wave-normal inclined at about 31° to the optic axis, the difference between the observed and the calculated values was only two or three units in the sixth decimal place (in the seventh significant figure), which was about the probable error of the determinations. See page 60 of this volume.

‡ Sir Wm. Thomson has shown that if an elastic incompressible solid in which the potential energy of any homogeneous strain is proportional to the sum of the squares of the reciprocals of the principal elongations *minus* three is subjected to any homogeneous strain by forces applied to its surface, the transmission of plane waves of distortion, superposed on this homogeneous strain, will follow exactly Fresnel's law (including the direction of displacement), the three principal velocities being proportional to the reciprocals of the principal elongations. It must be a surprise to mathematicians and physicists to learn that a theorem of such simplicity and beauty has been waiting to be discovered in a field which has been so carefully gleaned. See page 116 of the current volume (xxv) of the Philosophical Magazine.

Let us first consider the facts to which a correct theory must conform.

It is generally admitted that the phenomena of light consist in motions (of the type which we call wave-motions) of something which exists both in space void of ponderable matter, and in the spaces between the molecules of bodies, perhaps also in the molecules themselves. The kinematics of these motions is pretty well understood; the question at issue is whether it agrees with the dynamics of elastic solids or with the dynamics of electricity.

In the case of a simple harmonic wave-motion, which alone we need consider, the wave-velocity (V) is the quotient of the wave-length (l) by the period of vibration (p). These quantities can be determined with extreme accuracy. In media which are sensibly homogeneous but not isotropic the wave-velocity V, for any constant value of the period, is a quadratic function of the direction cosines of a certain line, viz: the normal to the so-called "plane of polarization." The physical characteristics of this line have been a matter of dispute. Fresnel considered it to be the direction of displacement. Others have maintained that it is the common perpendicular to the wave-normal and the displacement. Others again would define it as that component of the displacement which is perpendicular to the wave-normal. This of course would differ from Fresnel's view only in case the displacements are not perpendicular to the wave-normal, and would in that case be a necessary modification of his view. Although this dispute has been one of the most celebrated in physics, it seems to be at length substantially settled, most directly by experiments upon the scattering of light by small particles, which seems to show decisively that in isotropic media at least the displacements are normal to the "plane of polarization," and also, with hardly less cogency, by the difficulty of accounting for the intensities of reflected and refracted light on any other supposition.* It should be added that all diversity of opinion on this subject has been confined to those whose theories are based on the dynamics of elastic bodies. Defenders of the electrical theory

* "At the same time, if the above reasoning be valid, the question as to the direction of the vibrations in polarized light is decided in accordance with the view of Fresnel. . . . I confess I cannot see any room for doubt as to the result it leads to. . . I only mean that *if* light, as is generally supposed, consists of transversal vibrations similar to those which take place in an elastic solid, the vibration must be normal to the plane of polarization." Lord Rayleigh "On the Light from the Sky, its Polarization and Color;" *Phil. Mag.* (4), xli (1871), p. 109.

"Green's dynamics of polarization by reflexion, and Stokes' dynamics of the diffraction of polarized light, and Stokes' and Rayleigh's dynamics of the blue sky, all agree in, as it seems to me, irrefragably, demonstrating Fresnel's original conclusion, that in plane polarized light the line of vibration is perpendicular to the plane of polarization." Sir Wm. Thomson, *loc. citat.*

have always placed the electrical displacement at right angles to the "plane of polarization." It will, however, be better to assume this direction of the displacement as probable rather than as absolutely certain, not so much because many are likely to entertain serious doubts on the subject, as in order not to exclude views which have at least a historical interest.

The wave-velocity, then, for any constant period, is a quadratic function of the cosines of a certain direction, which is probably that of the displacement, but in any case determined by the displacement and the wave-normal. The coefficients of this quadratic function are functions of the period of vibration. It is important to notice that these coefficients vary separately, and often quite differently, with the period, and that the case does not at all resemble that of a quadratic function of the direction-cosines multiplied by a quantity depending on the period.

In discussing the dynamics of the subject we may gain something in simplicity by considering a system of stationary waves, such as results from two similar systems of progressive waves moving in opposite directions. In such a system the energy is alternately entirely kinetic and entirely potential. Since the total energy is constant, we may set the average kinetic energy per unit of volume at the moment when there is no potential energy equal to the average potential energy per unit of volume when there is no kinetic energy.* We may call this the equation of energies. It will contain the quantities l and p, and thus furnish an expression for the velocity of either system of progressive waves. We have to see whether the elastic or the electric theory gives the expression most conformed to the facts.

Let us first apply the elastic theory to the case of the so-called vacuum. If we write h for the amplitude measured in the middle between two nodal planes, the velocities of displacement will be as $\frac{h}{p}$, and the kinetic energy will be represented by $A\frac{h^2}{p^2}$, where A is a constant depending on the density of the medium. The potential energy, which consists in distortion of the medium, may be represented by $B\frac{h^2}{l^2}$, where B is a constant depending on the rigidity of the medium. The equation of energies, on the elastic theory, is therefore

$$A\frac{h^2}{p^2} = B\frac{h^2}{l^2} \qquad (1)$$

which gives

$$V^2 = \frac{l^2}{p^2} = \frac{B}{A}. \qquad (2)$$

* The terms *kinetic energy* and *potential energy* will be used in this paper to denote these average values.

In the electrical theory, the kinetic energy is not determined by the simple formula of ordinary dynamics from the square of the velocity of each element, but is found by integrating the product of the velocities of each pair of elements divided by the distance between them. Very elementary considerations suffice to show that a quantity thus determined when estimated per unit of volume will vary as the square of the wave-length. We may therefore set $Fl^2 \frac{h^2}{p^2}$ for the kinetic energy, F being a constant. The potential energy does not consist in distortion of the medium, but depends upon an elastic resistance to the separation of the electricities which constitutes the electrical displacement, and is proportioned to the square of this displacement. The average value of the potential energy per unit of volume will therefore be represented in the electrical theory by Gh^2, where G is a constant, and the equation of energies will be

$$Fl^2 \frac{h^2}{p^2} = Gh^2 \qquad (3)$$

which gives

$$V^2 = \frac{l^2}{p^2} = \frac{G}{F}. \qquad (4)$$

Both theories give a constant velocity, as is required. But it is instructive to notice the profound difference in the equations of energy from which this result is derived. In the elastic theory the square of the wave-length appears in the potential energy as a divisor; in the electrical theory it appears in the kinetic energy as a factor.

Let us now consider how these equations will be modified by the presence of ponderable matter, in the most general case of transparent and sensibly homogeneous bodies. This subject is rendered much more simple by the fact that the distances between the ponderable molecules are very small compared with a wave-length. Or, what amounts to the same thing, but may present a more distinct picture to the imagination, the wave-length may be regarded as enormously great in comparison with the distances between neighboring molecules. Whatever view we take of the motions which constitute light, we can hardly suppose them (disturbed as they are by the presence of the ponderable molecules) to be in strictness represented by the equations of wave-motion. Yet in a certain sense a wave-motion may and does exist. If, namely, instead of the actual displacement at any point, we consider the average displacement in a space large enough to contain an immense number of molecules, and yet small as measured by a wave-length, such average displacements may be represented by the equations of wave-motion; and it is only in this sense that any theory of wave-motion can apply to the phenomena of light in transparent bodies. When we speak of displacements, amplitudes, velocities (of displacement), etc., it must therefore be understood in this way.

The actual kinetic energy, on either theory, will evidently be greater than that due to the motion thus averaged or smoothed, and to a degree presumably depending on the direction of the displacement. But since displacement in any direction may be regarded as compounded of displacements in three fixed directions, the additional energy will be a quadratic function of the components of velocity of displacement, or, in other words, a quadratic function of the direction-cosines of the displacement multiplied by the square of the amplitude and divided by the square of the period.* This additional energy may be understood as including any part of the kinetic energy of the wave-motion which may belong to the ponderable particles. The term to be added to the kinetic energy on the electric theory may therefore be written $f_D \frac{h^2}{p^2}$, where f_D is a quadratic function of the direction-cosines of the displacement. The elastic theory requires a term of precisely the same character, but since the term to which it is to be added is of the same general form, the two may be incorporated in a single term of the form $A_D \frac{h^2}{p^2}$, where A_D is a quadratic function of the direction-cosines of the displacement. We must, however, notice that both A_D and f_D are not entirely independent of the period. For the manner in which the flux of the luminiferous medium is distributed among the ponderable molecules will naturally depend somewhat upon the period. The same is true of the degree to which the molecules may be thrown into vibration. But A_D and f_D will be independent of the wave-length, (except so far as this is connected with the period,) because the wave-length is enormously great compared with the size of the molecules and the distances between them.

The potential energy on the elastic theory must be increased by a term of the form $b_D\, h^2$, where b_D is a quadratic function of the direction-cosines of the displacement. For the ponderable particles must oppose a certain elastic resistance to the displacement of the ether, which in æolotropic bodies will presumably be different in different directions. The potential energy on the electric theory will be represented by a single term of the same form, say $G_D\, h^2$, where a quadratic function of the direction-cosines of the displacement, G_D, takes the place

* For proof *in extenso* of this proposition, when the motions are supposed electrical, the reader is referred to volume xxiii of this Journal, page 268.

of the constant G, which was sufficient when the ponderable particles were absent. Both G_D and b_D will vary to some extent with the period, like A_D and f_D, and for the same reason.

In regard to that potential energy, which on the elastic theory is independent of the direct action of the ponderable molecules, it has been supposed that in æolotropic bodies the effect of the molecules is such as to produce an æolotropic state in the ether, so that the energy of a distortion varies with its orientation. This part of the potential energy will then be represented by $B_{ND}\frac{h^2}{l^2}$, where B_{ND} is a function of the directions of the wave-normal and the displacement. It may easily be shown that it is a quadratic function both of the direction-cosines of the wave-normal and of those of the displacement. Also, that if the ether in the body when undisturbed is not in a state of stress due to forces at the surface of the body, or if its stress is uniform in all directions, like a hydrostatic pressure, the function B_{ND} must be symmetrical with respect to the two sets of direction-cosines.

The equation of energies for the elastic theory is therefore

$$A_D\frac{h^2}{p^2} = B_{ND}\frac{h^2}{l^2} + b_D h^2, \tag{5}$$

which gives

$$V^2 = \frac{l^2}{p^2} = \frac{B_{ND}}{A_D - b_D p^2}. \tag{6}$$

The equation of energies for the electrical theory is

$$Fl^2\frac{h^2}{p^2} + f_D\frac{h^2}{p^2} = G_D h^2, \tag{7}$$

which gives

$$V^2 = \frac{l^2}{p^2} = \frac{G_D}{F} - \frac{f_D}{Fp^2}. \tag{8}$$

It is evident at once that the electrical theory gives exactly the form that we want. For any constant period the square of the wave-velocity is a quadratic function of the direction-cosines of the displacement. When the period varies, this function varies, the different coefficients in the function varying separately, because G_D and f_D will not in general be similar functions.* If we consider a constant direction of displacement while the period varies, G_D and f_D will only vary so far as the type of the motion varies, *i. e.*, so far as the manner in which the flux distributes itself among the ponderable mole-

* But G_D, f_D, and V^2, considered as functions of the direction of displacement, are all subject to any law of symmetry which may belong to the structure of the body considered. The resulting optical characteristics of the different crystallographic systems are given in volume xxiii of this Journal, page 273.

cules and intermolecular spaces, and the extent to which the molecules take part in the motion are changed. There are cases in which these vary rapidly with the period, viz: cases of selection absorption and abnormal dispersion. But we may fairly expect that there will be many cases in which the character of the motion in these respects will not vary much with the period. $\frac{G_D}{F}$ and $\frac{f_D}{F}$ will then be sensibly constant and we have an approximate expression for the general law of dispersion, which agrees remarkably well with experiment.*

If we now return to the equation of energies obtained from the elastic theory, we see at once that it does not suggest any such relation as experiment has indicated, either between the wave-velocity and the direction of displacement, or between the wave-velocity and the period. It remains to be seen whether it can be brought to agree with experiment by any hypotheses not too violent.

In order that V^2 may be a quadratic function of any set of direction-cosines, it is necessary that A_D and b_D shall be independent of the direction of the displacement, in other words, in the case of a crystal like Iceland spar, that the direct action of the ponderable molecules upon the ether, shall affect both the kinetic and the potential energy in the same way, whether the displacement take place in the direction of the optic axis or at right angles to it. This is contrary to everything which we should expect. If, nevertheless, we make this supposition, it remains to consider B_{ND}. This must be a quadratic function of a certain direction, which is almost certainly that of the displacement. If the medium is free from external stress (other than hydrostatic), B_{ND}, as we have seen, is symmetrical with respect to the wave-normal and the direction of displacement, and a quadratic function of the direction-cosines of each. The only single direction of which it can be a function is the common perpendicular to these two directions. If the wave-normal and the displacement are perpendicular, the direction-cosines of the common perpendicular to both will be linear functions of the direction-cosines of each, and a quadratic function of the direction-cosines of the common perpendicular will be a quadratic function of the direction-cosines of each. We may thus reconcile the theory with the law of double refraction, in a certain sense, by supposing that A_D and b_D are independent of the direction of displacement, and that B_{ND} and therefore V^2 is a quadratic function of the direction-cosines of the common perpendicular to the wave-normal and the dis-

* This will appear most distinctly if we consider that V divided by the velocity of light *in vacuo* gives the reciprocal of the index of refraction, and p multiplied by the same quantity gives the wave-length *in vacuo*.

placement. But this supposition, besides its intrinsic improbability so far as A_D and b_D are concerned, involves a direction of the displacement which is certainly or almost certainly wrong.

