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DANA'S WORKS.

IVISON, BLAKEMAN, TAYLOR & Co., Publishers, New York.—**Manual of Geology. Second Edition** (1874.) 828 pp. 8vo. $5.00. — **Text-book of Geology. 2d ed.** (1874). 358 pp. 12mo. $2.00.—**The Geological Story Briefly Told.** 264 pp. 12mo. 1875.

J. WILEY & SON, Publishers, New York.—**Treatise on Mineralogy.** 5th edit. xlviii and 828 pp. 8vo. 1868. $10.00. Also, Appendix I. by Prof. Brush. 1872. Appendix II, by Edward S. Dana, 1875. The 5th "subedition" was issued by Wiley & Son in April, 1874. Each "subedition" (or issue from the stereotype plates), contains corrections of all errors discovered in the work up to the date of its publication.

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[THIRD SERIES.]

ART. I.—*Contributions to Meteorology, being results derived from an examination of the observations of the United States Signal Service and from other sources;* by ELIAS LOOMIS, Professor of Natural Philosophy in Yale College. Thirteenth paper, with two plates.

[Read before the National Academy of Sciences, Washington, April 20, 1880.]

Great and sudden changes of temperature.

IN my third paper (this Journal, vol. x, p. 10,) I called attention to the great and sudden changes of temperature which frequently occur in some parts of the United States, and noticed a very remarkable case which occurred at Denver, Colorado, in January, 1875. As the observations for this month at all the stations of the Signal Service have now been published, I propose to examine this case more particularly, and also to present some additional facts connected with the same subject. My third paper contains two tables, showing for each station of the Signal Service for the years 1873 and 1874, the number of cases in which the difference between the maximum and minimum temperatures of the same day amounted to at least 40°. I have extended this comparison to the four years of observations since published in the Annual Reports, and find 118 stations at which at least one such case was reported. As the table is too large to be published entire, I have retained only those stations at which the average number of cases amounted to at least six annually. The following table exhibits these stations arranged in the order of frequency of great changes of temperature. Column first shows the names of the stations; column second their latitude; column third their longitude from Greenwich; column fourth their elevation above the sea; columns fifth to sixteenth show the total number of cases observed in each of the months of the year; column seventeenth shows the aggregate number of cases for each station; column eighteenth shows the number of months of observations at each station; column nineteenth shows the average number of cases for one year; and column twentieth shows the annual rain fall at each station expressed in inches. An asterisk shows that observations for the month indicated are wanting.

Diurnal change of temperature at least 40°.

Station.	Lat.	Long.	Elev. feet.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Sum.	Months.	Year.	Rain, inches.
	°	°																	
Wickenburg	34·0	112·7	2050	2	9			13	23	9	16	22	21	21	10	146	11	160	4·99
LaMesilla	32·3	106·8	4000	14	12	7	17	8	12	*			4	17	5	96	11	105	3·56
Campo	32·4	116·5	2486	1		3	2	7	12	7	28	18	*	*	*	78	9	104	18·53
Tucson	32·2	110·9	1898	*	5	13	6	9	8	*	*	*	*	*	*	41	5	98	13·03
Prescott	34·5	112·5	5580	8		4	3	7	20	*	*	6	8	13	12	81	10	97	13·81
Ft. Craig	33·7	107·1	4619			4	8	6	4		8	6	8	2	1	47	12	47	
Colorado Sp.	38·9	105·0	6032	22	11	11	6	12	19	8	1	3	7	8	9	117	30	47	15·84
Winnemucca	41·0	117·7	4335	2			2	2	1	6	14	7	7	1	1	43	12	43	5·66
Uvalde	29·2	99·7		4	4	4				6	6	2	3	6	3	38	11	41	23·31
Benton	47·9	110·5	2674	5	7	7		2				6	7	1	1	36	12	36	12·17
Denver	39·7	105·1	5269	20	7	17	13	10	24	16	9	29	18	10	11	184	69	32	13·81
Graham	33·0	98·5	900	*	4	8	2	1				*	*	*	*	15	6	30	18·28
North Platte	41·1	100·9	2838	10	7	10	9	1	4	2	1	6	21	11	5	87	42	25	28·77
Visalia	36·3	119·3	348							6	14	2				22	12	22	10·49
Fredericksb'g	30·3	98·7	1614	3	5	3				*	*	*	*	*	2	13	7	22	27·73
Stockton	30·8	102·8	4950	2	2	3	4		1	*				5	2	19	11	21	14·63
Concho	31·4	100·3	1750	4	4	7						1	1	1	2	20	12	20	23·83
Camp Verde	34·4	111·9	3160		1	3	2	*		3	7	2				18	11	20	10·81
Pilot Point	33·3	96·8			2	1	3	1		1	5		1	1	1	16	11	17	31·37
Cheyenne	41·2	104·7	6057	5	2	2	4	4	22	22	8	17	4	6	3	99	69	17	13·50
Dodge City	37·6	100·1	2486	4	10	12	4	3	2			1	11	10	4	61	45	16	24·87
Umatilla	45·9	119·3	461					3	4	2	6					15	11	16	8·36
Florence	33·0	111·3					1	2	2	*	*	*	*	5		10	8	15	7·18
Ft. Sully	44·6	100·7	1678	6	3	3	4	3	5	3	11	10	18	2	4	72	60	14	12·16
Ft. Griffin	32·9	99·3		2	4	2	3	1								12	12	12	37·96
Breckenridge	46·2	96·3	968	2	6	4	1	7	3	5	1	10	20	5	4	68	69	12	38·57
York Factory	57·0	92·4	55	1		1	1		2	10	1					16	17	11	14·54
Rockliffe	46·2	77·7	418	2		2	3	2	5	1	1					16	18	10	
Yankton	42·7	97·5	1275	11	6	1	3	2	1			3	9	6	4	46	57	10	28·63
Pembina	49·0	97·1	790	2	2	2	2	12	2		4	5	10	3	5	49	62	9	22·47
Bismark	46·8	100·6	1706	5	1				2	2	2	4	12	2	3	33	45	9	18·37
Ft. Garry	49·9	97·0	754	3	3	3	2	13	6	3	3	3	5	2	3	49	66	9	29·19
Geneva	42·9	77·1	567				1	4	5							10	15	8	27·46
Brackettville	29·3	100·4	1026	1	2	1				2			1			7	12	7	26·18
Chatham	47·0	65·5	56	4	12	7	2	5							1	31	57	7	45·67
Parry Sound	45·4	80·2	635	3	5	2	2	1						1	4	18	34	7	40·44

Of the thirty-six stations here enumerated about half are situated south of latitude 35°, and these are the stations where the great fluctuations of temperature occur most frequently, while the fluctuations of pressure attending the progress of the storms of the middle latitudes are but little felt. Moreover it will be noticed that these great fluctuations of temperature occur more frequently in summer than in winter. Hence it may be inferred that the principal cause of these fluctuations is independent of the progress of storms. This will appear if we examine the cases at Wickenburg, which stands at the head of the list. The following are the cases in which the diurnal change of temperature at Wickenburg exceeded 60°:

		Max.	Min.	Diff.			Max.	Min.	Diff.
1877.	July 27,	106°	42°	64°	1877.	Aug. 1,	109°	37°	72°
	28,	110	40	70		2,	107	43	64
	29,	106	44	62		3,	108	44	64
	30,	106	43	63		13,	112	46	66
	31,	106	30	76		14,	113	50	63

Wickenburg is situated in a desert region where the annual rain-fall is only five inches; where, during the day, the sand becomes intensely heated by the sun's rays; and where, on account of the dryness of the atmosphere the loss of heat by radiation at night must be about as great as at any other point of the earth's surface. A similar condition of things exists at all the stations named in the table south of latitude 35°.

At the stations further north, the rain-fall is generally small, and the air is ordinarily very dry. This remark will apply to all those stations at which the annual number of cases of these large fluctuations exceeds twelve. At some of the remaining stations, the fluctuations of temperature resulting from the progress of great storms becomes appreciable, viz: at Breckenridge, York Factory, Rockliffe, Yankton, Pembina, Bismark, Fort Garry, Geneva, Chatham and Parry Sound. Six of these stations are situated in that region where, after the passage of a center of low pressure with its high temperature, the cold winds from the north rush down with a violence unknown in any other part of the continent. It appears then that the most remarkable cases in the table are examples of the ordinary diurnal change of temperature unaffected by the passage of storms; and that the remaining cases are to be ascribed to the influence of storms combined with the ordinary diurnal change of temperature.

In order to test this question more fully, I determined the mean diurnal fluctuation of temperature at all the stations of the Signal Service west of the meridian of 90° from Greenwich. The annual reports of the Signal Service show the maximum and minimum temperature for each day of the year for each of the stations of observation. I determined the average of the maxima for each month, and also the average of the minima, and called the difference the mean diurnal fluctuation for that month. When there were observations for several years, I took the average of the numbers obtained for the corresponding months of the different years. The following table shows the results for the several stations arranged in the same order as in the preceding table:

Mean diurnal fluctuation of temperature.

Station.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Wickenburg	36°·0	35°·5	19°·7	19°·5	37°·0	43°·6	°	50°·2	40°·9	40°·2	42°·0	33°·4
La Mesilla	37·1	35·6	37·1	36·0	36·0	36·8		28·3	24·8	32·2	40·6	30·7
Campo	26·1	20·0	25·1	23·4	32·1	35·9	41·2	47·7	46·0			
Tucson		38·1	35·2	36·2	37·3	36·6						
Prescott	35·3	29·2	31·6	31·7	33·4	39·3			32·9	36·5	38·6	37·4
Ft. Craig	25·8	25·8	30·8	34·2	34·7	30·4	28·4	33·4	33·8	29·9	31·4	24·0
Colorado Sp.	29·0	28·7	28·2	30·0	29·5	32·4	28·8	29·1	28·4	28·7	28·3	30·2
Winnemucca	25·7	18·8	22·6	25·6	28·4	29·9	35·6	37·8	33·9	30·7	24·4	29·5
Uvalde	28·4	29·8	28·7	26·1	18·2	22·8		34·7	30·7	28·6	31·7	22·6
Benton	29·5	30·8	24·0	25·4	23·9	24·3	28·7	25·7	32·1	29·0	23·7	24·0
Denver	25·8	25·0	27·8	27·5	27·3	30·3	29·8	29·8	30·2	28·6	26·9	26·2
Graham		28·0	33·7	30·3	23·6	19·9	22·7	24·7				
North Platte	25·4	24·8	25·0	25·4	22·1	25·1	27·5	24·9	27·2	28·4	24·9	25·5
Visalia	18·7	15·9	19·1	22·5	29·1	33·3	35·8	38·0	33·9	28·1	24·0	19·0
Fredericksb'g	31·7	33·1	31·2	27·8	25·2	24·1	25·7					
Stockton	28·2	32·6	29·3	31·6	28·0	28·1		27·4	24·4	26·0	29·0	21·2
Concho	26·5	28·5	32·0	26·5	22·1	21·4	24·2	25·4	23·4	24·5	25·4	20·4
Camp Verde	28·0	28·7	29·6	27·3		33·5			29·9	30·0	34·0	20·3
Pilot Point	24·1	28·6	32·5	30·2	31·0	26·1	30·6	35·1	29·4	24·1	26·3	25·1
Cheyenne	23·1	23·0	24·9	24·6	26·1	30·4	30·4	30·1	29·3	26·0	23·6	23·2
Dodge City	22·1	24·5	26·8	25·2	24·0	24·4	24·3	22·9	24·6	26·3	26·0	24·1
Umatilla	13·6	16·0	22·2	25·6	28·3	30·6	29·8	32·4	27·2	25·0	15·5	10·2
Florence	28·1	26·9	26·3	26·4	32·3	31·0					34·3	22·8
Ft. Sully	24·8	21·7	21·8	24·3	23·8	26·7	28·0	28·4	27·2	25·9	21·5	22·2
Ft. Griffin	23·4	28·0	31·4	29·1	25·9	21·8	25·8	25·2	25·3	19·6	23·1	19·8
Breckenridge	21·0	21·3	21·7	20·4	23·8	22·7	25·0	22·8	24·7	24·7	18·2	20·4
York Factory	17·0	19·1	22·3	21·2	19·7	23·3	24·8	21·7	16·2	12·4	15·7	15·9
Yankton	22·9	21·8	19·3	23·2	21·0	20·4	21·7	23·0	22·5	23·7	21·0	20·0
Pembina	20·9	21·1	23·0	22·7	25·3	23·1	24·9	25·1	23·7	23·0	18·7	21·5
Bismark	19·6	19·6	19·2	20·3	22·1	22·4	24·3	25·9	24·7	28·3	20·9	20·0
Ft. Garry	20·1	18·7	22·9	22·1	26·0	25·2	27·1	24·8	25·5	21·9	18·0	21·4
Bracketville	24·3	25·9	24·7	23·3	18·1	21·2	28·2	27·1	25·4	24·0	24·0	18·8

This table shows that the ordinary diurnal fluctuation of temperature at the more southern stations is enormously great, and in some places exceeds 40° for months in succession. There can be no doubt that this fluctuation is mainly due to the direct effect of the sun's rays during the day, combined with the effect of radiation at night.

In order to study the same phenomenon in a dry climate in a different part of the world, I took Barth's Travels in Central Africa, 1849–55. Dr. Barth started from Tripoli, crossed the Great Desert of Africa, going south to latitude 9½° N. and returned to Tripoli. During this journey many observations of the thermometer were made, but the record was very fragmentary and seldom included both early morning and mid-day. The following are the only cases I have found in which two observations of the same day differed as much as 40°. The table shows the date of observation; the temperature observed; the difference between the two observations of the same day; the latitude in which the observation was made and the elevation above the sea as accurately as can be determined from the published maps of the expedition:

Temperature in Central Africa.

Date.	Temp.	Diff.	Latitude.	Alti'e feet.
1850.				
April 13. 5.15 A. M.	50°	41·8°	30° 37′	531
2 P. M.	91·8			
14. 5 A. M.	43·2	42·8	30 37	531
Noon.	86			
24. 5.30 A. M.	40·1	42·3	28 20	696
Noon.	82·4			
25. 5 A. M.	46·4	63·0	27 46	921
2 P. M.	109·4			
July 12. 5.15 A. M.	65·3	41·4	25 37	1435
1 P. M.	106·7			
18. 4.45 A. M.	64·4	41·4	25 05	1349
2.15 P. M.	105·8			
Nov. 12. Sunrise.	43·7	42·3	18 23	1894
1.15 P. M.	86			
1851.				
Mar. 18. Sunrise.	64·4	44·6	12 47	1360
1 P. M.	109			
1852.				
Jan. 7. Sunrise.	59	41·4	10 18	900
1.30 P. M.	100·4			
1852.				
Jan. 26. Sunrise.	52·7°	40·5°	11° 36′	900
1.30 P. M.	93·2			
Mar. 23. Sunrise.	58	43·5	11 47	830
2 P. M.	101·5			
April 1. Sunrise.	63	43·2	11 40	900
1.30 P. M.	106·2			
Nov. 25. Sunrise.	41	50	12 55	880
1.30 P. M.	91			
Dec. 5. Sunrise.	47	47	13 0	900
1.30 P. M.	94			
1853.				
April 12. Sunrise.	64	44	13 15	
2 P. M.	108			
April 13. Sunrise.	66	43	13 15	
2 P. M.	109			
1855.				
June 18. Sunrise.	69	40	19 42	1000
2 P. M.	109			

These observations bear an obvious resemblance to those made in Arizona, and show that in a very dry climate the diurnal fluctuations of temperature are excessive, and seem to leave no doubt that this is the chief cause of the great changes of temperature shown in the table on page 2, and that at the more northern stations this cause is combined with the fluctuations which result from the passage of violent storms.

There is one important circumstance of which no account has thus far been taken, viz: the extreme suddenness of the changes of temperature which are sometimes experienced and of which an example occurred at Denver, January 15, 1875. What is the cause of these sudden changes? The first fact, which attracts our attention, is that the air at Denver and its vicinity is ordinarily very dry. This will appear from the following table showing for the year 1878 the mean relative humidity at all the stations of the Signal Service between the Sierra Nevadas and the meridian of 90° west longitude:

Stations.	Humid.	Stations.	Humid.	Stations.	Humid.
Pioche, Nev.	40·3	Dodge City, Kan.	62·3	Vicksburg, Miss.	69·0
Santa Fe, N. Mex.	42·4	St. Louis, Mo.	63·9	Shreveport, La.	69·3
Winnemucca, Nev.	42·4	Corsicana, Tex.	65·7	Davenport, Iowa	69·5
Denver, Col.	44·0	Bismark, Dak.	66·4	Omaha, Neb.	69·6
Salt Lake City, Ut.	45·1	Denison, Tex.	66·7	Yankton, Dak.	69·7
Cheyenne, Wyo.	50·8	Ft. Gibson, Ind. T.	67·5	Keokuk, Iowa	70·3
Boise City, Idaho	54·1	Dubuque, Iowa	67·9	Pembina, Dak.	72·1
Virginia City, Mont.	54·5	New Orleans, La.	68·5	Duluth, Minn.	73·0
Red Bluff, Cal.	54·7	Leavenworth, Kan.	68·7	Indianola, Tex.	73·3
Umatilla, Oregon	59·5	Memphis, Tenn.	68·8	Galveston, Tex.	74·7
North Platte, Neb.	61·6	St. Paul, Minn.	68 8	Breckenridge, Minn.	76·0
Pike's Peak, Col.	62·0	LaCrosse, Wisc.	68·9		

Plate I exhibits the curves of equal relative humidity for the stations east of the Rocky Mountains, showing that on the east side of these Mountains there is a narrow belt of territory where the mean relative humidity is less than one-half; and there is a belt at least 400 miles wide where the mean humidity is less than two-thirds; and in advancing eastward we find the humidity to increase still further. What is the cause of this dry atmosphere? Only one explanation seems possible. The westerly winds from the Pacific Ocean have their moisture mostly condensed in passing over the Sierra Nevadas, so that between these Mountains and the Rocky Mountains, the air is generally extremely dry. By passing over the Rocky Mountains there is a further condensation of vapor, so that when the air descends on the eastern side of these Mountains it is almost destitute of moisture. The vapor which comes up from the Gulf of Mexico is diffused over the Mississippi Valley, and mingles with the dry air which comes from beyond the Mountains, so that the dryness of the air rapidly diminishes as we advance eastward from the Rocky Mountains.

In order to determine whether the sudden changes of temperature, sometimes experienced near the level of the sea, ever result from the sudden descent of cold air from a great height, I have made an extensive comparison of the observations at Denver and Pike's Peak. The mean temperature at Pike's Peak is 30·8° below that at Denver, and the difference of elevation is 8882 feet, showing a fall of temperature of 1° for an elevation of 288 feet. This represents nearly the condition of equilibrium of a vertical column of the atmosphere. If the air at Pike's Peak should be 40° colder than at Denver it would tend to sink, and the air at Denver would tend to rise. I accordingly selected from the volumes of published observations (Nov. 1873 to Jan. 1875, and from Jan. 1877 to May 1877) all the cases in which the temperature at Pike's Peak was 40° lower than at Denver. The number of these cases in twenty months of observations was 343. Only thirty-nine of these cases occurred during the seven winter months of observations, and they occurred most frequently in the month of May. As this table is too extensive to be published entire, I selected those cases in which the temperature at Pike's Peak was at least 45° lower than at Denver. These cases are exhibited in the following table, where column first shows the number of reference; column second shows the date of the observation. [The 7.35 A. M. observation is denoted by the figure 1 attached to the date; the 4.35 P. M. observation by the figure 2, and the 11 P. M. observation by the figure 3.] Column third shows the temperature on Pike's Peak; column fourth the relative humidity, and column fifth the direction and force of the winds on Pike's Peak; column sixth shows the temperature at Denver; column seventh the difference between the temperature at Denver and that at Pike's Peak; column eighth shows how much the pressure at Denver differed from the mean pressure for the month; column ninth shows the relative humidity; column tenth the direction and force of the winds; and column eleventh shows the direction of the upper clouds at Denver, with the amount of cloudiness (estimated in fourths of the visible heavens.)

The average humidity at Pike's Peak at the time of these observations was sixty-two, which was exactly the average humidity for the entire year 1878. The winds on Pike's Peak generally blew from a western quarter, and in only nineteen cases did they blow from any eastern quarter. The average velocity of these easterly winds was twelve miles per hour. The fluctuations of the barometer at Denver were generally small, being sometimes above and sometimes below the mean; but the average pressure was 0·10 inch below the mean. The easterly and westerly winds at Denver were almost exactly equal in frequency, but the velocity of the west winds was more than double that of the east winds. The upper clouds at Denver were almost invariably from the southwest or west, and were never from any easterly point, and the average cloudiness of the sky was more than one-half. The most noticeable circumstance exhibited by this table is the dryness of the air at Denver, the average relative humidity being only fifteen percent. There appears to be only one possible explanation of the source of this dry air, viz: that it came from the west side of the Rocky Mountains.

The facts thus stated appear to show that at the dates given in the preceding table there was seldom any extraordinary disturbance on Pike's Peak. In two cases (Nos. 60 and 61) hail was reported; in four cases (Nos. 23, 32, 43 and 59) sleet was reported, and in fifteen other cases there was either rain or snow. These facts seem to indicate an occasional uprising of

Temperature on Pike's Peak 45° *lower than at Denver.*

	PIKE'S PEAK.					DENVER.							
	1874.	Tem.	hum.	Winds.		Tem.	Diff.	Barom.	hum.	Winds.		Clouds.	
1	Jan. 27.2	1°	43	N.W.	24	46°	45°	+ ·18	13	N.W.	18	0	
2	March 2.2	11	61	S.W.	30	56	45	− ·27	19	S.	15	4	W.
3	12.2	13	62	S.W.	20	58	45	+ ·11	12	S.	3	1	W.
4	15.2	5	100	S.	16	54	49	− ·40	10	S.	15	4	W.
5	April 2.2	9	58	S.W.	16	55	46	+ ·14	22	E.	10	0	
6	2.3	−6	62	S.W.	36	39	45	+ ·10	55	S.	5	0	
7	9.2	12	80	N.	12	59	47	+ ·07	21	N.	4	0	
8	10.2	21	58	S.W.	10	70	49	− ·02	8	E.	5	1	S.W.
9	11.2	12	52	S.W.	28	64	52	− ·21	7	S.	15	2	
10	19.2	7	77	N.	12	53	46	− ·19	42	S.W.	5	1	N.W.
11	24.2	12	81	N.	16	60	48	− ·07	23	N.W.	18	2	N.
12	25.2	20	70	S.W.	32	68	48	− ·01	21	S.E.	8	2	S.W.
13	26.2	23	47	N.W.	20	71	48	− ·08	9	W.	11	3	S.W.
14	27.2	20	22	N.W.	16	66	46	+ ·23	19	S.E.	6	0	
15	28.2	25	50	W.	20	73	48	+ ·16	13	E.	5	1	N.W.
16	29.2	28	30	N.W.	16	79	51	− ·01	11	S.	6	2	
17	30.2	27	32	W.	36	81	54	− ·22	10	W.	5	2	W.
18	May 1.2	25	39	S.W.	20	73	48	− ·50	16	N.E.	38	4	
19	2.2	7	55	W.	36	56	49	− ·25	15	N.W.	22	4	S.W.
20	8.2	25	39	S.	30	77	52	− ·47	5	S.W.	32	4	S.
21	8.3	14	100	S.W.	36	59	45	− ·32	27	S.	16	1	
22	9.1	6	100	S.W.	20	51	45	− ·42	45	S.	6	2	S.W.
23	9.2	11	90	N.W.	28	56	45	− ·54	22	N.	12	4	
24	10.2	18	69	W.	20	63	45	− ·22	15	N.W.	24	3	S.W.
25	13.2	21	86	W.	20	70	49	− ·04	12	N.W.	7	2	S.W.
26	14.2	18	84	N.W.	24	64	46	+ ·10	34	W.	3	3	S.W.
27	15.2	26	52	W.	16	72	46	+ ·17	14	S.E.	3	1	S.W.
28	16.2	30	78	N.	12	81	51	+ ·09	11	N.W.	7	2	
29	17.2	31	38	S.W.	16	76	45	+ ·13	19	N.	22	4	S.W.
30	18.2	29	78	N.	8	87	58	+ ·07	14	E.	6	4	
31	19.2	30	100	E.	4	82	52	+ ·05	12	S.W.	13	4	S.W.
32	20.2	27	100	S.	12	80	53	+ ·05	18	S.	16	4	S.W.
33	21.2	35	55	N.W.	12	80	45	·00	18	N.W.	11	4	S.W.
34	22.2	38	37	S.W.	12	85	47	− ·03	15	N.E.	6	4	W.
35	23.2	37	45	S.E.	6	83	46	− ·09	11	S.	16	4	S.W.
36	24.2	30	78	S.	4	81	51	+ ·08	22	E.	6	1	S.W.
37	25.2	36	61	S.	16	89	53	− ·04	13	S.E.	12	1	S.W.
38	26.2	32	89	W.	20	78	46	− ·18	19	W.	20	4	
39	27.2	37	52	S.W.	24	87	50	− ·35	10	S.	16	3	S.
40	27.3	27	100	S.	48	75	48	− ·36	15	S.	20	4	
41	28.2	31	39	S.W.	44	83	52	− ·35	5	S.W.	15	2	S.W.
42	June 1.2	26	77	S.W.	77	71	45	− ·09	28	S.	4	2	W.
43	3.2	32	79	S.W.	36	81	49	− ·15	20	S.	8	4	S.W.
44	5.2	36	61	S.W.	30	83	47	− ·09	21	N.E.	4	4	S.W.
45	6.2	36	62	S.W.	40	81	45	− ·10	29	S.E.	12	4	S.W.
46	12.2	33	52	S.W.	36	85	52	− ·14	15	E.	4	4	S.W.
47	17.2	41	33	S.W.	18	90	49	− ·11	7	N.E.	12	3	W.
48	19.2	45	19	W.	20	90	45	+ ·06	24	E.	23	4	S.W.
49	20.2	48	23	S.E.	6	93	45	+ ·13	13	S.E.	12	3	W.
50	22.2	50	11	S.E.	14	98	48	− ·10	8	S.E.	20	2	
51	July 1.2	38	46	S.	20	86	48	− ·02	12	W.	14	4	S.W.
52	2.2	48	10	S.E.	10	95	47	− ·04	10	S.E.	9	0	
53	3.2	49	11	N.E.	8	97	48	− ·07	4	N.W.	8	0	
54	4.2	54	4	S.	16	100	46	− ·15	0	E.	9	2	
55	8.2	49	29	N.E.	22	96	47	− ·05	7	N.E.	8	4	N.W.
56	12.2	50	22	N.E.	8	95	45	− ·14	9	N.E.	6	1	S.W.
57	15.2	40	91	N.E.	14	85	45	+ ·11	27	N.E.	4	3	

	PIKE'S PEAK.					DENVER.							
	1874.	Tem.	hum.	Winds.		Tem.	Diff.	Barom.	hum.	Winds.		Clouds.	
58	July 16.2	42°	83	S.E.	6	91°	49	−·07	12	N.	12	3	N.W.
59	17.2	42	83	S.E.	10	90	48	−·14	22	S.E.	16	4	
60	Aug. 6.2	40	82	S.W.	16	85	45	+·01	26	E.	4	4	S.W.
61	8.2	43	83	S.E.	12	92	49	−·04	11	E.	8	4	W.
62	15.2	47	29	N.E.	8	93	46	+·01	14	W.	4	4	S.W.
63	16.2	45	52	W.	8	90	45	+·02	12	N.E.	4	4	
64	23.2	38	55	N.E.	8	86	48	+·02	17	N.	2	3	S.W.
65	Sep. 18.3	16	83	W.	32	76	60	−·01	39	E.	1	3	S.W.
66	23.2	23	100	N.E.	24	70	47	+·02	33	N.E.	7	3	W.
67	24.2	28	48	N.E.	22	74	46	−·10	28	Calm.		0	
68	25.2	31	69	N.	14	80	49	−·19	3	N.W.	8	1	W.
69	28.2	35	52	N.E.	6	81	46	+·02	10	N.E.	2	0	
70	30.2	35	31	N.	2	82	47	−·01	11	E.	4	3	W.
71	Oct. 2.2	34	79	S.W.	32	81	47	−·25	21	S.W.	5	4	S.W.
72	9.2	29	46	N.	16	76	47	+·06	54	N.E.	11	0	
73	24.2	19	69	S.W.	52	65	46	−·42	16	N.E.	9	0	
74	28.1	2	100	W.	60	47	45	−·39	23	N.W.	8	2	N.W.
75	Nov. 1.2	19	29	W.	22	64	45	+·06	0	N.W.	18	0	
76	4.2	12	61	N.W.	44	57	45	−·28	14	W.	26	2	N.W.
77	5.2	20	70	S.W.	44	67	47	−·07	15	S.	10	0	
78	6.2	20	70	S.W.	60	70	50	−·29	9	S.	17	4	S.W.
79	7.3	5	50	W.	56	51	46	−·08	23	N.E.	1	1	
80	13.2	21	81	S.W.	60	66	45	−·25	10	N.E.	11	2	S.W.
81	20.2	9	57	W.	40	54	45	−·18	17	N.W.	18	0	
82	22.2	1	100	W.	52	46	45	−·33	24	W.	24	1	S.W.
83	25.2	23	60	W.	44	69	46	−·16	21	W.	19	1	N.W.
84	Dec. 12.2	15	13	N.W.	19	60	45	−·16	18	N.	15	3	W.
	1877.												
85	Feb. 7.2	−5	100	N.E.	30	40	45	+·02	40	N.	20	0	
86	Mar. 11.2	15	85	W.	42	61	46	−·12	5	N.W.	15	0	
87	11.3	8	66	W.	39	54	46	+·05	39	E.	2	0	
88	13.2	18	61	N.W.	28	64	46	+·09	8	N.W.	15	0	
89	15.2	25	40	W.	32	73	48	−·11	–	W.	20	2	W.
90	18.2	22	27	N.W.	31	70	48	+·01	3	N.W.	22	2	W.
91	20.2	25	47	N.W.	26	70	45	+·04	4	N.W.	28	2	N.W.
92	31.1	−3	100	W.	24	42	45	−·45	13	W.	4	4	
93	April 3.2	12	61	N.W.	18	57	45	−·08	15	N.W.	15	2	S.W.
94	4.2	20	55	S.W.	10	65	45	−·04	6	N.W.	10	0	
95	5.2	20	70	S.E.	10	66	46	−·04	7	W.	4	2	W.
96	13.2	19	84	S.W.	23	64	45	−·09	20	S.E.	10	2	W.
97	15.2	22	72	W.	24	68	46	−·14	7	N.E.	5	2	
98	20.2	21	70	S.W.	41	70	49	−·44	6	S.E.	28	0	
99	21.1	5	100	S.W.	78	50	45	−·31	14	S.W.	10	0	
100	21.2	17	83	S.W.	30	68	51	−·33	—	S.W.	20	2	
101	30.2	16	66	N.W.	10	63	47	·00	19	S.W.	5	2	S.W.
102	May 4.2	16	83	N.W.	20	65	49	−·21	10	W.	16	3	W.
103	8.2	23	60	W.	25	76	53	−·09	7	S.	5	4	S.W.
104	9.2	23	60	W.	18	75	52	−·08	6	S.	5	2	
105	14.2	21	50	S.W.	43	74	53	−·07	0	W.	20	2	S.W.
106	15.2	29	67	S.	15	74	45	+·09	5	E.	4	3	W.
107	17.2	21	85	S.W.	28	72	51	−·20	6	S.E.	4	4	
108	19.2	17	100	S.W.	28	65	48	−·13	14	E.	3	2	
109	26.2	32	64	W.	2	79	47	+·11	11	S.	8	2	S.W.
110	27.2	33	74	W.	17	83	50	+·06	0	N.E.	4	2	S.W.
111	28.2	30	63	S.W.	35	82	52	−·07	7	S.E.	12	3	S.W.
112	29.2	27	55	S.W.	42	81	54	−·35	3	S.	4	2	
113	29.3	19	85	S.W.	54	66	47	−·36	14	S.W.	12	2	
114	31.2	14	83	W.	28	60	46	−·23	19	W.	20	4	

the warm air, but it is remarkable that so few such cases occurred, and it will be noticed that a difference of temperature of at least 45° between Pike's Peak and Denver often continued from day to day for a long period. In May, 1874, it continued for sixteen successive days, and in April, 1874, it continued for nine successive days. Hence it may be inferred that during these periods there was no general uprising of the warm air, and descent of cold air. I think we may hence infer that dry air even when greatly heated, has but little ascensional

Temperature on Pike's Peak higher than at Denver.