We are thus driven to suppose that the undisturbed medium is in a state of stress, which, moreover, is not a simple hydraulic stress. In this case, by attributing certain definite physical properties to the medium, we may make the function B_{ND} become independent of the direction of the wave-normal, and reduce to a quadratic function of the direction-cosines of the displacement.* This entirely satisfies Fresnel's Law, including the direction of displacement, if we can suppose A_D and b_D independent of the direction of displacement. But this supposition, in any case difficult for aeolotropic bodies, seems quite irreconcilable with that of a permanent (not hydrostatic) stress.

For this stress can only be kept up by the action of the ponderable molecules, and by a sort of action which hinders the passage of the ether past the molecules. Now the phenomena of reflection and refraction would be very different from what they are, if the optical homogeneity of a crystal did not extend up very close to the surface. This implies that the stress is produced by the ponderable particles in a very thin lamina at the surface of the crystal, much less in thickness, it would seem probable, than a wave-length of yellow light. And this again implies that the power of the ponderable particles to pin down the ether, as it were, to a particular position is very great, and that the term in the energy relating to the motion of the ether relative to the ponderable particles is very important. This is the term containing the factor b_D, which it is difficult to suppose independent of the direction of displacement because the dimensions and arrangement of the particles are different in different directions. But our present hypothesis has brought in a new reason for supposing b_D to depend on the direction of displacement, viz: on account of the stress of the medium. A general displacement of the medium midway between two nodal planes, when it is restrained at innumerable points by the ponderable particles, will produce special distortions due to these particles. The nature of these distortions is wholly determined by the direction of displacement, and is hard to conceive of any reason why the energy of these distortions should not vary with the direction of displacement, like the energy of the general distortion of the wave-motion, which is partly determined by the displacement and partly by the wave-normal.†

* See note on page 467.

† The reader may perhaps ask, how the above reasoning is to be reconciled with the fact that the law of double refraction has been so often deduced from the elastic theory. The troublesome terms are b_D and the variable part of A_D,

But the difficulties of the elastic theory do not end with the law of double refraction, although they are there more conspicuous on account of the definite and simple law by which they can be judged. It does not easily appear how the equation of energies can be made to give anything like the proper law of the dispersion of colors. Since for given directions of the wave-normal and displacement, or in an isotropic body, B_{ND} is constant, and also A_D and b_D, except so far as the type of the vibration varies, the formula requires that the square of the index of refraction (which is inversely as V^2) should be equal to a constant diminished by a term proportional to the square of the period, except so far as this law is modified by a variation of the type of vibration. But experiment shows nothing like this law. Now, the variation in the type of vibration is sometimes very important,—it plays the leading rôle in the phenomena of selection absorption and abnormal dispersion,—but this is certainly not always the case. It seems hardly possible to suppose that the type of vibration is always so variable as entirely to mask the law which is indicated by the formula when A_D and b_D (with B_{ND}) are regarded as constant. This is especially evident when we consider that the effect on the wave-velocity of a small variation in the type of vibration will be a small quantity of the second order.*

The phenomena of dispersion, therefore, corroborate the conclusion which seemed to follow inevitably from the law of double refraction alone.

Art. XLI.—*Notes on the Surface Geology of Southern Oregon;* by Henry J. Biddle.

During the Summer of 1887, the writer had occasion to visit that portion of southern Oregon which lies within the area of interior drainage, and forms the northwestern part of the Great Basin. In the intervals of other work, some notes on the surface geology of the region were made, which, though necessarily fragmentary and incomplete, may yet be of suffi-

which express the direct action of the ponderable molecules on the ether. So far as the (quite limited) reading and recollection of the present writer extend, those who have sought to derive the law of double refraction from the theory of elastic solids have generally either neglected this direct action—a neglect to which Professor Stokes calls attention more than once in his celebrated "Report on Double Refraction" (Brit. Assoc., 1862, pp. 264, 268,)—or taking account of this action they have made shipwreck upon a law different from Fresnel's and contradicted by experiment.

* See volume xxiii of this Journal, pp. 271, 272, or Lord Rayleigh's "Theory of Sound," vol. i, p. 84.

cient interest to justify their publication. This region was reconnoitered by Mr. I. C. Russell in 1881 and 1882; and to his description* reference must be had for a complete account of its topography and surface geology. These notes are merely intended to supplement some of the observations of that writer, and to call attention to a few points not previously noted. A portion of northern California, which has the same topographical features and geological structure as southern Oregon, is included in the following observations.

The first region to be considered is Warner Valley. This is a long, narrow valley, bounded on both sides by fault scarps of grand proportions, and extending in a nearly north and south direction. Its southern end is close to the point where the dividing line between California and Nevada meets the southern boundary of Oregon. This valley, as already noted by Russell,† was occupied by a Quaternary lake, which never overflowed; and in its lowest portions are, at present, a chain of shallow lakes, and marshes. These lakes all drain, during the wet season, into the northernmost lake; and are consequently, with the exception of the latter, nearly or quite fresh. The northernmost lake, on the contrary, is alkaline and brackish. A sample of this body of water, collected in September, was found to contain about four grams of solid matter to the liter. Qualitative analysis showed the presence of sodium, magnesium, traces of calcium and potassium, chlorine, sulphuric and carbonic acids,—the chief constituent being common salt. The salts contained in this lake do not, however, represent the total amount left by the evaporation of the ancient lake. On the east side of the valley, near its northern end, is a group of ponds and marshes, the waters of which are highly concentrated salt solutions. When dried by the heat of summer they leave crusts of various salts. The common salt from these ponds, though somewhat impure from the admixture of sulphates, has become of importance to the country round about; and several hundred tons are collected annually for salting sheep and cattle. As the supply is renewed every year, it is reasonable to infer that the salt is derived from the sediments in the bed of the ancient lake, which absorbed most of the salts left upon its desiccation. In addition to sodium chloride, the waters of these ponds contain a great quantity of sodium and magnesium sulphates, and a trace of borax. In the mud beneath the ponds are crusts of sodium sulphate, and nodules, up to three inches in diameter, of a mineral which has the composition of Ulexite, a borate of soda and lime.

* Fourth Annual Report of the U. S. Geological Survey. A Geological Reconnaissance in Southern Oregon, by I. C. Russell.

† Loc. cit., p. 459.

Next to be considered is the region embraced in the valleys of Summer, Abert and Goose lakes. While each of these lakes has its own system of drainage, all being at present without outlet, yet from the fact that they are only separated by divides of slight elevation in comparison to the surrounding mountains, they can conveniently be grouped together. Another reason for considering them together is, as will be shown, the probability that they once belonged to the same drainage system.

The valleys of Summer and Abert lakes, together with the low region between them, now occupied by the Che̊waucan Marsh, were filled, during the Quaternary period, by a lake of considerable size. The boundaries of this ancient lake have been mapped by Russell.* In the lowest portions of its bed are the existing lakes, Summer and Abert. They resemble each other in many respects, and are both highly charged with various salts in solution; but the waters of Abert lake contain about twice as great a percentage of total solids as those of Summer lake. Qualitatively the salts in both lakes are the same. A sample of the water of Abert lake was collected on the 18th of September, 1887, off a rocky point near the middle of the west shore. It was taken one foot below the surface and about ten yards from land; the depth of the water being five feet, and temperature 15° C. The following analysis of this sample by Dr. T. M. Chatard, of the U. S. Geological Survey, is published by permission.

Specific Gravity 1·03117 at 19·8°.
In 25 c.c. = 25·77295 grams.

	A.	B.	Average.	Grams in a liter.	Percentage of total solids.
SiO_2	0·0063	0·0053	0·00580	0·232	0·59
K	0·0133	0·0136	0·01345	0·538	1·37
Na	0·3674	0·3671	0·36725	14·690	37·51
SO_3 }	0·0148	0·0146	0·01470	0·588	1·50
O }	0·0030	0·0029	0·00295	0·118	0·30
Cl	0·3365	0·3366	0·33655	13·462	34·37
CO_2 }	0·1755	0·1757	0·17560	7·024	17·93
O }	0·0615	0·0616	0·06155	2·462	6·28
H in bicarbonates				0·058	0·15
			Grams	39·172	100·00

Hypothetical Composition.

	Grams in a liter.	Percentage of total solids.
SiO_2	0·232	0·59
KCl	1·027	2·62
NaCl	21·380	54·58
Na_2SO_4	1·050	2·68
Na_2CO_3	10·611	27·09
$NaHCO_3$	4·872	12·44
	39·172	100·00

* Loc. cit., map 83.

An analysis, quoted by Russell,* of a previous sample from this lake showed a remarkably high percentage of potassium salts. The above analysis, on the contrary, shows a less proportion of potassium than reported in the waters of Mono Lake, Owen's Lake, or Great Salt Lake.† The writer is at a loss to account for the wide variation between these analyses. Both show a very low percentage of sulphates, far less than in the other lakes of the Great Basin mentioned.

The occurrence of tufa deposits in the bed of the ancient lake alluded to has not previously been reported. In the low region between the existing water bodies fragments of a calcareous crust, usually less than one-half inch in thickness, together with concretions of small size, lie sparsely scattered on the surface. Near the shore of Summer Lake the sands are cemented into a crust from one-eighth to one-half inch thick, which appears to be of very recent formation, and might have been formed when the lake stood but a few feet higher than at present. These facts merely go to show that the history of this ancient water body was, in a small way, similar to that of the larger inclosed lakes of the Great Basin.

Goose Lake Valley is south of the region just described; it extends nearly north and south, and lies partly in Oregon, partly in California. At its northern end it is connected by a low pass with the southern end of the depression in which Abert Lake lies. This valley was occupied by an ancient lake, the boundaries of which have never been mapped. It had about twice the area of the present Goose Lake, and a depth approaching 300 feet. As the hillsides in this region are in part clothed with forest, the ancient beach lines do not form as noticeable a feature as in the arid valleys north and east of it. Near the town of Lakeview, however, is a conspicuous and well defined terrace, showing the surface level of the ancient lake. This terrace is deeply cut into the spurs of the mountain side, having in places a width of several hundred feet. It has two minor benches, at an elevation respectively of 250 and 280 feet above the floor of the valley.‡ These benches are in places level, but usually have a lakeward slope of about 5°, and are separated by a somewhat steeper slope. On the side toward the valley the slope increases abruptly, reaching 25°, while toward the mountain there is a gradual increase of slope until the normal inclination of the mountain side is attained. There is no cliff separating the terrace from the mountain slope. The surface of the two benches is often covered with

* Loc. cit., p. 454.

† For a comparison of the analyses of these, and other inclosed lakes, see Monograph XI, U. S. G. S. Geological History of Lake Lahontan, by I. C. Russell, Table C.

‡ These measurements are by aneroid.

rounded and subangular pebbles, though in places these occur but sparingly. In the northernmost part of the ancient lake basin is a row of round topped hills, stretching five or six miles from the mountain border on the west and nearly spanning the valley. These hills rise fully 200 feet above the level plain at their feet, and are covered from base to summit with water-worn gravel. While it is evident that these vast accumulations of gravel were formed by the waves and currents of the ancient lake, yet it is not clear to the writer how they obtained their present form. The supposition that an ancient, and once continuous, gravel bar or embankment has been cut to its base, at several points, by lines of recent drainage, partially explains the peculiar topography.

Passing to the extreme northern end of the valley, the pass leading to Abert Lake is found to be lower than the ancient beach lines and gravel accumulations alluded to. At the divide in this pass, and thirty or forty feet above the lowest point, a considerable quantity of water-worn pebbles may be seen on the hillside. Taking these facts into consideration, it is impossible to avoid the conclusion that when Goose Lake Valley was filled to its highest beach line its waters overflowed this pass, and communicated with the lake north of it. But the ancient shore lines cannot be traced from one valley to the other, owing chiefly to the broken nature of the country; and the evidence of this fact is not as clear as could be wished. When the pass alluded to was overflowed it must have formed a narrow strait, of no great depth, connecting two large bodies of water. Goose Lake found an outlet at its southern end, and hence this strait might have furnished an outlet to the ancient lake north of it, by which it could discharge its surplus water. This question will be referred to later on.

Although Goose Lake does not at present overflow, yet a rise of but a few feet would cause its waters to discharge southward into the North Fork of Pit River, and thence into the Sacramento. This is reported by Russell* to have taken place as recently as 1869, and again for a short period in 1881. When the lake stood at the level of its highest beach line, it is evident that the valley of Pit River was yet to be cut; and the depth to which the waves eroded the mountain side shows that for a long time the lake maintained a nearly constant level, and nothing was accomplished toward deepening the channel of discharge. But when the cutting down of this channel commenced it must have been comparatively quickly accomplished, as is shown by the absence of beach lines at lower levels than those mentioned. Perhaps other lakes, on the lower courses of Pit River, had first to be drained; and not until this had been

* Reconnaissance in Southern Oregon, p. 456.

effected did the outflowing waters have sufficient fall to carry on the work of erosion. Of course the hypothesis is admissible that the lake had at first no outlet, and was in course of time tapped by a stream belonging to another drainage system, cutting back its channel across the divide. Had the climatic conditions of a former period continued to the present day, the work of deepening the channel of outflow would most likely have gone so far as to completely drain the valley, and leave only marshes and meadows in place of the present water body. But before this task was accomplished the supply of water was so diminished that the lake disposed of it all by evaporation, and none escaped to continue the cutting down of the outlet.

The question naturally occurs, did the great lake north of this also cut down its outlet? But as there is no evidence of erosion by running water in the pass mentioned, which was once a strait connecting the two water bodies, the question must be answered in the negative. Naturally nothing could be accomplished toward deepening this channel until the level of Goose Lake had been lowered to about the level of the bottom of the strait. As has been shown, a long period must have elapsed before this was the case; and if at the end of this period, the humid climate of Quaternary times was giving place to the later aridity, the lake would have no surplus waters to discharge. Indeed, we know that many of the lakes of this region never overflowed, even during the periods of greatest humidity; and with a large surface for evaporation and comparatively small tributary drainage area, the lake in question may never have had any surplus water to dispose of.

The waters of Goose Lake do not appear ever to have deposited tufa. The existing lake is very nearly fresh, containing less than one thousandth of solids in solution, and is inhabited by fish. Unfortunately there are no good exposures in the bed of the ancient lake, and the character of its sediments is unknown.

South of the region just described is a basin, drained by Pit River, known as Warm Spring Valley. Although the district has not been visited by the writer, yet from the topography it seems safe to assume that this valley has also contained an ancient lake which was drained by the cutting down of its outlet. When the surface geology of this region shall be systematically studied, traces of many extinct lakes hitherto unnoticed will no doubt be found.

The next region to which these notes have reference is Surprise Valley, lying in the northeast corner of California. This valley contained a Quaternary lake which never overflowed. Its modern representatives are three shallow lakes occupying the deepest portions of the basin, and known respectively as

Upper, Middle, and Lower, Alkali Lake. During the summer these lakes often dry up completely, leaving broad, level stretches of fine-grained yellow mud. When visited by the writer in September, 1887, the middle lake was quite dry, the others nearly so. The water in the upper or northernmost lake was found to be a strong saline and alkaline solution. It contained about 45 grams of solids to the liter, mostly sodium chloride. By digging into the mud near the center of the middle lake the following section was obtained, beginning at the surface: 4 feet of yellow fine-grained mud, 3 inches of fine white volcanic dust, 3 feet of black mud smelling of hydrogen sulphide. At the depth of seven feet the hole in the lake bed filled with brine, which was found to contain about 38 grams of salts to the liter—mostly sodium chloride, with some carbonate and sulphate. This shows what has become of the salts which must have accumulated during a long period in the basin of the ancient lake. But a fraction of the total amount exists in the shallow lakes of to-day; the greater portion must be looked for in the brine saturating the mud beneath them to an unknown depth.

The existence of a stratum of volcanic dust in this valley is a fact of interest hitherto unreported. Similar strata occur among the sediments of the ancient Lake Lahontan, as reported by I. C. Russell.* That writer regards them as derived from the craters about Mono Lake, Cal., and has observed such material up to 200 miles from the supposed place of eruption. The middle of Surprise Valley is about 250 miles from Mono Lake, but less than half that distance from the volcanic region of Mt. Shasta and Lassen's Peak. Further observations are necessary to determine from which direction the volcanic dust of Surprise Valley was derived. There seems to be in this occurrence evidence of very recent volcanic activity. The time in which a narrow lake, receiving annual supplies of sediment-laden water and æolian dust, has deposited four feet of mud in its bed, can hardly be very great.

The region next to be considered lies on the border of the Great Basin, and possesses the same topographical features as the valleys previously mentioned; but now belongs partly to the hydrographical area of the Pacific. This is the region embraced in the valleys of Rhett Lake, and the Upper and Lower Klamath lakes. It lies partly in Oregon, partly in California. The whole may be regarded as one valley, formed by a complicated system of faults, with a nearly level floor on which the lakes mentioned lie. Two of these lakes, the Upper and Lower Klamath, discharge their waters by way of the Klamath River into the Pacific, while Rhett Lake on the other hand

* Lake Lahontan, p. 146.

has no outlet. But a slight rise in the water of the latter would cause it also to become tributary to the Klamath River, as there is no high ground between.

There seems to be no doubt that this system of valleys was occupied by a large lake, which has been nearly drained by the cutting down of its outlet. The writer was, however, unable to detect any beach lines which would show the extent and depth of the ancient lake. It is possible that it was so shallow that its waves had little force, and left no trace of their action. But fortunately the sediments in its bed are in places exposed. Lost River, an affluent of Rhett Lake, has cut its channel into the floor of the valley to the depth in places of 40 feet. A bluff on the south side of this stream, about 10 miles southeast of the town of Linkville, shows a good section of the lake beds. They are seen to consist chiefly of a light gray, fine-grained earth, which at first sight might be taken for chalk. Interstratified with this are occasional layers, but a few inches thick, of sand and pebbles with a ferruginous cement.

When the earth forming the mass of these deposits is examined under the microscope it is seen to consist wholly of infusorial remains. It is homogeneous and of exceedingly fine texture; compact enough to form steep bluffs, but in small lumps easily crushed between the fingers. It is so light as to float for a moment in water, and adheres slightly to the tongue. The strata dip about northeast, or toward the mountains, at an angle of 12°. This dip may be due to deposition in inclined layers; but in that case one would expect to find the slope in the opposite direction, or toward the middle of the valley. Without more extended observations it can not, however, be maintained that a tilting of these beds has taken place. At the top of the bluff they are seen to be overlaid by a horizontal layer of gravel, containing rounded lumps of the infusorial earth.

A system of joints extends through the beds in a plane about parallel to the strike and at right angles to the dip. For a considerable distance the channel of Lost River lies in the infusorial beds, and wherever exposed the jointing is a noticeable feature. The same material may be traced for about 10 miles along the northeast edge of the basin in which Linkville lies; the total extent of the deposit is yet to be determined.

Mr. J. S. Diller, of the U. S. Geological Survey, has called attention* to similar infusorial deposits on Pit River and the lower courses of the Klamath. They occur, as in this case, in the beds of extinct lakes. The writer desires to express his obligation to Mr. Russell, of the U. S. Geological Survey, for his kind assistance and advice; to Dr. Chatard, of the Survey, for his analysis quoted; and to Mr. Merrill, of the U. S. National Museum, for the microscopic determination of volcanic dust.

* U. S. G. S. Mineral Resources, 1886, p. 588.

ART. XLII.—*Some Nickel Ores from Oregon*; by F. W. CLARKE.

IN or about the year 1881, extensive deposits of nickel silicates were discovered in Douglas County, Oregon. In appearance, the ores are identical with the so-called "garnierite" and "noumeaite" of New Caledonia, and many specimens bearing those names have found their way into collections of minerals. At present, the deposits at Riddle, Oregon, are being worked by the Oregon Nickel Company, and through the kindness of Mr. Will Q. Brown, an admirable series of the ores was recently sent to the United States Geological Survey for investigation. According to Mr. Brown the deposits all lie at or near the surface, in beds from four to thirty feet thick. Mining is carried on through open cuts or quarries, and no second bed has ever been found underlying the first.

The specimens at my disposal represent a wide range of appearances. They include samples of the country rock and of the associated chromite, and the nickel silicates themselves vary much in color and texture. The finest specimens are bright apple green, and quite compact, and from this they range through duller shades into masses of distinctly earthy texture. Most of them are intermixed with oxides of iron and with quartz, and even the purest mineral, like the garnierite of New Caledonia, is seamed with thin sheets of chalcedony. All of the nickel bearing samples are much decomposed; and one particularly beautiful specimen is distinctly a conglomerate or breccia, having nodules of the green ore imbedded in it side by side with pebbles and fragments of other material. Like all the nickel silicates which have been so far observed in nature, these ores are unmistakably products of alteration; and the problem of their genesis is somewhat interesting. For comparison with them I had a suite of the New Caledonia minerals, received from Professor Liversidge, and a large series of the genthites from Webster, N. C., collected last summer by Mr. W. S. Yeates. All three localities have much in common, and the three sets of specimens point clearly to one conclusion, which will be stated farther on after the evidence for it has been presented.

In composition, the nickel silicates from any locality vary widely; for the earthy nature of the material renders it impossible to secure anything like a homogeneous substance for analysis. The purest specimen of the Riddle ore was dark apple green, compact, and amorphous; but so permeated with films of silica that a definite mineral could not be isolated. With the best material obtainable I secured the following results; which I give side by side with two published analyses by Hood,* in order to show the variations.

	Clarke.	Hood.	Hood.
Loss at 110° C.	8·87 }	6·63	7·00
Loss on ignition	6·99 }		
$Al_2O_3 + Fe_2O_3$	1·18	1·38	1·33
SiO_2	44·73	48·21	40·55
MgO	10·56	19·90	21·70
NiO	27·57	23·88	29·66
	99·90	100·00	100·24

Neither lime, sulphates, chromium, nor cobalt could be detected. Like the New Caledonia garnierite, the fragments of this silicate fell to pieces when immersed in water.

Of the New Caledonia silicates many analyses have been published, notably by Liversidge and Leibius, Typke, Damour, Garnier and Ulrich, and they vary between widely separated extremes. Not only are there the variations due to mutual replacements of nickel and magnesia, with a range in the percentage of NiO from 0·24 to 45·15 per cent, but there are also great differences in silica and in hydration. It is therefore impossible to say whether we have to deal with one nickel salt, varying only in its impurities, or with several compounds: although the general similarity of the material from different localities renders the former supposition the more probable. According to Ulrich† the noumeaite and garnierite consist of a soapstone-like base, with a hydroxide or silicate of nickel distributed through it in veins and patches; while Des Cloizeaux‡ regards noumeaite as a magnesian hydrosilicate impregnated with nickel oxide. The latter view, however, is hardly probable, especially when we consider the origin of the minerals; and Typke§ has cited evidence against it. The prevalent opinion, that we have to deal with one or more definite hydrosilicates of nickel, is best sustained by careful comparative study of the specimens, even though the salts may not be obtained pure or positively formulated. The reciprocal variation of nickel and magnesia in more than twenty published analyses, excludes from further consideration the idea that the nickel is present to any great extent as hydroxide. For temporary convenience we may use the well-recognized name "genthite" generically, and apply it to all the nickel silicates from the above-named localities.

Of the "country rock" surrounding the Oregon beds one large, clean, fresh specimen was received. This was subjected

* Mineral Resources of the United States for 1883.
† This Journal, III, xi, 235. ‡ Bull. Soc. Min., i, 29. § Chem. News, xxxiv, 193.

to analysis, and also, through the kindness of Mr. J. S. Diller, to careful microscopic study. The olivine separated from it by Mr. Diller was analyzed as well, although the material was not absolutely free from enstatite and chromite, and both analyses are here presented together.

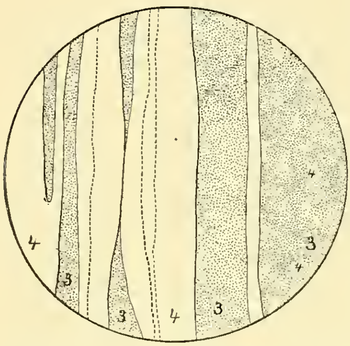
	Rock.	Olivine.
Ignition	4·41	·57
SiO_2	41·43	42·81
Al_2O_3	·04	----
Cr_2O_3	·76	·79
Fe_2O_3	2·52	2·61
FeO	6·25	7·20
NiO	·10	·26
MnO	none	none
CaO	·55	none
MgO	43·74	45·12
	99·80	99·36

It will at once be seen from these data that the rock contains nickel, and that the olivine separated from it contains even a larger proportion. This fact suggests a probable source of derivation for the nickel in the altered beds of ore, and this view is maintained by the microscopic investigation. Concerning the latter, Mr. Diller reports as follows, discussing both the rock and the genthite.

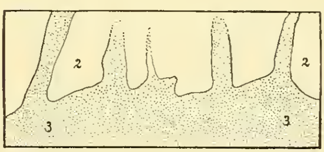
"The high specific gravity and dark yellowish green color of the country rock with which the genthite is associated at Riddle, Oregon, at once suggests that it belongs to the peridotites, and such it is proved to be by investigation. It is a holocrystalline granular rock, composed essentially of olivine and enstatite with a small percentage of accessory chromite and magnetite. The olivine predominates, so that the enstatite forms less than one-third of the mass. Both of these minerals are clear and colorless, but may be readily distinguished by their cleavage and optical properties. They are allotriomorphic, i. e. not bounded by crystallographic planes, and do not contain prominent inclusions, excepting a few grains of chromite and magnetite and fine ferritic dust. Notwithstanding the comparatively fresh condition of the rock, to which, according to Wadsworth, the name Saxonite may be applied, it is completely permeated by a multitude of cracks filled with serpentine resulting from alteration. Quartz also results from the metasomatic changes in the saxonite, and wherever the genthite occurs it is always associated with either quartz or serpentine."