	PIKE'S PEAK.						DENVER.						
	1873.	Tem.	hum.	Winds.		Clouds.	Tem.	Diff.	Barom.	hum.	Winds.		Clouds.
1	Nov. 28.1	6°	76	W.	40	4	0°	6°	−·09	71	Calm.		0
2	Dec. 20.1	4	50	W.	20	4 N.W.	2	2	+·06	74	Calm.		1
3	28.1	41	25	W.	6	0	27	14	−·07	63	S.	3	0
	1874.												
4	Jan. 4.3	1	12	N.	18	0	−4	5	+·20	47	S.	6	0
5	5.1	10	20	N.	30	0	8	2	+·07	66	S.	6	0
6	Feb. 26.3	22	39	W.	32	0	13	9	+·16	62	S.	4	0
7	Dec. 14.1	15	48	N.	18	2	14	1	+·17	63	S.	5	0
8	17.3	0	70	N.	40	0	−5	5	+·25	26	S.	5	0
9	19.1	6	52	N.	6	0	5	1	−·03	50	S.	4	0
10	29.1	5	75	W.	15	0	4	1	+·05	74	N.E.	6	0
	1875.												
11	Jan. 8.1	−2	100	S.W.	22	Fog.	−10	8	+·12	77	N.E.	12	4
12	8.2	0	100	W.	42	Fog.	−14	14	+·28	100	N.E.	5	4
13	9.1	−18	100	S.W.	38	2	−23	5	+·29	100	Calm.		0
14	12.1	−5	100	S.W.	1	4	−8	3	−·11	100	N.	5	4
15	12.2	−2	100	S.W.	24	4	−9	7	−·04	100	N.E.	8	4
16	12.3	−12	100	W.	32	4	−15	3	+·04	100	E.	4	2
17	13.1	−11	100	S.W.	36	4	−22	11	+·02	100	S.E.	4	1
18	13.2	−2	100	S.W.	24	Fog.	−11	9	+·06	00	N.E.	6	4
19	13.3	−3	100	S.W.	38	Fog.	−10	7	+·08	54	N.E.	5	3 N.
20	14.1	1	100	S.W.	36	0	−14	15	+·15	100	S.E.	2	0
21	14.2	8	100	S.W.	28	Fog.	−4	12	−·06	64	N.E.	4	1 W.
22	14.3	5	100	S.W.	45	Fog.	1	4	−·21	71	N.E.	3	3 W.
23	15.2	12	100	S.	40	Fog.	10	2	−·07	17	N.E.	8	4
24	16.2	15	100	S.W.	40	Fog.	10	5	+·14	58	N.	3	2 W.
25	16.3	11	100	S.W.	55	Fog.	7	4	+·08	77	Calm.		2
26	17.1	10	100	S.	20	Fog.	1	9	−·02	71	N.	6	2
27	17.2	16	100	S.	42	Fog.	4	12	−·03	74	N.	8	4
28	18.1	11	100	S.W.	20	Fog.	1	10	+·12	71	N.	1	0
29	18.2	15	100	W.	35	Fog.	14	1	+·03	63	N.	2	4 W.
30	18.3	13	100	W.	20	Fog.	12	1	+·05	61	S.	3	3 W.
31	19.1	10	100	W.	30	1	9	1	·00	57	S.	6	0
	1877.												
32	Jan. 11.3	7	100	S.W.	15	4	2	5	+·05	100	N.E.	5	4
33	12.1	2	100	N.W.	8	Fog.	−6	8	+·07	81	Calm.		0
34	12.3	8	100	S.W.	8	Fog.	7	1	+·10	77	S.	5	0
35	13.1	7	100	S.W.	8	Fog.	1	6	−·02	72	S.	1	0
36	15.3	−5	100	S.W.	32	4	−10	5	−·16	77	S.	2	0
37	18.1	0	70	S.W.	46	2 S.W.	0	0	+·05	85	Calm.		0
38	22.3	11	75	W.	19	1	−5	16	+·19	82	S.	5	0
39	24.1	7	54	S.W.	26	3	0	7	+·30	85	S.	4	0

force, and that the violent uprising of heated air, which is frequently witnessed in humid climates, especially during thunder storms, is mainly due to the presence of a large amount of aqueous vapor.

I next made a comparison of the cases in which the temperature at Denver was lower than at Pike's Peak. These cases are thirty-nine in number, embraced in a period of twenty months' observations, and they are shown in the preceding table which is arranged like that on pages 8 and 9.

It will be noticed that thirty-one of these cases occurred in the month of January, and all occurred in the four months from November to February. The average relative humidity on Pike's Peak at these dates was eighty-four, and at Denver seventy-one. On Pike's Peak about half of the winds were from the southwest, and none of them were from any eastern point. The average velocity of the winds was twenty-seven miles per hour. At Denver the wind never blew from any western point, and its average velocity was only four miles per hour. At Pike's Peak the average cloudiness (counting fog as sky entirely overcast) was 0·71; and at Denver 0·36. The barometer at Denver was sometimes below the mean and sometimes above it, but the average was ·06 inch above the mean. One of the most noticeable circumstances exhibited by this table is the humidity of the air at Denver, showing that this air did not come from the west side of the Rocky Mountains, and the same fact is indicated by the observed direction of the winds.

We thus learn that during periods of severe cold at Denver, the thermometer is frequently lower there than it is on Pike's Peak, and hence we must conclude that this cold did not result from the subsidence of air from the upper regions of the atmosphere.

In order to test this conclusion more fully, I selected all those cases in which the thermometer at Denver sunk as low as +5° from November, 1873, to June, 1878, and the lowest temperature at Pike's Peak for the same date was entered in the same table. The number of these cases was ninety-nine. The average of these observations at Denver was $-2·4°$, and the average at Pike's Peak was $-9·0°$, showing that it was only 6·6° colder at Pike's Peak than at Denver.

I next made a similar comparison for Mt. Washington and two neighboring stations. I selected all the cases from November, 1873, to June, 1878, in which the thermometer at Burlington, Vt., sunk as low as +5° and determined the lowest temperature on Mt. Washington for the same dates. The number of these cases was 145. The average of these observations at Burlington was $-2·7°$, and at Mt. Washington $-18·9°$, showing a difference of 16·2°. The average difference of temperature of these stations, as determined from six years' observations, is 19·0°. I next selected all the cases in which the thermometer at Portland, Me., during a period of five years sunk as low as +10°, and determined the lowest temperature on Mt. Washington for the same dates. The number of these cases was 111. The average of these observations at Portland was +3·2°, and at Mt. Washington was −19·7°, showing a difference of 22·9°. The average difference of temperature of these stations for a period of six years has been 19·7°. If we take the average of the results for Burlington and Portland, we shall find that during these cold periods the difference of temperature between Mt. Washington and the level of the sea was identically the same as shown by the daily observations of six years.

These results do not sustain the theory which I formerly advocated, that periods of severe cold are mainly the result of cold air descending from the upper regions of the atmosphere. The high temperature, shown on Pike's Peak at the time of the observations on page 10, appears also in the average temperature at that station for the winter months, and may reasonably be ascribed to the heat developed during the winter months by the condensation of vapor on the Sierra Nevadas and the western slope of the Rocky Mountains.

The way is now prepared for a consideration of the sudden changes of temperature which frequently occur at Denver and other places in its vicinity. These changes occur most frequently in the months of November, December and January; and the month of January, 1875, was specially noticeable for the magnitude and suddenness of these changes. The following are the principal cases which occurred in the last-mentioned month. January 3d the thermometer fell 28° between 3 and 5 P. M.; January 5th the thermometer fell 8° in less than thirty minutes; January 8th the thermometer fell 54° in six hours from 1 to 7 A. M.; January 14th the thermometer rose 39° in thirty-five minutes; January 15th the thermometer fell 48° in one hour. In my third paper (this Journ., x, p. 12) I stated the principal facts relating to the last two changes. In order to study this subject more fully I have selected from the volumes of published observations, the temperature at Denver, and the neighboring stations for the dates of the three regular observations (7:35 A. M., 4:35 P. M. and 11 P. M.) during the period including the changes above mentioned. I have also added a second table showing the relative humidity for the same stations at the same dates.

Thermometer, January, 1875.

Date.	Salt Lake C.	Virginia City.	Cheyenne.	Denver.	Pike's Peak.	North Platte.	Dodge City.	Bismark.	Ft. Sully.	Yankton.	Pembina.	Breckenridge.	Omaha.	Ft. Gibson.
	°	°	°	°	°	°	°	°	°	°	°	°	°	°
3.1	27	26	22	32	−4	3	1	−16	−9	−7	−20	−22	1	32
3.2	41	−5	2	40	−2	4	4	−5	−1	0	−12	−9	6	33
3.3	32	−7	−8	3	−5	−3	1	−12	−2	−1	−17	−14	4	29
4.1	25	−12	−12	0	−8	−8	1	−15	−10	−10	−16	−14	−1	15
5.2	28	−2	−2	4	0	5	9	−5	3	4	−11	−2	10	26
5.3	19	−6	0	3	−7	−7	2	−6	−3	6	−10	−4	8	26
6.1	14	−8	−4	−12	−13	−18	−9	−18	−10	−16	−24	−15	−1	22
6.2	27	10	21	15	−7	5	10	2	11	2	−12	−1	15	30
6.3	23	2	9	6	−16	−10	−2	−15	−4	−11	−21	−16	6	29
7.1	23	16	13	10	−10	−17	0	−21	−12	−17	−17	−22	5	26
7.2	34	−8	31	44	2	15	12	−5	11	7	−7	0	20	32
7.3	38	−22	−3	39	−1	25	22	−20	−2	13	−15	−5	19	24
8.1	36	−30	−23	−10	−2	−18	−12	−27	−26	−22	−31	−30	−10	27
8.2	31	−24	−16	−14	0	−15	−12	−27	−21	−19	−30	−27	−15	7
8.3	23	−28	−37	−4	−6	−16	−10	−26	−19	−31	−33	−29	−15	−3
13.1	18	−44	−23	−22	−11	−22	−19	−33	−26	−23	−28	−30	−17	8
13.2	24	−35	−1	−11	−2	−13	−13	−25	−21	−20	−19	−20	−11	13
13.3	21	−40	−13	−10	−3	−14	−14	−28	−23	−24	−17	−28	−14	8
14.1	34	−35	−11	−14	1	−13	−14	−30	−27	−25	−28	−30	−13	2
14.2	43	−22	−1	−4	8	−6	−9	−15	−6	−12	−15	−12	−5	16
14.3	43	−26	24	1	5	−11	−3	−15	−10	−7	−23	−26	−6	11
15.1	32	−33	28	43	6	−8	6	−22	−10	−10	−14	−12	−6	9
15.2	26	−18	5	10	12	−1	6	−12	−7	−4	−10	−4	9	39
15.3	23	−27	−6	13	10	−4	−2	−22	−10	−8	−20	−23	1	29

Relative Humidity, January, 1875.

Date.	Salt Lake C.	Virginia City.	Cheyenne.	Denver.	Pike's Peak.	North Platte.	Dodge City.	Bismark.	Ft. Sully.	Yankton.	Pembina.	Breckenridge.	Omaha.	Ft. Gibson.
3.1	77	77	72	30	100	73	71	68	56	59	100	81	100	89
3.2	30	66	100	28	100	87	74	63	52	56	75	68	52	90
3.3	60	63	100	73	100	69	71	75	67	68	69	82	100	89
4.1	63	54	100	69	100	58	71	47	54	54	70	85	100	83
5.2	44	69	67	100	100	100	78	26	46	73	77	68	68	63
5.3	54	81	100	19	100	63	72	61	66	76	77	83	100	88
6.1	64	61	80	50	73	66	58	34	54	69	51	85	..	95
6.2	77	40	39	14	59	75	58	44	78	58	50	67	65	59
6.3	73	72	57	52	70	54	69	42	65	72	61	85	76	68
7.1	73	66	61	38	100	68	69	0	50	68	69	80	87	82
7.2	69	61	48	9	100	82	80	63	40	65	80	70	77	60
7.3	46	24	100	38	100	75	72	100	67	71	100	91	84	74
8.1	45	43	100	77	100	67	50	47	..	59	100	90	100	88
8.2	71	59	73	100	100	42	50	48	..	65	100	85	..	80
8.3	60	49	100	82	100	40	54	0	..	62	100	85	..	52
13.1	68	0	..	100	100	60	30	0	..	57	..	82	..	78
13.2	61	32	84	0	100	47	52	53	..	64	65	64	..	46
13.3	71	..	47	54	100	72	45	45	..	57	68	85	..	68
14.1	61	30	76	100	100	74	72	0	..	53	..	83	..	72
14.2	50	63	68	64	100	61	66	42	57	74	71	67	82	33
14.3	50	54	60	71	100	76	66	100	77	79	59	85	100	60
15.1	84	36	67	21	100	79	52	60	54	76	72	85	88	78
15.2	52	39	75	17	100	68	52	50	59	65	54	66	67	37
15.3	73	52	61	44	100	64	67	..	52	58	64	85	85	89

These observations show considerable changes of temperature at Denver, but they do not show the entire range of the thermometer, and they give no adequate idea of the suddenness of the changes. We perceive that between 11 P. M., January 14th, and 7 A. M., January 15th, the thermometer at Denver rose 42°. We also perceive that the relative humidity fell from 71 to 21. The wind, which had previously blown from the northeast with a velocity of 3 miles per hour, at 9 P. M. (Denver time) veered suddenly to southwest with a velocity of 12 miles per hour. These three circumstances, viz: the direction of the wind, the dryness of the air and its high temperature, prove beyond doubt that this air came from the west side of the Rocky Mountains. On the previous day the temperature at Salt Lake City was 43°, and the relative humidity was 50°. An area of low pressure passed over San Francisco, January 14th about 4 P. M. During the following night the center passed near Salt Lake City, and at 4 P. M., January 15th, the center was near Leavenworth, having traveled about 1,400 miles in twenty-four hours. It was this storm which brought the air from the west side of the Rocky Mountains over to Denver. The vapor contained in this air would be mostly precipitated on the west side of the Rocky Mountains, so that it would descend on the east side deprived of its moisture and with a temperature above that which prevailed in the Salt Lake basin, on account of the latent heat liberated in the condensation of the vapor. This warm and dry air supplanted the cold air which previously prevailed at Denver, and which still prevailed at neighboring stations east and north of Denver. A similar change, but of less magnitude, occurred at Cheyenne a little before the change at Denver, while at Dodge City and Omaha the change was still less, and at stations further north the change was scarcely appreciable. After the center of low pressure had passed Denver, the northeast wind returned and brought back the cold air which had constantly prevailed at stations not very distant. A similar change occurred at Cheyenne, apparently at about the same hour. Thus we see that in winter, during periods of extreme cold on the east side of the Rocky Mountains, when the temperature at Denver sometimes sinks more than 20° below zero, there prevails in the Salt Lake Basin an average temperature of about 30°; and when by changes of atmospheric pressure this air is carried over the mountains it may reach Denver with a temperature of 50°, resulting from a precipitation of its vapor on the mountains. We then find a mass of air having a temperature of +50° in close proximity to a mass of air having a temperature of —20°, and by the movements of the atmosphere attending the progress of a great storm these different masses of air may be brought successively over the same station, causing a change of temperature of 50° in a single hour.

The other cases of sudden change above enumerated admit of similar explanation. During January 7th there was a great rise of the thermometer at Denver, accompanied by a dry wind from the southwest. The next morning the thermometer fell suddenly with a wind from the northeast, which brought back the cold air which steadily prevailed at stations in the north. This change also accompanied the progress of an area of low pressure, which was apparently central near Virginia City on the morning of the 7th, and was central at St. Paul on the morning of the 8th. This storm was accompanied by similar changes of temperature at Virginia City, Cheyenne, and the other stations within the area of low pressure, but at none of them were the changes as great or as sudden as at Denver, for the reason that Denver is most favorably situated for feeling the influence of the mountains. The stations of the Signal Service which are nearest to the dividing ridge of the Rocky Mountains are Denver, Cheyenne and Virginia City. On the West of Denver, at the distance of only 40 miles, rises a continuous mountain range of 12,000 feet elevation, while at Cheyenne the mountains are more distant and of less height, and near Virginia City the height of the mountains is still less.

On the morning of January 3d the wind at Denver blew from the West with a velocity of 12 miles per hour. The air was warm and very dry. Between 3 and 5 P. M. the thermometer fell suddenly with a north wind. Similar changes were experienced at Virginia City and Cheyenne, accompanied by an area of high pressure pursuing an area of moderately low pressure. The case of January 5th was more remarkable for the suddenness of the change of temperature than for the magnitude of the change, and resulted from the passage of an area of slight barometric depression.

Barometric minima cross the Rocky Mountains.

In former papers, particularly Nos. 8 and 9, I have shown that areas of low barometer coming from the Pacific Ocean frequently cross the Rocky Mountains and travel eastward across the United States. In order to investigate this subject more fully, I selected from the published observations of the Signal Service (Sept., 1872, to Jan., 1875, and Jan. to May, 1877,) all those cases in which the barometer at Corinne or Salt Lake City was at least 0·4 inch below its mean height for that month. [The observations at Corinne ceased March 19, 1874, and those at Salt Lake City commenced the next day.] These cases are shown in the following table, in which column 1st gives the number of the storm; column 2d the date of the observation;

Barometer 0·40 inch below the mean at Corinne and Salt Lake City.

No.	Date.	Barom.	Wind.	Rain 8 hours.	Low center.	First appearance.	Reached the Atlantic Ocean.		Wind on Pike's Peak.
							Date.	Lat.	
	1872.								
1	Nov. 8.2	29·61	S. 19	·00	350 E.N.E.	Portland, Or.	Nov. 12	45°	
	8.3	·72	N. 30	·02	600 E.N.E.				
	9.1	·76	W. 4	·14	750 E.N.E.				
2	12.1	·72	N.W. 31	·08	200 E.	Portl., Or. & Virg. C.	Nov. 15	47	
	1873.								
3	Jan. 3.2	·62	S. 20	·00	120 N.	Portland, Or.	Jan. 6	48	
4	26.2	·63	S. 16	·43	80 N.	Portland, Or.	?	?	
	26.3	·59	N.W. 22	·03	Corinne.				
5	30.1	·64	Calm.	·00	300 W.N.W.	Portland, Or.	Feb. 5	45	
	30.2	·52	N. 7	·00	300 W.N.W.				
	30.3	·60	E. 4	Snow	580 W.N.W.				
	31.1	·65	S.W. 2	·33	580 W.				
6	Feb. 23.3	·52	N. 12	·00	250 W.	San Francisco.	Feb. 28	43	
	24.1	·49	N. 1	Snow	300 W.				
	24.2	·41	S. 26	·14	120 W.				
	24.3	·38	S.W. 20	Rain	200 W.				
	25.1	·53	S. 5	·24	50 W.				
7	March 6.1	·68	S. 20	·00	470 N.E.	Portland, Or.	March 9	45	
8	April 2.3	·47	S. 11	·00	120 N.	Portland, Or.	?	?	
9	Sept. 25.1	·59	S. 8	·00	480 N.	Portland, Or.	?	50 +	
	25.2	·60	S.W. 22	·00	680 E.N.E.				
	25.3	·63	N. 24	·00	710 E.N.E.				
10	26.3	·62	N. 14	·00	175 W.	San Francisco.	Sept. 29	50	
11	Oct. 7.1	·71	N. 14	Rain	400 N.	Portland, Or.	Oct. 12	44	
12	Dec. 7.1	·61	S. 5	·16	100 W.	Portland, Or.	Dec. 9	45	S.W. 18
	7.2	·61	S.W. 6	·11	Corinne.				S.W. 32
	1874.								
13	Jan. 2.1	·62	S. 12	·03	700 N.E.	Ft. Benton.	Jan. 5	45	W. 40
	2.2	·22	S. 20	·00	700 E.N.E.				S.W. 20
	2.3	·58	S. 2	·04	700 E.				S.W. 30
14	16.2	·60	S. 10	·00	350 N.W.	Portland, Or.	Jan. 20	45	W. 18
	16.3	·67	E. 2	·00	560 N.E.				W. 50
	17.1	·63	S. 2	·00	800 N.E.				W. 30
	17.3	·53	S.E. 2	Snow	700 E.N.E.				S.W. 20
15	19.3	·64	S. 20	·00	70 N.	Portland, Or.	Jan. 23	45	S.W. 10
	20.1	·59	W. 10	·00	130 N.				W. 20
16	Feb. 11.3	·56	W. 12	·00	770 E.	Portland, Or.	Feb. 14	49	S.W. 26
	12.1	·55	Calm.	·00	950 E.				W. 16
	12.2	·53	S. 20	·00	250 N.				W. 25
	12.3	·56	S. 20	Snow	500 N.W.				W. 20
17	18.1	·59	S. 12	Snow	600 E.N.E.	Portl., O. & Ft. Bent.	Feb. 20	47	S.W. 16
	18.2	·61	S. 4	·41	700 E.				S.W. 20
18	March 16.1	·45	Calm.	Snow	600 E.N.E.	Portl., O. & Virg. C.	March 20	50	W. 24
19	April 11.2	·51	S. 17	·00	200 N.N.W.	San Francisco.	April 15	48	S.W. 28
20	Oct. 23 2	·58	S. 12	·00	Salt Lake C.	Bismark.	Oct. 28	47	S. 11
	24.2	·61	S. 12	·05	470 E.N.E.				S.W. 52
	24.3	·56	S. 4	·00	700 N.E.				S. 60
21	Nov. 6.2	·50	N.W. 15	·02	700 E.N.E.	Portland, Or.	Nov. 10	48	S.W. 60
22	21.2	·45	S. 12	·00	700 E.N.E.	Bismark.	Nov. 24	50	S.W. 32
	21.3	·41	S.W. 8	·00	700 E.N.E.				S.W. 28
	22.1	·54	Calm.	·00	840 E.N.E.				N.W. 65
23	Dec. 26.2	·67	N.W. 10	·05	Salt Lake C.	Portland, Or.	Dec. 29	47	S.W. 12
	1875.								
24	Jan. 11.2	·53	Calm.	·22	350 E.	Portl., O. & Virg. C.	Jan. 14	48	S.W. 25
	1877.								
25	Jan. 10.2	·62	S. 4	·02	580 E.	Ft. Sully.	Jan. 13	43	W. 24
	10.3	·67	N.W. 12	·00	600 E.				N.W. 10
26	14.2	·59	S.E. 3	·01	650 E.	San Diego.	Jan. 16	45	S.W. 7
27	16.2	·60	E. 4	·00	420 N.W.	Portland, Or.	Jan. 21	48	W. 38
	16.3	·56	S. 8	·00	500 N.W.				W. 58
	17.1	·62	S. 16	·00	600 N.W.				W. 54
28	Feb. 23.2	·63	S.E. 4	·00	Salt Lake C.	Portland, Or.	—	—	S.W. 10
29	March 2.2	·47	S. 4	·23	320 E.	Portland, Or.	March 5	47	W. 30

column 3d the height of the barometer; column 4th the direction and force of the wind; column 5th the rainfall during the preceding 8 hours; column 6th the direction and distance of the low center from the place of observation; column 7th the station where the low center first made its appearance; column 8th the date at which the low center reached the Atlantic Ocean; column 9th the latitude of that point; and column 10th the direction and force of the wind on Pike's Peak at the date given in column 2d.

It will be noticed that the highest velocity of the wind at Corinne and Salt Lake City was 31 miles per hour, and the average velocity at the dates mentioned was less than 11 miles per hour. Southerly winds were three times as frequent as northerly winds. In only six of the cases did the wind blow from any eastern quarter, and its greatest velocity from this quarter was four miles per hour.

The amount of rain or snow attending these storms was very small, the average during the eight hours preceding the dates of observation being less than 0·05 inch. In eight cases rain or snow is mentioned in the column headed "state of the weather," when no entry is made in the column headed "rainfall."

In a few cases the low center appears to have passed directly over the station of observation, but generally it passed a little north of Salt Lake, and in no case did it pass south of it. Of the twenty-nine storms here enumerated, the stations at which the first indications of the low area are noticeable are as follows:

Portland, Or.,	17 cases.	San Diego,	1 case.
Portland, Or., & Virginia City,	3 cases.	Fort Benton,	1 case.
Portland, Or., and Fort Benton,	1 case.	Bismark,	2 cases.
San Francisco,	3 cases.	Fort Sully,	1 case.

In twenty-one of these cases the low appeared first at one of the stations on the Pacific coast, and we may reasonably infer that it came from the Pacific Ocean. In four other cases the low appeared simultaneously at Portland, Or., and Virginia City or Fort Benton, and it is probable that these storms came from the Pacific Ocean, but came from a latitude north of 50°, so that they appeared in the United States on both sides of the Rocky Mountains at about the same time. There remain only four cases, viz: Nos. 13, 20, 22 and 25. In these cases the disturbance apparently originated on the east side of the Rocky Mountains and thence extended to Salt Lake and the Pacific coast. In none of the cases did the low appear to originate between the Sierra Nevadas and the Rocky Mountains.

In all but three of these storms the low area can be traced to the Atlantic Ocean, which it reached in a latitude between

43° and 50°, averaging about 47°. No. 9 moved northward beyond our stations of observation, and probably reached the Atlantic Ocean somewhere north of lat. 50°. No. 4 apparently moved southward toward the Gulf of Mexico. Nos. 8 and 28 apparently declined soon after the dates given in column 2d, and cannot be satisfactorily traced to the Atlantic Ocean.

The following general conclusions seem to follow from the preceding observations:

1. No great barometric disturbances originate in the Salt Lake Basin.

2. Nearly all the great barometric disturbances experienced in the Salt Lake Basin come from the Pacific Ocean, and they generally come from the northwest.

3. Nearly all the great barometric disturbances experienced in the Salt Lake Basin can be traced to the Atlantic Ocean. They generally meet it near lat. 47° and occupy from two to six days in the passage, making an average of 3½ days, which corresponds to a movement of about 700 English statute miles per day.

There is a noticeable uniformity in the direction of the winds on Pike's Peak at the date of the preceding observations. The winds were generally from the west or southwest, and in no case from north, northeast, east or southeast. The average direction of the winds on Pike's Peak, as determined from the observations of five years, is N. 75° W. The average of the directions in the preceding table is S. 65° W., differing 40° from the mean direction. This result indicates that at the time of the preceding observations there was some cause in operation which deflected the winds from their average course. If we suppose that the abnormal winds on Pike's Peak are governed by a center of low pressure, according to the same law as the surface winds, then we may infer that in 27 of the preceding cases the position of this low center corresponded nearly with that observed at stations nearer the level of the sea. In five of the cases the low center appears to be somewhat northwest of that observed at the other stations; in one case it was somewhat north, in one case it was west, and in two cases it was east of the low center observed at the other stations.

These results accord reasonably well with those found in my tenth paper for Mount Washington, and seem to indicate that at great elevations the winds occasionally circulate about a low center as they do near the level of the sea; but the position of this low center at the height of 14,200 feet sometimes differs considerably from the low center prevailing at the surface of the earth, and this deviation is generally toward the northwest.

There are three methods by which the progress of areas of low pressure across the Rocky Mountains may be readily indicated. One is by curves representing from day to day the fluctuations of the barometer at the various stations, as shown in Plates I and II, accompanying my ninth paper. These curves indicate distinctly the eastward progress of low areas, but they do not show the center of a low area, and therefore do not indicate the exact path of the low center. There are two methods by which the position of the center of a low area can be traced from day to day, viz: by *isobaric* lines or *isabnormal* lines. If we employ isobaric lines, it is requisite that the observations at all the stations should be carefully reduced to sea level, and, in the case of the mountain stations, this involves the decision of questions respecting which meteorologists may be expected to differ. But after reducing the observations to sea level by any of the methods which different meteorologists may be supposed to advocate, we still find evidence that areas of low pressure frequently travel from the Pacific Ocean across the Rocky Mountains and thence eastward toward the Atlantic. The isobars drawn to represent the observations at the mountain stations are seldom as symmetrical as they are over a level country. This may be due partly to the obstacles which the mountains present to a system of circulating winds, and partly to the influence of the heavy precipitation of vapor upon the mountains. In many cases, however, the isobars show considerable symmetry, and this is most noticeable in very violent storms. Plate II exhibits the isobars for April 11, 1874, at 4:35 P. M. This is a storm which was noticed in my ninth paper, and a map was then given showing the isobars for April 12th at 7:35 A. M. By comparing the two maps it will be seen that during this interval of fifteen hours the isobars retained nearly the same general form, and the distance between the two low centers remained almost exactly the same, the two systems of isobars, with the intermediate high area, having been transferred eastward about 420 miles, being at the rate of 28 miles per hour. While, however, the second low center followed nearly in the track of the first low, and maintained nearly the same distance during the whole time of crossing the United States, the high center moved from Lake Superior to Norfolk, Va.; that is, from northwest to southeast, maintaining during the whole time nearly the same pressure.

The direction of the winds, April 11th at 4:35 P. M., west of the Mississippi river, corresponded with what is usually observed about a low center, with the exception of Portland, Or., and Virginia City. The latter observation seems to indicate that the center of the low area was further north than is represented upon the map; but we find frequent anomalies in the direction of the winds at the mountain stations, as will be seen from the map which accompanied my ninth paper. These anomalies indicate that while a regular system of circulating winds may prevail above the tops of the mountains, this system is obstructed in the valleys between the mountain ridges, so that here the direction of the wind may be opposite to that which prevails above the mountains.

If we attempt to trace the progress of storms across the Rocky Mountains by curves of isabnormal pressure, we have no occasion to reduce the observations to sea level; nevertheless, when we aim at great precision we find a difficulty in comparing mountain stations with stations at a lower level, inasmuch as the barometric fluctuations generally diminish as we rise above the level of the sea. In order to find what correction is due to this cause I determined the mean monthly range of the barometer at all the stations of the Signal Service west of the Mississippi river according to the published observations (now amounting to thirty-five months). The following

Mean monthly range of the Barometer.

	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
Portland, Or.	1·15	0·95	0·82	0·85	0·62	0·54	0·33	0·43	0·56	0·62	0·98	1·04	0·74
San Francisco	0·81	·70	·51	·54	·37	·41	·39	·35	·37	·48	·51	·64	·51
San Diego	0·46	·56	·41	·42	·31	·29	·27	·25	·35	·37	·45	·44	·38
Virginia City	0·88	·82	·66	·61	·58	·51	·35	·34	·66	·66	·85	·86	·65
Corinne	1·19	·93	·83	·96	·67	·47	·42	·35	·66	·60	·81	·77	·72
Cheyenne	0·78	·71	·76	·71	·64	·48	·42	·40	·69	·71	·79	·75	·65
Salt Lake City	·77	·69	·75	·39	·48	·53	·36	·32	·66	·79	1·00	·84	·63
Denver	·85	·77	·81	·77	·69	·54	·46	·43	·76	·72	·84	·76	·70
Pike's Peak	·65	·60	·69	·49	·68	·50	·38	·34	·41	·65	·75	·87	·58
Santa Fe	·72	·59	·66	·53	·41	·43	·39	·24	·41	·51	·61	·63	·51
Ft. Benton	1·23	·92	·99	1·07	·79	·62	·68	·63	1·01	·87	1·22	1·00	·92
Bismark	1·32	1·17	·97	1·14	1·29	·86				1·30	1·84	1·44	
Ft. Sully	1·50	1·37	1·45	1·13	1·11	·90	·90	·82	1·16	1·24	1·21	1·31	1·18
Yankton	1·44	1·38	1·34	1·13	1·03	·80	·76	·69	1·15	1·13	1·41	1·15	1·12
Omaha	1·36	1·39	1·37	1·09	·91	·71	·71	·57	·87	1·05	1·39	1·16	1·05
North Platte	1·41	·97	1·30	1·25	1·10	·78				1·29	1·65	1·13	
Dodge City	1·45	·86	1·29	1·00	·91	·88				1·10	1·33	1·11	
Pembina	1·45	1·27	1·25	1·07	1·08	·80	·78	·73	1·06	1·00	1·36	1·32	1·10
Duluth	1·35	1·38	1·24	1·12	·95	·98	·67	·63	·88	1·11	1·44	1·33	1·09
Breckenridge	1·42	1·32	1·34	·99	1·11	·87	·76	·62	·97	1·18	1·42	1·32	1·11
St. Paul	1·27	1·39	1·34	·92	·91	·80	·63	·61	·91	1·12	1·34	1·29	1·04
La Crosse	1·20	1·43	1·25	·95	·87	·75	·63	·59	·84	1·14	1·30	1·34	1·02
Dubuque	1·14	1·32	1·24	1·06	·75	·66	·65	·61		1·24	1·45	1·21	
Davenport	1·14	1·44	1·21	·99	·77	·61	·56	·55	·73	1·00	1·32	1·17	·96
Leavenworth	1·30	1·34	1·25	1·07	·77	·61	·61	·53	·82	·97	1·29	1·13	·97
St. Louis	1·17	1·20	1·19	·94	·71	·56	·51	·55	·67	·84	1·22	1·08	·89
Cairo	1·14	1·02	1·16	·91	·58	·52	·45	·45	·48	·70	1·07	·89	·78
Ft. Gibson	1·28	1·06	1·04	·95	·77	·49	·54	·46	·63	·91	1·11	1·02	·86
Memphis	1·05	·97	1·01	·88	·58	·45	·43	·38	·43	·59	1 02	·91	·73

table shows the results obtained. The first three stations are situated near the Pacific coast; the next seven stations are situated among the mountains; the next seven stations are situated east of the Rocky Mountains at elevations between 1,000 and 3,000 feet; and the last twelve stations are elevated less than 1,000 feet above the sea.

I next proceeded in the manner described in my twelfth paper, page 90. I determined the mean annual range of the barometer at a point on the Pacific coast, and also the range at a point in the Mississippi valley, each having the same latitude as one of the mountain stations. Between the two results thus obtained I interpolated a value corresponding to the difference of longitude between the given station and the two points above named. The result is regarded as the barometric range at the level of the sea directly under the given station. A similar computation was made for each of the mountain stations, and the ratio of the observed range to the range thus computed was determined. This comparison indicates that the barometric fluctuations observed at Salt Lake City should be increased by 8 per cent, and those at the other mountain stations, viz: Virginia City, Cheyenne, Denver and Santa Fe, should be increased by 25 per cent. I have drawn the isabnormal curves for a large number of cases, employing these corrections, and find that the curves are generally more symmetrical than when no correction is applied.

In preparing the materials for this article I have been assisted by Mr. Henry A. Hazen, a graduate of Dartmouth College of the class of 1871.

ART. II.—*On the Geological relations of the Limestone Belts of Westchester County, New York;* by JAMES D. DANA.

WESTCHESTER County is comprised within the Green Mountain region; and my studies of the County have been carried on with special reference to the subject of Green Mountain geology.[1]

In commencing my observations in Western New England, I had in view the following points:

(1) To determine the limits of the series of rocks associated conformably with the limestone of the Green Mountain region; and (2), since the limestone is of Lower Silurian age as is shown by its fossils, to determine, consequently, the limits of the Lower Silurian in the Green Mountain region.

(3) To ascertain the kinds of metamorphic rocks constitu-

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[1] For my former papers, see this Journal, third Series, iv. 362. 450, 504; v, 47, 84; vi, 257, 1872, 1873; xiii, 332, 406; xiv. 36, 132, 202, 257, 1877; xvii, 375; and xviii, 61, 1879; xix, 191, 1880.

ting these Lower Silurian beds; and (4), to ascertain, consequently, how far the kinds of crystalline rocks found in the conformable series can be used as a test of geological age.

As the fossils of the limestone had been discovered only in Vermont, it was required, in order to extend the conclusions to the rest of the Green Mountain region, that the Vermont limestone should be proved to be the same stratigraphically with that of the region to the south; and this was done by ascertaining (1) the essential continuity of the limestone from the north to the south and south-southwest, and (2) its association with similar rocks from north to south, under similar stratigraphical relations; and finally (3), by the discovery of Lower Silurian fossils in the part of these belts of limestone that reach into and beyond Dutchess County, and also in the associated Taconic schists of that County.[2]

By these means, it has been shown that the schists of the Taconic range, the limestone belts on either side, and various conformable schistose rocks and limestone belts farther east and west, are comprised within the Lower Silurian formation, and that the whole series was displaced together in the upturning and metamorphism by which the Green Mountains were made.

The demonstration in my former papers does not reach into the region south of the limits of Dutchess County and of the corresponding parallel in Connecticut. I present now observations on the same points from this more southern region in the State of New York, leaving the discussion of the facts from Connecticut for another paper. I have not undertaken to work up thoroughly Westchester County geology, but simply so much of it as bears directly on the great question in view.

In my paper "On the Hudson River age of the Taconic Schists," published in this Journal in 1879, the accompanying map exhibits the fact that the Lower Silurian schists and limestones of Dutchess County have their southern limit against or among the Archæan rocks of the Highland range. The Highland Archæan area extends eastward from the Hudson, over Putnam County, to a distance less than twenty miles, falling short of the New England boundary by four or five miles—the rocks at Brewster, west of and along the Harlem railroad being of the Highland character, even to the existence of a great iron-ore bed, while those farther east are mostly distinct in kind and system. The extreme breadth of the area is about fifteen miles; but the outside rocks, just referred to, send prolongations through its supposed boundary, and cover part of its interior.

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[2] T. Nelson Dale, this Journal xvii, 57, 1879; the writer, ibid., xvii, 375, and xviii, 61, 1879; W. B. Dwight, ibid., xvii, 389, and xix, 50, 451, 1880; R. P. Whitfield, ibid., xviii, 227, 1879.

Westchester County comprises all of Southern New York between Putnam County and New York Island; and thus it borders the southern side of the Putnam County Archæan, as Dutchess County does the northern. It resembles in its rocks that part of the Green Mountain region which now makes Western Connecticut. New York Island is topographically and geologically a portion of it.

The only published geological reports treating of the Geology of the county are that of Mather, in his Report on New York (1843), and that of Percival on the Geology of Connecticut (1842). Mather mentions the principal kinds of rocks, various localities for those that are of special or economical interest, and some stratigraphical facts. Many localities of limestone are given, and I have thence derived much aid in the study of the region. On his map the positions of several of the areas are laid down, but mostly with miles of inaccuracy. The report bears evidence of being compiled from the notes of the assistant geologist by one not familiar with the region. Percival's map of Connecticut gives the areas which lie near the Connecticut boundary, with the general correctness characteristic of his work.

In presenting my observations I will speak *first*, of the rocks; *secondly*, of the general distribution of the limestone areas or belts; *thirdly*, of the special positions and stratigraphy of the limestone areas; and *fourthly*, of the relations of the rocks to one another and to the Green Mountain system.

1. The Rocks.

The rocks are (1) the ordinary metamorphic rocks of the County, not calcareous; (2) Calcareous rocks or limestones; (3) Serpentine and other hydrous materials; (4) Augitic and Hornblendic rocks not included above.

(1.) *Ordinary metamorphic rocks of the County, not Calcareous.*

Of these metamorphic rocks, the prevalent kinds are micaceous gneiss, mica schist, ordinary gneiss, and hard feldspathic and granitoid gneiss. Besides these, and subordinate to them, there are hornblendic varieties of mica schist and micaceous gneiss, and hornblende schist. Granulyte is also found, especially in the northeastern part of the County, and in some places metamorphic granite.

In the mica schist and gneiss, both of the two common kinds of mica, the black (biotite) and the light-colored (muscovite) are usually present together;[3] but the black greatly predominates. True muscovite gneiss or muscovite mica-schist is

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[3] The black may be in part lepidomelane, a point not investigated, as it requires a series of chemical analyses.

of rare occurrence. Blackish gray beds, owing their dark color to the very large proportion of black mica, often alternate with whitish or light-colored beds in which muscovite is the most abundant mica. Frequently, also, mica schist graduates into gneiss in the direction of the bedding as well as transverse to it. The distinction of gneiss from mica schist is, therefore, made often with difficulty, and the restriction of the latter term to kinds consisting of mica and quartz without feldspar is impracticable. The rocks of New York Island are good examples of the ordinary rocks of Westchester County, both as to kinds and their transitions.

Garnetiferous varieties of the mica schist and gneiss are common. A variety of micaceous gneiss in Singsing, contains large elliptical crystallizations of muscovite. A *cyanitic* mica schist is met with on New York Island, as announced by Professor D. S. Martin.[4] A dark gray *fibrolitic* gneiss, containing some tourmaline has been described by Professor A. A. Julien, as occurring at New Rochelle.[5] (The minerals cyanite and fibrolite are alike in composition, they being chemically similar aluminum silicates, and differing only in crystallization.)

Hydromica schist, of the slightly crystalline variety, resembling closely a glossy roofing slate, occurs in the northwestern part of the County, north and northeast of Peekskill, on the borders of the Archæan of the Highlands. It is called talcose slate by Mather. Nothing nearer to argillyte (phyllyte) is found in the County. Across the Hudson River, in Rockland County, in the continuation of the same stratum, near Tompkins' Cove, the slate is very carbonaceous, as Mather's report states, and much of it is still less metamorphic in its aspect.

Quartzyte constitutes a stratum several hundred feet thick in the vicinity of the hydromica schist, north of Peekskill, as pointed out by Mather. But a large part of the rock in that region contains more or less feldspar, and often also mica in rather indistinct grains; looking either like an underdone micaless granite or granitoid gneiss. It is usually much jointed and without distinct bedding. The northern part of the mass, at the mouth of the river north of Peekskill, is a true siliceous quartzyte, fine-grained, and even in bedding; while on the southern side it graduates into the slate. It thus varies greatly in constitution, but in a way to make it certain, that, although so feldspathic in portions, the whole of it is one quartzyte formation. Further, it is evident, from the facts, that the quartzyte and slate are stratigraphically the same rock; one changing to the other, and taking the same positions with reference to an associated stratum of limestone. In the Rockland County

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[4] Proc. Lyceum Nat. Hist. New York, i, and this Journal, II, iv, 237.

[5] Amer. Quart. Micr. J., Jan. 1879.

continuation of the formation (which extends for about two miles from Tompkins' Cove to Stony Point village, where the Mesozoic Red sandstone appears in force), the slate changes in places to a massive quartzyte, often containing much blackish slate material, and looking as if it had been made out of a mixture of mud and quartz sand, with at times some feldspar. Remembering that the making of beds of sand by moving waters involves the making of mud not far away, such transitions are no occasion for surprise; and in view of the fact that the Highland Archæan is close at hand—not three miles distant—the presence of feldspar is intelligible.

A bed consisting chiefly of radiated actinolite occurs west of Kingsbridge, north of the Harlem River. It is so deeply decomposed at the exposure that I failed to obtain a specimen from the unchanged bed. The looseness of texture shows that something has been removed, and this is probably, in part at least, calcareous material; and if so the bed should be classed with the limestone beds. This locality is by the west side of the eastern of two bridges, near the Spuyten Duyvil Iron Foundry, and stratigraphically but a short distance from the belt of limestone of the northern end of New York Island.

The metamorphic strata stand every where at a high angle—seldom under 40°, very frequently above 80°. The bedding, while generally regular in its strike or direction, is often contorted, especially to the east and north, showing that much torsion accompanied the upturning. As usual elsewhere in metamorphic regions, the limestone beds (owing to the stiff unpliant nature of limestone) are at times very various in strike when the schists of the vicinity have the bedding even or nearly so. This great amount of torsion has a sufficient explanation in the fact that Archæan rocks bound the County on the north; and, moreover, along the northern half of the County they are not far distant to the west of Hudson River, not a dozen miles intervening in the latitude of Singsing. No true unconformability between the limestone and other strata has been observed, though local cases of non-conformity occur that are due to the contortions and accompanying faults.

Granite veins are common both in the gneiss and mica schist, though most numerous in the former; and they are often of very large size. They usually consist of coarsely crystallized orthoclase and quartz, with some muscovite-mica and albite or oligoclase. Black mica is often sparingly present, and sometimes prominently so; and when present the plates are frequently of oblong-rectangular outline. The most common accessory minerals are garnet and black tourmaline; beryl or columbite I have not found. As in other regions of highly crystalline metamorphic rocks, veins of quartz are not common.

The rock that adjoins a belt or stratum of limestone is commonly a mica schist or micaceous gneiss in which black mica abounds; or, at times, hornblendic varieties of these rocks, or else hornblende schist; and the beds are not unfrequently pyritiferous. But the rock may also be ordinary gneiss, or a light-colored feldspathic gneiss; or it may consist of intercalations of these with the more micaceous kinds, and in the northeastern part of the County it is in some places granulyte. More remote from the limestone strata, the rock is generally less micaceous, and either ordinary gray gneiss, or hard feldspathic and thick-bedded gneiss.

This association of the limestone with rocks containing much black mica or hornblende is, in fact, association with rocks containing *much iron*:—an association which exists in similar cases throughout the Green Mountain region, and corresponding regions in the State of Pennsylvania and others farther to the southwest; as is indicated by the rusting tendency of the schists in the vicinity of limestone beds, and, still more, by the occurrence of great limonite beds made from the iron of the limestones and adjoining schists.

Furthermore, this quality of these metamorphic schists is a consequence of the ferruginous character of the original sedimentary beds underlying or overlying the limestone strata. The iron of those sediments went, for the most part, at the time of metamorphism, to make the black iron-bearing mica or hornblende, the rest of it entering mainly into pyrite and, sometimes, garnet. The distinction between these schistose micaceous rocks and a hard thick-bedded feldspathic gneiss is, to a large degree, therefore, the equivalent of that in regions of sedimentary rocks between highly ferruginous and slightly ferruginous beds, and hence it is not necessarily of much geological importance. This fact, which is abundantly established by the frequent abrupt gradations in such rocks from extreme micaceous to feldspathic kinds, teaches that it is unsafe to infer from the looks or composition alone, that the hard, gray feldspathic gneisses are really the more ancient. Moreover, the preponderance, in such schists, of biotite over muscovite is not due to a deficiency of potash in the original sediments, for each is a potash-mica, and contains ordinarily 8 to 9 per cent of the alkali, or three-fourths of the amount that exists in a potash feldspar; but chiefly to the presence of iron. Hornblende has been formed where iron existed without enough of potash for making mica. The facts also show that the foliation of such gneisses is a consequence of the original bedding.

(2.) *Calcareous Rocks.*

The limestone of the County is, in general, coarsely crystalline, and of a white to grayish-white color, and in many places it is quarried for use as an architectural marble. But in the northwestern part of the County, in the vicinity of the Archæan, it is feebly crystalline, and in part has the gray color and texture of the unaltered rock. The absence of crystallization is so marked in the part of the northwestern belt which occurs on the west side of the Hudson River, at Tompkins' Cove, that much of it, especially in the western beds toward the Archæan, is like ordinary gray and unaltered limestone, so that if the rock is without fossils—a point yet to be made certain—the reason is not their obliteration by metamorphism.

According to the few analyses that have been published, the rock is a magnesian limestone or dolomite. Iron replaces in some beds a portion of the magnesium ; and when so the blocks of " marble " show it by becoming rusty in color after exposure. Iron is not unfrequently present also in pyrite (FeS_2) another source of rust and destruction, and less frequently in pyrrhotite (Fe_7S_8); chalcopyrite (or copper pyrites) is of occasional occurrence. Scales of mica, mostly of the species muscovite, are often distributed through the beds, and such micaceous limestones graduate in many places into calciferous mica schist. The calcium-magnesium silicate, tremolite (or white hornblende) is very common in bladed crystals and fibrous or asbestiform masses, and sometimes is the chief constituent of a bed. Green hornblende in minute rounded crystals are occasionally found disseminated through the limestone ; and radiated actinolite is at times a constituent, if the bed referred to on page 25, is really a calcareous one. White to grayish green pyroxene has been reported from a few localities, as in the Singsing limestone, (especially its southern portion in Sparta,) and in the limestone of New York Island near 208th street, localities mentioned by Mather, and the latter from the observations of Professor Gale. I have not succeeded in my attempts to verify the fact at either place.

Chlorite in scales is distributed through some limestone beds in the southern part of the County, as, for example, at a locality a mile northeast of Central Bridge, over Harlem River, and in Eastern Morrisania. Graphite is sometimes sparingly present, and more rarely small crystals of sphene. Apatite is found only in an occasional minute crystal. Chondrodite has not been observed.

Much of the limestone crumbles on exposure, making sandy hills of its outcrops ; but this is true of the same rock in Western Connecticut and Massachusetts.

The Westchester County limestone beds are much thinner than those of Dutchess County or Western Connecticut. This may be a consequence of their having been subjected to hotter silicated solutions in the metamorphic process, that is, to intenser metamorphic conditions, such as the coarse crystallization of the rocks would have required. But while there may be doubt as to the thinning in particular cases by this means, there is none as to the dissolving power of such hot silicated waters, and the tendency of their action to substitute silicates for the carbonate. Tremolite and light-colored pyroxene, as long since suggested by the writer,[6] are among the products that would naturally come from this action—dolomite being a calcium-magnesium carbonate, and the minerals mentioned being silicates of the same bases. The fact that experiment has obtained pyroxene in crystals by heating together the ingredients favors the conclusion. The tremolite of the more southern portion of the Singsing limestone area often makes a thick envelope about portions of limestone, showing that it was formed between fragments out of their material. If the dolomite is a ferriferous variety, the action might, in the same way, produce green hornblende or actinolite, or green pyroxene. The only other magnesian silicate often present, and abundant in the adjoining schists, is biotite; and this could have been produced only where iron also was at hand. Chlorite might have been formed under nearly the same conditions as biotite. Whatever the limestone beds lost through the action of the silicated solutions must have gone either to the making of these silicates or of other more soluble silicates; for muscovite contains but one per cent or less of calcium or magnesium, and orthoclase none of either of these elements.

Westchester County, like the Green Mountain region generally, owes much as regards its topographical features to the limestone belts. These belts, because of the easy erosion of limestone, have determined the courses of river-valleys, and of lines of marshes along such valleys, and many a lake has been located by them. The beds of this soft rock stand nearly vertical, thus favoring the excavation of deep channels. The valleys are sometimes abrupt on both sides, but usually have one side high, precipitous and rocky, and the other gently sloping; and this is largely due, in connection with the erosion, to the pitch or dip of the beds. The annexed figure illustrates the

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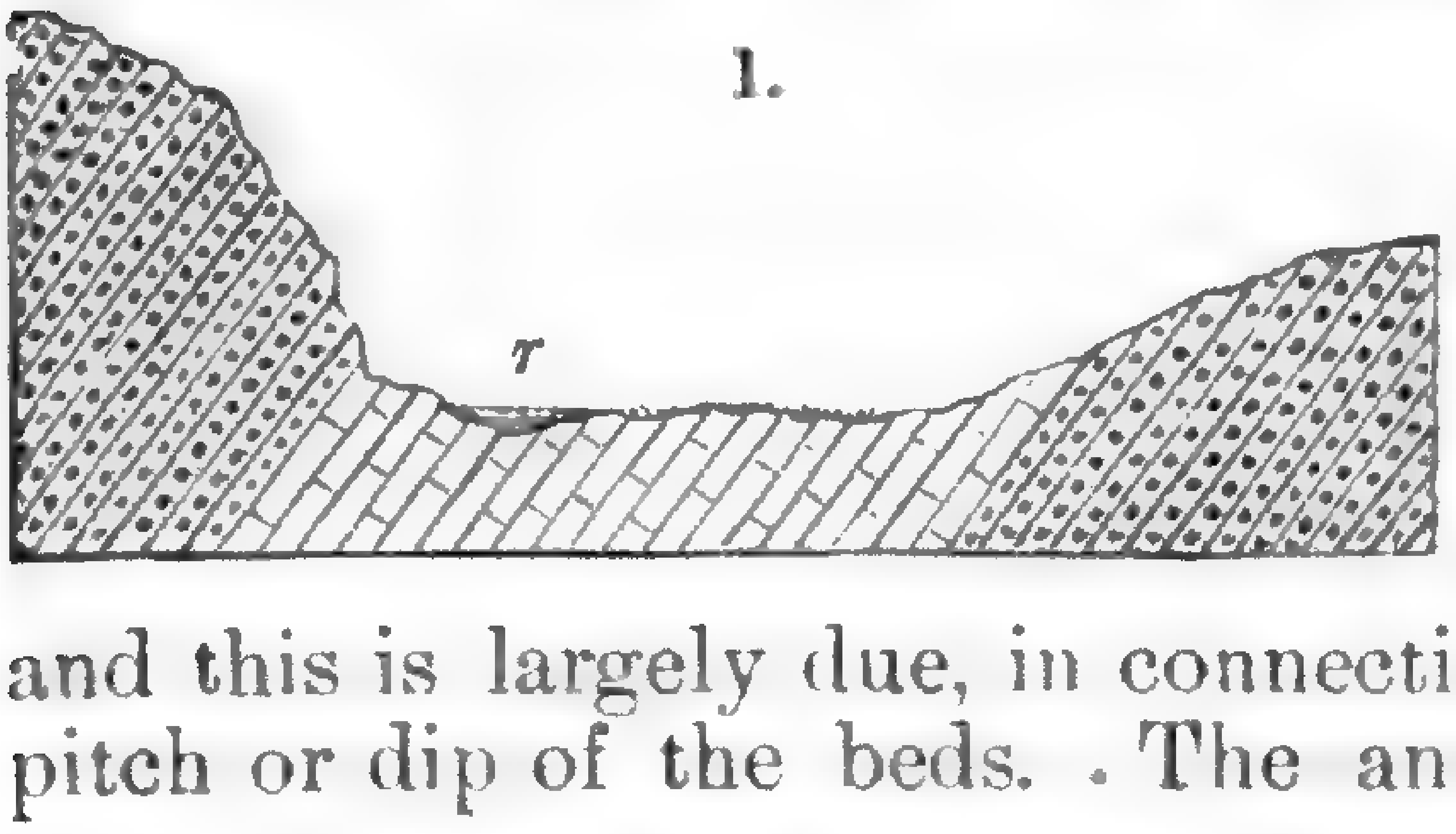

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[6] J. D. Dana, on the Composition of Corals, and the production of the phosphates, aluminates, silicates, and other minerals of crystalline limestones, by the metamorphic action of hot water, in this Journal, I, xlvii, 135, 1844. See also Bischof's Lehrbuch Chem. Phys. Geol., 2nd edit., Engl. Transl., 1866, iii, 28.

ordinary facts. The underdipping side of the limestone area is the steep side of the valley, because of the undermining which the position of the limestone stratum favored; and, for the same reason, the river channel (*r*) is made to hug the same side, and leave the other for wide strips of marshy land, with sometimes pond-like broadenings of the stream. This point was observed by Percival in his survey of Western Connecticut and the adjoining portions of New York State.

But the pitch of the beds has not been the only cause of this form of the valleys. The throw of the waters against the right bank of a stream (the western if flowing south, or northern if flowing west), in consequence of the earth's rotation, must have had its effects, and may account for the cases in which the western side is the steep one, notwithstanding a vertical or even a high eastern pitch. During the progress of the Glacial era, the subglacial streams would have felt this throw and worked in accordance with it; and afterward, when the Glacial flood, from the melting, was at its height, the rushing waters would have swept the earth away from the same side, and transferred much of it to the opposite.

Not unfrequently the profile of a valley and its marsh at bottom are, for long distances, all the evidence there is in sight to suggest the presence of limestone beneath; and hence come uncertainties as to the true limits of a limestone belt, which only deep diggings through the alluvium or stratified drift of the valley can remove.

The mapping of the limestone areas has other difficulties in consequence of the frequent intercalations of beds of mica schist or gneiss. Percival includes in his areas the interstratified schists; and this method is often unavoidable, except on a map of very large scale, after a careful survey. But not even the utmost thoroughness would always secure accuracy of details in this respect, because of the prevailing cover of marshes and ponds. But this alternation is sometimes only apparent; that is, in place of two distinct limestone strata with an intervening stratum of schist, there is often *one folded* stratum of limestone whose enclosed schist (mica schist or gneiss) has come out to view through denudation. If the fold is one having a horizontal axis, the denudation, if alike in all parts, would reduce it to two limestone bands and one of schist intermediate; but if its axis is inclined—the common fact—the two limestone bands may be separated by schist only for part of its length. This point is illustrated by several of the belts, and is explained in connection with the description of belt No. 1 beyond, and further exhibited on the map of Westchester limestone areas, accompanying this memoir.

(3.) *Serpentine and other Hydrous Minerals.*

The limestone areas, at several widely distant points, are associated with or contain serpentine, with sometimes also talc and hydrous anthophyllite. It is embedded in small masses in the northwestern limestone area, or that of Canopus Hollow, at a quarry two and one-half miles north-northeast of Peekskill; more sparingly in the southern part of the Singsing area, which is near the central latitude of the County: and to the south, with hydrous anthophyllite; in eastern Morrisania, near 142d street; and also at some points on New York Island. It is (as has long been known) the chief constituent of large beds near New Rochelle and Rye, at both of which places the area is embraced, like the ordinary limestone belts, between conformable beds of micaceous gneiss.[7]

The New Rochelle serpentine area is on Davenport's Neck, a nearly north-and-south peninsula bordering on Long Island Sound. The outcrops occur over the northern half of the western portion of the peninsula, and near the middle of the northern shore. At the eastern end of the last mentioned exposure, the rock is mostly crystalline limestone; but the thickness of the limestone portion of the belt is uncertain because earth covers the next two hundred yards, and then succeeds the gneiss. In Rye, the serpentine area commences one mile north of the railroad station at Rye, and extends northward for over a mile and a half. The rock contains some limestone disseminated through it, and the removal of it by percolating waters has made its surface portions cavernous, and some parts light and porous. The associated limestone, both at New Rochelle and Rye, is dolomite, and partly, if not wholly, a ferriferous dolomite.[8]

The serpentine of these regions varies in color from pale green to blackish green, dark brownish green, brownish yellow and brick-red. Part of it at New Rochelle is whitish and translucent, resembling retinalite and deweylite. The fibrous variety, chrysotile, is also met with. The rock is much rifted, and impure with disseminated magnetite, talc, "hydrous anthophyllite," and other materials.

The propriety of classing these serpentine areas with those of limestone is sustained by the following considerations: (1.) The stratigraphical position accords with this view; (2) the presence of dolomite, disseminated through the serpentine rock or associated with it, favors it; and (3) the fact that the

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[7] Mather's N. Y. Report, p. 462.

[8] For the facts as to the stratigraphical positions of the serpentine areas and the adjoining schists, see the remarks beyond on the areas, Nos. 5 and 6.

Mather mentions, in his N. Y. Report (p. 461), the occurrence of serpentine three or four miles southeast of White Plains. I have looked for the locality without success.

serpentine and other hydrous silicates originated from minerals that are common in the Westchester County limestone (dolomite) beds, and that this change has taken place in many beds that are still chiefly limestone, gives it support. The following are some examples under the last point:

The hydrous anthophyllite (first known from New York Island) was long since shown to be altered tremolite, the most common of the limestone minerals; and limestone has often been observed in close association with this hydrous mineral, or as the adjoining or containing rock. At the most important locality—between 57th and 63d streets on the western side of New York Island—Dr. Gale describes it as associated with serpentine and limestone.

The small serpentine masses, embedded in the limestone of Canopus Hollow (Sprout Brook Valley) referred to above, I have found to present sometimes the forms of a group of distinct crystals of tremolite; and the same is true with that of the Singsing limestone area. The New Rochelle and Rye serpentine is often largely made up of crystallizations of tremolite in all stages of alteration, from the unchanged mineral to amorphous serpentine; while other portions contain the allied mineral, actinolite, under the same conditions. Some of the silicates are changed also to talc, making pearly plates distributed sparingly through the serpentine. The dolomite has also participated in the change and been turned into serpentine. One piece of the serpentine obtained at New Rochelle looks like a pseudomorph after a large and fine crystal of pyroxene; but it is rough, and I am doubtful as to this origin. Mather, however, speaks of the occurrence of pyroxene with the serpentine of that locality; and it is possible that this mineral made part of the original material. It has already been stated that tremolite is abundant in the Westchester County limestone, and occasionally makes up the greater part of some beds. Actinolite is not common; but one bed of it has been mentioned (p. 25) as occurring just west of the Kingsbridge limestone.

The serpentine has also originated in part—how large a part is uncertain—from enstatite, another mineral of the hornblende family; and some, at least, of the talc has the same origin. Unaltered portions have the infusibility or near infusibility of this mineral, and show by their optical characters, as has been observed by Mr. G. W. Hawes, that the crystallization, unlike that of the tremolite, is orthorhombic. This mineral is yet unknown from any of the limestone beds or other rocks of the county, and, were it not for the tremolite and dolomite, would suggest other relations for the beds.

Many disseminated grains and masses of serpentine in the New Rochelle serpentine have the yellow and brownish yellow colors of chondrodite, and look as if they had been derived from that mineral. But the cleavage of some of the large masses so colored, and other peculiarities, show that this idea is not tenable, and evince that the color has come from oxidized iron. The change to serpentine—a hydrous magnesian silicate—would have set free the iron in the minerals undergoing the alteration—whether actinolite, ferriferous dolomite, or tremolite (this last containing one-half to two per cent, and actinolite three to twelve per cent); and thence would have come by oxidation the limonite, which is the source of the color. But magnetite (Fe_3O_4) also occurs in much of the serpentine in disseminated grains, and this contains another part of the oxidized iron—a point well illustrated by the facts with regard to serpentine pseudomorphs at the Brewster (Tilly Foster) Iron Mine, in Putnam County, New York.[9]

In view of the facts with regard to the character of the limestone (dolomite) beds, and those of serpentine, we may deem it probable that the beds which now contain, or consist mainly of, serpentine, or of "hydrous anthophyllite," were (A) *originally* beds of uncrystalline limestone (dolomite); that (B) they became beds penetrated with tremolite, actinolite, and other mineral silicates, at the time of the first metamorphism of the limestone —and that this change in some cases may have gone so far as to use up the most of the limestone of a bed; further, (C) that these beds afterward underwent a later transformation, converting the tremolite and other magnesian silicates, and part of the remaining dolomite, into *hydrous* magnesian silicates, and mostly to serpentine. This later transformation was probably due to movements attending some subsequent disturbance of the region, by which, through friction, the heat was produced needed for making silicated solutions.

No large beds of limonite (or brown hematite, as it used to be called) have been found in connection with the limestone and adjoining schists of Westchester County. Such beds in other regions are seldom extensive except where the schists are the semicrystalline hydromica schists. In the serpentine region of Rye, limonite has resulted from the alteration of the serpentine rock, and the bed has been opened, though not with good prospects of profit. The limonite in this case has come chiefly from the oxidation of the iron of the ferriferous dolomite associated with the serpentine, and that of the disseminated magnetite.

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[9] See the author's memoir on the serpentine pseudomorphs of the Tilly Foster Iron Mine, in this Journal, III, viii, pages 454, 455, 1874.

[To be continued.]

ART. III.—*Observations on Mount Etna;* by S. P. LANGLEY.

DURING the winter of 1878, in the course of a visit to Europe, I spent some time upon Mount Etna, and at the request of Captain Carlisle P. Patterson, the Superintendent of the United States Coast Survey, gave attention there to the character of the astronomical vision, in order to enable comparisons to be made with observations taken under similar conditions in our own territories. I have thought that in view of the present attention to mountain sites for observatories, the results might be of interest to others, and I have obtained the kind permission of the Superintendent to the publication of the following extracts from a report made to him on my return. It is proper to preface them by the request that the reader will remember that the observations are not the results of an organized expedition, but merely such as a single traveler, unprovided with large instrumental means, might attempt in a limited time.

The progress of modern optics is now furnishing observers with telescopes of a power which exceeds the capacities of our lower atmosphere for their constant employment. The obstacles to definition due to this atmosphere, and which increase nearly in proportion to the increase of optical power, have grown to be so nearly a barrier to any rapid progress, that attention has been much given of late to the conditions of vision, which it is very commonly supposed will be found to be best on mountain summits. On this point, however, we have scarcely any exact information, Professor Smythe's expedition to the Peak of Teneriffe, (see "An Astronomer's Experiment"); some interesting remarks by Professor Henry Draper on the Wahsatch Mts., (this Journal, vol. xiii, p. 89); and some incidental notes by temporary observers in the Himalayas, making the sum of our scanty knowledge. It seemed to me that I could best employ my limited time and means by selecting, as a station, a point generally admitted to be the most favorable of any in Europe, and there attempting to gather some sort of quantitative estimate of the degree of transparency and definition, to take the place of vague statement, and to give a kind of standard for comparison with sites in our own territory.

Very concurrent testimony points to the atmosphere of the shores and islands of the Mediterranean, and particularly of Sicily, as being on the whole superior to that of Northern Europe, and in Sicily, Mount Etna has not only long been distinguished for the extraordinary extent of the prospect, undisturbed by haze, but by its recent selection as a site for a mountain observatory by the Italian authorities guided by the competent judgment of Professor Tacchini. This was the selected site for experiment, but instead of finding myself upon the ground in October, as I had intended, it was not until the 25th of December, that I finally ascended the mountain; when the lateness of the season brought bad weather, which made the opportunity for observation limited. According to local opinion, the air is, if anything, clearer in winter here than in summer, when it is not actually cloudy. However this may be, the chief drawback on observation was the number of stormy days, by which I mean that the character of the vision on those which were fine, seemed as good as that which any season could have furnished.

Etna is a mountain of great extent, its lower cultivated slopes being very gradual, so that for five or six miles of gentle ascent from its base, it is ringed with a zone of rich vegetation, where the population is among the densest in Sicily. At an altitude of about 2000 feet, cultivation seems to cease abruptly, so that a rather sharp line of demarcation can be drawn between this and the upper region, which presents a remarkable contrast; covering the great extent of something like two hundred square miles, almost without a house or an inhabitant. Some thin and scattered plantations of chestnut trees reach on the southeastern side to an altitude of 4 or 5000 feet, but this region is, as I say, uninhabited, and above this, all is barren, consisting of wastes of lava. There is at the foot of the final cone, a hut called Casa Inglese, used in summer by the few tourists to the summit, and deserted during the rest of the year, during a considerable part of which, it is usually, in fact, buried beneath the snow. This being some eight hours journey beyond food, fuel or water, can only be used for a few hours, except by a permanently organized occupation, such as is in fact to be undertaken with the resources of the local government, which proposes to make of it the Etnean Observatory. This point being quite out of the question, for me, as a residence, I was advised at Catania to make my stay at Nicolosi, the highest village on the mountain, and whose elevation is a little over 2000 feet. It seemed, however, that a higher altitude would be desirable, but the difficulty was to find a station where wood and water could be had with some kind of shelter. Fortunately there exists about three hours' journey above Nicolosi, a cistern containing excellent water, near which is a hut built of lava, known as "Casa del Bosco." It is scarcely the "house" its title denotes it to be, but it has walls, a roof, and even a kind of fire-place, while the chestnut plantation in the vicinity makes it possible to obtain fuel.

I had no hesitation in choosing this, then, and though the quarters were certainly not as comfortable as those I had left at Catania, I found them sufficient. The hut stands at an elevation of about 4,200 feet, on the southeast slope of the mountain. It is in lat. 37° 38′ 55″·5 N. and long. $6^h\ 08^m\ 11^s{\cdot}5$ east of Washington.*

After a preliminary visit, I ascended the mountain on Dec. 25th, 1878 (Christmas day), leaving Catania in the morning, and reaching the "Casa" after dark. I had no aid or assistant, but was accompanied by a native guide and by soldiers (Carabinieri) sent by the Prefect of Catania, all of whom remained with me. These soldiers were sent on the application of the Honorable Mr. Marsh, Minister of the United States at Rome, who kindly and effectually interested himself to procure me official introductions from the Italian ministry to the Prefect of Catania, and I was obliged in this as in other instances, by every attention which our own consular officers or the Sicilian authorities could render.

My instruments consisted of a telescope of 3¼ inches aperture, mounted equatorially (but without circles), and resting upon a tripod stand. It is the property of the United States Naval Observatory, and for its loan I am specially indebted to the kindness of Admiral John Rodgers, the Superintendent. With this was a spectroscope, belonging to the Allegheny Observatory, provided with a Rutherfurd speculum metal grating of 17,296 lines to the inch, and with collimating and observing telescopes of 1·1 inch aperture and 14 inches focal length. I had no chronometer, nor any means for observations of precision.