"The genthite from Oregon varies in color from green to pale apple or yellowish green in reflected light, and is compact with a faint suggestion of fine granular structure. Generally it is dull, but where most compact and traversed by a series of minute fissures or seams of quartz it has a decidedly waxy luster. Under the microscope it usually appears to be an aggregation of irregular grains which have in transmitted light a pale yellowish green to coffee-brown color, and a peculiarly clouded waxy aspect. Where the grains are very thin the genthite may be said to be transparent and isotropic, but the majority of them are only translucent. In the narrow seam of genthite lying between seams of quartz the former is indistinctly fibrous and feebly double-refracting; but its system of crystallization could not be definitely determined. In small veins it is free from grains of other minerals, but elsewhere it is very intimately commingled with quartz. The relation of the two minerals is shown in the accompanying figure 1, in which the shaded portions (3) are genthite, and the clear one (4) are quartz. The commingling of the two minerals is so intimate as to make it evident that both were deposited from solution in circulating waters. Veinlets of quartz are frequently found cutting across those of genthite, and in general it appears to be true that the latter mineral was laid down first, although it is probable that both were precipitated at about the same time. Although the purest genthite is to be found with quartz, the mineral is more commonly associated with serpentine; and this relation is a most important one in its genetic significance. The accompanying figure 2 represents the edge of one of the larger veins of genthite (3), with numerous veinlets or fissures extending out into the serpentine (2). The tributaries are abundant on both sides of the vein. Figure 3 shows a vein of genthite (3) in the serpentine (2), which envelopes small masses of residuary oxide of iron (1), left by the decomposing olivine. The area represented is only 0·64 of a millimeter in diameter and contains no olivine; but less than half a millimeter from the boundary of the vein much olivine still remains, although deeply coated with oxide of iron and serpentine. The branching streamlets from the vein

1.

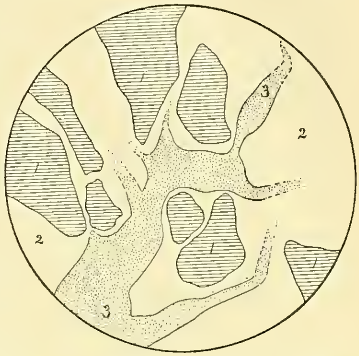


2.



of genthite, together with the manner in which the arms gradually fade away into the serpentine at once suggests the source from which the genthite has been drawn. The genthite and serpentine are thoroughly intermingled, but the former is generally present in such small quantities as to be overlooked unless it is the object of special research. It occurs in the serpentine directly connected with the grains of olivine from which the serpentine has been derived, and there is every reason to believe that the genthite came from the same source."

3.



In order to secure completer confirmation of the idea that the nickel of the greater silicate deposits is derived from the alteration of nickeliferous olivine, Mr. Diller at my request, also examined specimens from Webster, N. C., and from New Caledonia. Concerning the Webster genthite Mr. Diller reports that "it is almost identical with that from Oregon, excepting that it is not so thoroughly intermingled with quartz. The relation of the genthite to the serpentine and the olivine at the Webster locality is exactly the same as at Riddle. The rock at Webster differs slightly from that at Riddle in containing a smaller proportion of enstatite, and belongs to the peridotites to which the name 'dunyte' has been applied" He also finds the New Caledonia mineral to be identical with genthite in its physical properties, and says—"Under the microscope it varies from pale yellowish green to light coffee-brown, and is either completely isotropic or exhibits only faint aggregate polarization. Like the genthite of Oregon it is deposited in layers and cavities thoroughly intermingled with quartz, and in the same thin section may be seen serpentine with traces of olivine and enstatite so disposed as to clearly indicate that the serpentine, noumeaite, and other secondary products have resulted from the alteration of peridotite." This observation confirms the earlier one of Des Cloizeaux (l. c.), who stated that the noumeaite was imbedded in a serpentine rock which appeared to be derived from olivine, and which contained crystals of the latter mineral plentifully disseminated through it. A similar suggestion is made by Mr. H. J. Biddle,* who regards the nickel of the Webster deposits as an original constituent of the olivine rock, and cites an experiment of Mr. G. B. Hanna, who found 0·15 per cent of nickel oxide in a chrysolite from Waynesville, N. C.

* Mineral Resources of the U. S., 1886.

So far, the case appears to be clearly and conclusively settled as to the origin of the nickel silicates under discussion. Nickel is almost always present in small quantities in olivines, and T. Sterry Hunt, in reporting genthite from Michipicoten Island* calls attention to the fact that the metal is rarely absent from the serpentines, steatites, diallages, and actinolites of the Quebec group. Nevertheless, one other possible source of nickel must be noticed. Roth,† in speaking of the genthite from the chrome mines of Pennsylvania, attributes it to the alteration of nickeliferous chromite; and the almost universal association of the latter mineral with genthite, renders the view deserving of attention. But it must be remembered that chromite alters with great difficulty, while olivine decomposes with extreme ease; and morever the genthite from Oregon contained no chromium, although that metal was diligently sought for. Furthermore, Mr. Diller examined some of the chromite from the Riddle mines, and found that although it was penetrated by crevices filled with secondary minerals containing genthite, the chromite itself showed no evidence of alteration.

Concerning the other silicates of nickel, described under the names of pimelite, alipite, conarite, röttisite, refdanskite, etc., little need here be said. Some of them are probably similar in origin to the better known genthite, although the conarite and röttisite, which contain small amounts of sulphur and arsenic, probably came from nickeliferous sulphides. For the other minerals above named there is too little evidence upon record to warrant any serious attempt at discussion.

Laboratory U. S. Geological Survey, March, 1888.

Art. XLIII.—*Note on the Secondary Enlargement of Augites in a Peridotite from Little Deer Isle, Maine*; by George P. Merrill.

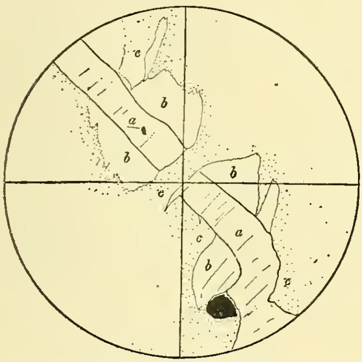
While engaged in the study of sections of a peridotite from Little Deer Isle in Penobscot Bay on the Maine coast, the writer observed certain peculiarities of the augitic constituent which, if rightly interpreted, seem worthy of notice in the columns of this Journal.

The rock consists essentially of olivine and augite, with accessory magnetite, chromite, apatite, and rarely a plagioclase feldspar (?) It therefore belongs to the variety of peridotites which Professor Rosenbusch designates as *picrite*.

* Report Geol. Survey of Canada, 1863, p. 506.
† Allgem. und Chem. Geologie, vol. i, p. 225, 1879.

Olivine is the prevailing constituent and in nearly every case examined has gone over completely into serpentine. The augite, which is the only constituent to which particular attention need here be called, is of the normal type, of a faint yellow or wine red color in the thin section, and gives maximum extinction angles on clinopinacoidal sections of 40°. The mineral occurs in the form of broad plates with deep, rounded embayments and in long armlike forms reaching out and enfolding the altered olivines, the peculiar habit of the mineral in acting as a binding constituent being here displayed in its best development. On casual inspection by ordinary light the mineral presents no features other than of the ordinary type, the rounded forms of the altered olivine abutting closely against the fresh augite, while the line of separation is perfectly sharp and distinct as I have attempted to show in figs. 1 and 2. Here the portions marked (*a*) and bounded

1.



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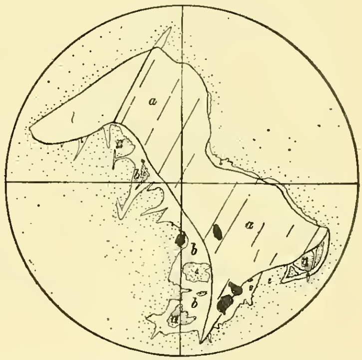

by the heavy wavy line represent in each figure a single augite individual.* More careful inspection, however, shows that in nearly every instance the augite is surrounded more or less completely by a narrow and extremely irregular colorless border which projects in the form of sharp teeth or tongue-like prolongations for a considerable distance into the serpentine (olivine) granules. This is shown by the portions marked (*b*) in the figures and is very noticeable when the section is viewed between crossed nicols. This irregular border I am inclined to consider as a true secondary growth, formed since the consolidation of the rock and analogous to the hornblendic, feldspathic and quartzose enlargements described by F. Becke,† Irving‡ and Van Hise.§

* In fig. 1 the rock has been fractured and re-cemented by serpentine. The portions in the upper left and lower right field forming originally one crystal.

† Min. u. Petr. Mittheil., vol. v, 1883. ‡ Bull. U. S. Geol. Survey, No. 8, 1884.

§ This Journal, May, 1887.

I am led to these conclusions from a consideration of the following facts: (1.) It would seem very improbable that the augite first separated from the molten magma in such irregular forms; (2.) The original outline of the augite is perfectly sharp and smooth, eminently characteristic of augitic outlines in this class of rocks; (3.) The new portion is much the lighter in color being in fact so nearly colorless as at first to be wholly overlooked when examining the section by ordinary light; (4.) It projects in very irregular and jagged forms into the serpentinized olivine (*c* in the figures). Indeed its appearance is such as to suggest that not only was its formation subsequent to the consolidation of the rock, but that it is an accompaniment of the alteration, the sharp tooth-like edges projecting into the olivines along the curvilinear lines of fracture much like the ordinary beginnings of serpentinization. The new growth, it should be stated, possesses in all cases the same crystallographic orientation as the original, the entire mass extinguishing simultaneously between crossed nicols when in the position indicated in the figures. The new portion is therefore not a secondary hornblende such as Mr. Van Hise has shown occurring as a secondary growth on the augites of certain Wisconsin diabases.

The figures given were drawn with the aid of a camera lucida and show correctly the relative width of the borders and the primary augites in two rather pronounced cases. No attempt has been made to draw in the serpentine portions of the slide, the mineral being merely indicated by the dotted areas (*c*) in the figures. The black opaque spots, it is scarcely necessary to say, represent magnetite.

The writer wishes here to acknowledge his indebtedness to Dr. G. H. Williams, under whose instruction this and other rocks soon to be described were studied during the winter of 1887–88 in the laboratories of the Johns Hopkins University.

National Museum, Washington, Feb. 15, 1888.

Art. XLIV.—*On a New Meteorite from the San Emigdio Range, San Bernardino County, California*; by George P. Merrill.

The fragments of the meteorite briefly described below were given the writer in March, 1887, by Mr. Thomas Price, the well-known Assayer and Bullion Melter of San Francisco, California. The stone was stated by Mr. Price to have been found by a prospector in the San Emigdio Mts., and to have been sent him for assaying, it being mistaken for an ore of one of the precious metals. Unfortunately, before its true nature was discovered the entire sample received was put through a crusher and hence pieces larger than of a few grains weight are unobtainable.

To the unaided eye the stone is of a dull reddish brown color and shows an irregular fracture, presenting on casual examination nothing indicative of its meteoric origin. A polished surface however, at once reveals its true nature.

The stone belongs to the chondritic variety of meteorites and in thin sections under the microscope is seen to be composed of olivine and enstatite chondri rarely more than one or two millimeters in diameter, imbedded in a base the structural features of which are greatly obscured by stains of iron oxide. It is apparently composed of the same substances as the chondri themselves, but in a fragmental and finely divided condition. The chondri are often of irregular and angular form and show every indication of being themselves *fragments* of some preexisting meteorite rather than mere products of rapid crystallization. Nickeliferous iron constitutes 6·21 per cent by weight of the stone and occurs in the forms of lumps and irregularly outlined areas often partially surrounding the chondri and acting to some extent as a binding constituent. It is closely associated with pyrrhotite. There is also present in very minute crystals a colorless, polysynthetically twinned mineral which is presumably a monoclinic pyroxene. The minuteness of the crystals and their imperfect outlines renders a satisfactory determination impossible.

An analysis of the stone by Mr. J. E. Whitfield of the U. S. Geological Survey yielded results as follows:

Metallic portion	6·21 per cent.
Soluble in dilute HCl	51·26
Insoluble "	42·23

The metallic portion yielded iron 88·25 per cent; nickel 11·27 per cent; cobalt 0·48 per cent. The portion soluble in HCl includes the olivine, iron oxides and pyrrhotite; the insoluble portion includes the enstatite and twinned pyroxene. The great amount of oxidation which the metallic portion has undergone renders both chemical and microscopic examinations far from satisfactory. Nevertheless as the stone presents very interesting structural features it has been my intention to describe it in detail as soon as proper drawings could be prepared for illustration. In view of the fact that the paper has already been delayed several months it is deemed best to devote a little space to the subject here. I hope to give a more complete description in the near future.

National Museum, Washington, Feb. 15, 1888.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Relative Size of Molecules.*—An attempt has been made by Jäger to determine the relative diameters of some of the elementary molecules and of certain atomic groups, based upon Kohlrausch's investigations on the electric conductivity of certain metallic hydrates and salts in aqueous solution. If in a cylinder of unit length and unit cross section of such a solution there are m molecules; then, the electromotive force along the axis being unity, we may represent by V the velocity with which the kathion will be propelled in the one direction, and by U the velocity of the anion in the other. If ε represent the quantity of positive or negative electricity belonging to each molecule the coefficient of conductivity $\varkappa$ will equal $(u+v)m$, in which $\varepsilon U=u$ and $\varepsilon V=v$; and the specific molecular conductivity λ will be equal to $u+v$. But, according to Hittorf, $\frac{v}{u+v}=n$, in which n is the number of molecules passing through unit space in unit time. Hence $u=(1-n)\lambda$ and $v=n\lambda$. Since the molecules of the ions have a certain velocity, they must meet in unit time a certain number of molecules of a different kind moving in the opposite direction; and therefore they will require energy to overcome the resistance, proportional to their rate of passage. Assuming the molecules to be spheres, and assuming the solution so dilute that no interaction takes place between the molecules of the dissolved substance; then, if the number of molecules in unit volume is α, and if a molecule of radius r passes in a certain direction through an environment of molecules whose radius is ρ, we have $r+\rho=R$, by resolving the forces in two directions. The result is the same if the radius of the moving molecule is R and the molecules of the environment are mathematical points. If for one given molecule we have $v=\frac{C}{R^2}=\frac{C}{(r+\rho)^2}$ in which C is a constant of integration; while for another molecule $v'=\frac{C}{(r'+\rho)^2}$; then, dividing the first formula by the second, we have $\frac{v}{v'}=\frac{(r'+\rho)^2}{(r+\rho)^2}$ from which $r=(r'+\rho)\sqrt{\frac{v'}{v}}-\rho$. Substituting in this equation the values for the relative velocities determined by Kohlrausch, and using to find r' and ρ, the diameters of the molecules of water and chlorine as calculated by O. Meyer; i. e. for water 96×10^{-9} and for chlorine 44×10^{-9} centimeters, the value of U for water being 49, Jäger has obtained the formula for calculating the diameter of a given molecule $d=\sqrt{\frac{960400}{v}}-44$, the values obtained being ex-

pressed in 10^{-9} centimeters. The following are the results obtained.

H	$\frac{1}{2}H_2$	I	Br	(CN)	Cl	K	(NH_4)	(NO_3)	(ClO_3)	$\frac{1}{2}K_2$	$\frac{1}{2}(SO_4)$	Ag
15	32	91	91	95	96	97	99	100	111	111	111	111

$\frac{1}{2}(NH_4)_2$	$\frac{1}{2}(CO_3)$	$\frac{1}{2}Ag_2$	Na	F	$\frac{1}{2}Ba$	$\frac{1}{2}Cu$	$\frac{1}{2}Sr$	$\frac{1}{2}Ca$	$\frac{1}{2}Mg$	$(C_2H_3O_2)$
117	119	129	132	135	138	138	141	148	160	160

$\frac{1}{2}Na_2$	$\frac{1}{2}(SO_4)$	Li	$\frac{1}{2}Zn$	$\frac{1}{2}Mg$	$\frac{1}{2}Zn$	$\frac{1}{2}Cu$	$\frac{1}{2}Li$
165	165*	170	175	218*	239*	239*	251*

The values marked with a star were obtained from the electric conductivity of magnesium, copper, and zinc sulphates. It will be noted that not only do the linear dimensions of molecules vary very widely, but that the diameter of a double molecule is greater than twice that of a single molecule; a necessary result of uniting two equal spheres. Moreover, the values for allied elements are nearly the same; as in the group chlorine, iodine and bromine; or barium, strontium and calcium. Again if the number of molecules in unit volume is proportional to the molecular volume, then by multiplying this volume by the molecular weight, we should obtain values proportional to the densities of the elements concerned. Since this relation does not hold good, except for closely allied elements, it follows that the ultimate particles of different molecules are differently arranged.—*Monatsheft*, viii, 498–507; *J. Chem. Soc.*, liv, *Abstr.* 217, March, 1888. G. F. B.

2. *On the Chemical Decomposition produced by Pressure.*—The researches of Spring have shown that many substances which exert no action upon each other at atmospheric pressure, may be made to combine more or less completely if subjected to a pressure sufficient to cause a perceptible condensation. Since the substances experimented with had a smaller volume after union than that of their constituents, it became an interesting question to ascertain whether, in the case of a substance whose volume is greater than that of its constituents, the temperature of conversion can be lowered by pressure. SPRING and VAN'T HOFF have examined this action by submitting finely pulverized copper-calcium acetate to a pressure of 6000 atmospheres at a temperature of 16°. The powder, though reduced to a crystalline mass resembling marble, showed no sign of decomposition. It was then subjected to the action of a screw press at a temperature of 40°. The results were marked, three-quarters of the mass being liquefied, and becoming solid again when the pressure was removed. The sides of the containing vessel were covered with a coating of copper and small leaves of copper could be picked out of the mass. The dark blue of the acetate had changed to green, interspersed with white points indicating the separation into copper acetate and calcium acetate. Since the thermic effect of the compression was less than corresponds to a rise of 1°, the above result must have been due entirely to a change of volume. At

50° the piston sank through the mass without resistance. On repeating the first experiment using a lever press, the piston sank 1·25^{mm} in an hour; a rate which would require 110 hours to decompose the entire mass. Under the same conditions, potassium sulphate gave no perceptible diminution of volume. Since the chemical change is a function of the time, the acetate being decomposed more rapidly the higher the temperature and pressure, it is evident that the molecules of a substance do not assume the arrangement which corresponds to the given volume the moment it is reached. Moreover, a substance can be compressed without altering its state if the pressure does not last too long.—*Zeitschr. Physikal. Chem.*, i, 227–230; *J. Chem. Soc.*, liv, Abstr. 341, April, 1888. G. F. B.

3. *On the Vapor-density of Ferric Chloride.*—GRUNEWALD and VICTOR MEYER have made a series of careful determinations of the vapor-density of ferric chloride at various temperatures, with a view of fixing its molecular formula. The chloride was prepared by passing dry chlorine gas over fine iron wire, and after sublimation, appeared as hexagonal plates, of a cantharides-green color by reflected, and purplish red by transmitted light. For the vapor-density in sulphur-vapor, 448°, the apparatus of Victor Meyer was used, filled with nitrogen, the bulb of which was only 45^{mm} in diameter and 125^{mm} long, while the whole apparatus was 670^{mm} long. The boiling sulphur was contained in an iron tube 60^{mm} in diameter, and 620^{mm} long, heated in an air bath by six Bunsen burners. As a mean of four accordant experiments, the vapor-density at 448° was found to be 10·487. The chloride after the experiments was carefully tested and found to contain no trace of ferrous chloride. It therefore appears that even at the temperature of boiling sulphur, the density of ferric chloride is lower than 11·2, the value required by the formula Fe_2Cl_6. The determinations were then repeated in the vapor of boiling phosphorus pentasulphide, 518°, in that of stannous chloride 606°, and in Perrot's furnace at about 750°, 1050° and 1300°. The mean vapor densities of ferric chloride at these temperatures were found to be 9·569 at 518°, 8·383 at 606°, 5·459 and 750°, 5·307 at 1077°, and 5·135 at 1320°. It was found however that a progressive decomposition took place at these temperatures, about a tenth of the chloride being decomposed at 518°, an eighth at 606° and a third at 750° and above. The authors conclude that since at 448° the vapor density of ferric chloride is less than corresponds to the formula Fe_2Cl_6, and since experiments at lower temperatures are not feasible, it follows that no temperature exists at which ferric chloride has a density corresponding to Fe_2Cl_6; and consequently since the vapor-density is lower, it must correspond to the formula $FeCl_3$. In order if possible to check the dissociation of ferric chloride into ferrous chloride and chlorine, the experiments were repeated in an atmosphere of chlorine; the vapor-densities obtained, however, were nearly the same as those obtained in nitrogen. These results agree with those obtained for

aluminum chloride by Nilson and Pettersson, which led them to give to this substance the formula $AlCl_3$.—*Ber. Berl. Chem. Ges.*, xxi, 687–701, March, 1888. G. F. B.

4. *Application of interference fringes to Spectrum Analysis.*—HERMANN EBERT, working in the same direction as Professor Michelson, shows that the method of interference can be used to measure wave-lengths and to detect slight changes in refrangibility of spectral lines. In the latter respect he believes that the method is far more delicate than the ordinary spectrometric methods. One can measure displacements of fringes amounting to $\frac{1}{10}$ of the breadth of the fringes, or $\frac{1}{800}$ of the distance of the components of the sodium line, or a change in the velocity of light of $\frac{3}{8}$ of a kilometer.—*Ann. der Physik und Chemie*, pp. 39–90, No. 5, 1888. J. T.

5. *Penetration of light beneath the surface of water.*—In continuation of his work upon this subject, M. F. A. FOREL finds that, for chloride of silver, the limits of absolute darkness range from 45 meters in July to 110 in March. The variations in these limits correspond closely with those for visibility. The water of Lake Geneva, in which these experiments were tried, is more limpid in winter than in summer.—*Comptes Rendus*, April 3, p. 1004. J. T.

6. *Velocity of Sound.*—MM. J. VIOLLE and TH. VAUTIER conclude from their researches that the velocity of a sound wave diminishes with its intensity; and that the pitch of the sound has no influence on the velocity of the wave.—*Comptes Rendus*, April 3, p. 1003. J. T.

7. *Magnetism and diamagnetism of gases.*—At a meeting of the Physical Society held in Berlin, March 16, Helmholtz described a method of measurement due to Professor Töpler, of Dresden. An index drop of petroleum is placed in a glass tube bent at a very obtuse angle; on one side of the index is the gas which is to be investigated, and on the other side is atmospheric air. When placed between the poles of a powerful electro-magnet, the index is moved according as the gas is more or less strongly attracted than the air; the amount of displacement is measured by a microscope. The delicacy of the method is extremely great. It was observed that oxygen is most magnetic, then come air and nitric oxide; nitrogen, hydrogen, carbonic oxide, carbonic acid gas and nitrous oxide, on the other hand, are diamagnetic. The method can also be employed for the determination of the pressure of small columns of gases.—*Nature*, April 12, 1888. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Three Cruises of the United States Coast and Geodetic Survey Steamer Blake in the Gulf of Mexico, in the Caribbean Sea, and along the Atlantic Coast of the United States;* by ALEXANDER AGASSIZ. In two volumes of 314 and 220 pages 8vo, with numerous maps, plates and figures in the text. Boston

and New York, 1888. (Houghton, Mifflin & Co.) Bulletin of the Museum of Comparative Zoology at Harvard College, Cambridge, Mass.—These volumes by Prof. Alexander Agassiz contain the best general review of the deep-sea conditions and pelagic and deep-sea life which has been published; and, at the same time, they give a detailed physical and biological account of one of the most interesting regions for deep-sea study in the world, with illustrations of the best kind in profusion.

The three cruises of the Blake occurred in the seasons of 1877–78 from December to March, 1878–79 commencing in November, and in 1880 commencing late in June. The first expedition was under the command of Lieut. Commander C. D. Sigsbee, U. S. N., and the second and third under Commander J. R. Bartlett, U. S. N. The methods of sounding and dredging were gradually perfected with the progress of the work; Mr. Agassiz remarking, in his introductory chapter, that the criticisms of the first equipment and the suggestions of the Commanders and of the Lieutenants and other officers of the ship, constantly modified the methods of work and so changed the apparatus that "it would have been difficult to recognize the original dredging implements as first devised." The character of the final equipment of the "Blake" is the subject of the first chapter, which, like the others, has its many detailed illustrations.

The various lines of sounding and dredging covered, as shown on a large map, the region about the Windward and other West India Islands, the northern half of the Caribbean Sea, a portion of the Gulf of Mexico, and along the Atlantic Coast. Besides these explorations of the American side of the ocean, there is also the work, as the Historical Sketch states, of the Fish Commission under the direction of Prof. Baird, which began in 1871 with naval tugs, but was carried on in 1882 with the steamer "Fish Hawk" and in 1883 and since with the "Albatross," and the still earlier dredging by Pourtalès, an assistant of the Coast Survey, in the years 1867, 1868. "To the memory of L. F. Pourtalès, a pioneer in deep-sea dredging," Agassiz has dedicated his work. Further, the important deep-sea explorations of the Challenger in these waters took place in 1873.

Among the topics treated in the volumes, there are the following: The Florida coral reefs, and connected with it, the subject of the origin of the reefs; the topography of the eastern submarine coast region of the North American Continent and the causes determining the existing features illustrated by several bathymetric maps; the relations of the American and West Indian fauna and flora, embracing the west-American or Pacific as well as east-American, and including the subject of changes in the course of the Gulf Stream, and the geological consequences; the permanence of continents and oceanic basins, a doctrine fully sustained by the facts gathered; the deep-sea or sea-bottom formations; the deep-sea fauna, and in connection the deep-sea rocks and fauna of ancient or geological time; the pelagic fauna and flora, or that of the open sea not of great depths; the temperatures of the Caribbean Sea, Gulf of Mexico and western Atlantic, illustrated by deep-sea sections of the ocean, and a colored map of the bottom temperature-areas of both the North and South Atlantic; the Gulf Stream; submarine deposits; the physiology of the deep-sea life including the subject of the constitution of sea-water, the degree of darkness of the depths, and other topics; and finally, descriptions of the West Indian fauna and sketches of the characteristic deep-sea types through the various subdivisions of the animal kingdom from Vertebrates to Sponges, which occupy the second volume and are illustrated by nearly 500 figures of species—the work in part of various zoologists whose labors are acknowledged in the Introductory Chapters.