The observations were to be directed to the sole end of determining the character of vision, as tested at night by observations on stars and nebulæ, and by day upon the sun. I was furnished by the kindness of Mr. Burnham, of Chicago, with a list of test objects, which included, however, many very difficult with such an aperture, or indeed beyond its reach, as the list was made at my request, in expectation of the use of a larger instrument than the one actually employed. I confined myself chiefly to the examination of a small number of very familiar and mostly easy test objects, adopting the plan of limiting the aperture by graded diaphragms, until the smallest one was found through which the object could be steadily seen. The same objects can always be tried with the same apertures elsewhere, but not always with the same eye, and since eyes differ, it is important to say that my own possess no special sensitiveness. In former years, while engaged with others upon such delicate objects as the inner satellites of Saturn, or on double-star work, I have never been able to flatter myself that my vision in this respect was at all keener than the average. My eye, for instance, on clear nights, at ordinary ele-

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* I am indebted for these determinations to the kindness of Professor C. H. F. Peters.

vations, does not recognize *steadily* more than six stars in the Pleiades, and sees a seventh and eighth by glimpses, and on an ordinary clear night at Allegheny, I cannot steadily see the companion of Polaris with less than two inches aperture.

I proceed to give some of the tests of light from observations made on the nights of December 28th, 31st, 1878, and January 1st, 4th, 10th, 13th, 1879. The aperture employed is 3¼ inches, where not otherwise stated.

Pleiades with naked eye, moon not set, *nine* stars steadily visible.

Companion of Polaris (position previously unknown), recognized with 1·6 in. aperture.

Companion of Rigel steadily seen with 1·6 in. aperture, not seen with 1·4 in.

β Leporis. Companion (mag. 11) seen with full aperture.

α Tauri. Companion (mag. 11·2) an easy object with full aperture.

December 31st. The nebula in Orion being about 40° high and moon half full, the 5th star in the trapezium was seen with full aperture.

ι Orionis. The 3d star (11th mag.) seen with 3¼ in. A little later, however, the definition being worse, could not discern the 11th mag. star preceding σ Orionis.

January 4th. 5th star in trapezium of Orion steadily seen, but could not be sure of 6th.

3d star of ι Orionis (11th mag.) seen with 3¼ in. in spite of moonlight.

January 10th, 11th mag. star preceding σ Orionis, also 11th mag. star of ι Orionis well seen in spite of moon and the tremor from wind.

The observations for stars included many others, which were less satisfactory, and I select from them this small list, with the remark that in the five nights which were all that presented themselves for this work, the wind was an almost constant obstacle to steady vision, while I was compelled to observe in the moonlight, and while from the construction of the tripod stand, I was generally obliged to omit objects at an altitude of much over 60°. Considering the distinctness with which objects of 11 to 11·2 magnitude were seen under these circumstances, I think we shall be justified in stating that the limit, for an ordinary eye and the aperture employed (3·25 in.), at this altitude on Etna cannot be far from the 11·5 magnitude of the Bedford catalogue, or the 10·2 magnitude of Struve's scale. I have employed the scale of the Bedford catalogue partly because Mr. Webb, in his very excellent little manual, makes the remark that to an ordinary eye and telescope, the 11th magnitude (of this catalogue) is the limit of vision to 3·7 in. aperture (in England), and because in the absence of more exact data, we may be interested in observing what this will give as the relative transparency of the respective atmospheres. For this purpose, let the absolute light of the 11th magnitude star be unity and as that of the 10th is approximately 2½ times, and that of the 12th $\frac{2}{5}$ of this; that of the 11·2 (the smallest certainly seen), is represented by the number whose logarithm is $\left(1-\frac{\log.\ 2{\cdot}5}{5}\right) = {\cdot}83$ and $\left(\frac{3{\cdot}25}{3{\cdot}7}\right)^2 :83 = {\cdot}64$. This would appear to show that stars of about $\frac{2}{3}$ the brightness of those visible in England under like telescopic power can be seen on Etna at the altitude of Casa del Bosco.

We may obtain means for comparing the transparency of the atmosphere at any station on successive evenings, or at any number of different stations, by observing with the naked eye, two stars, one high and one low in altitude, which appear to have the same brightness at a given time; for the light of the lower one must have been diminished by a calculably greater amount than that of the upper, and this difference will furnish a measure of the absorptive power of the atmosphere.

Thus let a be the coefficient of transmission of our atmosphere, so that a star in the zenith whose absolute light is L, appears with a light $\mathrm{L}\,a$, to an eye viewing it through the intervening vertical column of atmosphere $(=1)$. A star L, at the zenith distance z, whose light is more absorbed by the longer column of air $(=\sec z_1)$ will appear of the brightness $\mathrm{L}_1 a^{\sec z_1}$ that of a lower star L_2 of the brightness $\mathrm{L}_2 a^{\sec z_2}$ and if these two appear equally bright, $\mathrm{L}_1 a^{\sec z_1} = \mathrm{L}_2 a^{\sec z_2}$, whence

$$\log a = \frac{\mathrm{Log}\ \mathrm{L}_1 - \mathrm{Log}\ \mathrm{L}_2}{\sec z_2 - \sec z_1}.$$

(We neglect the effects of refraction and of selective absorption). We need the relative lights only, and these we obtain by assuming as before that the light of each magnitude is 2½ times that of the next below, an assumption which is sufficiently close to fact for our present purpose.

The following stars were thus compared. The times of comparison were taken from a common watch, and from these the zenith distances are found by subsequent computation, the magnitude being here taken from Heiss and Argelander reduced to Peirce's scale.

If any conclusion may be drawn from so very limited a number of comparisons, we may infer then, that at this station about nine-tenths of the light of a zenith star reaches us, and, that only one-tenth is absorbed by our atmosphere, but it is probably that this absorption is in reality somewhat greater.

Station, Catania.

Stars Matched.	Date.	ζ	Mag.	Log L.	$\frac{\sec \zeta_2}{\sec \zeta_1}$.	$\frac{\text{Log } L_1}{\text{Log } L_2}$.	log *a*.	*a*.
γ Cephei	Dec. 23d, 1878	45° 12′	3·55	−1·42				
ζ Urs. Maj.	8^h 53^m M. T.	84 52	2·1	−0·84	+9·76	−0·58	−0·059	0·87
δ Cassiop.	Dec. 23d, 1878	28 49	3·0	−1·20				
η Draconis	9^h 06^m M. T.	79 25	2·8	−1·12	+4·30	−0·08	−0·019	0·96
γ Cephei	Dec. 23d, 1878	52 40	3·55	−1·42				
η Urs. Maj.	11^h 08^m M. T.	79 45	2·07	−0·83	+3·97	−0·59	−0·149	0·71
β Cassiop.	Dec. 24th, 1878	21 27	2·35	−0·94				
β Urs. Maj.	6^h 17^m M. T.	83 27	2·1	−0·84	+7·69	−0·10	−0·013	0·97
							Mean	0·88

Station, Casa del Bosco.

Stars Matched.	Date.	ζ	Mag.	Log L.	$\frac{\sec \zeta_2}{\sec \zeta_1}$.	$\frac{\text{Log } L_1}{\text{Log } L_2}$.	log *a*.	*a*.
γ Geminorum	Jan. 4th, 1879	38° 46′	2·6	−1·04				
γ Leonis	9^h 07^m M. T.	79 52	2·1	−0·84	+4·40	−0·20	−0·046	0·90
Mean of β & δ Aurigae	Jan. 4th, 1879	(12°)	(3·15)	−1·26				
β Leonis	10^h 50^m M. T.	80° 10′	2·1	−0·84	+4·84	−0·42	−0·087	0·82
ζ Tauri	Jan. 4th, 1879	17 54	3·55	−1·42				
a Can. Ven.	11^h 05^m M. T.	75 30	3·07	−1·23	+2·94	−0·19	−0·065	0·86
ε Persei	Jan. 10th, 1879	19 10	3·25	−1·34				
β Can. Min.	6^h 53^m M. T.	74 44	3·15	−1·26	+2·74	−0·08	−0·029	0·94
γ Cassiop.	Jan. 10th, 1879	26 31	2·1	−0·84				
β Urs. Maj.	7^h 00^m M. T.	75 57	2·1	−0·84	+3·00	±0·00	0·000	1·00
γ Persei	Jan. 13th, 1879	15 22	3·07	−1·23				
γ Urs. Min.	7^h 28^m M. T.	69 01	2·9	−1·16	+1·76	−0·07	−0·040	0·91
							Mean	0·90

These general conclusions as to the clearness of the atmosphere must not lead us to think that it is uniformly clear, or that the definition is uniformly good at such a mountain station, or that we have not to exercise patience and wait for opportunity as well there as below. Thus I find such entries as these frequently recurring:

"Jan'y 1st, '79.—Definition very ordinary, with haziness of sky. Companion of Rigel not conspicuous with full aperture."

Jan'y 13th.—The sky seems clear, yet I cannot see the companion of 84 Ceti (9–10 mag.) with full aperture. The night is like one at home, with no good view of faint objects, though with fair definition," etc.

Reviewing my experience, I should say that the gain on Etna over a lower station, as tried by the tests of a double-star observer, was more in clearness of the atmosphere than in that freedom from tremor which accompanies good definition. The latter was indeed upon the whole better than below, but not conspicuously so.

I had occasion in August, 1878, to notice the remarkable extent and brightness of the milky way, as seen from the Colorado plains, and still more from Pike's Peak. The appearance of a nebula is perhaps indeed the best test to an experienced eye, of the quality of transparency in any atmosphere, and I was desirous of making a sketch of the nebula of Orion, as a useful measure of this transparency at my station. It was not easy to do this, however, as in most of the few clear hours which presented themselves, I was troubled by moonlight. The whole time I was thus able to give the sketch was hardly equal to more than two or perhaps three consecutive hours, although something was done at it on every opportunity, when other work permitted. With undivided attention I believe many more details might have been gathered.*

At the present time, the study of the sun is of increasing importance, and the obstacles to clear telescopic vision in our lower atmosphere are found to be of more consequence, relatively to it, than to nocturnal observations. This arises in part from the greater disturbance of the air by the direct solar heat during the day, than in the night, when it is withdrawn; but this is not the only cause. In observations of precision, we generally seek before everything an optically tranquil atmosphere, and it is a fact familiar to every observer, that the best nights for all accurate measurements of position, are very commonly not the clearest, and that at night sharp definition is, almost as a rule, associated with more or less imperfect transparency; the latter being in itself of course a loss, but bringing an over-compensation in the steadiness of vision which accompanies it. This is so distinctly the case, that even minute points of light are then often best seen, as in the well-known instance of the discovery of the 8th satellite of Saturn by Bond, on a night when stars below the 4th magnitude were invisible to the naked eye.

Now in solar work we have to distinguish two classes of phenomena,—(1) those of the photosphere, seen directly by the telescope or recorded by photography; and (2) those pursued by the spectroscope, chiefly upon the chromosphere. For the first class, in general the condition of successful observation is an optical tranquillity of atmosphere rather than transparency.

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* **The drawings made are not reproduced here, but the originals are at the service of any one desiring to institute a comparison under like conditions.—S. P. L.**

For all eye-studies of the photosphere, transparency is of so little value, that I have uniformly found direct telescopic study at Allegheny to be most successfully pursued on hazy days; the very finest definition I have ever obtained of the minute features of the photosphere and spots, being at times when the sun could be viewed with little danger to the naked eye, while even in solar photography it is found best to take advantage of the optical tranquillity of the atmosphere, just after the rising of the sun, in spite of the great loss of light from atmospheric absorption at that low altitude.

For the second class of observations, in which we may include, together with spectroscopic studies, many of those upon the sun's radiant heat, the conditions of success are notably different. Very faint uniform haze in the air, such as is quite consistent with the common impression of a bright sunny day, and passes unnoticed to the ordinary eye, puts an absolute stop to the study of the more delicate chromospheric phenomena. For these, a sky which remains of a deep blue even in the neighborhood of the sun (and which is not frequent with us in the Eastern United States), is welcomed even at the cost of poor definition in other respects, although the latter is here also very desirable. It is rarely, indeed, with us that the two conditions are united.

For tests of telescopic definition upon the surface of the photosphere, an experienced eye needs nothing more than the appearance of the cloud-forms there; for translucency of the atmosphere, the appearance of the chromospheric forms; and for the union of both requisites, the visibility of those chromospheric lines which, being due to vapors lying close to the solar limb, are hidden by the least agitation of the image. For the latter the lines *b*, and 1474 Kirchhoff were chosen, partly because I had understood from Professor Resphigi that their reversal formed severe tests of atmospheric definition, as tried by the conditions found at the Observatory of the Capitol (Rome), and also because Professor Tacchini mentions them as with difficulty seen by four inches aperture at Palermo.

I shall best give an idea of what may be expected on a mountain site, by direct extracts from my journal.

"December 28th, 1878, 10 A. M. The air perfectly tranquil to the naked eye, and a calm so absolute that the sound of voices in conversation is heard at a distance of half a mile.

Looked at sun with an aperture of one inch and lowest power. Definition *very* bad. 11.30 A. M. The sky is nearly as clear as I have ever seen it in Colorado or Egypt—not quite. Carrying the naked eye toward the sun, which is just shaded by a screen, there are very slight indications of a milkiness in the blue as the edge is approached,* but there is not that blackness, which I have

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* This extremely simple test of transparency is the best I know.

observed in using the same test on Pike's Peak, or from the summit of the Pyramid of Gizeh. The transparency of the air is nevertheless such as is very rarely seen in the Eastern United States; but all this while, the *definition* continues very bad—almost as bad as I ever saw it anywhere.

December 29th, 1878. Morning warm and calm with light cirrus clouds. Examined sun with 2d power (70). Definition only ordinary, yet caught glimpses of "rice-grain" structure, such as could not have been seen at Allegheny under like definition (i. e. the extreme transparency which would almost never be found associated with even ordinary definition at home here told in favor).

December 31st, 1878. The sky of as transparent a blue as I have seen, and optically tranquil. The so-called "rice-grain" structure of the solar surface is beautifully defined with the highest telescopic power (212), and this is the best evidence of the possibilities of vision here, as I have *never* before seen such definition upon the sun, anywhere, and least of all under a blue sky. With the spectroscope, using the small Rutherfurd grating, work is difficult, owing to the absence of clockwork and the presence of wind. Yet under these disadvantages, D_3 can be used for viewing the forms of two adjacent protuberances, nearly as well as C, 1474 Kirchhoff is reversed, occasionally shining out nearly as bright as the "Helium" line, while b_1 is repeatedly seen bright also.

January 1st, 1879. No good definition anywhere. Much of day passed in fruitless attempts to get results from spectroscope.

January 2d, 1879. Sky milky blue near horizon, deep blue above, but not so deep as I have seen it on one or two exceptional occasions at Allegheny. I much regret not having a cyanometer but judge that this, an ordinary blue here, is deeper and purer than any but the very best, of the skies of the Eastern United States.

January 3d, 1879. Calm and warm, with light haze rendering work with spectroscope on chromosphere fruitless. D_3 only caught by glimpses.

January 4th, 1879. Sky deep blue but with occasional cirrus clouds about sun. Wind constant and day passed in waiting fruitlessly for a minute of steady vision.

January 5th, 1879. A violent wind, but sky clear, round sun. Whirlwinds and dust make it difficult to do anything, but a drawing of the E lines is made* 1474 K is doubled, and eight lines discerned between D_1 and D_2 (high sun).

I remained upon my Etnean station until the 14th of January, at which time the snow line had descended to some distance below me, and the weather became so bad that there was no prospect of adding materially to the results already obtained.

During my brief stay in Europe I had the pleasure of meeting several distinguished continental observers, and learned

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* Not reduced here.

from them as far as I could, their opinions as to the conditions of observation at their respective positions. I found during a few days' stay in Egypt, a sky which appeared to give almost unequalled definition. I carried no instruments with me, but by the kindness of General Stone, of the Khedive's staff, had the loan of a small telescope, which I used on several nights, from the roof of my hotel in Cairo. Judging by this (if the nights were fairly typical, as they seemed to be), the winter climate of Egypt must be almost unequalled for astronomical purposes, the transparency and definition being alike admirable, and the freedom from tremor such that the discs of the stars I examined, seemed fixed in the center of interference rings, as sharp and motionless as engraved lines. The days were uniformly fine, but a slight haziness appeared, I thought, in the lower atmosphere, due, perhaps, to dust; which was surmounted by a moderate elevation.

From the top of the Great Pyramid at noon, I particularly noticed that the sky remained of a deep blue without a trace of "milkiness," while the eye was carried up almost to the very disc of the sun. This was equal to anything of the kind I have seen in the Rocky Mountains, but this was the only time when I found conditions of the kind as good here as I have seen them in our own western territory. I found only on this occasion, an absolutely *perfect* sky for the purposes of the student of chromospheric phenomena; but all the days were good in my brief stay, and I particularly noticed at other times the resemblance of the Egyptian atmosphere to that of our Colorado plains, as shown by the extreme definiteness of the desert horizon, which appears as a hard line, with a sky as blue at the very verge of vision as that we ordinarily see at the zenith.

The climate of lower Egypt, like that of our elevated western plains, is exceptionally dry, and I should have had, myself, little hesitation in stating that for most solar observations at least, the most promising conditions were found associated with such a dryness of atmosphere. I ought to state, however, that I found the opinion of M. Janssen (an eminently competent judge in such matters), to be that the best conditions exist when there is a great humidity in the atmosphere, *if without haze.* His experience in the Himalayas appears to confirm the impression I have gathered from all my own experience, that the mere fact of a high elevation by no means ensures good vision, though, other things being equal, the chances are better at a considerable altitude. Thus as I learned from him he found in 1869, both the definition and transparency at Simla (altitude 7,000 feet), generally worse than at Guntoor, near the sea level, while at the Neilgherry's, at an altitude of 6 or 7,000 feet, the winter vision was admirable, and this commonly was associated with a heavy fall of dew.

High elevations have undoubtedly the advantage of diminishing the atmospheric absorption of the more refrangible rays, an absorption so important that it probably cuts off from us the larger portion of the ultra-violet spectrum. M. Cornu, whose work on this portion is so well known, informed me that he found himself able to add about 1 c.m. (on the scale of his map) to this ultra-violet end, for each 500 m. of altitude, and that it was his intention in order to extend his work further, to make the Furca pass in the Alps his observing station during the present year; a testimony of importance to the gain in this direction to be expected from mountain observatories.

It appears from all that has preceded, that the balance of advantages is most likely to be found in a dry atmosphere, and certainly at a great elevation. The gain for observations of precision will be, though positive, not in itself probably such as to justify (unless for the work of the double-star observer), the difficulty and expense of such a site; but for the study of the nebulæ and stellar photometry the gain is very essential indeed, while for almost every problem in solar physics we may say without reserve that for rapid progress, such observatories have now become not merely desirable but indispensable.

The summit of a very lofty mountain is, however, even apart from any consideration of its inaccessibility, not a desirable station. At an altitude of 10 or 11,000 feet we may still enjoy all the conditions of health which fit us for labor, but if we ascend considerably beyond this, we find unfavorable conditions increasing very fast. If I may be allowed to quote from my own experience of a stay of ten days upon Pike's Peak, at an altitude of between 14 and 15,000 feet, and from what I learned from others, I should say that at this altitude the attenuated atmosphere makes a long stay impossible for some, while even for the healthiest, the conditions of life begin to be such as to render continuous hard work scarcely possible. At the same time, the mountain condenses about itself continuous clouds, so that, except during a brief period in the autumn, the opportunities for observation are far rarer than on the plains.

A dry climate and a table land at an elevation of something like 10,000 feet, sheltered on the side of the prevalent winds by a mountain range which precipitates their moisture in clouds that rarely advance beyond the observer's horizon, appear to be the most promising conditions in our present knowledge.

Upon the whole, then, though the ideal station, where atmospheric tremor does not exist, and the observer pursues his studies in an ever-transparent sky, is not to be found on any part of the earth's surface yet examined, we find within our own territory in the dry and elevated table lands of Colorado or New Mexico, every condition which experience points out as favorable. We shall find in the same territory contiguous stations under not dissimilar circumstances, where these favorable conditions do not exist; and, where so much is dependent upon a judicious choice, the preceding observations, I hope, may in spite of their incompleteness, furnish useful material for a more exact qualitative comparison, than has heretofore been practicable.

Art. IV.—*On the Antiquity of Certain Subordinate Types of Fresh-water and Land Mollusca;* by C. A. White, Paleontologist to the U. S. National Museum.

Among existing fresh-water and land Mollusca there are certain comprehensive genera, which may be divided into a greater or less number of more or less distinctly definable groups, that are respectively recognizable by certain common characteristics, less conspicuous than those which separate the larger genera from each other. These minor groups have been treated as genera, sub-genera, or as still less important sections, by the various authors who have discussed them, according to the individual estimate that has been placed upon the relative value of the characters by which they are recognized. It is my present purpose, not to discuss the value of these distinctions as means of zoological classification, but to show that a considerable number, not only of the larger genera of living North American fresh-water and land Mollusca, but also a large proportion of the minor or subordinate types which those genera respectively embrace, had their origin as such, at least as early as the closing epochs of the Cretaceous, or the immediately following epochs of the Eocene Tertiary Period.

The fossil collections upon which these observations are based, and which alone are referred to in the following remarks, are those which have been obtained by the different U. S. Government Surveys in the western portion of our national domain. The strata which have furnished these fossils are, in the ascending order, those of the Fox Hills, Laramie, Wahsatch, Green River and Bridger groups. The first named of these groups is unquestionably Cretaceous, and the three last are as unquestionably Eocene Tertiary. The second I regard as representing a transitional epoch, but some geologists assign it to the Cretaceous period because of the presence of dinosaurian remains in its strata. Others refer it to the Tertiary, because of the characteristics of its floral remains. It is sufficient for my present purpose to say that the molluscan types here discussed are found in strata which range from the Cretaceous to the close of the Eocene, inclusive.

The comprehensive genera that embrace the minor types which are here more especially discussed or referred to are *Limnæa*, *Planorbis*, *Physa*, *Helix*, *Pupa*, *Succinea* and *Unio.* The minor types that may be mentioned as having representatives among the fossil collections already referred to are especially noticeable among the pulmonate Gasteropoda and the Unionidæ. The principal examples of the former are indicated by the following list of the names by which the types are known and which have been applied to them by different authors in either a generic or sub-generic sense. These examples by no means represent even approximately the full molluscan fanuæ of which they form a part, but they are selected for the special purpose already indicated.

LIMNÆINÆ.

1. *Acella* Haldeman.
2. *Leptolimnea* Swainson.
3. *Limnophysa* Fitzinger.

PLANORBINÆ.

4. *Planorbis* (typical), Guettard.
5. *Bathyomphalus* Agassiz.
6. *Gyraulus* Agassiz.

PHYSINÆ.

7. *Physa* (typical) Draparnaud.
8. *Bulinus* Adanson.

HELICINÆ.

9. *Aglaia* Albers.
10. *Arianta* Leach.
11. *Patula* Haldeman.
12. *Strobila* Morse.
13. *Triodopsis* Rafinesque.

PUPINÆ.

14. *Lucocheila* Alh. & Mart.
15. *Pupilla* Leach.
16. *Holospira ?* Albers.*

SUCCINÆ.

17. *Brachyspira* Pfeiffer.

It should be mentioned that these subordinate types were originally recognized among, and their names applied wholly to, living forms. The discovery of fossil forms of those types is a gratifying confirmation of their genuineness (time being the crucial test of permanency), and proof of the sagacity of their authors.

Acella is represented by *A. Haldemani* White† from the Laramie strata of Bear River Valley, Wyoming. With the probable exception of an undescribed form in the Green River strata of Wyoming, no other fossil species of that type is yet known; but the *Limnæa* (*Pleurolimnæa*) *tenuicostata* of Meek and Hayden, from the Laramie strata of Montana, is a closely allied form. *Limnæa* (*Leptolimnea ?*) *minuscula* White, from the Green River strata of Wyoming, appears to possess the characteristics of *Leptolimnea* Swainson. The earliest known species of *Limnophysa* is *L. nitidula* Meek, which is associated with *Acella Haldemani*, just mentioned. Two other species from the Green River group of Wyoming are referred to that type, namely, *L. vetusta* and *L. similis* Meek.

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* *Holospira* is placed here under the *Pupinæ* only conventionally.

† The species herein mentioned are described and in part figured, in the following publications: Annual Reports U. S. Geol. Sur. Terr.; vol. ix, (4to Ser.) of the same; Bulletin of the same; Powell's Rep. Geol. Uinta Mts.; U. S. Expl. and Sur. west or the 100th Merid., vol. iv; U. S. Geol. Sur. 40th Parallel. vol. iv; Simpson's Rep. Great Basin Utah; and Proc. U. S. National Museum, vol. iii. (The latter now in press).

Planorbis proper is represented by *P. æqualis* White, in the Green River strata of Wyoming. *Bathyomphalus* has two representatives, namely, *P.* (*B.*) *Kanabensis* White, and *P.* (*B.*) *planoconvexus* Meek & Hayden; both in the Laramie Group. The former comes from Southern Utah, and the latter from Montana. *Gyraulus* appears to have several representatives in both the Laramie and Green River strata; but *G. militaris* White, from strata probably of the Laramie period, is the only one yet published.

A considerable number of species of the Physinæ are known in the Laramie, Wahsatch and Green River groups, and the subfamily was well established before the first named period. It is an interesting fact, in confirmation of the latter statement, that a typical species of *Physa*, *P. Carletoni* Meek, has been found in estuary strata at Coalville, Utah, which rest upon marine Cretaceous strata, and have more than 1,000 feet of similar marine Cretaceous strata resting upon them. This is the earliest *Physa* known in American strata. *Physa pleromatis* White, is a widely distributed species in the Wahsatch group of Wyoming, Colorado and Utah, but true *Physa* is not common in the Laramie group, although that genus prevailed both before and after. In the last named group *Bulinus* is somewhat common; *B. atavus* White, and *B. subelongatus* Meek & Hayden, being published examples.

The *Helicinæ* appear to have been almost as diversely differentiated during the Laramie, Wahsatch and Green River epochs as they are at the present day; no less than five of the subordinate types embraced in that sub-family having been more or less satisfactorily recognized among the molluscan faunæ of those epochs. *Aglaia* is represented by *Helix peripheria* White, in the Green River group of Utah; and *Arianta* by *H. reparia* White in the same group of Southern Wyoming. *Helix Kanabensis* White, seems to possess the distinguishing characteristics of *Strobila*. It occurs in the upper part of the Laramie group of Southern Utah. *Patula* is represented by *Helix sepulta* White, in the coal-bearing strata of Evanston, Wyoming, which belong either to the upper part of the Laramie group, or the base of the Wahsatch, probably the former; and apparently also by an undescribed species in the Green River group of Wyoming. *Triodopsis* is represented by *Helix Evanstonensis* White, which is associated with *H. sepulta*, just mentioned.

The *Pupinæ* have been recognized only in the Green River and Bridger groups; four species only having yet been discovered. The true character of the aperture has been ascertained only in one of these, and they are therefore assigned to the types mentioned, with some doubt. Their diverse forms, however, indicate that a wide differentiation had taken place in the *Pupinæ* at that early time. *Pupa arenula* and *P. atavuncula* White, discovered in the Green River strata of Wyoming, are referred provisionally to *Pupilla*, and an associated species *Pupa incolata* White, to *Lucocheila*. Mr. Meek referred his *Pupa Leidyi* doubtfully to *Holospira*. It is from the Bridger strata of Wyoming.

Only one species of the *Succininæ* has yet been discovered in any of the strata here considered, namely, *Succinea papillispira* of the Green River strata of Wyoming. This is plainly referable to *Brachyspira*.

The *Unionidæ* of the fossil molluscan faunæ, herein discussed, are found to have become differentiated to a remarkable extent, especially during the Laramie epoch. An exceedingly interesting and suggestive fact in connection with this differentiation is that the subordinate types are largely indentical in character with some of those which are now living in the waters of the Mississippi River system, and which are recognized by malacologists as distinctively North American types. Illustrative of this relation of the fossil to the recent forms, the following parallel lists are presented, those of the left-hand column being a part of the fossil species now known in the Laramie strata of Wyoming and Utah; and those of the right-hand column being the living species of the Mississippi River system which are selected as their respective type-congeners.

Unio propheticus White.	*U. clavus* Lamarck.
U. proavitus W.	*U. ridibundus* Say.
U. gonionotus W.	*U. multiplicatus* Lea.
U. holmesianus W.	*U. apiculatus* Say.
U. Couesi W.	*U. complanatus* Solander.
U. Endlichi W.	*U. gibbus* Barnes.
U. brachyopisthus W.	*U. circulus* Lea.

Still other examples might be given of close resemblances between fossil and recent forms of *Unio*, but these suffice to suggest, in a very forcible manner, that the *Unione* fauna of the Mississippi River system is genetically related to that of the Laramie period. It is true that in the Laramie fauna there are certain minor types of *Unio* which are not so closely like any living forms as those are which have been cited, and that close congeners of certain living types have not been discovered among the fossil forms; but these facts do not necessarily affect the legitimacy of the conclusion that the living has genetically descended from the fossil fauna. A like conclusion is also reached with reference to the pulmonate gasteropods which have already been discussed; but in view of the magnitude of the physical changes which have taken place since the close of even the latest epoch here considered, the survival of the types of the branchiferous Mollusca, and their transference from lacustrine to fluvatile waters, is a most remarkable circumstance.

Reviewing the collections which represent the fossil faunæ herein discussed, so many familiar forms are seen that it is difficult to realize the fact that a large proportion of them, including those especially which have been mentioned by name in this article, were living contemporaneously with the last of the Dinosaurs. Yet such is the fact, and the shells of the former are often found commingled with the bones of the latter. What were the successive steps in the history of the transmission of these types from that remote time to the present we are unfortunately without the means of knowing with certainty, because of the remarkable paucity of molluscan remains in all the deposits of the great interior region later than the Eocene. All the molluscan remains, which have been found in these later deposits, belong to familiar living types, although of extinct species.

That the palustral and land pulmonates might have been, and perhaps were, preserved under immediate conditions differing from those which insured the survival of the Unionidæ is evident; but certain facts point to the conclusion that the peculiar "North American" types of Uniones which prevailed in the Laramie epoch were not transmitted through the Eocene, Miocene and Pliocene epochs as denizens of the fresh-water lakes which succeeded the brackish water of the Laramie sea, and each other, in their occupancy of a great part of the interior region of North America, up to at least near the close of the Pliocene epoch. The Eocene fresh-water deposits contain a considerable number of species of *Unio*, it is true, but they are all, so far as known, of a smooth surface and oval form, and constitute a type which, although common among living Uniones, is exceedingly rare if not entirely wanting in the Laramie group. The conclusion therefore seems necessary that those peculiar and varied forms of *Unio* which have been mentioned in the preceding list, with their faunal molluscan associates, escaped from the Laramie lacustrine waters before the close of that epoch, into those fluviatile waters which formed the outlet to the lacustrine, and which became a part of the Mississippi drainage system, as the elevation of the continent progressed.*

The magnitude of the physical changes which have taken place upon the North American continent since the epochs in which the Mollusca lived, which are discussed in this article, has already been referred to. These changes were no less than the gradual desiccation of the region formerly occupied by great inland lakes, which for magnitude have now no equals upon the earth; the elevation of the whole Rocky Mountain system, and the establishment of the present great interior river systems. Through all these changes these molluscan

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* This subject is discussed at some length in Bull. U. S. Geol. Sur. Terr., vol. iii, p. 615.

types have come down to us in unbroken lines some of which, to speak figuratively, were of remarkable tenuity. It is true there has been a dropping out of some of the earlier associated types and an introduction of new ones as the epochs passed, but the lines of descent of the numerous types which have reached us unbroken, seem to be almost parallel, so little have they changed with the lapse of time. So slightly divergent are these lines, considered as lines of differentiation, that if we bound them all by two imaginary straight lines, we shall have an evolutional parallax that would carry back the origin of these types to a period inconceivably remote. We must therefore conclude that their origin was, at least in some degree, saltatory; but the real conditions under which they originated must probably always remain obscure. I have, however, elsewhere* suggested, that the differentiation of the Unionidæ took place under the influence of salt in the water in which they lived; but it is plain that this explanation will not apply to the case of the palustral and land mollusca.

ART. V.—*Description of a new Position Micrometer*; by LEONARD WALDO.

THERE has lately been added to the instrumental equipment of the Winchester Observatory of Yale College, a position micrometer, of a new design, though the separate ideas embodied in it I have gathered from other observers' experience as well as my own.†

There are two sources of trouble in the filar micrometer as ordinarily constructed. The unguent used, if it has enough body to it to be really serviceable, becomes waxy and stiff in the cold of winter's nights. As a result, the screw, whether bearing at its point or at a shoulder, only gradually comes to a fixed position as it is turned. The spring which is used to take up the dead motion of the screw varies its pressure from one-fourth to three-fourths or more of its whole amount as the micrometer frame is moved from one end of its box to the other end.