The deep-sea soundings made under the direction of the U. S. Coast and Geodetic Survey in the West Indian seas have brought to light some marvellous facts with regard to depths, which Mr. Agassiz has finely illustrated by maps as well as descriptions. The facts were for the most part first announced in 1884 by Mr. Hilgard, the superintendent of the Coast Survey, citations from whose paper are introduced. A fact of special interest is the great and abrupt depth close along the north shore of the West Indian range of islands, "the 2000-fathom line nowhere more than 14 miles from land," and in one place 1976 fathoms "only $2\frac{1}{2}$ miles out, a declivity of 38°; and, in this line, a depression over 4000 fathoms deep within 75 miles of Porto Rico, the deepest sounding giving 4561 fathoms, indicating a mean submarine slope from the Porto Rico coast-line of 1:14. Further, from this deep depression a trough of 2000 fathoms (the soundings 2000 to 2326 fathoms) extends westward by the north shore of San Domingo, between it and the reef islands north, with slopes part of the way on either side of 1: $8\frac{1}{2}$; and this deep trough diminishing probably to 750 fathoms on the ridge between San Domingo and Cuba, commences again on nearly the same course close by the most southern Cuban shore (within 25 miles) by a trough of 3138 and 3180 fathoms, and is continued westward by two other areas of 3428 and 3206 fathoms pointing down to the southwest angle of the west-Caribbean or Cuban Sea north of Honduras. Agassiz's maps, figs. 56 and 57, show these troughs and the view on page 94 of a model of the Gulf made under Mr. Hilgard's direction, exhibit it still more strikingly through the greatly exaggerated vertical scale. Mr. Agassiz suggests one explanation for the origin of the great depths and correlately for mountains on the borders of the ocean on page 132, and another for some of the depressions on page 104.

Another feature in the sea-bottom topography illustrated by the soundings is the absence, between a point just south of Cape Hatteras and the Bahamas of that steep side-slope of the Atlantic basin along the 100-fathom line which prevails north of the Cape. In place of it, there is a very gradual inclination outward to the 600-fathom line and then a dip off to greater depths, making thus a plateau 250 to 300 miles wide which is named the "Blake plateau." Southeast of Savannah and east of Jacksonville the area between the 400-fathom and 500-fathom line is 140 miles broad. The origin of this feature is attributed by Mr. Agassiz to the abrading and transporting action of the Gulf Stream. He states that off Charleston the bottom for the whole width of the Gulf Stream was swept clean of mud or ooze and almost so of living species, proving thus the action of the great stream which along that part of the Atlantic border has a velocity between 3 and 4 miles an hour and a width of 50 to 75 miles.

In the account of sea-bottom formations it is stated that the sediment of the great Mississippi River extends into the Gulf not over 100 miles; beyond this there is the usual sea-bottom life.

The volumes are full of facts of interest relating to the material and nature of the bottom, the condition of the waters, the bathymetric and geographical distribution of living species, and all the various topics alluded to above; and they are made attractive to the general as well as scientific reader by their clear and excellent literary style, the maps, and the many illustrations of the life of the dark depths.

2. *Descriptions of new Fossil Fishes;* by J. S. NEWBERRY.—Dr. J. S. Newberry has a description in volume VI of the Transactions of the N. Y. Academy of Sciences of a new species of Titanichthys larger than the *T. Agassizii* described by him in the Geological Magazine in 1883. The *T. Agassizii*—a fish related to Dinichthys—had a cranium 4 feet 8 inches broad at the occiput, and the mandibles were long slender rods, gently bent upward at the anterior extremity, and there excavated in a deep furrow apparently for the reception of some kind of dental organs. The remains of the new species, including several more or less complete specimens, were found by Dr. Wm. Clarke, at Berea, Ohio, and is named *T. Clarkii.* The cranium is broadly triangular in outline and *five feet* or more between the posterior lateral angles. The mandibles are three feet long, the posterior end, spatulate, six inches wide and turned downward; and the anterior end is turned up like a sled-runner, and has a deep furrow, like *T. Agassizii*, but the whole jaw is much heavier and broader. The under side of the body was protected by a triangular plate three feet long and nearly as broad.

In volume VII of the Transactions Dr. Newberry describes a new and large species of *Rhizodus* from the St. Louis limestone at Albion, Illinois, which he has named *Rhizodus anceps;* it is near *R. Hibberti* Ag., of the Carboniferous limestone of Scotland. The specimen is an anterior half of the dentary bone carrying a large number of acute conical striated teeth about half an inch long, with three great laniary teeth, the anterior and most perfect one of which projects two inches above the margin of the jaw; it differs from the corresponding *R. Hibberti* in being more compressed and double-edged. Dr. Newberry speaks of the discovery of *R. Hardingi* Dawson, in the Lower Carboniferous of

Horton Bluff, Nova Scotia, and remarks that the genus is probably confined to this period.

Other fossil species are described in the same volume from the Erie shale of Ohio—the western extension of the Chemung and Portage rocks of New York and Pennsylvania. They include *Cladodus Kepleri* Newb., *Actinophorus Clarkii* Newb., *Dinichthys curtus* Newb., *D. tuberculatus* Newb. *D. curtus* has been found in the Chemung of Pennsylvania.

The Annals of the New York Academy of Sciences for February, 1888 (vol. iv), contains a description and figures by Dr. Newberry of a new and gigantic species of Edestus, *E. giganteus*, from the coal measures of Decatur, Illinois, with a history of the genus and notes on the species. The specimen is shown to be the dorsal spine, of a gigantic Plagiostome. The spine, which was 18 inches or more in length, had the great breadth of 7½ inches including the denticles, and was two inches thick at center; the broad triangular denticles were 3½ inches long with the edges coarsely denticulate. The species was much larger than *E. vorax* of Leidy or *E. Heinrichsii* of Newberry and Worthen, and different also in the form of the teeth. An admirable figure of the specimen accompanies the paper, with also figures of the other American species.

3. *Natural History of New York. Palæontology*, vol. vii, with Supplement to vol. v, part II; by JAMES HALL, State Geologist and Palæontologist, assisted by John M. Clarke. pp. lxiv, 236, 4 to 45 plates, and pp. 42, with 18 plates. Albany, 1888.—This new volume of the Palæontology of New York is devoted principally to the Devonian Crustacea of North America, exclusive of the subclass Ostracoda. The introduction presents a brief historical sketch of the class as limited to American forms; also, a table showing a systematic arrangement of the subclasses, orders, families and genera, followed by a discussion and tabulation of their chronological distribution. It is shown that the richest trilobitic fauna is in the Corniferous limestone, which has afforded 52 species of crustacea, of which 49 are trilobites and 3 are cirripeds. The generic synonymy and a diagnosis of each genus, with outline figures in the text, precede the main descriptive matter of the volume, and will furnish much assistance to the student of this class of fossils, as well as many valuable references and suggestions to the systematic palæontologist.

The descriptions of species are given in a logical and complete manner. There are 127 species and varieties of Devonian crustacea described, which are arranged in 28 genera. The trilobites include 10 genera and 83 species; the Xiphosura 1; the Eurypterida 2 genera and 3 species; the Phyllocarida 8 genera and 26 species; the Decapoda 1 genus and a single species; the Phyllopoda 2 genera and 2 species; and the Cirripedia 4 genera and 11 species.

One of the most interesting of the genera of Trilobites considered in the volume is that of *Dalmanites.* It comprises 25 species and varieties, which are arranged in six subgeneric groups. The genus in its early development includes species principally of the type of *D. Hausmanni.* Variation takes place mainly in the lobes and furrows of the glabella and in the ornamentation of the margins of the cephalon and pygidium. During the period of the deposition of the Helderberg series the culmination of development was reached, and many deviations from the original simple type were introduced. The ornamental and defensive armature became extravagantly developed, and several species reached a large size. One form, *D. myrmecophorus*, is estimated from a careful restoration based on a large pygidium, to have had a length of 398^{mm} or 16 inches. The genus Lichas exhibits a similar development and variety of form. It includes the largest and most remarkable of Devonian trilobites, the *Lichas* (*Terataspis*) *grandis* Hall, with individuals reaching a length of nearly two feet and bearing numerous spines and tubercles. The majority of the species of trilobites discussed in this volume are found in the Lower Devonian, and all the genera made their appearance in earlier Palæozoic time.

To many students the portion of the volume relating to species not trilobitic will have the greatest interest on account of the rarity and diversity of the material and its relations with existing forms. This non-trilobitic crustacean fauna holds an important place in the middle and upper Devonian, and but three or four of the nineteen genera here noticed, were continued from earlier faunas.

The supplementary matter is in continuation of vol. v, pt. II, published in 1879, and relates to the classes Pteropoda, Annelida and Cephalopoda. A specimen borrowed from the U. S. Geol. Survey, through C. D. Walcott, and referred by him to *Proëtus marginalis* Con. (Walcott, Monogr. U. S. Geol. Surv., vol. viii, Pal, Eureka Dist., p. 210, 1884), is redescribed as *Proëtus Nevadæ* Hall. This method of treating borrowed type specimens will not meet with general approval. C. E. BEECHER.

4. *Geology of Minnesota, Bulletin No.* 2, 1887. *Preliminary description of the peridotytes, gabbros, diabases and andesytes of Minnesota;* by M. E. WADSWORTH. 160 pp. 8vo, with 12 colored plates of rock-sections.—This Report discusses critically the characteristics of the many rocks studied, their interior changes and other points of petrological interest. It is preliminary to a final report on the Minnesota rocks.

5. *Building-Stone in the State of New York;* by J. C. SMOCK.—Bulletin of the New York State Museum of Natural History, No. 3, March, 1888. Albany, 1888.

6. *Carboniferous Trilobites.*—Lieut. A. W. Vogdes has a paper on American Carboniferous trilobites in the Annals of the N. Y. Acad. Sci., Febr., 1888, reviewing the synonymy and the character of the species, adding notes, and giving figures of 19 species.

7. *Les Dislocations de l'écorce terrestre: Essai de Définition et de Nomenclature par* EMM. DE MARGARIE, á Paris, et Dr. ALBERT

Heim, á Zurich, 154, pp. 8vo. Zürich, 1888.—This memoir is a thorough systematic descriptive review of the various kinds of faults or displacements, flexures and folds, in rocks, with definitions of the terms used by writers on the subjects, and is both in the French and German languages. Its illustrations are numerous, and illustrate well all the various conditions of rocks described, and its references to authorities are very full. It is therefore an excellent aid to the geological student.

8. *Index der Krystallformen der Mineralien*, Band II, Hft. 1, 2, 3; Bd. III, Hft. 1.

Ueber Projection und graphische Krystallberechnung. 97 pp.

Ueber krystallographische Demonstration mit Hilfe von Korkmodellen mit farbigen Nadelstiften, with 6 colored plates. von Victor Goldschmidt. Berlin, (Julius Springer.)—Something more than a year has passed since the completion of the first volume of Goldschmidt's Index (see this Journal, xxxi, 475, xxxii, 485.) The work which the author has undertaken is a formidable one involving a heavy amount of labor for him, and yet benefitting greatly all workers in this line; it is to be hoped that he may before long be able to bring it to a successful completion. The numbers now issued (in separate parts for the convenience of those using the work) cover all mineral species in F, G, H, with also quartz (vol. III, No. 1), and the execution is of the same excellence as in the earlier parts. The scheme of notation with the methods of projection and calculation which the author has developed with such exhaustive completeness in the Introduction to vol. I of the Index are further elucidated in the accompanying memoirs. The reader who masters them fully will be better able to appreciate the advantages of the author's method. An ingenious device is adopted for the purpose of demonstration by the use of cork blocks with needles bearing colored heads to show the symmetry of the different systems and the relation of the forms belonging to them.

III. Botany and Zoology.

1. *Flora of the Hawaiian Islands;* by William Hillebrand, M.D. Annotated and published after the author's death, by W. F. Hillebrand [New York, B. Westermann & Co. 8vo, p. 673, with 4 maps of the Islands.]

Dr. Hillebrand resided for twenty years in Honolulu, engaged in the successful practice of an exacting profession, finding recreation in an exhaustive study of the vegetation of the Sandwich Islands. The plants were examined by him not only in their native haunts but also after they had been transferred to his garden. where they could be investigated under the most favorable conditions. In this way he accumulated the materials for his Flora. These materials were carefully elaborated during his examinations of the leading Herbaria, and the work was ready for the printers early in the summer of 1886.

Dr. Hillebrand's death occurred shortly after the first proofs had been received and corrected, so that the task devolved upon his family of presenting to the world this Flora as a memorial. The task was one of considerable difficulty, inasmuch as certain portions of the treatise had been left in a form which appeared to demand modification. The work has, however, been most skillfully done, and reflects credit on the judgment, learning and good taste of those to whom it was entrusted. In the face of serious difficulties the undertaking has been carried through to a successful completion.