In the micrometer about to be described, both of these difficulties seem to be overcome. The screw bears, without any unguent, against an agate plane, and the pressure of both the springs is practically constant in any position of the micrometer frame, which is liable to occur in actual use. In the sketches, $s\,s'$ represents the screw which is 19 cm. long, and 8 mm. in diam-

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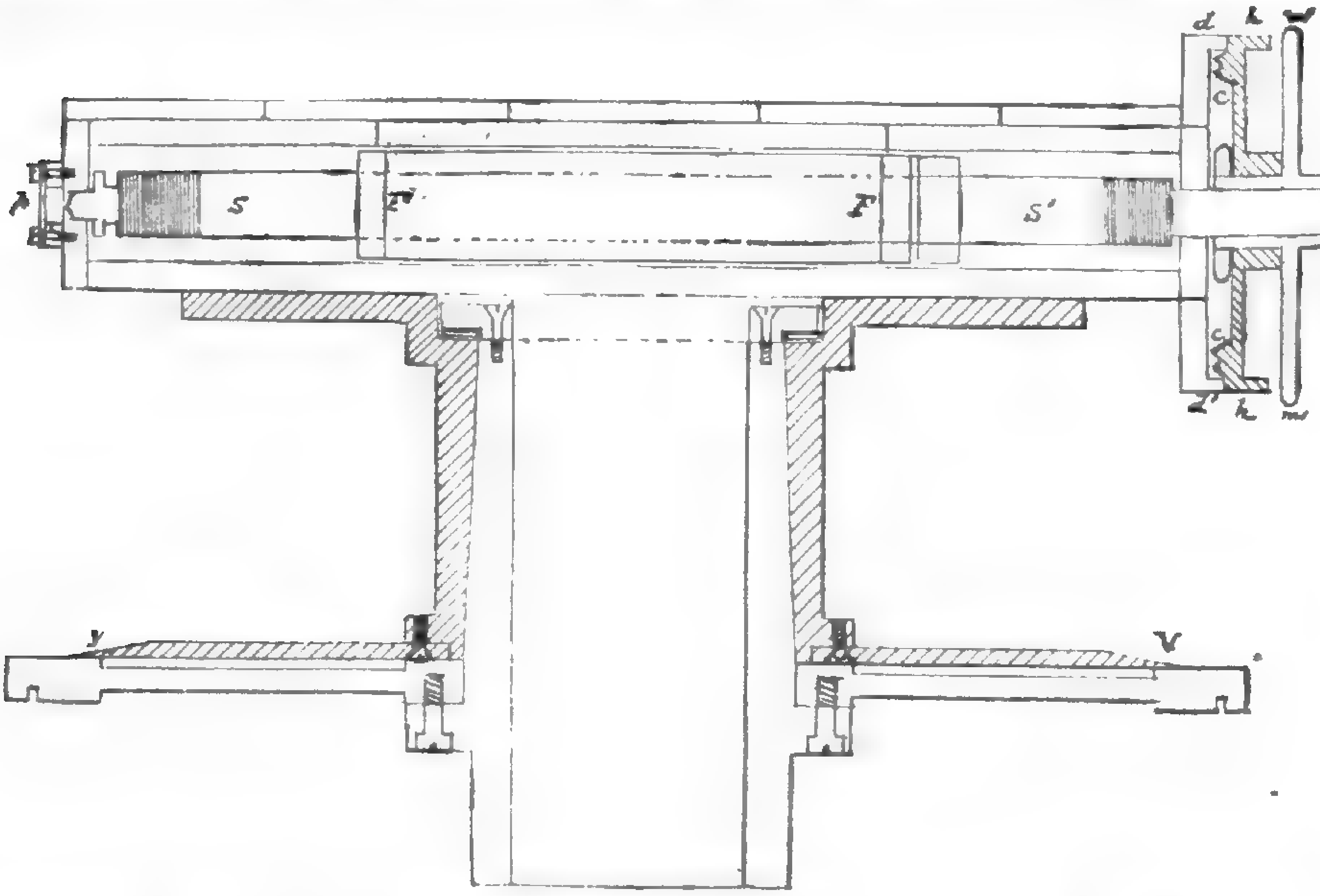
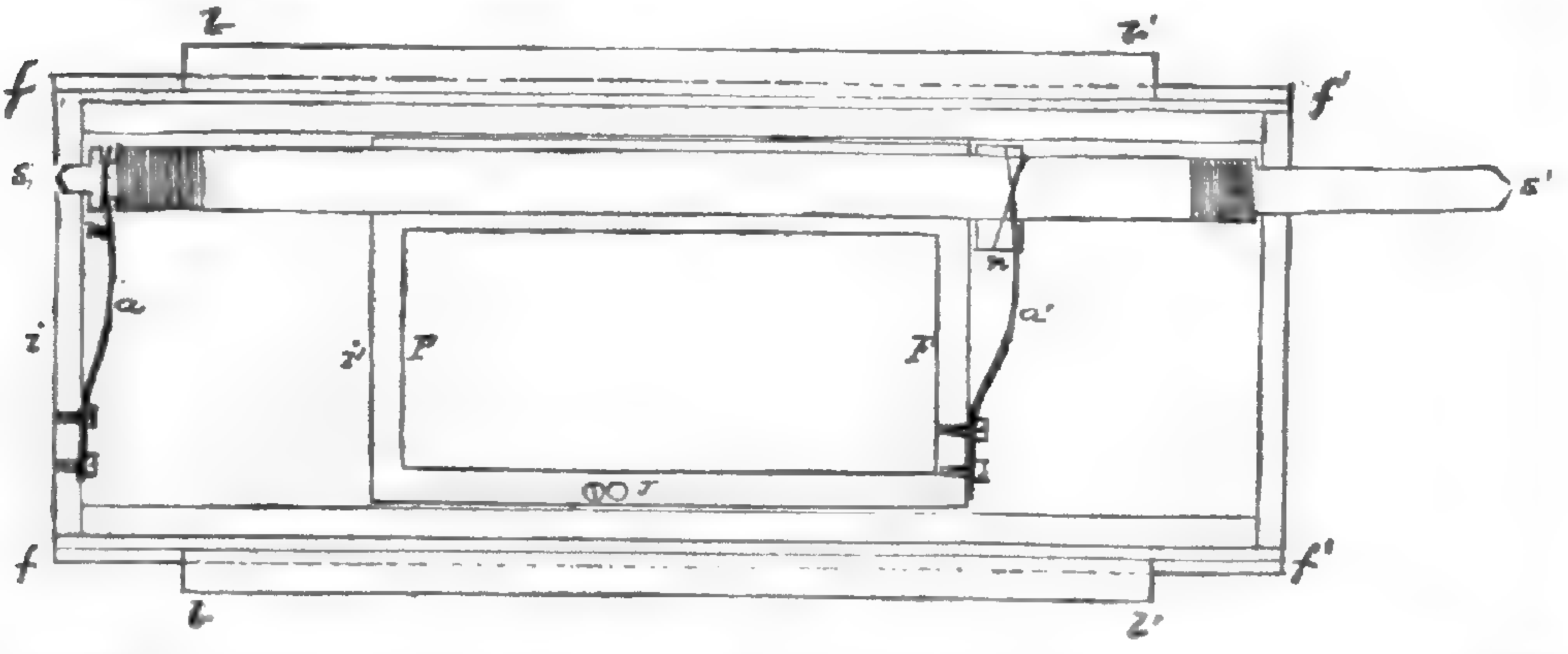
* Bull. U. S. Geol. Surv. Terr., vol. iii, p. 623.

† I am principally indebted to Professors Lyman and Harkness, and the Messrs. Repsold.

eter at the part where the thread is cut. The thread is cut for a length of 14·3 cm. and is evidently meant to be 80 revolutions to the inch. The frame FF which carries the movable webs, is cut its whole length as a matrix through which the screw works; and in order that this frame shall have no dead motion, there is a small matrix, *n*, about 1 mm. distant from it, which is prevented from rotating as the screw is turned, and against which the spring *a′* presses. This spring having one end screwed to the frame, and the other end pressing against the small matrix, tends to push them together, and thus the dead motion of both is destroyed.





The end of the screw at *S* is held firmly against an adjustable agate plane at *p*, by means of a second spring *a* which acts against a collar *m*. This spring needs to be quite stiff, for in one position of the micrometer box the weight of the screw and frame must be supported by it.

An adjustable agate jewel at *J* is the only point upon which the frame rests upon its box; and as pointed out by Lord

Lindsay[*] this form of mounting the frame is most likely to secure permanency in the errors of the screw, so that when once determined they may be assumed to remain constant for long intervals.

The micrometer frame *fff′f′* may be moved in the grooved bearings *b b b′ b′* by a screw, which is not shown in the sketch, opposing the micrometer.

The eye pieces also have a parallel motion by rack and pinion. The screw head may be read by two pointers *d* and *d′*, and the whole revolutions are registered by a toothed wheel which gears into the thread cut on the micrometer head and shown at *c c*. The milled head, *m m*, is larger than the disc carrying the graduations. The bright web illumination is effected in a manner similar to that adopted by Alvan Clark & Sons. There is an aperture at *i* protected by a glass cover and a similar one at *i′* which allows the light from a lamp to impinge on the webs in the frame.

The position circle reads by two verniers to 30″ and is provided with a coarser graduation to single degrees. The workmanship throughout is in the highest degree creditable to its makers, Messrs. Fauth & Co. of Washington, D. C.

The following observations on the revolutions of the screw between 22·50 rev. and 27·50 rev. were made with the microscope comparator I have previously described.[†]

I.	II.	III.	IV.
Rev.	d.	d.	mm.
22·500			
22·750	5·07	+0·02	+0·00031
23·000	4·95	−0·10	−0·00157
·250	5·03	−0·02	−0·00031
·500	5·12	+0·07	+0·00110
23·750	5·10	+0·05	+0·00079
24·000	5·00	−0·05	−0·00079
·250	5·03	−0·02	−0·00031
·500	5·05	0·00	0·00000
24·750	5·07	+0·02	+0·00031
25·000	5·08	+0·03	+0·00047
·250	4·97	−0·08	−0·00126
·500	5·16	+0·11	+0·00173
25·750	5·03	−0·02	+0·00031
26·000	5·00	−0·05	−0·00079
·250	5·06	+0·01	+0·00016
·500	5·05	0·00	0·00000
27·750	5·03	−0·02	−0·00031
27·000	5·10	+0·05	+0·00079
·250	5·03	−0·02	−0·00031
27·500	5·07	+0·02	+0·00031

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[*] Dun. Echt. Obs. Pub., vol. ii, p. 53.

[†] Proc. Am. Acad. Arts and Sci. Bost., vol. xiii, for 1877–78, p. 352.

Column I gives the readings of the position micrometer. Column II, which is the mean of three readings, is the value in terms of the microscope micrometer scale of the interval 0·250 rev. occurring between the two successive readings of the position micrometer. Column III is the deviation of these intervals from the mean in terms of the microscope micrometer. Column IV gives these deviations expressed in millimeters.

The small residuals in column IV would apparently indicate that there are no greater errors to be apprehended from this form than from the ordinary construction. and it seems to possess very marked advantages for use in all observations which are carried throughout the year, and where the micrometer will be used on the same objects under the diverse conditions of winter and summer. This would seem to be particularly desirable for researches upon the stellar parallaxes.

ART. VI.—*On Boltzman's Method for Determining the Velocity of an Electric Current;* by E. H. HALL.

IN the June number of this Journal is mentioned a note relative to the velocity of electricity, published by Prof. Boltzman in the *Kaiserliche Akademie der Wissenschaften in Wien*, Jan. 15th, 1880. In this note Prof. Boltzman points out a method by which, as he thinks, the absolute velocity of current electricity may be determined from the results furnished by the study of a phenomenon lately described in this Journal* under the title, "A New Action of the Magnet on Electric Currents." Quite recently there has appeared in the *Kais. Akad.*, etc., an account of experiments and calculations made by Albert v. Ettinghausen, whereby he deduces for the electrical current sent by "one or two Daniels' cells" through his strip of gold the velocity 1·2 mm. per second.

Unless I have misunderstood Prof. Boltzman's note, however, there is a fatal objection to the fundamental assumption which he makes. I will give very briefly his method of reasoning as I understand it.

We know, as Prof. Boltzman says, that a conductor bearing a current is acted upon by a force tending to move it in a direction at right angles to the direction of the magnetic force acting upon it. We know, moreover, from the new phenomenon that there is at the same time a difference of potential set up between points on opposite sides of the conductor, and that the electromotive force thus arising is in the same line as the above force acting upon the conductor.

Consider now any particle of electricity in the conductor.

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* March, 1880, p. 200.

It is acted upon by the newly-discovered transverse force, tends to move accordingly, and tends to draw the conductor with it. Imagine enough particles of electricity crowded into the conductor, and we have the explanation of the familiar action between magnets and conductors bearing currents. Knowing, therefore, the strength of our magnetic field, the strength of the primary current and the consequent difference of potential on opposite sides of the conductor, we can calculate exactly the amount of electricity contained in unit length of the conductor, at any moment while the current is flowing. Knowing, moreover, the amount of electricity passing through the conductor in unit of time, which quantity is of course what we call the strength of the current, it is a perfectly simple matter to determine the velocity of the current.

This question meanwhile presents itself. If the very slight difference of potential existing between opposite sides of the conductor is sufficient, when acting upon the electricity contained within the conductor, to cause the strong action which everyone has observed between magnets and conductors bearing currents, why is there not an enormously greater force always acting upon the conductor in the direction of the primary electromotive force and primary current?

To get a more definite view of the matter, suppose we send through a strip of gold leaf a centimeter wide and of any length a current of strength ·05 (cm-grm-sec.), and place the strip in a magnetic field of strength 4000. A certain difference of potential would now be observed between points opposite each other on the edges of the strip. This difference of potential, E′, would in the case imagined be perhaps $\frac{1}{3000}$ the difference of potential, E, for two points a centimeter apart in the line of the main current. Now, the force acting upon a unit length of the conductor to move it across the lines of magnetic force would be 4,000 × ·05 = 200 dynes.

This force everybody knows to exist. Let us suppose for the moment, with Prof. Boltzman, that it is due to the difference of potential E′ acting upon the electricity in the conductor. But now we have the difference of potential E, 3,000 times as great as E′, acting upon the same electricity but acting in the direction of the current.

To be consistent, therefore, we must look for a force in this direction equal to 3,000 × 200 = 600,000 dynes, a force equal to the weight of about 600 grams, acting upon each unit length of the gold leaf strip. Thus in following out Prof. Boltzman's assumption to what seems to me its necessary consequences we are led to a manifest absurdity.

Another objection to the above assumption, and a serious one apparently, is found in a fact not known to Prof. Boltzman when his note was written.

The transverse electromotive force in iron is opposite in direction to that in gold. According to the theory proposed, therefore, an iron wire bearing a current should move across the lines of magnetic force in a direction contrary to that followed by wires of other materials, which it does not do.

In view of these difficulties, it seems hardly possible at present to accept Prof. Boltzman's method of calculating the velocity of electricity.

Anyone desiring to see Prof. Boltzman's note will find a translation of the same in the Philosophical Magazine of April, 1880, p. 308. A rather confusing inaccuracy in translation is, however, to be found about the middle of page 308 in the sentence, "Hence, if the force above denoted by K *itself* acts upon, etc." This should read, "Hence, if the force above denoted by K acts upon the movable electricity *itself* in the gold leaf, etc." The position of the pronoun is here a matter of considerable importance, as anyone will see who reads Prof. Boltzman's note with care.

ART. VII.—*Mineralogical Notices;* by CHARLES UPHAM SHEPARD, Emeritus Professor of Natural History in Amherst College.

1. *A peculiar mineral of the Scapolite family.*

THE substance here described was sent to me by that zealous mineralogist, Mr. John G. Miller, of East Templeton, Ottawa County, Canada. It occurs in the bluish gray saccharine limestone of Galway, Ontario County, Canada. It had been referred with a query to chiastolite, which it certainly resembles in several respects. It presents itself in distinct and rather large crystals, thickly disseminated through the gangue, crossing each other in various directions. Their form is that of a right square prism, with truncated lateral edges. Their terminations are imperfect, and when well defined even, are still rough and drusy. They exhibit no combinations with the prismatic planes. The usual habit of the crystals is distinctly quadrangular, though in the larger individuals they are octangular, having their sides about equally produced. Their length is many times their thickness; and they are uniformly straight and sharply defined. The largest have a diameter of an inch, the smallest are rarely below one-eighth of this size. They preserve the same diameter throughout their length, with the exception of a single example, where one of the larger size, shows a tendency to a regular acumination. The length of this crystal is 3½ inches, its diameter at the larger extremity being half an inch, and at the smaller, but one-third. All the crystals have much evenness of surface and considerable smoothness, notwithstanding a slight degree of pitting or indentation, which almost requires a microscope for observation. They are without striation. The color is black, with a slight intermixture of gray and blue. In a few instances an area of cyanite-blue occupies a face of the larger crystals, but only to a slight depth from the surface. This part of the crystal is semi-transparent; while for the rest, the entire mineral is dark ash gray to bluish black, and only translucent on the edges. The vertical cleavages, parallel with the primary prism, are distinct, though effected with difficulty. They take place parallel with the narrower planes in the quadrangular prisms. Only traces of a transverse cleavage exist. A marked peculiarity of the larger crystals is the regular interlamination of thin films of white calcite, parallel with the eight sides of the prism. These layers, to the number of two or three, are equi-distant, thus imparting to the fractured ends of the crystals a checkered aspect, strongly suggesting the structure of chiastolite.* Luster, resinous to vitreous. Hardness = 7· . . . 7·5. Specific gravity, 2·608.

A very striking peculiarity of the mineral is the extremely fetid odor occasioned by its fracture; nor does this cease to be emitted until the fragments are reduced to an impalpable powder. The color of the powder is a bluish ash gray. It cannot be regarded as a hydrated mineral, as its content of water does not exceed 1·6 p. c. By exposure, however, to full ignition in a shallow platinum dish for several hours, it loses 4·6 p. c., this loss proceeding from the presence of organic matter, graphite, and carbonic acid from the decomposition of carbonate of lime. The powder still partially retains its grayish tint after long ignition; and it is only before the blowpipe that the portion most strongly heated loses its color. The thinnest part then undergoes fusion, attended by a feeble ebullition, into a colorless transparent glass.

Owing to the variable presence of graphite, calcite and quartz, the chemical examination is attended with uncertainty. The $\ddot{\text{Si}}$ varied from 48·65 to 51·30; the $\dddot{\bar{\text{Al}}}$ from 13·45 to 19·62; the $\dot{\text{Ca}}$ from 17·43 to 21·6, and the $\ddot{\text{Ti}}$ from 4·35 to 5·21. In a single trial, $\dot{\text{Na}}$ 4·35, and $\dot{\text{K}}$ 1·109, $\dot{\text{Mg}}$ 0·468 were obtained. The powder is very feebly acted upon by the strong acids.

From the foregoing it would appear that the mineral differs chemically from normal scapolite, and especially from the

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* Prof. E. S. Dana has kindly made a section of one of the crystals, and examined it in polarized light. He finds "the black color to be due to foreign matter, present in the form of minute grains that may be metallic, making up no small part of the whole," and is of the opinion that "its analysis is not a guide to the real composition of the mineral."

vitreous couseranite of Saleix (Pyrenees) analyzed by Pisani; though it must be kept in mind that the example analyzed by him had been so much altered as to have its hardness reduced to 3. I am therefore led to regard the Galway crystals as the original, unaltered mineral, from which couseranite and dipyre have originated through hydration,* in the same manner as scapolite has given rise to wilsonite, huntite, algerite and terénite. Should it prove a new species, I propose to call it *Ontariolite.*

2. *Cassiterite at Coosa, Ala.*

Among the smaller fragments and grains of tantalite from this interesting locality, I find numerous crystals of cassiterite, the largest of which do not exceed the size of a pea. Some of them are well-formed octahedral crystals, showing, however, narrow faces of the primary prism, between the pyramids. When heated before the blowpipe on charcoal, along with soda, metallic tin is plentifully afforded. It is at present unknown whether this very desirable ore exists in workable quantity.

3. *Yttro-tantalite.*

A single small crystal supposed to be yttro-tantalite was detected along with the cassiterite. Its form is that of a right rhombic prism of about 122°, having its acute terminal angles replaced by two planes, inclining to one another across the obtuse lateral edge of the prism at an angle of very near 125°. Specific gravity =6·001.

4. *Note upon the Paracolumbite.*

This ambiguous mineral, whose locality at Taunton, Mass., was lost sight of for many years, has been re-discovered; and still continues to be met with in collections under the above name. The analysis of Pisani proved that it had no chemical relation to columbite, but gave a result not altogether satisfactory for ilmenite, (menaccanite) to which he referred it. In view of its decidedly lower specific gravity than ilmenite, its fusibility before the blowpipe, and its large content of silicate of alumina, it remains undecided whether it properly belongs where Pisani has placed it; and I would therefore suggest that until farther information is obtained, the name paracolumbite be changed to para-ilmenite.

5. *Hemihedral forms of Staurolite.*

Among the large and perfect crystals of this mineral, found loose at Morganton, Ga., hemihedral forms are not unfrequent, both as single and compound crystals. The hemihedism relates to the alternate obtuse terminal angles, which are replaced by broad single planes.

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* Possibly chiastolite may have been similarly produced, though the origin must have been attended with a more radical metamorphism.

6. *Fergusonite from Mitchell County, North Carolina, and identical with Rutherfordite.*

I have detected along with the samarskite of this locality a few very small crystals of fergusonite closely resembling those originally described by Haidinger as coming from Greenland, and nearly identical with those found in the sands from the gold washings of Rutherford, N. C., named by me as rutherfordite, and which I now consider as belonging to the species fergusonite.

7. *Green Pagodite in Georgia.*

A very handsome green variety of this mineral is found on Beaver-dam creek, nine miles west of Washington. It first attracted the notice of Mr. Ufford Jennings, of Charleston, S. C., as a material likely to be useful in ornamental stone-work. Its color, especially when polished, is between apple and emerald green. It has considerable translucency. Structure coarsely schistose, with a splintery fracture. Very tough. It is more or less interlaminated with coarse scales of muscovite; and is often freckled and blotched with a copper-red rutile; the latter impurity sometimes imparting after polishing, a resemblance to blood-stone. Hardness = 3. Gr. = 2·86. Before the blow-pipe in thin fragments, turns white and suffers slight fusion. Colors borax, apple-green. Uniformity of composition imperfect, owing to presence of muscovite and rutile. The trials gave

$\ddot{\mathrm{Si}}$ 48· to 52·, $\dddot{\bar{\mathrm{A}}}\mathrm{l}$ 22·6 to 34·, $\dot{\mathrm{Fe}}$ 2·10, $\dot{\mathrm{Na}}$ 5·12, $\dot{\mathrm{K}}$ 4·43, $\dot{\bar{\mathrm{H}}}$ 3·5,
($\dot{\mathrm{Cr}}$ and $\ddot{\mathrm{Ti}}$ undetermined).

It probably forms a stratum of considerable dimensions in a mica-slate formation.

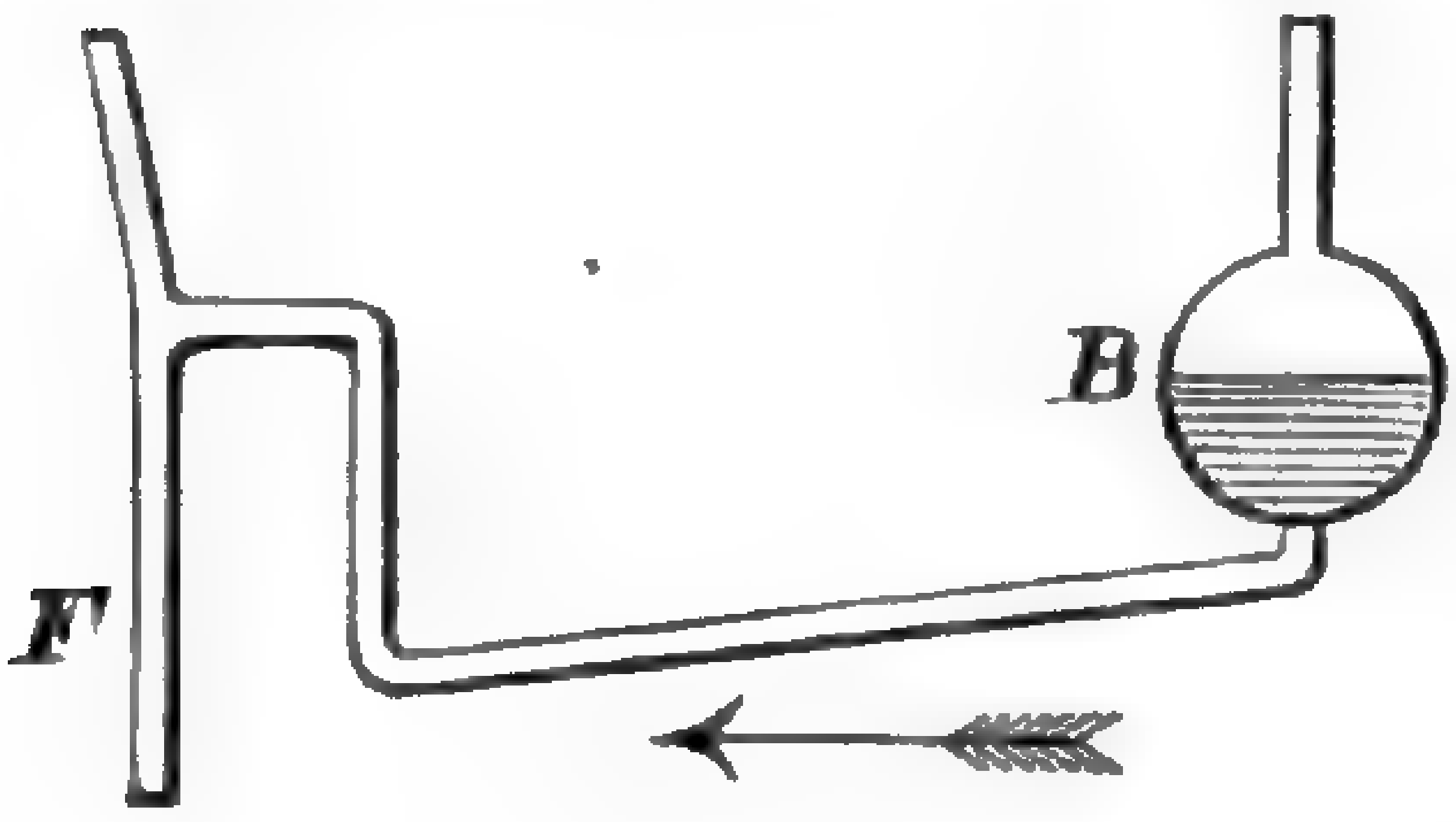
New Haven, May 8, 1880.

ART. VIII.—*On an improvement in the Sprengel Pump;* by Professor O. N. ROOD, of Columbia College.

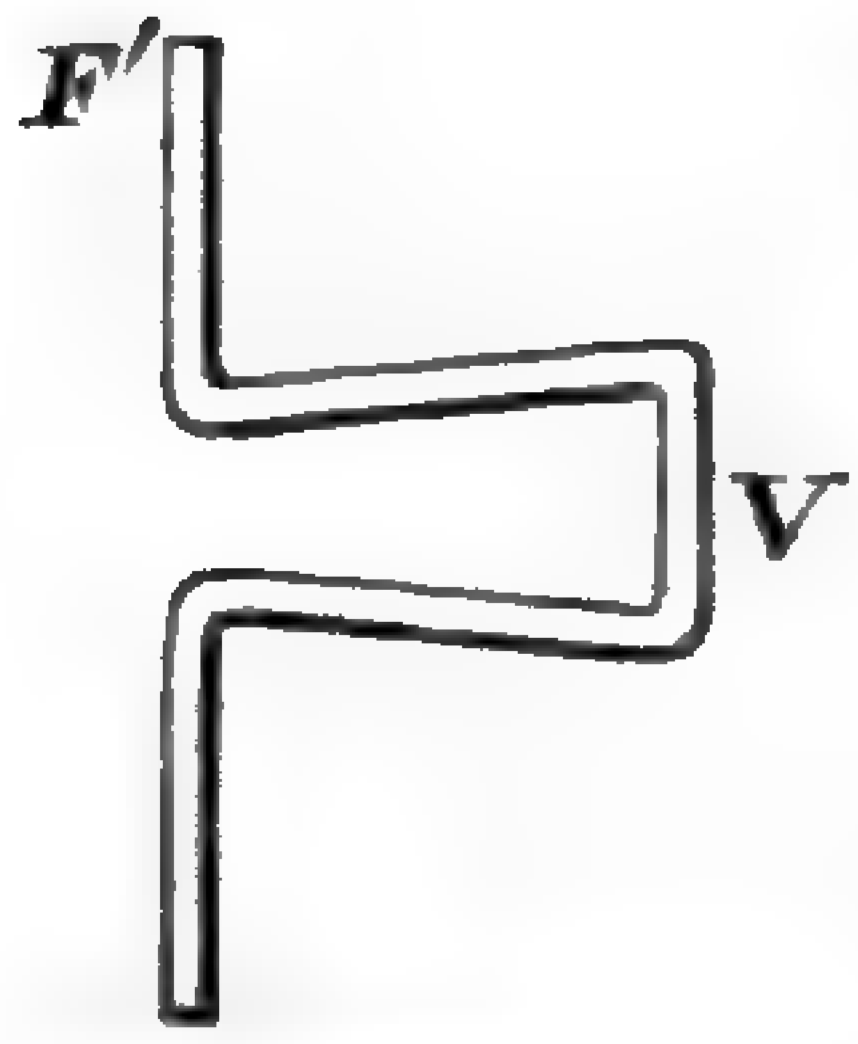
IN this notice I propose to indicate very briefly the nature of an improvement that I have lately made in the form of the Sprengel pump, which enables the experimenter easily to obtain a vacuum as high as $\frac{1}{90,000,000}$ or $\frac{1}{100,000,000}$, reserving the details of manipulation, etc., for more extended notice hereafter.

(1.) The improvement consists, first, in an arrangement by means of which the mercury, instead of being at once introduced into the pump, passes beforehand through an exhausted bulb B, thus freeing itself in great measure from air and moisture. It afterwards passes through a nearly horizontal tube, finally reaching the fall-tube F, as shown in the diagram.

(2.) The second part consists of what amounts to an almost theoretically perfect fluid valve, which prevents the air that has passed out of the fall-tube from returning into it; this is accomplished by merely bending the fall-tube as indicated at V. As for the rest, the pump is contrived so as to be free from stop-cocks and grease.



By inclining the pump somewhat, the bulb can be exhausted once for all, as matters can easily be arranged so that when the atmosphere is allowed to enter the pump, the exhaustion of the bulb remains intact.



The action of this pump is very rapid, two hours or less sufficing to reduce the vacuum from $\frac{1}{20,000}$ to $\frac{1}{100,000,000}$, the total capacity of the pump being 100 cubic centimeters.

The exhaustion in these experiments was always accomplished by mechanical, not by chemical means; chemical substances being introduced solely for the purpose of drying the air. In the total absence of all such substances I have obtained a vacuum as high as $\frac{1}{30,000,000}$. The means of measuring these vacua and other details will be given as soon as a set of experiments that are being made on the caliber of the fall-tube is finished.

New York, June 10th, 1880.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Carbonyl Bromide.*—Emmerling has met with serious difficulties in the attempt to prepare carbonyl bromide by the method proposed some years ago by Lengyn and himself for the preparation of carbonyl chloride, i. e., by the oxidation of chloroform by means of a mixture of potassium dichromate and sulphuric acid. The more energetic action of the oxidizing agent upon bromoform, especially when the proportions were used, which were found best for chloroform, caused so copious an evolution of carbon dioxide that the condensation of the carbonyl bromide by a freezing mixture was rendered well nigh impossible. By using a larger proportion of the dichromate—20 to 25 parts to 50 parts sulphuric acid and 5 to 10 bromoform—a somewhat less violent reaction takes place. Moreover in place of removing

the free bromine produced in the reaction by means of antimony, it was allowed to condense in the receiver with the bromide, and a crude product colored by bromine, was obtained, which weighed only 25 grams, after repeating the operation fifteen to twenty times. Subsequently by distilling this through a tube containing antimony, a colorless heavy liquid was collected, having the same penetrating suffocating odor that carbonyl chloride has, and whose vapor caused a remarkable swelling up of the vulcanized rubber connections. On fractioning, the thermometer rose from 12° to 30°; proving that the product was not pure. On analysis, it was found to contain carbonyl chloride.—*Ber. Berl. Chem. Ges.*, xiii, 873, May, 1880. G. F. B.

2. *On the Hydrate of Barium dioxide.*—SCHÖNE has made further analyses of the hydrate of barium dioxide, since his formula $BaO_2(H_2O)_8$, originally given for this substance, has been doubted by Berthelot, who assigns to it the composition $BaO_2(H_2O)_{10}$. The first set of analyses, in which he was assisted by Grigorieff, was made upon the product obtained by the spontaneous decomposition in water, of the compound $BaO_2 . H_2O_2$, at temperatures between 14° and 20° C. About 3¼ grams of the colorless crystals, prepared by mixing ice-cold solutions of ammonia and of hydrogen peroxide containing barium chloride, were placed in a flask with pure water, the progress of the decomposition being observed by collecting the evolved gas in a graduated tube. During the first seven days fifteen to thirty c.c. of gas was evolved in twenty-four hours. The crystal mass became at first yellow, and then colorless, and after four more days, during which only 4 c.c. of gas was evolved daily, there remained a colorless coarsely crystalline powder of the pure hydrate, weighing about five grams. A portion was dried rapidly by pressure between folds of paper. A second portion was rapidly dried by washing with alcohol and ether, Both samples on analysis gave the formula $BaO_2 . (H_2O)_8$. The second set of analyses was made on crystals obtained by pouring a dilute solution of hydrogen dioxide into barium hydrate solution in excess, all the operations being conducted between 0° and 5° C. The thin crystal plates were dried and analyzed. Allowing for a small quantity of carbonate formed, they gave the formula $BaO_2 . (H_2O)_8$ like the others. Hence this may be regarded as correct, corresponding as it does to the strontium and calcium compounds, which are $SrO_2 . (H_2O)_8$ and $CaO_2 . (H_2O)_8$.—*Ber. Berl. Chem. Ges.*, xiii, 803, Apr., 1880. G. F. B.