The descriptive part comprises the flowering plants and the vascular cryptogams; 884 species of the former, distributed through 335 genera, and 155 species of vascular cryptogams, in 30 genera. It is thought that 115 species of the above enumerations have been introduced since the discovery of the islands by Cook in 1779. Concerning the geographical relations of the islands and their general features, the lamented author has given a clear and concise account, and he has added some comparisons of the vegetation with that of other countries. The most striking point is the number of varieties in all the leading genera. The occurrence of these varieties is a source of embarrassment to the systematist, but it affords abundant material for the biologist who seeks to determine the range of variation in recent times. The attempt to discriminate between the species connected thus by innumerable intermediate forms has resulted in giving us a work which is unique. The author says: "the descriptions will be found to suffer from want of brevity, of terseness, which the student is inclined to expect in a work of this kind. As an apology I can only plead that my constant endeavor has been to be faithful to nature, that I have thought necessary in order to bring out the general transitions from one form to another to enter upon characters which often are considered of small importance." But no apology is needed. The descriptions though not brief are not prolix. Moreover, in the case of larger genera, analytical keys with emphasis on the more obvious characters, make the treatise an easy one to use.

To the volume is prefixed the sketch of Botany which was employed by Mr. Bentham in his British and Colonial Floras.

From the author's notes, which though somewhat fragmentary, have been wisely added with little if any change, we take the following statements: "Nature here luxuriates in formative energy. Is it because the islands offer a great range of conditions of life? Or is it because the leading genera are in their age of manhood, of greatest vigor? Or is it because the number of types which here come into play is limited, and therefore the area offered to their development comparatively great and varied?"

Such suggestive questions as these are scattered throughout Dr. Hillebrand's preliminary paper; similar enquiries arise when one examines almost any page of this work, which is his monument. G. L. G.

2. *Recent Advances in Vegetable Histology.*—Whether a new classification of the tissues can be properly regarded as an advance, may be open to question, but the following, applied to the secondary structure of wood, appears to have some advantages for comparative histology. It appears in a study of certain orders by Hitzemann, given in abstract in Bot. Centralbl. 1887, vol. xxxi, p. 91.

A. Elements containing starch. (Parenchymatous system.)

I. Parenchyma arranged radially. (Medullary rays.)

1. Cells chiefly perpendicular to the axis of the stem, generally forming plates of more than one layer of cells.

2. Cells parallel to the axis, almost always forming plates of a single layer of cells.

II. Parenchyma arranged tangentially, connecting the medullary rays.

3. Short cells, generally in groups of more than one row. Wood-parenchyma.

4. Elongated cells, in a plate of a single layer. Substitution fibers and fibrous cells, forming a transition to the next group.

B. Elements containing no starch.

I. Fiber-system. (Mechanical system.) Area of cross-section of the element is but a small fraction of that of a longitudinal section.

5. Pits not present, or very minute, or larger with no distinct border. Libriform-fibers.

6. Pits present and provided with a large border; no difference in size or structure between the bordered pits on the side and end walls. Tracheïd-fibers.

II. Trachael system. System for conducting water.

7. Pits of the side and end-walls show no marked difference in structure, but a great difference in size. Tracheïds.

8. Pits exhibit noticeable differences in structure, complete perforation of the partition. Ducts.

It will be observed that this classification is open to the objection which lies against every system thus far proposed, namely: that both morphological and physiological considerations enter into its construction. But for comparative studies like that undertaken by Hitzemann, the classification seems simple and may prove useful.

Berggren (in 1883) studied the economy of the spirally-thickened cells in the roots of some Taxineæ. In the leaves of certain species of Sansevieria, Areschoug (Bot. Centralbl. xxxi, 258) finds similar cells with extraordinary thickness, apparently serving as constituents of a true "water-tissue," instead of being, as in many other well-known cases, unequivocal tracheids.

Prael (Ber. Deutsch. Bot. Ges. 1887, 417) has lately investigated the structure of the wood which forms during the repair of young twigs and stems which have been injured. It has long been known that this new wood partakes somewhat of the nature of heart-wood rather than of sap-wood. The results of Prael's work may be interpreted as showing that the protective wood which grows over wounds always exhibits a notable agreement in all particulars with the heart-wood of the same plant, even sharing its tyloses, resins, gums, and to a certain extent its coloring matters.

The vascular bundles which are termed "concentric" are of two kinds: (1) the xylem is surrounded by the phloem, (2) the phloem is surrounded by the xylem. The first is characteristic of ferns, although examples are not wanting among flowering plants. Both of these kinds have been examined by Möbius (Ber. Deutsch. Bot. Ges. 1887, 2), who adds to the results of his special investigation a convenient synoptical table of the orders in which these different types are to be seen.

von Tavel (Ber. Deutsch. Bot. Ges. 1887, 438) gives an interesting account of his investigation of the mechanical structure of bulbs. Bulbs are, in general, reservoirs of food which grow under a certain amount of pressure from surrounding soil. In some cases the weight of superincumbent earth is very considerable. Under these restricting pressures the bulb would become much distorted were it not protected by strong mechanical elements. A study of the distribution of these elements and an examination of the epidermal structures of bulbs show that they have no relation whatever to the systematic place of the species, but that they are strictly adaptive.

The comparative histology of allied orders of flowering plants continues to attract a considerable number of investigators, but as yet without any very satisfactory results in the direction of generalization. Nor can it be expected that the survey of the limited fields thus far brought under observation can reveal any general laws, but the value of the results of such scattered and often very fragmentary histological studies cannot well be overestimated. Among those most recently published are the following: Hitzemann's examination of Ternstroemiaceæ, Dipterocarpeæ, and Chlænaceæ, and Saupe's investigation [Flora, 1887, p. 259] of the wood of the Leguminosæ. The conclusions reached by the latter may be briefly stated thus: (1.) It is impossible to separate the suborders Papilionaceæ Cæsalpiniaceæ, and Mimoseæ on the basis of wood-structure. But, on the other hand, it is perfectly practicable to distinguish in these suborders, closely related and sharply marked groups of small sizes. And, moreover, it is easy to detect, in some instances, a close anatomical resemblance between two members of some of these groups, even when they grow naturally under wholly diverse circumstances. But their species cannot as yet be distinguished clearly by means of the histological character of the wood. G. L. G.

3. *Forms of Animal Life.*—A Manual of Comparative Anatomy, with descriptions of selected types, by the late G. Rolleston, Linacre Prof. Anat. Phys., Oxford; second edition, revised and enlarged by W. H. Jackson, F.L.S., Nat. Sci. Lecturer, St. John's College. 938 pp., 8vo. Oxford: 1888. (Clarendon

Press.)—This large volume is a very full Manual of Comparative Anatomy for the student, and is well adapted to its purpose by the completeness of its explanations and directions and the number of prepared types which it discusses. These embrace species from all the grander divisions of the Animal Kingdom, in the following order: Mammals, Birds, Reptiles, Amphibians, Fishes, Ascidians, Gastropods, Lamellibranchs, Insects, Crustaceans, Asteroids, Chætopods, Hirudinea, Cestoda, Polyzoa, Anthozoa, Hydrozoa, Porifera, Infusoria and Amœbina. The subjects are illustrated by 14 excellent plates of the various subjects considered, besides various fine wood cuts.

4. *Die Japanische Seeigel von Dr. Ludwig Döderlein*, of Strassburg. 1 Theil. Fam. Cidaridæ und Saleniidæ, mit Taf. I–XI. Stuttgart, 1887 (E. Schweizerbart'sche Verlagshandlung).—This memoir has remarkably beautiful plates illustrating descriptions of some new species of Cidarids from Japan and also recent species of other regions described by different authors, and also gives a review in detail of the general character and history of the group.

5. *Bibliotheca Zoologica* II. Verzeichniss der Schriften über Zoologie welche in den periodischen Werken enthalten vom Jahre 1861–1880, selbständig erscheinen sind mit Einschluss der allgemein-naturgeschichtlichen periodischen und palæontologischen Schriften, bearbeitet von Dr. O. Taschenberg, Docent an der Univ. Halle. Fünfte Lieferung, Signatur 161–200. Leipzig, 1888. (Wm. Engelmann). The earlier parts of this important work have been noticed in volumes xxxiii and xxxiv of this Journal.

IV. Miscellaneous Scientific Intelligence.

1. *The Constant of Aberration.*—Professor Hall has published in the Astronomical Journal the results of his reduction of the observations made in the years 1862–7 upon α Lyrae by Professors Hubbard, Newcomb, Harkness and himself with the prime vertical transit instrument of the Naval Observatory, for the purpose of determining the constants of mutation and aberration. He obtains as the most probable value of the constant of aberration $20''\cdot4542\pm0''\cdot0144$. This with Michelson and Newcomb's velocity of light gives for the solar parallax $8''\cdot810\pm0''\cdot0062$.

2. *Discovery of Small Planets.*—The small planet (183) Istria was rediscovered by Paliser April 7th. Of the first 250 of the planets at least 238 have therefore now been observed at a second opposition. Only two of the exceptions are between (200) and (250). The planet (278) was discovered by Borelly at Marseilles, unless this should prove to be Xantippe (156).

3. *Michigan Mining School.*—This mining school, at Houghton, Michigan, is the only school of mining east of the Mississippi that is located in a region of mines. Being on Keweenaw Point, in the vicinity of the great copper mines, it has the special ad-

vantages necessary to successful instruction. The faculty include Dr. M. E. WADSWORTH, Director and Professor of mineralogy, petrography and geology; R. L. PACKARD, A.M., Professor of chemistry, and R. M. EDWARDS, E.M., Professor of mining and engineering. Dr. Wadsworth has recently been made State Geologist of Michigan.

Die Regen-Verhältnisse des Russischen Reiches, von H. Wild, mit seriem atlas; Supplement band zum Repertorium für Meteorologie, herausg. Kais. Acad. Wiss. St. Petersburg, 1887.

Nomenclator Floræ Danicæ, Auctore Joh. Lange, 354 pp. 4to, Leipsic, 1887 (F. A. Brockhaus).

The International Scientist's Directory of 1888, compiled and published by S. L. Casino, Boston, and just issued, contains complete lists of the geologists of Europe with their addresses, and also of other men of science. It is a very convenient volume for students in all departments of science.

The Manual Training School, comprising a full statement of its aims, methods and results, with figured drawings of shop exercises in woods and metals; by C. M. Woodward, A.B. (Harvard) Ph.D. Boston, 1887 (D. C. Heath & Co.)—Industrial Instruction: a pedagogic and social necessity, together with a Critique upon objections advanced; by R. Seidel, Mollis, Switzerland. Transl. by Margaret K. Smith, State Normal School, Oswego, New York. 160 pp. 12mo. Boston, 1887 (D. C. Heath & Co.)

The above are two valuable works; the first one of great importance to the scholars of a training school or for self-training.

A Treatise on Alcohol with tables of spirit gravities, by Thomas Stevenson, M.D., London. 2d edition. 74 pp. 12mo, London, 1888. (Gurney & Jackson.)

Introductory Text-book of Geology by David Page, LL.D., F.G.S., revised and in great part re-written by C. Lapworth, LL.D., F.G.S., Prof. Geol. and Pysiogr., Mason College, Birmingham, 12th edit., 316 pp., 12mo. Edinburgh and London, 1888. (Wm. Blackwood & Sons.)

OBITUARY.

GERHARD VOM RATH, Professor of Mineralogy at the University of Bonn, died on the 23d of April. He was born August 20, 1830, so that his life is cut off prematurely, and yet through his indefatigable energy and enthusiasm the amount of scientific work which he accomplished was truly remarkable. His inaugural dissertation, on the composition of the scapolites, was published in 1853 (Poggendorff's Annalen, vol. l) and from that time on he was never idle. There are but few important mineral species to our knowledge of which he has not contributed. The most intricate problems in crystallography were those in which he took most pleasure, and to his clear mind the complete twinning laws of the triclinic feldspars, the obscure distorted forms of gold and silver, and a host of similar problems presented no difficulty; and his skillful hand was always equal to the task of representing the forms on paper. A son-in-law of Gustav Rose, he was a worthy follower in his footsteps in the character and scope of his labors. He was a great traveler, especially during the later years of his life, and many are the papers he has written, mostly scientific, but others more popular, giving the results of his observations in Greece, Palestine, Mexico, the western United States, and other regions. Professor vom Rath had a most charmingly genial disposition, and a wide circle of friends, by no means limited to Germany, will mourn his too early death.

INDEX TO VOLUME XXXV.*

* This Index contains the general heads BOTANY, CHEMISTRY, GEOLOGY, MINERALS, OBITUARY, ZOOLOGY, and under each the titles of Articles referring thereto are mentioned.