3. *On Furfuran and Sylvan in Pine wood tar.*—ATTERBERG has further examined the earlier fractions of the distillation of pine wood tar, in which he discovered the terpenes, australene and sylvestrene. The most volatile portion consisted of a liquid of characteristic odor, boiling at 30° and having a sp. gr. of 0·779. After distillation over sodium, it gave 72·71 C., 9·32 H, and 17·97 O, and had a vapor density of 69·5. It was evidently a mixture, but its behavior toward hydrochloric acid showed it to

contain a body C_4H_4O, discovered by Limpricht in 1870 and called tetraphenol, a name subsequently changed by Baeyer to furfuran. The addition of this acid converts it at once into a solid and almost insoluble powder. Associated with this was a hydrocarbon, probably a valerylene. The next higher fraction boiled between 59° and 65°. Distilled from sodium, the larger part of it boiled at 63° to 63·5°, gave on analysis C 73·50, H 8·78, and had a vapor density 81·4 to 81·7. The formula C_5H_6O requires 73·17 C and 7·32 H and a vapor density of 82. This is therefore a homologue of furfuran, and the author calls it sylvan, from its origin. Most reagents only polymerize it giving resinous and tarry products. Permanganate oxidizes its methyl group to acetic acid.—*Ber. Berl. Chem. Ges.*, xiii, 879, May, 1880. G. F. B.

4. *On Crystallized anhydrous Oxalic acid.*—The common oxalic acid, as is well known, is a crystallized hydrate $C_2H_2O_4.(H_2O)_2$, which loses its crystal water on heating. VILLIERS has observed that this acid may be obtained in beautiful crystals containing no water by dissolving it in small quantities in warm concentrated sulphuric acid, about one part of oxalic acid to twelve of sulphuric. After some days, and even after months sometimes, octahedrons are deposited, having the composition $C_2H_2O_4$. They are bulky and very clear, and are right octahedrons with a rhombic base, generally modified by the face *p* of the fundamental prism. On exposure to the air, the crystals rapidly absorb water and lose their transparency, taking up two molecules of water, and efflorescing in a curious manner. A furrow is formed at first along each of the edges of the octahedron, and the crystal splits into eight tetrahedrons, which rapidly fall to powder. In this octahedric form oxalic acid has so strong an attraction for water that on dissolving it in ordinary sulphuric acid, crystals of the hydrate are deposited. It sublimes, giving long prisms quite different in appearance from the crystals obtained by solution. Whether the acid is dimorphous the author has not been able to determine, owing to the minuteness of the crystals.—*Bull. Soc. Ch.*, II, xxxiii, 415, May, 1880. G. F. B.

5. *On the Continuous Preparation of Ethyl Acetate.*—PABST has devised a continuous process for the preparation of acetic ether, analogous to that by which ethyl ether is made. A mixture of 50 c.c. of sulphuric acid and 50 c.c. of alcohol is introduced cold into a retort, and then by means of a funnel tube closed with a cock, equal molecules of alcohol and of glacial acetic acid—one liter of alcohol of 96 p. c., and one liter of acetic acid of 98 p. c.—are allowed to run into it slowly as soon as the temperature has reached 140°. At first a little ethyl ether distills over, but then a liquid begins to come over regularly which contains 85 p. c. of acetic ether. The reaction begins at 130° to 135°, and at 145° a little sulphurous oxide is formed. The sulphethylic acid formed is decomposed by the acetic acid and reformed again by the alcohol simultaneously added. The distillate is washed with a saturated solution of calcium chloride, dried over

the melted salt, and fractionated. In one operation 1350 grams of pure acetic ether was obtained, being 90 per cent of the theoretical yield. Methyl acetate is readily made in the same way, but amyl acetate requires too high a temperature.—*Bull. Soc. Ch.* II, xxxiii, 350, April, 1880. G. F. B.

6. *On the Alkaloids of Belladonna, Datura, Hyoscyamus and Duboisia.*—LADENBURG has continued his researches on the mydriatic—or pupil-dilating—alkaloids. He finds that *Atropa belladonna* contains at least two alkaloids, which, on account of their specific gravities, he distinguishes as heavy and light atropine. The former is the alkaloid known commonly by this name, $C_{17}H_{23}NO_3$. It is characterized by a lusterless gold salt fusing at 135°–137°. The latter fuses at 170°, forms a scarcely crystalline light powder, and gives a gold salt fusing at 159°. It must be considered as identical with hyoscyamine. *Datura stramonium* contains also two alkaloids, which also may be distinguished as heavy and light, the latter predominating. The difficultly soluble heavy daturine fuses at 113·5°–114°, and is a mixture of atropine and hyoscyamine, which may be separated by re-crystallizing the gold salts. Indeed, repeated re-crystallization of daturine from dilute alcohol, yields pure atropine. Light daturine is identical with hyoscyamine. *Hyoscyamus* contains two alkaloids, distinguished as crystalline and amorphous. The former gives a gold salt in brilliant plates fusing at 159°, and not fusing in boiling water like the atropine salt. Hyoscyamine itself fuses at 108·5°, atropine at 113·5°–114·5°. The former separates from its solutions as a gelatinous mass, and crystallizes only in fine needles. Amorphous hyoscyamine contains a new alkaloid, which forms a beautiful gold salt, fusing higher than those of atropine or hyoscyamine. The author is now investigating it. Duboisia yields only one alkaloid, duboisine, which the author has already identified with hyoscyamine.—*Ber. Berl. Chem. Ges.*, xiii, 909, May, 1880. G. F. B.

7. *On the Synthesis of Chinoline.*—KOENIGS has given a new and more convenient synthesis of chinoline. Baeyer's first synthesis was obtained with hydrocarbostyril, and the author's with allyl-aniline. He now finds that acrolein-aniline affords chinoline easily on dry distillation. The well-dried reddish-yellow mass was distilled in portions of 25 grams, and the distillate was purified by treatment with sulphuric acid and bichromate. It contains beside chinoline, a less volatile base. After repeated oxidation the chinoline was distilled from the alkaline liquid by a current of steam, and separated from the water by solution in ether. The yield is larger when one part aniline, 1½–2 parts sulphuric acid and one part of glycerin are heated to 180°–190°. Acrolein-aniline is formed and at once oxidized to chinoline. Skraup prefers a mixture of nitrobenzene and aniline, which affords 25 per cent of chinoline.—*Ber. Berl. Chem. Ges.*, xiii, 910, May, 1880. G. F. B.

8. *On two Compounds formed by Urea with Gold Chloride.*—HEINTZ has shown that when gold chloride and urea are dissolved together, yellow crystals are deposited which are a mixture of two compounds of the gold chloride and urea, which are easily separated by recrystallization. One of these crystallizes in orange-red needle-like prisms, permanent in the air, and having the composition $AuCl_4H(CH_4N_2O).H_2O$. The other has the composition $AuCl_4H(CH_4N_2O)_2$. It crystallizes in fine yellow needles, is permanent in the air, and fuses at about 100°. Very soluble in water and also in alcohol and ether.—*Liebig's Annalen*, ccii, 264, April, 1880. G. F. B.

9. *Relation between the Velocity of Light and the Density of Bodies.*—Herr H. A. LORENTZ refers to the fact that Maxwell's theory of light has been examined chiefly in relation to the questions of velocity and of reflection and refraction, and proposes to himself to examine the relation between the index of refraction n and the density d of a body, under the supposition that Maxwell's theory is true. He starts with the hypothesis that an ether exists between the molecules of a body, and that in the immediate neighborhood of the molecule the state of this ether does not differ from that which it possesses in a vacuum. He also supposes that in each molecule of an isotropic body an electromotive force awakens an electrical moment proportional to itself and directed in like manner; that Coulomb's law holds for very small distances. Under these suppositions the calculations conduct to a relation between the specific inductive capacity K of a non-conductor and its density. Connecting this result with the equation $K=n^2$ found by Maxwell, the author finds that with a change of density the equation

$$\text{eq. (1)} \quad \frac{n^2-1}{(n^2+2)d} = \text{constant} = k$$

must hold. Under the supposition that all the molecules are not equal, one can obtain formulas for the index of refraction of a mixture. It follows that $\frac{n^2-1}{(n^2+2)d}$ also in this case must be equal to a constant, and also that between this value and the analogous constants

$$\frac{n_1^2-1}{(n_1^2+2)d_1}, \quad \frac{n_2^2-1}{(n_2^2+2)d_2} \text{ etc.,}$$

which result from the conditions of the mixture, the relation

$$\frac{n^2-1}{(n^2+2)d} = a_1\frac{n_1^2-1}{(n_1^2+2)d_1} + a_3\frac{n_2^2-1}{(n_2^2+2)d_2} + \text{etc.}$$

must hold. In this latter equation a_1, a_2, etc. are the units of mass of the portions in the unit of weight. The constant k in eq. (1) is found to be independent of the wave length of light; but calculations and comparisons are given which show that indices of refraction of glycerine, alcohol, chloride of zinc and sulphide of carbon change less than the theory indicates as the wave length of light diminishes. The author concludes that the departures of the observed from the calculated values, both in the case of solid and fluid bodies must be ascribed to the same cause, and are in conformity with the fact that in flint glass the increase of the index of refraction is greater, the smaller the wave length employed, and that in crown glass the index of refraction diminishes with heating when great wave lengths are employed, and increases when small wave lengths are used. The author discusses the departures from his theory and intimates that they are due to certain electrical conditions among the molecules and atoms of compounds.—*Annalen der Physik und Chemie*, No. 4, 1880, p. 641. J. T.

10. *Aurora Borealis.*—In a recent paper read before the Royal Society, Mr. WARREN DE LA RUE and Mr. HUGO W. MÜLLER stated their conviction that at the height of 37·67 miles above the sea level, the atmosphere would have a pressure of 0·379 millim., and the display of the aurora would be of maximum brilliancy and would be visible at a distance of 585 miles. The greatest exhaustion they have been able to produce 0·000055 millim., corresponds to a height of 81·47 miles and 11,000 cells failed to produce a discharge in hydrogen at this pressure. At the height of 124·15 miles the pressure would be only 0·00000001 millim., and they do not believe that an electric discharge would occur "with any potential conceivable at such a height." The discharge in air at a pressure of 62^{mm} has a carmine tint, and corresponds to an altitude of 12·4 miles and would be visible at a distance of 356 miles. At pressure of $1·5^{mm}$ corresponding to a distance of 30·86 miles, the discharge becomes salmon colored and has lost the carmine tint. At a pressure of $0·8^{mm}$ corresponding to 33·96 miles, the discharge becomes of a paler salmon color, and merges into a pale milky white. The authors think it conceivable that the aurora "may occur at times at an altitude of a few thousand feet."—*Nature*, May 13, 1880, p. 33. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Report on the Geology of the High Plateaus of Utah*, with Atlas; by C. E. DUTTON, Captain of Ordnance, U. S. A., U. S. Geogr. and Geol. Survey of the Rocky Mountain Region, J. W. Powell in charge: Department of the Interior. 307 pp., 4to, with eleven heliotype plates, and a folio Atlas. Washington, 1880.—The region which is the subject of this report is one of unexcelled grandeur in the extent of its mountain plateaus, in its simple system of geological structure and displacements, and in the magnitude and diversity of the effects of erosion, and Captain Dutton, in his account of it, shows that he is capable of appreciating and discussing the geological problems which it presents.

The High Plateaus, as the Report states, occupy a large part of the southern half of Utah, commencing, on the north, at a point in the Wahsatch range about 15 miles east of Mount Nebo, and having a length of about 175 miles, with a breadth of 25 to 80 miles. The region is divided by two profound, nearly north and south valleys; a western, along the Sevier River, which here flows north to the westward bend that takes it to Sevier Lake, "a wretched salina of the Great Basin;" and an eastern, called Grass Valley, along two tributaries of the Sevier, a northern and southern, which combine to make the "East Fork of this river." On the west of the Sevier Valley, three plateaus are distinguished, namely, commencing to the north: the Pavant, "a curious admixture of plateau and sierra;" the Tushar, "its northern half a wild, bristling cordillera, its southern, conspicuously tabular;" and the Markágunt, "a true plateau," about 11,000 feet in height. Between the Sevier and Grass Valleys there are two plateaus, the Sevier, 80 miles long, cut through near its middle by the east-and-west gorge of the East Fork; and south of this the Paunságunt plateau, "bounded on three sides by lofty battlements of marvelous sculpture and glowing color." East of Grass Valley, and its line to the south (along which commences the Paria River), three plateaus are distinguished: the Wahsatch, extending somewhat farther north than the Pavant (to the parallel of 40°), where it joins, in an *en echelon* way, the Wahsatch range proper; the Fish-Lake plateau east of Fish Lake, but 15 miles long, yet 11,400 feet high; the Awapa plateau, which almost blends with the preceding but is of less altitude, and is 30 miles long by 20 in breadth, its top a treeless, rolling prairie, sloping feebly to the eastward; and the Aquarius, 11,600 feet high in its eastern part, 35 miles in length by 10 to 18 in breadth, the grandest of all the High Plateaus, its "three sides, the south, west and east, walled by dark battlements of volcanic rock," and descending to "the dismal desert in the heart of the Plateau country," while its broad summit is clad with forests of spruce, and has its grassy parks and scores of snow-fed lakes.

The wonderful contrast between the desert country below to the south and southeast, "dismal and suggestive of the terrible," and the forest-covered summit of the Aquarius plateau, has much meteorological interest as regards the whole mountain region, and we cite a paragraph from page 285 of the report.

"The ascent leads us among rugged hills, almost mountainous in size, strewn with black bowlders, along precipitous ledges, and by the sides of cañons. Long detours must be made to escape the chasms and to avoid the taluses of fallen blocks; deep ravines must be crossed, projecting crags doubled, and lofty battlements scaled before the summit is reached. When the broad platform is gained the story of 'Jack and the beanstalk,' the finding of a strange and beautiful country somewhere up in the region of the clouds, no longer seems incongruous. Yesterday we were toiling over a burning soil, where nothing grows save the ashy-colored sage, the prickly pear, and a few cedars that writhe and contort their stunted limbs under a scorching sun. To-day we are among forests of rare beauty and luxuriance; the air is moist and cool, the grasses are green and rank, and hosts of flowers deck the turf like the hues of a Persian carpet. The forest opens in wide parks and winding avenues, which the fancy can easily people with fays and woodland nymphs. On either side the sylvan walls look impenetrable, and for the most part so thickly is the ground strewn with fallen trees, that any attempt to enter is as serious a matter as forcing an *abattis.* The tall spruces (*Abies subalpina*) stand so close together, that even if the dead-wood were not there a passage would be almost impossible. Their slender trunks, as straight as lances, reach upward a hundred feet, ending in barbed points, and the contours of the foliage are as symmetrical and uniform as if every tree had been clipped for a lordly garden. They are too prim and monotonous for a high type of beauty; but not so the Engelmann spruces and great mountain firs (*A. Engelmanni*, *A. grandis*), which are delightfully varied, graceful in form, and rich in foliage. Rarely are these species found in such luxuriance and so variable in habit. In places where they are much exposed to the keen blasts of this altitude they do not grow into tall, majestic spires, but cower into the form of large bushes, with their branchlets thatched tightly together like a great hayrick."

This meteorological contrast, as the author remarks, is explained by the fact that the summit receives not far from 30 inches of rain a year, because so high among the clouds, while the low country around has but 4 to 8 inches.

The southern boundary of these High Plateaus is near the southern boundary of Utah, the parallel of 37°. Beyond, lies the Plateau country, described by Powell, the region of the Shiwits, Uinkaret, Kanab, Kaibab and Paria plateaus, on the north side of the "Grand Cañon" of the Colorado,—which here extends nearly east and west between the parallels of 36° and 36° 30′,—and of "Marble Cañon," "Kanab Cañon," "Hurricane Cliffs," "Echo Cliffs," and other remarkable features.*

The Henry Mountains, described by G. K. Gilbert, stand 30 miles to the east of the Aquarius plateau.

In the geological account of these plateaus the author treats of the geological formations, the positions and disturbances of the strata, and the bearing of the facts on questions connected with mountain-making, the distribution and character of the igneous rocks, the nature and origin of volcanic action, and the results, methods and period of erosion.

The distribution of the formations is exhibited on a large colored chart. They include the *Carboniferous*, making the summit and western side of the Pavant or northwestern plateau; the *Triassic*, in Western Utah, at the eastern base of the Awapa and Aquarius plateaus, and with it the *Jurassic*, and the latter also outcropping in narrow strips in the Sevier River Valley; the *Cretaceous* (with which the Laramie or Lignitic group is united by Captain Dutton), bordering the plateaus and rising, in several of them, nearly to the summit; the *Eocene Tertiary*, constituting part of the slopes on the north, south and east of the plateaus,

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* See Powell's Report on the Uinta Mountains; also this Journal, III, xii, 420, and Dana's Manual of Geology, edition of 1880, page 792.

and making the summit formation of the Wahsatch Plateau on the north, of small portions of the Fish-Lake and Tushar plateaus, and of a large part of the Markágunt plateau in the southwest. Going from the southern plateaus southward to the Colorado, a wide area of Eocene Tertiary is first passed; then bands, in succession, of Cretaceous, Jurassic, Upper Trias, Lower Trias, (Shinarump Group), and Carboniferous.

The youngest group in the series clearly made out (the Quaternary excluded) is thus the Eocene; and it would be the summit formation generally were it not for the erosion that has taken place, and still more for the covering of igneous rocks. These Eocene beds are part of an extended lacustrine formation—as first recognized by Marsh. They are described as 5,000 feet thick around the flanks of the Uintas and southern Wahsatch, and as thinning, outward from these mountains, to nearly or quite 2,000 feet.

The volcanic rocks are spread over the summits of the Aquarius, Awapa and Fish-lake Plateaus on the east, the great central Sevier Plateau, and the Tushar and Markágunt Plateaus on the west; and they have a thickness in some parts of 4,000 or more feet. The rocks are chiefly trachytes, with some andesyte, propylyte and doleryte; and the trachytes are described as intermediate in age between the andesyte and propylyte, which are the oldest, and the dolerytes, but as in alternating beds in some places with the last. In the Awapa and Aquarius Plateaus, the trachyte shows a thickness, in some of the profound gorges, of 3,000 feet. The volcanic eruptions are stated to have begun in the middle Eocene, and a few of the foci are still distinguishable. The basaltic eruptions in some places look, "so far as appearance is concerned," as if they "might have been erupted less than a century ago." Besides the eruptive beds, volcanic conglomerates are widely distributed, they covering an area of 2,000 square miles, and being in some parts 2,500 feet thick. In some places they have been so changed as to lose their fragmental character, and become in appearance closely like true eruptive rocks (a fact which has been observed also in the Andes and in Mexico). But they fail, says Captain Dutton, of the fluidal character and glass inclusions of the latter. For the author's discussions with regard to the volcanic rocks and volcanic action and its causes, the reader is referred to the Report.

The disturbances in the plateau region have resulted in a general uplifting, and also in monoclinal flexures, and in fractures and faults; and the faults are mostly in the line of monoclinal uplifts, as brought out by Powell in his description of the Colorado region on the South. The flexures and faults, as is well illustrated in the Atlas, have approximately a north-and-south course, and are, in part, a continuation of those of the Colorado region on the South. The "Hurricane fault" has its southern limit at some undetermined point in Arizona, south of the Colorado, and, at its crossing of the Grand Cañon, it is the line of a displacement of 1800 feet. It is the western boundary of the Markágunt uplift (the southwestern), making at one place a displacement of 5,000 feet, and at the southwest base of the Markágunt elevation, bringing up the Carboniferous to a level with the Tertiary, a displacement of 12,000 to 13,000 feet. It reaches north to the west side of the Tushar plateau and by the east side of the Pavant. Other faults have less extent, but there is great similarity among them in character and direction. The amount of throw is, in general, from a few hundred feet to 3,000 feet. The time when these displacements took place is not indicated by the displaced beds, for no beds occur later than Eocene. Captain Dutton refers the principal displacement to the middle Pliocene, and suggests, on the ground of facts connected with the erosion of the region, that some may have been formed even as late as subsequent to the Glacial period. These displacements are wholly distinct from those which occurred at the mountain-making epoch after the Laramie period, upturning the Cretaceous and inferior beds, being a result of subsequent movements. After that epoch a large part of the Rocky Mountains was raised from near the ocean's level; and the production of the monoclinal flexures, long lines of faults, great volcanic eruptions, and profound denudation must have been dependent more or less on this grand movement or the causes producing it.

Captain Dutton points out the contrast between the simple mononclinal flexures and nearly horizontal bedding of the Plateau mountain region and the high dips and numerous folds of the Appalachians. The contrast is not so striking when the comparison is made with the Cumberland Table Land and its continuation southwestward into Tennessee and northward into Southern New York and the Catskills, which are parts of the results of the Appalachian revolution; and may it not be that the High Plateaus are in a similar way the denuded outskirts of the Wahsatch, which afterward became somewhat crumpled and displaced, while the uplift of the Rocky Mountain region was in progress.

The subject of erosion is treated ably and with full appreciation of the grandeur and geological interest of the results in this Plateau region; and several heliotypes represent some of the wonderful scenes in the mountains. The author estimates that on an average, at least 6,000 feet of rock in depth have been removed from the Plateau Province since the erosion began, that is, during the Miocene and subsequent time—from an area of 10,000 square miles. The erosion was least in the High Plateaus, the average being less than 1,000 feet, chiefly because of the protection they received from the covering of volcanic rocks. He says (pp. 21, 22):

"The great erosion of the Plateau Province was most probably accomplished mainly in Miocene time, but continued with diminishing rapidity throughout the Pliocene. But it is necessary to say that the terms Miocene and Pliocene have here no definition. They cannot be correlated except in a very general manner with events occurring outside the province. We have only a vast stretch of time, with an initial epoch near the close of the local

Eocene. The greater part of the denudation is assigned to the Miocene, because the conditions appear to have been more favorable to a rapid rate of destruction in that age than subsequently. The climate appears to have been humid, while the elevation was at the same time gradually increasing, both conditions being favorable to a rapid disintegration and removal of the rocks. The Pliocene witnessed the gradual development of an arid climate similar to that now prevailing there. To this age belong the cañons and the great cliffs, which could not have been produced in an ordinary or humid climate, nor at low altitudes. That this aridity is by no means a condition of recent establishment is indicated by many evidences. They consist of remnants of a former topography, preserved in a few localities from the general wreck of the land, and which show the same general facies of cliffs and cañons as those of more recent formation. And as the more recent sculpture owes its peculiarities in great part to the aridity, so, we conclude, must these more ancient remnants. The Kaiparowits Plateau presents an excellent example. Its surface is in many places rendered utterly impassable by a plexus of sharp narrow cañons, of which the heads have been cut off by the recession of the gigantic cliff which forms the eastern wall of the plateau. They have long been dug, and have remained with but little change for an immense period of time.

"And now the relation of the High Plateaus to the Plateau Province at large becomes evident. They are the remnants of great masses of Tertiary and Cretaceous strata left by the immense denudation of the Plateau Province to the south and east. From the central part of the province the Tertiary beds have been wholly removed and nearly all of the Upper Cretaceous. A few remnants of the Lower Cretaceous stretch far out into the desert, and one long narrow causeway, the Kaiparowits Plateau, extends from the southeastern angle of the district of the High Plateaus far into the Central Province and almost joins the great Cretaceous mesas of Northeastern Arizona, being severed from them only by the Glen Cañon of the Colorado. The Jurassic has also been enormously eroded. This formation, which is of great importance and bulk in the northern and northwestern portion of the province, and especially around the High Plateaus, appears to have thinned out toward the south and southeast. In large portions of New Mexico it is wholly wanting and was probably never deposited there. In the northwestern portion of that Territory only a few thin beds of that age are found. But in the northern part of the province a conspicuous and wonderful sandstone formation of most persistent character is found, overlaid and underlaid by shales holding a distinctly Jurassic fauna. This formation once extended over the Grand Cañon area probably as far south as the river itself, and possibly farther, but has all been swept away as far north as the southern end of the district of High Plateaus. From the region east of the High Plateaus also very large areas of it have been removed. The Upper

Trias has also been greatly denuded, and the Lower Trias nearly as much so. The erosion of the Carboniferous has been small, being confined chiefly to the cutting of cañons—most notably the Grand and Marble Cañons, which are sunk wholly in that series; and in several places have been cut through the entire Palæozoic series system."

In the discussions with regard to the nature of volcanic action and the origin of mountain disturbances, Captain Dutton rejects the idea of the earth's interior liquidity, and holds that the theory of the earth's contraction, as a cause of movement, is inadequate to account for the facts. At the same time he acknowledges that, in his view, the source of the heat of volcanic action, and that of the force producing the greater changes of level in the earth's surface, are yet without satisfactory explanation. In connection with his remarks on the erosion in the Plateau region, he queries whether the removal of 6,000 to 10,000 feet of rock material over so large an area would not "have disturbed the earth's equilibrium of figure, and the earth, behaving as a quasi-plastic body, have re-asserted its equilibrium of figure, by making good a great part of the loss by drawing upon its whole mass beneath?" He further says that, to account for the uplifts as well, we must almost necessarily refer to the operations of "that mysterious plutonic force which seems to have been always at work and the operations of which constitute the darkest and most momentous problem of dynamical geology;" and also "recognize the coöperation of that tendency, which indubitably exists within the earth, to maintain the statical equilibrium of its levels." But to appreciate rightly the relations of the uplifts to the erosion, and their relative influence on this equilibrium, we have to remember that during the very period of erosion, when 6,000 feet in average depth was being removed (that is, after Eocene time), the mountain region was undergoing an elevation of full twice 6,000 feet.

But the reader should refer to the volume for the author's full discussions on these and the other topics, here briefly reported. The Report is made in all parts very readable by the author's graphic descriptions of the region and of the events in its geological history. J. D. D.

2. *Pennsylvania Geological Survey. The Geology of Mercer County;* by I. C. White. Report No. QQQ. 234 pp. 8vo, with a colored geological map of the county and 119 vertical sections.–This Report is occupied mostly with details respecting the strata and their coal beds, which pertain to the "Productive Coal measures," the conglomerate measures underneath, and the sub-conglomerate, which last are exposed to view only along the principal streams. A large part of the county is covered by Drift, and interesting observations are presented with regard to it. The distribution of large bowlders over the top surface of the Drift, and also in the body of it, leads the author to the conclusion that the transportation was not done by icebergs but by glacier ice. The fact that these bowlders are limited in their southward distribution in Western Pennsyl-

vania by the Ohio River, that they occur abundantly north of it, "covering the surface like flocks of sheep," and not south of it, where there is nothing in the topography to give such a limit to transport by icebergs, is stated to be evidence on this point. The author observes that the rivers of the county, like those of the adjoining Beaver and Lawrence Counties, discussed in his former report (No. QQ), flow over a great thickness of stratified silt, sand and gravel, even 700 feet in some cases, showing that the original rocky bottom is thus deeply buried.

3. *Annual Report of the Wisconsin Geological Survey for the year* 1879; by T. C. Chamberlin, Chief Geologist. 72 pp. 8vo. Madison, Wisconsin, 1880.—Besides details respecting the distribution of collections of fossils, this Report contains descriptions of new Paleozoic fossils by R. P. Whitfield, and descriptions of three species of Fungi by W. F. Bundy. Of the fossils the following are from the Potsdam sandstone: *Holopea Sweeti*, *Conocephalites? quadratus*, *C.? explanatus*, *Ptychaspis striata*, *Dicellocephalus Lodensis*, and *Aglaspis Eatoni*. Mr. Whitfield describes also new species from the Trenton, Hudson River group, and Niagara, and one, a Discina, from beds of the Hamilton period.

4. *Report on the Florida Reefs;* by Louis Agassiz. Accompanied by illustrations of Florida Corals from drawings by A. Sonrel, Burkhardt, A. Agassiz and Rœtter. Memoirs of the Museum of Comparative Zoology at Harvard College, vol. vii, No. 1. 62 pp. 4to. Plates i to xxiii. Cambridge, 1880.—This publication, by the Museum of Comparative Zoology, of Professor Louis Agassiz's Report on the Florida Coral Reefs, only extracts from which had appeared in the Coast Survey Report for 1851, is making accessible one of the most interesting of his memoirs, and giving it augmented value through the addition of plates of Florida Corals. These plates, which have great beauty and perfection, were drawn and lithographed for the original report, but were never published. To the volume Mr. Alexander Agassiz has added the sketch of Florida from Professor Agassiz's "Methods of Study," based upon his investigations of the reefs (all which were carried on under the auspices of the Coast Survey), and, for the convenience of the reader, a sketch map of Southern Florida and the Keys, compiled from Coast Survey Maps.

5. *Early Man in Britain, and his place in the Tertiary Period;* by W. Boyd Dawkins, M.A., F.R.S., etc. 538 pp. 8vo, with many wood-cuts. London, 1880. (Macmillan & Co.).—This treatise, on Early Man in Britain, is by one of the ablest and most judicious geologists of Great Britain, who has done much "cave hunting," and speaks largely from personal observation. It follows a work on Cave Hunting by the same author, published in 1874. While devoted especially to facts in Britain, it gives a general review of those of Europe; and, besides treating of human remains, relics and early history, it embraces a comprehensive sketch of the Tertiary Mammalia, and of the geographical and climatal conditions and changes during the Tertiary and Quater-

nary. The illustrations—over 160 in number—are excellent, and include maps, copies of many sketches or drawings of the Stone age, and representations of human remains and implements, and other objects throwing light on ancient human history. With regard to man in the Tertiary, we cite a few sentences from the concluding chapter:

"Nor is it likely that he [Man] lived in Europe in the Pliocene age, after the land connecting Britain with Greenland had been submerged and the Atlantic was united to the North Sea and the Arctic Ocean, because the living species of Mammalia are so few. When the living species became abundant, he appears just in the Pleistocene stage in the evolution of Mammalian life in which he might be expected to appear. The River-drift man first comes before us, endowed with all human attributes, and without any signs of a closer alliance with the lower animals than is presented by the savages of to-day," "as a hunter, armed with rude stone implements, living not merely in Britain, but throughout Western and Southern Europe, Northern Africa, Asia Minor, and India. Next follows the Cave man, possessed of better implements, and endowed with the faculty of representing animal forms with extraordinary fidelity, living in Europe north of the Alps and Pyrenees, as far as Derbyshire, and probably belonging to the same race as the Eskimos."

6. *Recent action of Mauna Loa and Kilauea ;* by T. Coan. (From a letter to the editors, dated Hilo, Hawaii, May 3d to 6th, 1880).—Hilo is in a haze of sulphur smoke, and we see the sun as through smoked glass. We have a grand volcanic eruption.

On the first inst. a little before daylight, a herdsman, who lives about two miles out of town, reported that he had seen a light on Mauna Loa. At 8 P. M. of the same day, my wife called my attention to an unusual light in the direction of the mountain. At first it was partly obscured by clouds, so that we hesitated to pronounce it volcanic. In a few minutes, however, the revelation was clear. The clouds dispersed and the spectacle of a burning mountain opened to our sight. The action was intense. The appearance was as if a vast column of melted rock, a mile in diameter, was being poured out of the mountain with amazing force and vehement heat. Brilliant corruscations shot out in all directions, lighting up the clouds to the apparent height of 30° and spreading out for many miles along the summit of the eastern side of the mountain. The outbreak was in full view from the west side of our house, which was brilliantly lighted up by the fires, while the front part was in a deep shade, rendering the contrast striking.

This eruption occurring in the night, we were unable to determine at once its exact locality. Some thought it was in the deep summit crater, Mokuaweoweo; and others that it was at a point a few miles north of it. Since that night the mountain has been so veiled in clouds and smoke that we have not been able to see the fire. Yesterday flocks of Pele's hair, and light particles of volcanic dust and sand were dropped upon our houses and in our streets, over our walks and our gardens, having been borne upon the winds for this great distance.

May 6. Our mail leaves to-day, and I deeply regret that we have not seen the great fire since the night of the first and second inst. A dense cloud has rested upon the mountain by night and day, so impervious that no light shines through it.

We have, however, learned by people coming from Puna, and from Kau, *via* Kilauea, that the roaring furnace is still in fierce blasts, and that its locality is probably in the terminal crater, Mokuaweoweo. Some affirm that there are three points of active eruption upon the mountain, and that lava streams are flowing, but these reports are not fully reliable.

Optical delusion and excited imagination often see unreal visions. During the terrific eruption and the rending earthquakes of 1868, men and women of entire veracity saw, as they thought, rivers of fire come down from the mountain and plunge into the sea, within three miles of them, and all this in open day, with nothing to obstruct their view, and yet, on going to the place where this lava flowed, as they asserted in all honesty, there was no mark or smell of fire.

Since my former letter, dated June 20, 1879, *Kilauea* has resumed great activity. Rarely in its recorded history have the fires been more intense or the filling up more rapid. The number of visitors is fast increasing, and they all bring glowing reports of the intense activity of the fires.

Lateral streams of liquid rock are bursting through the scoriaceous sides of Halemaumau—the lake and cone in the southwest part of the crater—and flowing down the declivities into the central depression, adding stratum to stratum, while the great lake boils, and dashes its waves against its walls, and sends its burning spray high into the air. The debris around the high walls of the lake is so hot and brittle that most parties who visit the crater do not venture near the burning cauldron, but mount some quiet eminence about one-quarter of a mile from its margin, where they can witness its ragings, and listen to its splashings and mutterings with safety.

7. *Glaciation of the Shetland Isles.*—A paper on this subject, well illustrated by a geological map showing the direction of the glacial striæ, by B. N. Peach and J. Horne, is published in the Quarterly Journal of the Geological Society for 1879.