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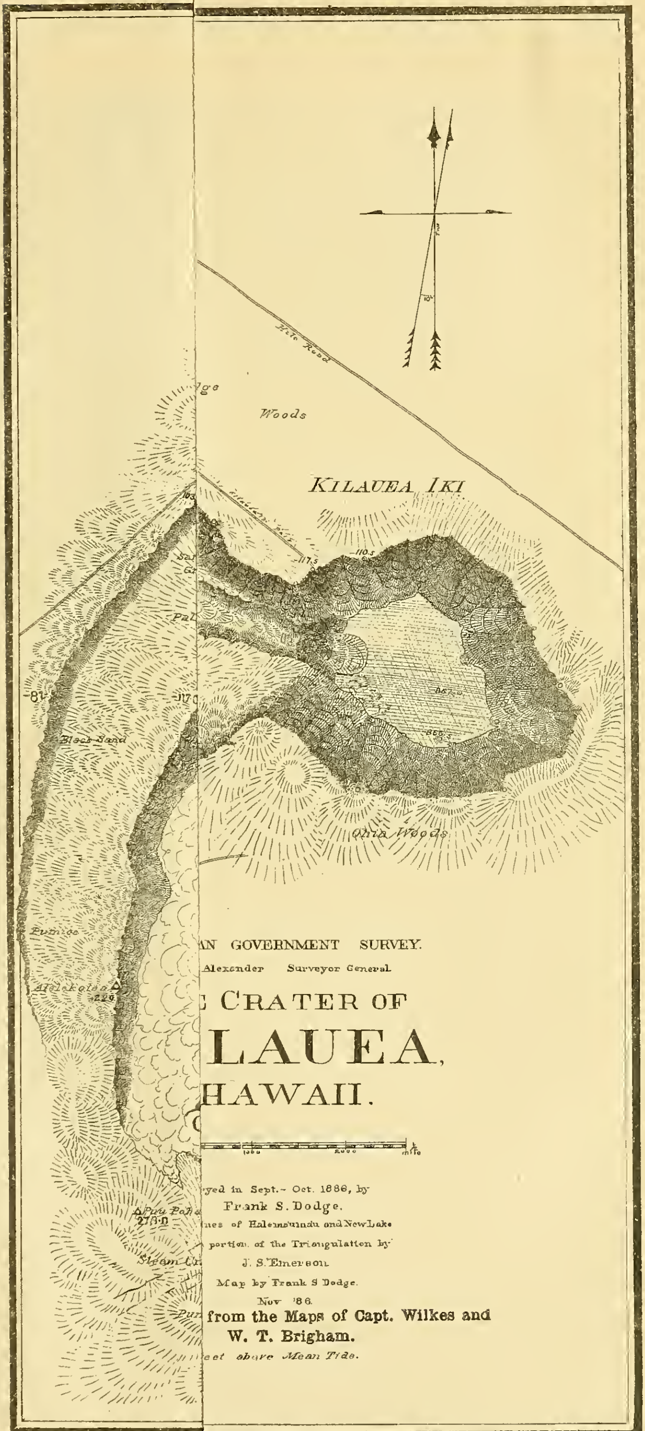
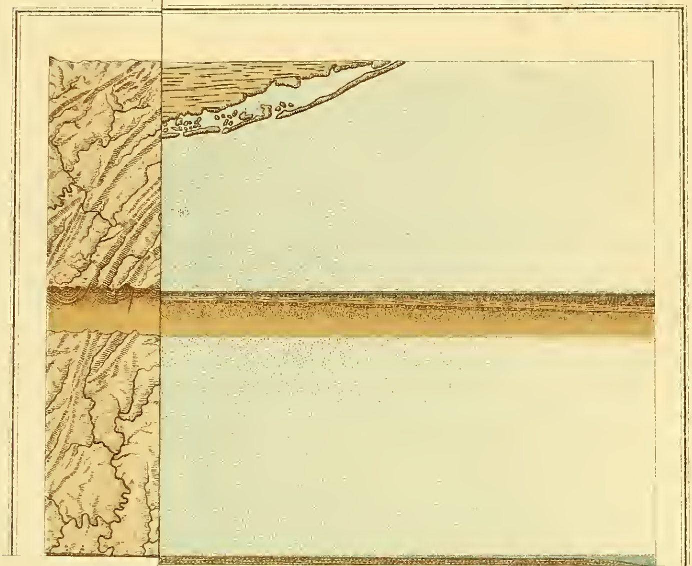


L.S.P... derson & Son, ... Haven, ...


HAWAIIAN GOVERNMENT SURVEY
W.D. Alexander Surveyor General
THE CRATER OF
KILAUEA,
HAWAII.
With additions from the Maps of Capt. Wilkes and
W. T. Brigham.
Frank S. Dodge
J. S. Emerson
KILAUEA IKI
KEANAKAKOI
VOLCANO HOUSE
SULPHUR BANK
NEW LAKE
HALEMAUMAU
Waldron's Ledge
Sandy Plain
Sulphur Beds
Kamohoalii
Uwekahuna
Gravel
Sand and Gravel
Pumice
Ohia Woods
Woods
Central Rock
Aa Patch



Drawn by J.H. Klemroth

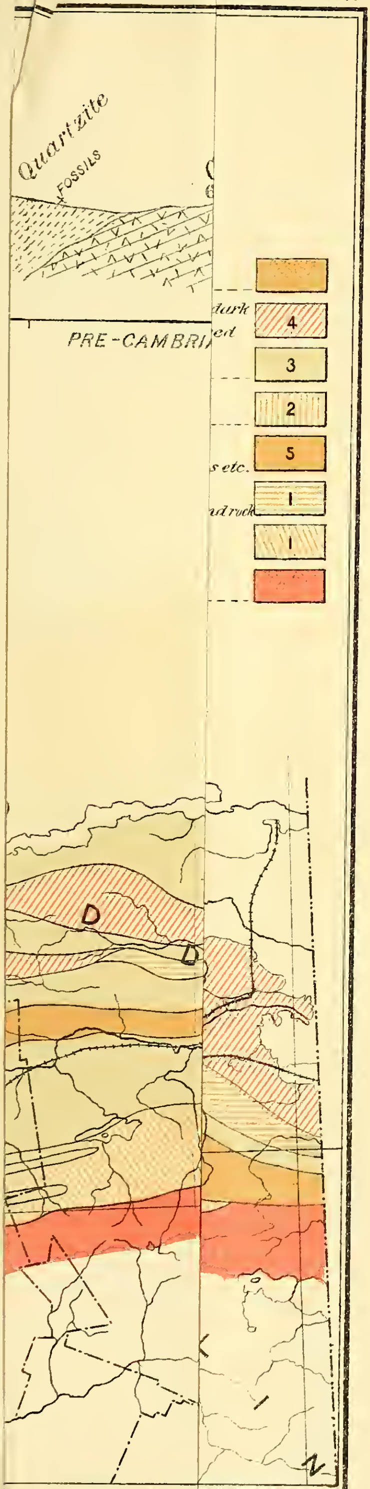
STEREOGRAM OF THE MIDDLE ATLANTIC SLOPE.

By W J. McGee, Geologist.

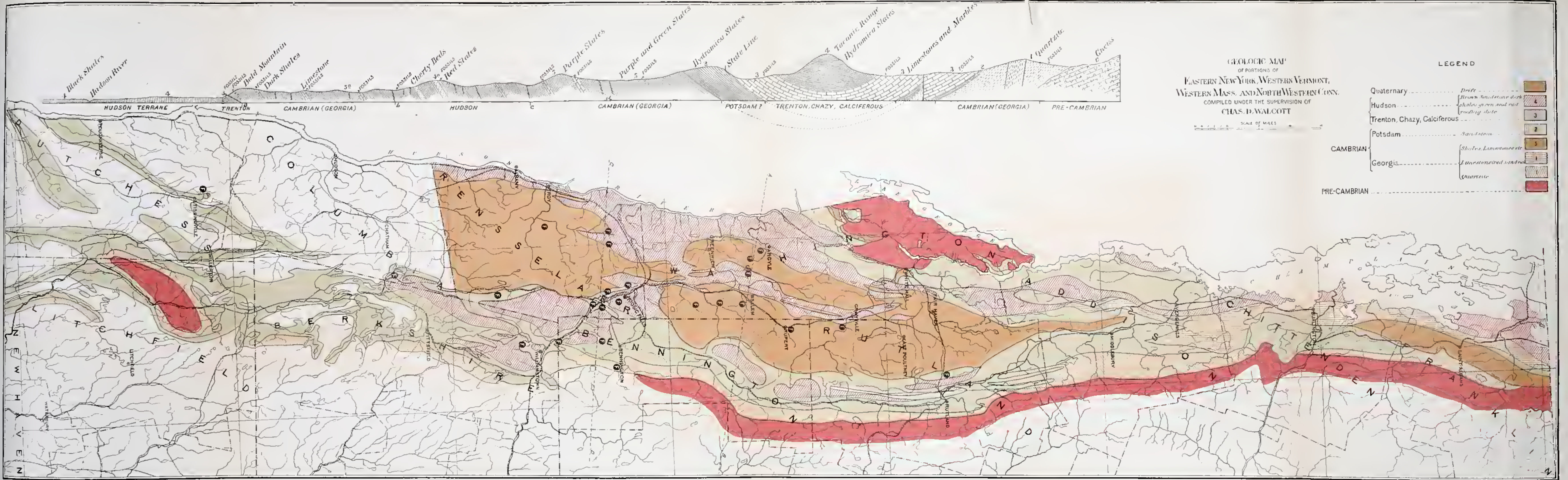
Horizontal Scale 1: 2,230,000 = 35 mi.: 1 in.

Vertical Scale 1: 425,000 = 35,000 ft.: 1 in.

PLATE III.



). PHOTO-LITH.


Black Shales
Hudson River
Bald Mountain
Dark Shales
Limestone
Cherty Beds
Red Slates
Purple Slates
Purple and Green Slates
Hydromica Slates
State Line
Taconic Range
Hydromica Slates
Limestones and Marbles
Quartzite
Gneiss
HUDSON TERRANE
TRENTON
CAMBRIAN (GEORGIA)
HUDSON
CAMBRIAN (GEORGIA)
POTSDAM ?
TRENTON, CHAZY, CALCIFEROUS
CAMBRIAN (GEORGIA)
PRE-CAMBRIAN
GEOLOGIC MAP
OF PORTIONS OF
EASTERN NEW YORK, WESTERN VERMONT,
WESTERN MASS. AND NORTH WESTERN CONN.
COMPILED UNDER THE SUPERVISION OF
CHAS. D. WALCOTT
SCALE OF MILES
LEGEND
Quaternary
Drift
Hudson
Trenton, Chazy, Calciferous
Potsdam
Sandstone
CAMBRIAN
Georgis
Quartzite
PRE-CAMBRIAN
DUTCHESS
COLUMBIA
RENSSELAER
WASHINGTON
ADDISON
CHITTENDEN
FRANKLIN
LITCHFIELD
BERKSHIRE
BENNINGTON
RUTLAND
NEW HAVEN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THIRD SERIES.

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WITH PLATE I.

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THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

Art. I.—*The Speed of Propagation of the Charleston Earthquake;* discussed by Professor Simon Newcomb, U. S. N., and Captain C. E. Dutton, U. S. A.

The investigation of the time data of the Charleston earthquake having been completed and a final result being reached, it is deemed proper, with the consent of the Director of the Geological Survey, to publish a brief abstract of the discussion. The full discussion will appear in the final report upon the earthquake, which report is now well advanced toward completion.

Immediately after the earthquake all practicable measures were taken to collect information, and special effort was directed to obtaining the largest amount of time data. Through the courtesy of the Associated Press, notices were published in nearly all the newspapers of the country requesting those who had made such observations to forward them to the Director of the Geological Survey. Many persons did so. The Chief Signal Officer instructed the observers of that bureau who had noted the time of the shock to report it, and he forwarded all such reports to the survey. The Western Union Telegraph Co. instructed its operators to forward reports and similar instructions were sent by the Lighthouse Board to light-keepers. Special effort was made to secure newspapers from as many localities as possible. Most of the leading papers of the country have an agent or reporter at Washington and he usually keeps a file of the paper he serves. The library of Congress keeps files of two or more papers from every State. As many of these as practicable were thoroughly examined. Many local papers were requested to furnish copies of their issues of Sept. 1st, 2d and 3d, and most of them complied. Many marked copies of papers were sent to the survey from unexpected sources. Altogether more than four hundred time reports were gathered.

As might be expected a portion of these were useless. In order that it may be apparent which were selected for consideration and which rejected, the following account is given. There were about thirty which stated that the shock occurred "about 10 o'clock" or "a few minutes before 10." As a single minute is a very important quantity here, all such reports were summarily rejected as too indefinite. The reports from lighthouses in most cases proved unavailable. These structures being situated most frequently where access to standard time is difficult, their clocks are regulated by the sun and an almanac. The uncertainties of this method of time keeping were evidently too great to justify any attempt to utilize them. But a few lighthouses keep standard time and in all such cases their reports were admitted to consideration. There were a few (nine or ten) which gave times so widely aberrant, differing by a quarter to half an hour from the great mass of records, that they were rejected. The whole number which received preliminary consideration was 316, many of which it was expected would also be rejected after a more thorough examination, due cause being assigned. These 316 observations were catalogued in alphabetical order, the latitudes and longitudes of the localities being roughly ascertained and also their distance from the centrum.

By far the most important time determination is that of the centrum, which was computed to be about six seconds earlier than that of Charleston. The time at Charleston is derived as follows. Among the numberless clocks stopped in that city by the earthquake, there were four which had compensated seconds pendulums and second hands and were of the pattern generally classed as "jewelers' regulators." All were compared daily with the time signal of the Western Union Telegraph Co., and the testimony is positive that none of them had errors on August 31st exceeding nine seconds, while the mean probable error of the four was certainly much less than this. The first was the regulator of James Allan & Co., Jewelers, No. 285 King street. It was regulated by means of a "sounder," which was daily put into circuit with the Western Union time signal wire. The clock was corrected only when its error exceeded

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