8. *Relief Geological Map of New Hampshire.*—A relief geological map of the State of New Hampshire, after Professor C. H. Hitchcock's geological map, on the scale of two and a half miles to the inch and measuring four feet by six, is being made by Mr. Joseph Schedler, a map engraver of New York City.

9. *Brief Notices of some recently described Minerals.—Fredricite:*—A mineral related to tetrahedrite, but characterized by its containing lead and tin. It occurs only massive; the color is iron-black; hardness =3·5; specific gravity =4·65. An analysis yielded:

S	As	Cu	Pb	Sn	Ag	Fe	Sb		
27·18	17·11	42·23	3·34	1·41	2·87	6·02	*tr.*	=	100·16

This corresponds to the general formula 4RS, As_2S_3, or that of an arsenical tetrahedrite. It is described by Hj. Sjögren as occurring with galenite and geocronite at the Faln mine in Sweden. —*Geol. För. Förhandl. Stockholm*, v, 82, March, 1880.

Orizite :—Occurs in minute crystals and crystalline grains, having the luster and color of rice kernels. Hardness =6; specific gravity =2·245. The composition is the same as that of heulandite with which it is considered by the describer, G. Grattarola, as dimorphous. Locality: the tourmaline granite of San Piero in Campo.—*Atti Soc. Toscana*, ii, 7.

Pseudonatrolite :—Occurs in minute colorless crystals, probably orthorhombic. Hardness =6; luster glassy to pearly. An analysis afforded:

SiO_2	Al_2O_3	CaO	MgO	Na_2O,K_2O		
62·64	14·76	8·54	*tr.*	1·00	=	101·76

It is regarded as a new zeolite. Described by Grattarola (l. c.) from the same locality as *orizite.*

Mallardite; Luckite :—Two minerals from the Lucky Boy silver mine, Butterfield Cañon, Utah; described by A. Carnot (C. R., lxxxviii, 1268, 1879). *Mallardite* occurs crystallized in a gray clay-like vein stone with quartz and barite. When fresh it is colorless but changes rapidly in the air, effloresces and becomes opaque. The composition is expressed by the formula $MnSO_4+$ 7 aq, or the same as the artificial salt.

Luckite is found in indistinct striated prisms of a bluish color, occurring in a black bituminous rock. It probably belongs to the monoclinic system. The composition, as given by the analysis, corresponds to the formula $(Mn, Fe)\ SO_4+7$ aq.' It is consequently near to mallardite but contains 21·7 p. c. FeO.

Guejarite :—Occurs with siderite in the copper veins in the distrite of Guejar, Andalousia. It is found in orthorhombic crystals of a steel gray color. Hardness =3·5; specific gravity =5·03. The chemical composition is given by the formula $Cu_2S+2Sb_2S_3$, which places it near chalcostibite. Described by Cumenge and Friedel.—*Bull. Soc. Min. France*, Nov., 1879.

Beccarite :—A variety of zircon, differing from that mineral in its optically biaxial character, and in composition. An analysis gave:

SiO_2	ZrO_2	Al_2O_3	CaO	Ign		
30·30	62·16	2·52	3·62	0·32	=	98·92

Brought by Dr. Beccari from Point de Galles, Ceylon, and described by G. Grattarola.—*Atti Soc. Tosc.*, vi, 1879.

Mixite :—An emerald- to bluish-green mineral as an incrustation on bismuth ochre, and also in granular, and irregular massive particles, sometimes spherical in form and in part crypto-crystalline. An analysis yielded:

As_2O_5,P_2O_5	Bi_2O_3	CuO	FeO	CaO	H_2O		
30·45	13·07	43·21	1·52	0·83	11·07	=	100·21

The empirical formula obtained is $Cu_{20}Bi_2As_{10}H_{44}O_{70}$. Described by Schrauf as occurring with torbernite and bismutite at Joachimsthal.—*Zeitsch. Kryst.*, iv, 277, 1880.

10. *Analysis of the Meteoric Iron from Cleberne Co., Alabama;* by J. B. MACKINTOSH, E.M. (Communicated by W. E. Hidden.)—The following is an analysis of the meteoric iron from Chulafinnee, Cleberne Co., Ala., described by W. E. Hidden, in the May number (p. 370) of this Journal; the analysis is by J. B. Mackintosh:

Fe 91·608, Ni 7·368, Co 0·500, P 0·170=99·646

11. Thirtieth and Thirty-first Annual Reports of the New York State Museum of Natural History. Albany, 1879.—The first of these reports, "transmitted to the Legislature April 13, 1877," contains the Report of the Botanist, C. H. Peck, occupying 56 pages; a paper on the lithology of the Adirondacks, by A. R. Leeds, 32 pages; another on the structure of *Astræospongia meniscus*, by Drs. J. W. Hall and R. Fritz-Gærtner, 6 pages; and entomological contributions, No. IV, by J. A. Lintner, 130 pages. The second contains: a Report of the Botanist, C. H. Peck; notes on some sections of Trilobites from the Trenton Limestone, note upon the eggs of the Trilobite, and descriptions of new species of fossils from the Chazy and Trenton Limestone, by C. D. Wolcott; and notes on Phlogopite, by R. Fritz-Gærtner.

III. BOTANY AND ZOOLOGY.

1. *Action of Light on Vegetation.*—It is well understood that, for a plant to complete its development and mature its seeds, a certain sum of heat is required, varying according to the species. It appears -- as indeed might antecedently be expected, — that we should rather say a certain amount of solar radiation; for light, to a certain extent, may replace temperature. This is shown in the effects of almost uninterrupted summer sunshine upon vegetation in high latitudes. According to Schübeler of Christiania and others, barley ripens in 89 days from the sowing in Finland, while it requires 100 days in the south of Sweden, though the latter enjoys a considerably higher temperature. A grain of wheat grown at near the sea-level in Norway, or in lower latitudes, when propagated at high elevations or in a high latitude will mature earlier, even although at a lower temperature; and it is said that, within limits compatible with its cultivation, the grain increases in size and weight. Is this the case with Minnesota and Manitoba spring wheat?

It is inferred, and in various ways seems to be made out, that this is owing to the greater amount of light of the prolonged summer days and of the higher altitude,—a natural explanation, since it is normally or mainly under light that nutritive matter is formed. But we are not told whether the crop of Finland barley raised in 89 days, was as large as that produced in 100 days in southern Sweden under a greater sum of heat but a smaller amount of light. It is said, indeed, that the grain of wheat under such conditions is of greater size and weight, but not that the produce to the acre, or the number of grains to the ear, is increased. From the analogy of Indian corn in this country, the contrary might be expected. This crop in Lower Canada may ripen in fewer days than in Alabama, but only a precocious variety of dwarf stature and scanty product can there be raised at all in the short interval between vernal and autumnal frosts. But maize may be regarded as a tropical plant, inured to northern latitudes only by the development of precocious and dwarf varieties, and, requiring a longer season and a greater sum of heat than barley, it cannot be grown at all in latitudes high enough to enjoy this short but almost continuous sunshine.

That prolonged illumination may thus make up for a certain diminution of temperature is also inferred from the fact that the plants of high northern Europe produce larger and greener leaves than southern individuals of the same species, and the increased brightness of color in blossoms is adverted to in the same sense. Schübeler is said to have shown that biennials and perennials under these conditions lay up a greater store of nutritive matter. Flahault has carried on a series of comparative experiments in this regard, simultaneously conducted at Upsal and Paris. The mean temperature of the summer months differs only slightly, and the rain-fall is nearly the same in the two places. But the mean length of the day, between the 15th of May and the 30th of July is 17 hours 49 minutes at Upsal; at Paris, 15 hours and 38 minutes. These experiments are detailed at length in his paper in Ann. Sci. Nat. (Bot.) 6th Ser., ix, p. 159, etc., March, 1880,—to be concluded in the April number. The results, so far, favor the above mentioned conclusion.

Schübeler also makes out that grain, after several generations of cultivation in the highest latitudes or the highest elevation compatible with its cultivation, will when transferred back to its original locality ripen earlier than grain which has not been moved. But it loses this precocity in a few generations, and the seeds gradually diminish to the former size and weight. Plants raised from seeds ripened in a high northern locality are hardier than those grown in the south, and are better able to resist excessive winter cold.

Analogous conclusions are reached from the celebrated recent experiments of Dr. Siemens in England, in which the work of the sun is done by the electric light. He confirms in a striking way, —what had been otherwise shown in France,—that artificial light, even lamp-light, when of sufficient intensity, will produce all the effects of sunlight; that the electric light is particularly efficacious in producing chlorophyll and promoting growth; that an electric light equal to that of 1400 candles at a distance of two meters from growing plants has about the effect of average day-light in England; and that, while under its influence plants can sustain high stove heat without suffering. As plants run their course advantageously in the continuous day-light of an arctic summer, with mere diurnal diminution at night-fall, so Dr. Siemens has shown that electrically illuminated plants require no diurnal rest, but can be forced on, at least for a considerable time, and their development be thereby greatly expedited. Plants can be grown, therefore, by electric light,—by its aid, energy can be stored up in food and fuel,—which is an interesting rounding of the cycle of transformation; and if the contemplated electro-horticulture fails to be established, it will be because it cannot be made to pay.

An interesting portion of Flahault's paper, above mentioned (pp. 171–177), is occupied with the investigation of the cases in which chlorophyll is formed in darkness. There are two kinds of cases. 1. The cotyledons of Pines, though colorless up to the moment of germination, then turn to bright green even when light has no access to them. Here the green is certainly due to the formation of chlorophyll, and to its production without the intervention of light. This chlorophyll is here formed at the expense of nutritive matter of the albumen of the seed, taken into the cotyledons, i. e., is formed from reserve-material. Flahault finds that the young leaves of Onion and of Crocus, developing from the bulb, fed by reserve-material, equally may form some chlorophyll in darkness. Various Ferns, growing almost in darkness, have a bright green color, from well-developed chlorophyll, which must also originate from stored nutritive material; for Borodine has shown that Fern-spores will not germinate and develope in darkness, although they contain a certain amount of nutritive matter. 2. The other case is the familiar one of a bright green embryo in the seed from the time of its formation, as in Radish, Violet, Maple, and many others. But here the embryo is not formed in darkness; the coverings or surrounding parts are to a certain and considerable extent translucent, and the chlorophyll is formed during the growth of the well-developed embryo. The peculiarity is, that this chlorophyll remains for a very long while unaltered in darkness, ready to perform its functions the moment that germination brings these green cotyledons to the light of day.

Finally, there are the new researches of Pringsheim of Berlin, on the nature and functions of chlorophyll, which have attracted much attention. He infers that the physiological use of the green matter is to protect the protoplasm from combustion, or to moderate respiration; the protoplasm itself being the true agent of assimilation. Apparently he does not raise the pertinent enquiry why it is only that protoplasm which is in direct connection or union with chlorophyll which assimilates carbon dioxide at all. We await the future paper, promised by Pringsheim, in which his results and inferences may be further and more clearly developed.

A. G.

2. *Criticism of the accounts of the Brains of the Lower Vertebrates given in Packard's Zoology;*[*] by Burt G. Wilder.—It is to be hoped that Dr. Packard may have the cordial coöperation of zoologists in the effort to free the second edition of his text-

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[*] Zoology for Students and General Readers; by A. S. Packard, Jr., M.D. The American Science Series, No. VI, 1879.

book from the defects which have in some degree impaired the usefulness of the first.

Notwithstanding the assistance of Professors Cope and Gill upon the parts relating to the Batrachians and Fishes, perhaps no portions of the work stand in greater need of revision than the accounts of the brains of these groups.

There are inconsistent, incomplete, unintelligible and incorrect statements, and for convenience I mention the more important imperfections under these heads.

A. Inconsistent statements.—(1) Page 407, the "nervous cord of Amphioxus does not enlarge in the head to form the brain;" page 640, "there is only a very slight enlargement of the anterior end of the spinal cord."

(2) Page 426," the brain of the Ganoids, including Dipnoans, is as in the Elasmobranchs;" page 428, "from the nature of their brain and heart the Dipnoans are quite different from all other fishes."

B. Seriously incomplete statements.—(1) The description of the brain of " Pisces " (p. 411) applies equally well to the Batrachians and lamprey eels. (2) Page 407, the ventricle on the dorsal side of the cephalic end of the spinal cord of Amphioxus is not mentioned. (3) There is no allusion to the size and complexity of the cerebellum of most sharks, or to the apparent consolidation of the so-called "hemispheres" into a single median mass. (4) Strictly speaking, and especially in view of the published opinion of the reviser as to the " taxonomic value of the brain and heart," none of the brains of "fishes" are sufficiently described.

C. Unintelligible Statements. — (1) The brains of Marsipobranchs (p. 409), of Elasmobranchs (p. 417), and of Batrachians (p. 469), are said to be "much as in the fishes" or, "like that of fishes in general." But the reader is left in doubt as to the meaning of the word "fishes," since in the section on Teleosts it is repeatedly used as a synonym of the bony fishes alone: on page 405 it is equivalent to " Pisces;" while in the Preface it evidently denotes all below Batrachians.

D. Incorrect statements. — (1) In whatever way the word " fishes " be interpreted, the intimations of any close resemblance between their brains and those of Marsipobranchs, Elasmobranchs, and Batrachians are without foundation in fact. Especially is this the case with the group last named, since neither the Ganoids proper nor the Teleosts have been shown to possess true hemispheres, lateral lobes containing each a ventricle.

(2) Page 409, the cerebellum of the Marsipobranchs is "apparently not differentiated from the medulla." This may be true of the hag-fishes, but in lampreys the cerebellum is perfectly distinct, and larger relatively than in Menobranchus.

(3) Page 417, " the brain of Elasmobranchs is like that of fishes in general, the olfactory lobes being large and long in the skates." All investigators of fish-brains agree that the brains of the sharks, skates, and Chimæra are difficult to homologize with those of other " fishes." The olfactory lobes are likewise large and long in some sharks.

(4) From the description and figure (pp. 440, 441) of what purports to be a typical Teleostean brain, the following inferences are inevitable: bony fishes have neither thalami nor olfactory lobes; the "hemispheres" are the most anterior pair of lobes, and are similar to the true hemispheres of Batrachians. As to the optic nerves, the professed anatomist might see in the appearances presented by the side view of the brain in fig. 400, signs of their origin from the optic lobes; but the "student and general reader" would hardly venture upon this interpretation in the absence of previous explicit statement with respect to any vertebrate, and against the more obvious signification of the following sentence upon page 440, "In front arise the very large and conspicuous optic nerves."

In view of the unsatisfactory nature of our knowledge of the structure and homologies of the brains of the lower vertebrates. would it not be well for the author to state the difficulty of giving brief and at the same time accurate generalizations concerning them, and to confine himself to a somewhat full account of the brain of some Batrachain, employing as a basis the admirable paper of the late Jeffries Wyman upon "The Nervous System of *Rana pipiens.*" Attention should be called to the fact that in frogs and toads the olfactory lobes, by a rare exception, are in contact upon the middle line. The brains of Menobranchus and other tailed Batrachians do not present this rather perplexing characteristic. Menobranchus abounds in the western lakes and rivers, and in the lakes of central New York, and has some other features which especially adapt it for dissection as a typical vertebrate.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Centennial of the American Academy of Arts and Sciences.*—The American Academy, (Boston and Cambridge), which received its charter from the Commonwealth of Massachusetts in May, 1770, celebrated its hundredth anniversary on the 26th of May last. Invitations had been duly sent to all the Associate Fellows resident in other States, and to its 70 Foreign Honorary Members. Societies with which it is in correspondence, both in this country and in the Old World, were apprised of this celebration. Several of the leading Scientific Societies of the United States were represented by a delegation, notably the American Philosophical Society at Philadelphia, which was incorporated a few months earlier, and which had celebrated the centennary of its charted existence in March, although the society was organized ten or twelve years earlier.

Several foreign academies sent formal responses and congratulatory addresses; a few were represented by delegates chosen by the several societies from among their American corresponding or honorary members, and one, the Cambridge Philosophical Society, sent a representative, Prof. Greenhill, a Fellow of Immanuel College, the college of John Harvard.

The officers of the Academy and the Committee of Arrangements, having charge of the celebration, received the invited guests and delegates at the Academy's rooms at noon, and escorted them to the "Old South" church, now a historical museum, where the public exercises were held. A historical address was there to have been pronounced by the distinguished President of the Academy, the Hon. Charles Francis Adams. But his strength gave way at the last moment, and he was unable even to be present upon the occasion. His address will, however, without doubt, form a part of the printed account of the centennial celebration. In his absence, and upon marvellously short notice, a most appropriate and excellent address was pronounced by the accomplished chairman of the committee of arrangements, the Hon. Robert C. Winthrop, a lineal descendant of the first president, Governor Bowdoin, and whose associations with the Academy were therefore little less intimate than those of Mr. Adams, whose father and grandfather had been presidents of the society before him.

A poem, written for the occasion, was delivered by Dr. Oliver Wendell Holmes, and short addresses followed from a surviving Ex-president (Professor Gray), Prof. Wm. B. Rogers, and from the Very Rev. Dr. Howson, the Dean of Chester, who was present as a guest.

The Fellows of the Academy then repaired to their hall, at the Athenæum, where a bountiful collation was spread. At its close short addresses were made by several delegates, by the President of Harvard University, and others.

At the adjourned annual meeting, on the 9th of June, Mr. Adams having declined further service, Professor Joseph Lovering was elected President, and Professor Oliver Wendell Holmes, Vice-President. Professors Cooke and Trowbridge were re-elected Secretaries.

2. *On the Recurrence of Solar Eclipses, with Tables of Eclipses,* from B. C. 700 to A. D. 2300.—This is the title of a paper by Prof. SIMON NEWCOMB, Superintendent of the American Ephemeris and Nautical Almanac, to which the attention of teachers should be specially called.

It is a new method, and by far the most simple and most remarkable that has ever been published; presenting an entirely new theory of their recurrence, founded on properties of the Cycle called the Saros, which have hitherto not been observed or utilized. The moon's orbit, as well as that of the sun, is divided naturally by this cycle into 223 equal parts, and the points of division are called by the author "conjunction points." All solar eclipses are then naturally divided into classes and grouped together by the conjunction point at which they must occur. Each group extends over a period of more than a thousand years, the individual eclipses of a group, however, being separated, of course, by the interval of the saros—18 years and 10 or 11 days. The number of eclipses belonging to each group is therefore between sixty and seventy. The first of a group occurring at the descending node takes place near the north pole of the earth, each succeeding one a little further south, and finally the last passes off near the south pole. The order is reversed for a group that occurs at the ascending node. Formulæ are deduced by which tables are so constructed that the time of the occurrence of any one of the group is found by first deducing approximately that of the central one, the number of the cycle of the required one, and thence the exact time of its occurrence. The number of eclipses of any year, and the time of their occurrence, is the work of but a few moments.

The student generally learns to compute eclipses altogether mechanically, without seeing any connection between his work and theory, and so loses very soon his interest in any of the usual methods. But experience with a small class proves it is not so with this. He realizes the connection between the tables and formulæ, seems to apprehend clearly every step he takes, is astonished to find he can so readily trace the shadow path over the surface of the earth, determine any phase at any point of it he chooses, and most of all, surprised to find he can do all this for an eclipse to occur a hundred years hence, a hundred years ago, or for *any one in the whole period of* 3,000 *years*, just as readily and accurately as for one that is to occur in the immediate future.

It is very desirable that an interest in the method may be taken by educators, such that the author may be induced to prepare an edition specially adapted to students. A. H. BUCHANAN.

Cumberland University, Lebanon, Tenn.

3. *Multiplication and Division Table, containing the products of numbers between* 1 *and* 100, *for the use of Accountants, Computers, and Teachers in the Primary Schools*; by LEONARD WALDO, S.D. (Harv.). New York, 1880. (John Wiley & Sons). Those who have much arithmetical computing to do, will find their work greatly facilitated by the use of these tables, and will appreciate their value. As regards clearness and neatness of typographical work they are all that could be desired; a smaller page might perhaps have been more convenient.

4. *Special Report of the New York State Survey on the Preservation of the Scenery of Niagara Falls, and Fourth Annual Report on the Triangulation of the State for the year* 1879; JAMES T. GARDNER, Director. 96 pp. 8vo. Albany, 1880.—This Report makes a strong appeal in behalf of a cause which is of universal interest, that is, the restoration and preservation of the natural attractions of Niagara Falls. It is to be hoped that the necessary action will be taken by the State to accomplish this important end. The volume contains a fine series of photographic views illustrating the points raised in the Report. The second part gives a statement of the results accomplished by the Topographical Survey in 1879.

The Winchester Observatory of Yale College: Circular of the Horological and Thermometrical Bureaus; published by the Observatory Board of Managers for the information of persons interested in these public services. Second Edition, 8 pp. 4to. New Haven, Conn., 1880.—This circular will be noticed in another number.

PLATE I

MEAN HUMIDITY OF THE ATMOSPHERE

Punderson & Crisand, New Haven, Ct.

[illegible]

PLATE II

Punderson & Crisand, New Haven.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

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Art. IX.—*On the effects produced by mixing White with Colored Light;* by Prof. O. N. Rood, of Columbia College.

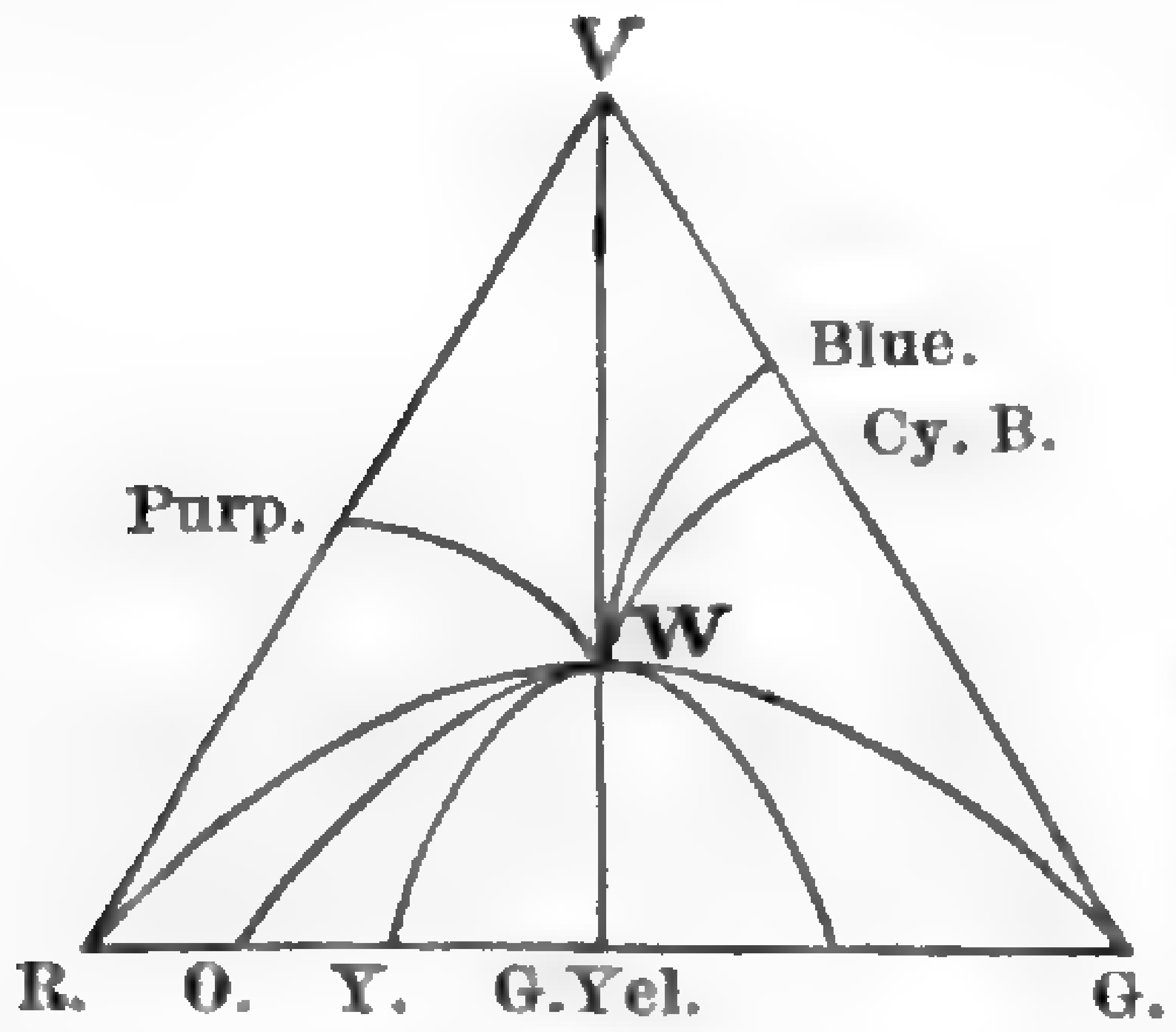
It was noticed several years ago that when white light was mixed by the method of rotating discs with light of an ultramarine (artificial) hue, the result was not what one would naturally have expected, viz: instead of obtaining a lighter or paler tint of violet-blue the color inclined decidedly toward violet, passing, when much white was added, into a pale violet hue. Two attempts have been made to account for this curious fact: Brücke supposes that the light which we call white is really to a considerable extent red, and that the mixture of this reddish white light with the blue causes it to change to violet. Aubert, on the other hand, following a suggestion of Helmholtz, reaches the conclusion that violet is really only a lighter shade of ultramarine-blue. He starts with the assumption that we obtain our idea of blue mixed with white from the sky, which, according to him, is of a greenish-blue color. We then apply, as he thinks, this idea to the case of a blue which is not greenish, namely, to ultramarine-blue, and are surprised to find that the result is different.

It will be shown in the present paper that these explanations are hardly correct, since they fail to account for the changes, which, according to my experiments, are produced in other colors by an admixture of white. I prepared a set of brilliantly colored circular discs which represented all the principal colors of the spectrum and also purple; these discs were then successively combined in various proportions with a white disc and the effects of rapid rotation noted, a smaller duplicate colored disc uncombined with white being used for comparison.

Under these circumstances it was found that the addition of white produced the changes indicated in the following table:

Vermilion became somewhat purplish.
Orange became more red.
Yellow became more orange.
Greenish yellow was unchanged.
Yellowish green became more green.
Green became more blue-green.
Cyan-blue became less greenish, more bluish.
Cobalt-blue became more of a violet blue.
Ultramarine (artificial) became more violet.
Purple became less red, more violet.

Exactly these same effects can be produced by mixing violet with the above mentioned colors. Let R, G, V represent the three angles of Maxwell's color-triangle, W being the position of white. Now, according to the received theory, as we mix white with different colors we advance in straight lines from the angles or sides of the triangle toward W; in point of fact, however, I find, as a result of the above-mentioned experiments, that we advance in curves toward W, these curves being similar to those roughly indicated in the figure. The only advance in straight lines is along the line joining violet with its complement greenish yellow. The other lines are disposed symmetrically about this line as an axis. These experiments serve to explain the singular circumstance that when complementary colors are produced by the aid of polarized light, it is difficult or impossible to obtain a red which is entirely free from a purplish hue, a quantity of white light being always necessarily mingled with the colored light. In the case of the red, orange, yellow, ultramarine, and purple discs, I succeeded in measuring the amount of violet light which different proportions of the white disc virtually added to the mixture, and found that it is not directly proportional to the amount of white light added, but increased in a slower ratio, which at present has not been accurately determined.



For the explanation of the above mentioned phenomena, Brücke's suggestion that white light contains a certain amount of unneutralized red light is evidently inapplicable, since the effects are such as would be produced by adding a quantity not of red but of *violet* light, and for the present I am not disposed to assume that white light contains an excess of violet light. The explanation offered by Aubert does not undertake to account for the changes produced in colors other than ultramarine, and even in this case seems to me arbitrary; neither have I succeeded in framing any explanation in accordance with the theory of Young and Helmholtz which seems plausible.

ART. X.—*On some Phenomena of Binocular Vision;* by JOSEPH LECONTE.

[Read before the National Academy of Sciences, April 20, 1880.]

XI.—*Laws of Ocular Motion.**

IN March, 1869, I published a paper "on the rotation of the eyes on their optic axes, in convergence." The results reached in that paper were briefly as follows:

1. In optic convergence in the *primary* visual plane there is a rotation of both eyes on their optic axes *outward*, and this rotation increases with the degree of convergence.

2. In inclining the visual plane downward the rotation for the same degree of convergence *decreases* until when the inclination is 45° below the primary position, the rotation becomes zero for all degrees of convergence. Below 45° the rotation becomes *inward*.

3. In elevating the visual plane the rotation, for strong convergence, *increases*.

There can be no doubt that the 1st law is plainly in violation of the *Law of Listing* which is supposed to govern all the movements of the eye: for that law requires that all movements of the eye in the primary plane are effected without any rotation on the optic axes (torsion). But it seems not impossible and perhaps not improbable, that the modifications of the effect of convergence in elevating and depressing the visual plane may be the result of the operation of that law; for by that law oblique position upward or downward and to one side or the other does produce rotation. Furthermore, according to Helmholtz, oblique position upward and to one side produces rotation (torsion) to the *opposite* side, and oblique position *downward* and to one side produces torsion to the *same* side. If this be true, then supposing the eyes under the influence of two laws, viz: a law of torsion by convergence, and a law of torsion by oblique position, in elevating and converging the eyes the two would coöperate and produce greater torsion, as indeed we find; and in depressing and converging the eyes, the two would antagonize and neutralize each other, and thus decrease the rotation, as we also find. This seems a simple and satisfactory mode of explaining the whole phenomena of torsion in convergence.

It was in this spirit and the expectation of this result, that I recently undertook a re-investigation of the whole subject of the laws of ocular motion. My first effort was directed to a thorough mastering of the law of Listing; for the statements

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* For the other papers on this subject, see this Journal, II, vol. xlvii, pp. 68 and 153, III, vol. i, p. 33, vol. ii, pp. 1, 314, 417, and vol. ix, p. 159.

concerning this law had seemed to me inconsistent with each other. I therefore read again carefully and thoughtfully Helmholtz's great work on Physiological Optics, the acknowledged standard on this subject. I read and re-read several times his chapter on the laws of ocular motion, and pondered upon his results. I repeated all his experiments, and made many more of my own. But so difficult and delusive are experiments of this kind, so beset on every side with sources of fallacy, that the more I experimented and pondered, the more I became bewildered. But now at last the whole subject has become clear, and all my experiments consistent with each other. I now see also, that the true cause of my bewilderment was not so much the delusiveness of the phenomena, but the too ardent desire to verify the results of others, rather than to determine the law for myself. I have been driven almost against my will to the conclusion that there are some strange and apparently inadvertent mistakes in Helmholtz's interpretation of Listing's law, and that this law governs the motions of the eyes only when they *move* parallel to each other, but cannot in any way account for the torsions of the eyes in convergence.

I will now detail the experiments upon which these conclusions are based.

It is well known that spectral images (accidental images of Helmholtz) are the most accurate means of determining the torsions of the eye. They are so because being the result of changes in the retina lasting sometimes a minute or more—being in fact the outward manifestation of images as it were burned into the retina—they must of necessity follow with the greatest exactness all the motions of the eye. There is no other mode of detecting torsions of the eyes, in *parallel motion.* All my experiments, therefore, were made with these images.

Experiment 1.—I darken the experimental room by closing the shutters, but allow the light to enter through a narrow vertical slit between two shutters. I now gaze steadily with head erect on the vertical slit for a minute or so. On turning to the blank white wall I see distinctly a colored vertical spectral image of the slit. I arrange my head if necessary, so that the image is perfectly vertical. If I now turn my eyes (without moving the head) horizontally right and left, the image remains vertical; if I turn my eyes directly up or down, by elevating or depressing the visual plane the image still maintains its vertical position. But if I elevate again the visual plane to the extremest degree, say 40°, and then move the point of sight horizontally as far as possible, say 40° to *the right*, the image is no longer vertical but inclines very decidedly to the right, thus / . If I move my eyes horizontally to the left, the image inclines equally to the left, thus \ . If, after renewing the spectrum, I now depress the visual plane 40°, and then cause the point of sight to travel 40° to the *right*, the image inclines to the *left*, thus \ ; if the point of sight moves to the extreme left, the image turns to the right, thus / .

In all cases the degree of inclination or torsion of the image increases with the degree of elevation or depression of the visual plane and the amount of lateral excursion of the point of sight, right or left. Also the degree and direction of the torsion of the image will be the same for the same position of the line of sight, however that position may have been reached, whether by two motions along rectangular coördinates, as in the preceding experiments, or by oblique motion from the first or primary position.

Experiment 2.—I next made similar experiments, using a *horizontal*, instead of a vertical image. Such an image may be made in the same way, by means of a horizontal slit in the window. When such an image is thrown on a perpendicular wall with the eyes in the primary position (i. e. with face perpendicular and the eyes looking horizontally) its position is of course horizontal. When the eyes move from side to side horizontally, or up and down vertically, it retains its perfect horizontality. But if the eyes be turned obliquely upward and *to the right*, the image inclines to the left, thus —; if upward and to the left, the torsion is to the right, thus —. In depressing the plane of sight, movement of the eyes to the right makes the image incline to the right, thus —, while movement to the left, makes it incline to the left, thus —.

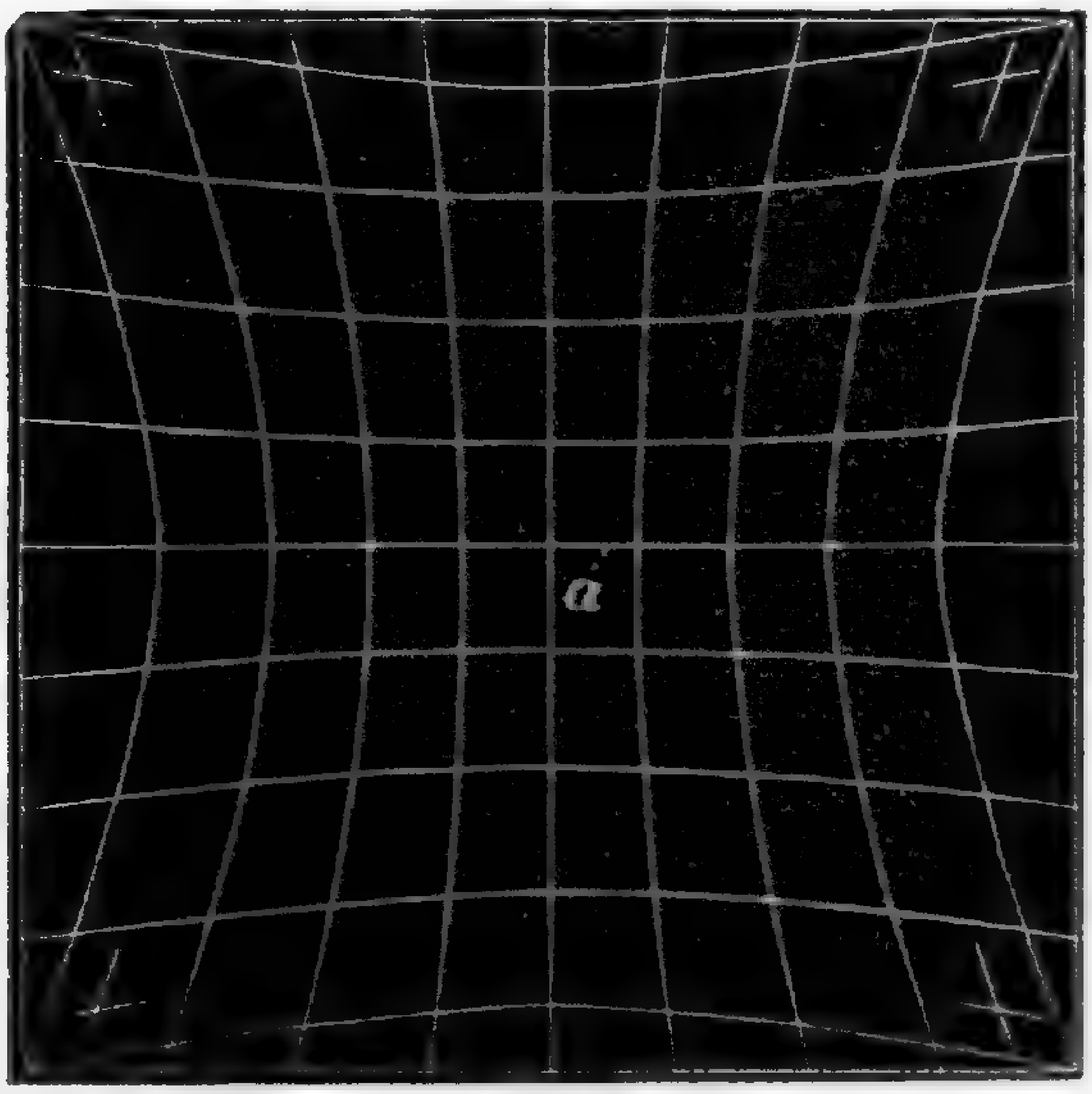
The *fact* and the *direction* of the torsion of the images, both vertical and horizontal, are very easily established by the somewhat rough method just described. But if we desire to *measure* the amount of torsion of the image, the wall or other experimental plane must be covered with rectangular coördinates vertical and horizontal. By this means I find that extreme oblique positions produce an inclination of the vertical image on the true vertical of the wall of about 15°, but of the horizontal image on the true horizontals of the wall of only about 5°. There is a reason for this difference, which we explain farther on.

Putting now all these results together, the following diagram (Fig. 1) shows the direction and the degree of inclination of the image for all positions of the point of sight—the center representing the primary position, and the corners extreme oblique positions of the point of sight.

Helmholtz's results are exactly the same as my own, except that he makes the inclination of the vertical and the horizontal image exactly equal, while I find the inclination of the horizontal image much less than that of the vertical image. He embodies his results, therefore, in a diagram like the above, except that the curves of the vertical and the horizontal lines are *exactly* equal each to each in every part of the diagram, while in mine the vertical curves are much greater.

The following diagram plainly shows that the apparent torsion of the vertical and horizontal images are in *opposite* directions. If the inclination or torsion of the images show a corresponding torsion of the eye, the evidence of the two images is contradictory. There must, therefore, be a fallacy somewhere. They both cannot be right; for when one indicates torsion of the eye to the right, the other indicates torsion to the left, and *vice versa*. The vertical and horizontal curves in the diagram are not everywhere at right angles to each other, as they ought to be, if they were both true representatives of ocular torsion. This is best shown by using an image in the form of a rectangular cross.

1.



Experiment 3.—If such an image, made by gazing on a cross slit in the window, be used in the experiments already described, then on turning the eyes obliquely upward and to the right, the cross by the turning of the two parts in opposite directions is distorted, thus +, so that the angles are not all right angles, but 70° and 110°. On turning the eyes upward and to the left, the cross becomes thus +, downward and to the right, thus +, to the left, thus +. The same mode of crossing is observed in the lines of the diagram, and in the crosses in the corners.

It is perfectly evident that this distortion is produced by *projection* of the image on a plane inclined to the line of sight. Helmholtz also attributes this distortion to projection, but he gives no experimental method of eliminating this source of fallacy. If he had done so he would have escaped what I conceive to be the error into which he has inadvertently fallen.

The method which I use to eliminate this source of fallacy is the obvious one of *projecting the image on a plane in every case perpendicular to the line of sight.**

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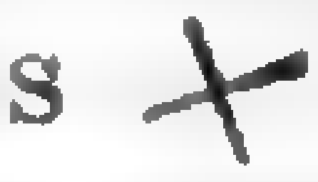
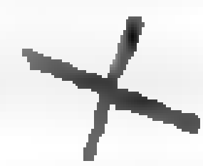
* With *one* eye "*line of sight*" is the proper term—but with two eyes "*median line of sight.*" But except in very near objects the difference is so small that I shall neglect it.

Experiment 4.—For this purpose I prepare a plane a yard square, and cover it with vertical and horizontal lines. In the center I place an upright rod and make it accurately perpendicular to the plane. I place the plane inclined from the perpendicular 30°–40°, and so set that with the face looking straight to the experimental window the plane is 30° or 40° above and to the right; and when I turn my eyes obliquely upward and to the right, I look directly on the end of the rod, so that it is projected as a spot on the plane. I thus know that the line of sight is perpendicular to the plane. Having arranged the plane and my own position to my satisfaction, I gaze on a cross slit in the window until the impression is as it were branded upon the retina, and then turning the eyes obliquely upward and to the right, I throw the image on the center of the plane. The cross image retains perfectly its rectangular symmetry, but is rotated *both parts alike, to the right*, thus,  plainly showing a torsion of the eyes in the same direction. I then make a similar experiment on the left side: the cross turns to the left thus . I now arrange the plane below the head and to the right, but perpendicular to the line of sight when the eyes are turned in that direction. When the image is thrown upon the plane, by turning the eyes obliquely downward and to the right, the cross rotates thus , or when placed on the left, thus . In every case the rectangular symmetry of the cross is perfectly preserved, a sure sign that there is no error by projection.

Experiment 5.—Determined to neglect no means of testing the correctness of these results, I next made experiments in the open air, using the sky as the plane upon which to cast the image. This spatial concave is of course everywhere perpendicular to the line of sight, and therefore eliminates every source of error from projection. Standing with head erect, I gaze on a perpendicular flag-staff until a strong impression is made on the retina. If now holding the head steady, I cast the image on the sky obliquely upward and to the right, the image inclines decidedly to the *right;* if thrown similarly to the left, it inclines to the *left.* With the head in this position, of course the ground prevents making the same experiments with the visual plane depressed. I therefore varied the conditions a little. Sitting on the ground in front of the college building, with the morning sun shining obliquely on its face, the perpendicular light-colored pilasters gleaming in the sunshine, contrast strongly with the shadows which border their northern margin. Gazing steadily on the building, I easily get a strong spectral image of the whole building, with its distinctly-marked vertical and horizontal lines. Now throwing myself flat on my back, I see the image perfectly erect, in the zenith. Turning now the eyes upward (toward the brows) and to the right and left; and then downward (toward the feet), and to the right and left, the whole image of the building rotates without distortion, precisely as indicated in my previous experiments.

I am perfectly confident then that I am justified in formulating the torsions of the eyes when moving together with their optic axes parallel, thus:

1. When the visual plane is *elevated* and the eyes move to the *right*, they rotate on their optic axes to the *right;* when they move to the *left*, they rotate to the *left*.
2. When the visual plane is *depressed*, then motion to the *right* is accompanied by rotation to the *left*, and motion to the *left* by rotation to the *right*.
3. The degree of rotation increases with the amount of elevation or depression of the visual plane, and of the lateral excursion of the point of sight.

Now, the above laws (1 and 2) concerning the direction of torsion, are precisely the reverse of those given by Helmholtz, and therefore of what I expected to find when I commenced this investigation. I quote from his work on Physiological Optics, French edition, 1867.* This edition was revised, corrected and added to by Helmholtz himself, and by his own statement is not only later but more authoritative than the German.

"When the plane of regard is directed upward, lateral displacement to the *right* makes the eye turn to the *left*, and displacement to the *left* makes it turn to the *right*.

"When the plane of regard is depressed, lateral displacements to the *right* are accompanied with torsion to the *right*, and *vice versa*.

"In other words, when the vertical and lateral angles are both of the *same sign*, the torsion is *negative;* when they are of *contrary signs* the torsion is *positive*."

The very reverse of every one of these propositions is demonstrably true.

I next set myself to find out how the mistake arose. I find its origin evidently contained in the following statement:

"If we throw a *vertical* image on the wall (supposed to be covered with rectangular coördinates vertical and horizontal), we obtain a rotation in direction contrary to that which we have just seen (in the case of the *horizontal* image). In fact, if one looks upward and to the right, the image *does not turn to the left*, but *to the right in relation to the vertical lines of the wall. But one cannot conclude* from this that there is a *rotation* of the eye

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* Optique Physiologique, p. 602 and 603.

to the right, for *in this case the vertical lines of the wall do not coincide with a projection, on the wall, of a perpendicular to the plane of regard. The latter would, on the contrary, appear turned in the same direction as the image, and at an angle much greater than that of the image.*"*

In other words, (since the plane perpendicular to the line of sight is the only true plane of projection, and verticals on that plane are perpendicular to the plane of regard), according to Helmholtz the horizontal lines on the wall are true terms of comparison for determining the rotation of spectral images, because they coincide with the horizontals on the plane perpendicular to the line of sight; but the vertical lines on the wall are not true terms of comparison, because they do not coincide with the verticals in the plane perpendicular to the line of sight. Now, the very reverse is true. It is the *verticals* on the wall which coincide with the verticals in the plane perpendicular to the line of sight or perpendiculars to the plane of regard, and the horizontals on the wall which do not coincide with the horizontals on that plane. Therefore, it is the verticals on the wall which are the true terms of comparison, by which to determine the direction of torsion of the eye, and horizontals which give deceptive results by projection.

As this is a fundamental point, I must pause to make it clear. Suppose, then, one stands in a room before a wall covered with rectangular coördinates, vertical and horizontal. Suppose, farther, such an one surrounded by a spherical wire-cage, constructed of rectangular spherical coördinates, or meridians and parallels, with pole above the head, and eye in the center. Evidently the surface of this spherical concave is everywhere perpendicular to the line of sight, and therefore like the sky, is a proper surface for testing the true direction of rotation of images in every position of the eye. Evidently, also, the meridians and parallels, everywhere at right angles to each other, are the true coördinates with which to compare the spectral images, in order to determine the direction and degree of their rotation. Now the simple question is: how do these meridians and parallels project themselves on the wall, to an observer at the center? How would their shadows be cast by a light at the center? Evidently the meridians would be cast as straight vertical lines, and therefore coincident with the verticals on the wall. But the parallels would be projected not as straight horizontal lines, and therefore not coincident with the horizontals on the wall, but *as hyperbolic curves inclined in the same way as the horizontal image in Helmholtz's diagram, but at much greater angle.* I repeat, then, that the inclination of the vertical image on the vertical lines of the wall gives the true

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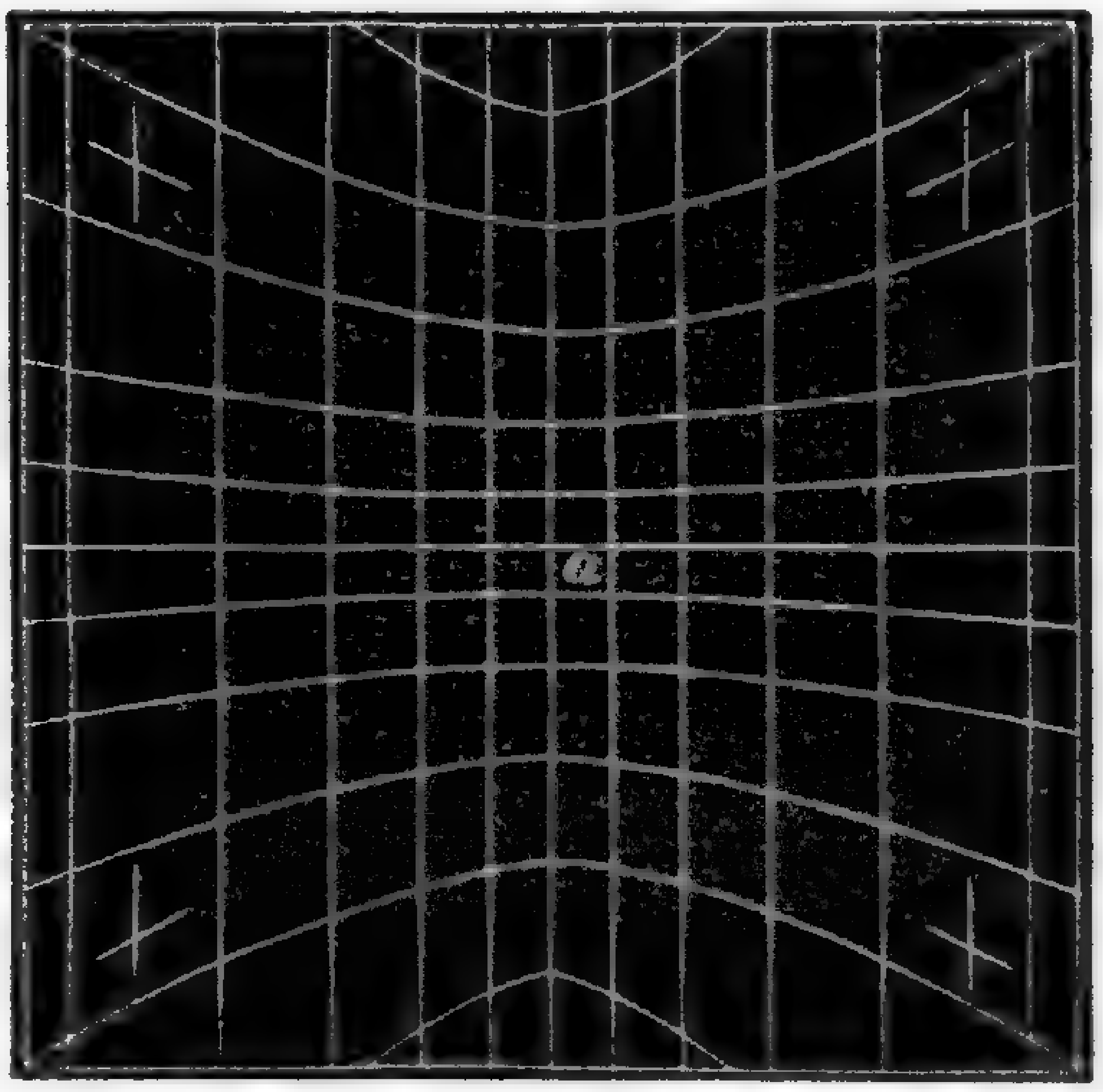
† Ibid, p. 605.

torsion of the eye, but the inclination of the horizontal image on the horizontal lines of the wall does not give the true torsion of the eye.

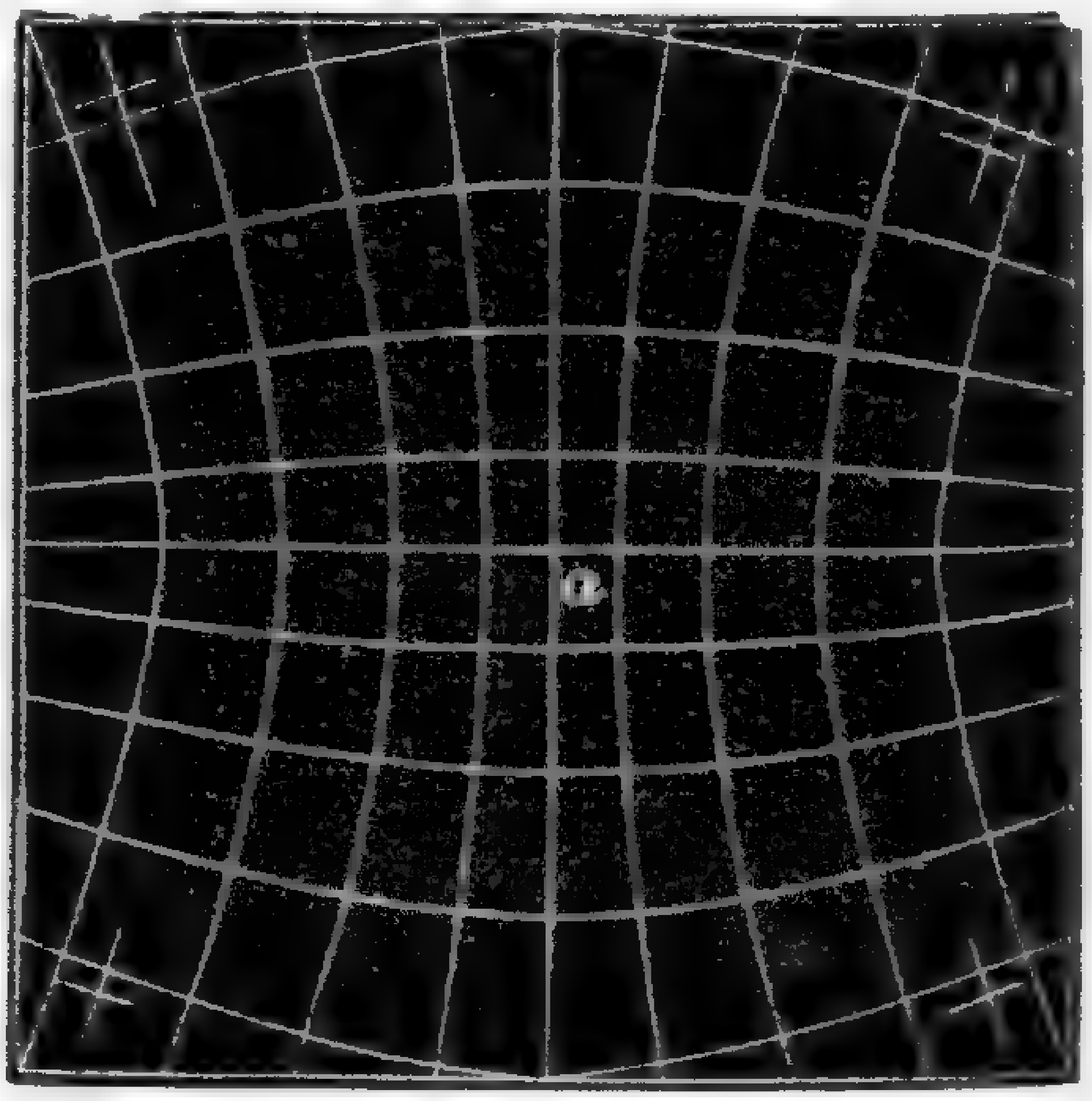
There are many other ways of testing the truth of this last proposition and the falsity of the reverse statement of Helmholtz. If we make, as before, a vertical image, and instead of turning the *eyes* upward and to the right, turn the *body* to the right and the *face* upward and cast the image on the extreme right and upper portion of the wall; the vertical image will be projected vertically on the wall, but a horizontal image cast to the same place, in the same way, will be inclined in the same way as in Helmholtz's diagram, but *at much greater angle.* In this case, the eyes are in the primary position, and therefore there is no rotation at all, the inclination of the horizontal image is the result of projection alone.

Without any attempt at mathematical accuracy, the diagram, figure 2, shows the manner in which spherical coördinates would project on a plane perpendicular wall. The crosses in the corners show how a rectangular cross image would be distorted by *projection alone.* Now by careful plotting, I have found that at a point 40° upward or downward, and 40° to one side right or left, the inclination of the hyperbolic curves with the true horizontals of the wall is about 20°—which makes the angles of the projected cross 70° and 110°. The rotation of such a cross 15°, would give exactly the results obtained by experiment. In figure 3, the heavy cross shows the position of the image when distorted by projection only, and the lighter lines the same as rotated 15° to the right. As the result of this rotation, the vertical line is inclined 15° *to the right,* while the horizontal line is inclined only 5° *to the left,* as we found by experiment.

2.



4.



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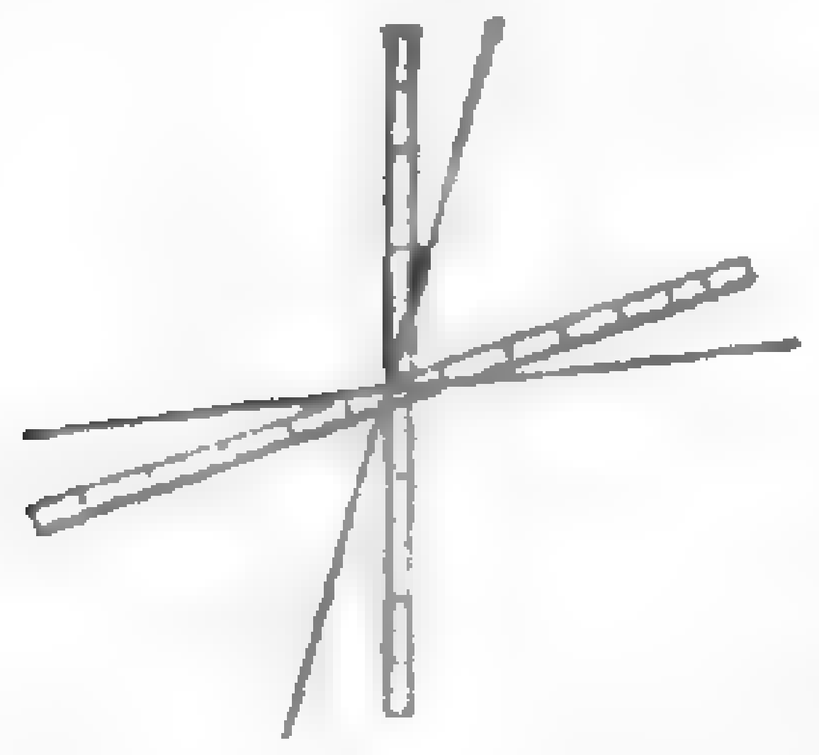

Therefore, the diagram which expresses correctly the real torsions of the eyes, in every position of the line of sight, or the diagram which shows the inclination of the vertical and horizontal images, when referred to the meridians and parallels of a spatial concave everywhere perpendicular to the line of sight, is shown in figure 4. In this diagram the lines representing the inclination of the vertical and horizontal images are everywhere at right angles to each other, and always turned in the same direction. By simple inspection of this figure the law of torsion of the cross images and therefore of the eyes in various positions is seen at a glance.

But again, and finally, Helmholtz's statements in regard to the direction of torsion are, it seems to me, in direct contradiction to his own general formulation of Listing's law, taken from Listing himself. This general formula is as follows: "*When the line of regard passes from the primary position to any other position, the angle of torsion of the eye in its second position, is the same as if the eye had come to this second position by turning about a fixed axis perpendicular both to the first and to the second position of the line of regard.*"* Now an axis which satisfies these conditions can be none other than an equatorial axis, i. e., an axis at right angles to the polar or optic axis. In turning from side to side horizontally, it is a *vertical* equatorial axis. In turning up and down, it is a *horizontal* equatorial axis. In turning obliquely, as in the experiments on torsion, it is an *oblique* equatorial axis. Now let any one take a globe, and placing the equator in a vertical plane, make a distinct vertical and horizontal mark across the pole. If now the globe be turned on an oblique equatorial axis so that the pole shall look upward and to the right, it will be seen that the polar cross is no longer vertical and horizontal, but has rotated *to the right*, not the left, as Helmholtz's statements would indicate. Turning of the globe on a fixed axis so that the pole looks upward and to the left, will cause the cross to rotate to the left. So turning downward and to the right, produces rotation to the left, and to the left rotation to the right. If the globe turns thus on an axis inclined 45° to the vertical, and through an arc of 90°, the rotation of the polar cross will be exactly 45°. Thus Listing's law, as understood by himself, is in exact accordance with my results.

I have now, I believe, established on the firm basis of experiment, the true law of torsion of the eyes, when moving parallel to each other. I have also shown that it is identical with Listing's law, properly understood, and I shall therefore continue to call it by that name. Misled by Helmholtz's very positive statements, I commenced this investigation with the expec-

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* Op. cit., p. 606.

tation that the operation of Listing's law, when combined with that of convergent motion, would completely explain all the phenomena described in my previous paper. In this expectation I have been disappointed. On the contrary, the investigation brings out in stronger relief than ever before, the *complete contrast* between the two laws. We would thus formulate the contrast:

1. When the eyes move in the *same direction* parallel to each other, in the *primary plane*, there is *no torsion* or rotation on the optic axis; but when they move in the primary plane in *opposite* directions as in convergence, they rotate outward, i. e., toward the temples, thus 

2. When the plane of sight is elevated, and the eyes move together parallel to each other, then if the lateral motion is to the right, the rotation is to the right, if to the left, the rotation is to the left; but when in the same position of the visual plane, the eyes move in opposite directions, as in convergence, then as the right eye moves to the left (toward the nose) it rotates to the right, and as the left eye moves to the right (i. e., toward the nose), it rotates to the left. If Listing's law operated at all in convergence, it would tend to neutralize the contrary effect of convergence; but such is not the fact.

3. When the visual plane is *depressed*, the direction of rotation is the same for parallel motion and convergent motion; in both cases the rotation is contrary to the direction of motion. But there is this great difference between the two; by the law of parallel motion, the rotation *increases* with the angle of depression, while by the law of convergent motion, it *decreases* to zero at 45°. If Listing's law operated at all in convergence, it would in this case coöperate and *increase* the motion, but the reverse is the fact, the rotation decreases.

4. There can be no doubt that in oblique motion the vertical and horizontal meridians of the eye become actually inclined on the true vertical and true horizontal, and that if we observed the iris of another person we would see it apparently rotated like a wheel. But although in deference to usage of other writers and to appearance, I have called this change a rotation on the optic axis, yet it seems to me it cannot be properly so called. For all parallel motions of the eyes are rotations on equatorial axes, and therefore on axes in a *plane perpendicular to the polar* or optic axis, and therefore cannot be resolved into rotations on the latter. In parallel rotation, therefore, the so-called torsion is only *apparent and the result of position*, or in other words the result of *reference to a new spatial meridian*. Turning the eye from side to side in the *primary* plane produces no torsion because all the spatial meridians are there *parallel*, but turning from side to side in an *elevated* plane pro-

duces apparent torsion, because the spatial meridians are there *convergent*. But in convergent motion, on the contrary, there is a *real* rotation on the polar or optic axis. This is shown by the fact proven in my previous paper* that one eye, without changing its position, will rotate through the influence of the convergent motion of the other eye.

5. It would seem at first sight, that spectral images might be used also for determining rotations of the eyes in convergence, but they cannot be used for this purpose at all. This brings into view another point of contrast, between convergent and parallel motion. In parallel motion spectral images follow all the motions of the eyes up and down, or to right and left, and all their rotations to one side or the other, with the utmost exactness. In convergent motion, on the contrary, though the eyes may each move through an angle of 45° or more, the position of the spectral image is the same, viz: in front; and though the eyes in extreme convergence may rotate in opposite directions each 10°, yet the spectral image retains its vertical position. The reason of this is that, although there are two retinal brandings, and therefore two spectral images, the external representatives of these brandings, yet the brandings being on corresponding points of the two retinæ, their external representatives, the two spectral images, are indissolubly united. Their separation, either wholly or partially, would be a violation of the law of corresponding points, a law which is never violated under any circumstances whatever.

In conclusion, then, it is evident that when the eyes move in the same direction, parallel to each other, as in ordinary vision of objects, all their motions are governed by the Law of Listing. But when, on the contrary, they move in *opposite* directions, as in strong convergence, then the law of Listing is entirely abrogated or overborne, and another law reigns in its place.

ART. XI.—*Bernardinite: Its Nature and Origin;* by J. M. STILLMAN.

IN a previous number of this Journal† I published the results of a chemical investigation of a resinous substance from San Bernardino, sent to me by Hon. B. B. Redding, which was said to occur in the form of vein in detached masses, and the vein to be traceable for three miles. The finders (farmers or "ranchers" of that vicinity) sent at the same time pieces of rock as vein-stuff which contained this peculiar resinous substance in the crevices. Some months later another specimen was sent to this University from Santa Aña in the same section

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* This Journal, II, vol. xlvii, p. 162.

† III, vol. xviii, p. 57.

of the country by a resident who stated in his letter that on throwing a match upon the ground he was surprised to see these rocks take fire and burn. He therefore sent a piece to be examined.

The specimens furnished to Mr. Redding were examined by me and the result published in the above mentioned article. The substance, which was extremely light, white and porous, almost chalky, was shown to be mainly a well-marked resin, leaving but a trace of an ash on combustion. No theory was advanced as to its origin, attention simply was called to its structure:—"On fracture it presents a slightly fibrous structure. Under the microscope it exhibits a two-fold structure,—a quantity of very fine, irregular fibers permeating a mass of a brittle, amorphous, structureless substance." Since that paper was written I have endeavored to obtain more definite information as to the origin and occurrence of this peculiar substance. The region of its occurrence is so remote and so inaccessible that it has been impossible for me to investigate the matter in person, and difficult to find competent persons whose business takes them into that region. However, from reports obtained through the agency of Mr. Redding, I feel tolerably confident that the true nature and origin of this substance has been cleared up.

It seems that there grows and probably has grown for a long time a species of conifer which exudes large masses of a resinous secretion from abrasions or wounds. These resinous masses are reported to attain considerable size, and to fall off from their own weight. However that may be, the detached resin either from fallen and decayed trees, or from living trees, becomes scattered over the surface of the country and mixed with surface soil and rocks. By a long process of evaporation, action of atmosphere, and the leeching and bleaching agency of the snow which covers the ground for a large portion of the year, these resinous masses lose all vestiges of volatile and soluble matter and at the same time, a fungus growth permeates and splinters the whole mass into minute fragments rendered coherent by the fibers of the fungus. Hence the two-fold structure noted, the fungus growth as shown in the previous paper, amounting to less than 10 per cent of the mass.

The perfect change which has taken place in the resin by these agencies evidence that the resin must have been exposed for an indefinite period to atmospheric agencies, and have attained a position of equilibrium toward its surrounding conditions. It is therefore apparently entirely a surface formation, which however has in process of time become so mixed in with surface soil and rocks as in some instances to present the appearance of being *in situ*.

University of California, May 13, 1880.

ART. XII.—*Recent Researches on the Lunar Theory;* by JOHN N. STOCKWELL.

IN the November and January numbers of this Journal I have given some account of the inequalities in the moon's motion, arising from the oblateness of the earth. I now propose to give a somewhat detailed account of my investigations into the general theory of the moon's motion as affected by the sun's attraction. Although this problem has undoubtedly received more attention from mathematicians and astronomers, during the past century, than any other arising from the general gravitation of matter, it is nevertheless conceded by those who have given most attention to the subject, that the best lunar theories of the present day are essentially defective and erroneous; and that they signally fail to represent the motions of the moon with a precision at all commensurate with the refinements of calculation.

Early in the year 1876, I called the attention of my friend, the late Leonard Case, to the unsatisfactory state of the lunar theory, and he immediately suggested that I should undertake a thorough and systematic examination of the physical theory of the moon's motion, for the purpose of ascertaining whether the acknowledged defect arose from some oversight committed in the development of the theory, or was due to the omission of some of the smaller terms of the series produced by an otherwise correct development. At the same time Mr. Case, with characteristic generosity, offered to defray all the expenses arising from the prosecution of these researches.

The opportunity thus presented for a thorough investigation of the lunar theory was therefore very cheerfully accepted, although I had some misgivings as to my ability to do justice to a subject which had successfully baffled the best efforts of mathematicians. I had, however, somewhat familiarized myself with some of the methods employed by mathematicians in the treatment of this and similar problems by devoting the little leisure at my command to this subject during a number of years. The subject was therefore quite in harmony with my previous course of reading, and notwithstanding some false steps have been made in the application of a new method of analysis, the results at last obtained are both interesting and satisfactory.

In my investigations thus far I have not, however, attempted to carry on the approximation to terms of so high an order of magnitude depending on the eccentricity and inclination of the orbit, as Delaunay and others have done. I preferred rather to first satisfy myself that no systematic error among terms of the third or fourth orders of magnitude depending on these quantities had by any means found its way into the calculation; because such errors would vitiate the calculations of the terms of a still higher order. My investigation includes all the terms of perturbation arising from the fourth, and inferior powers of the eccentricity and inclination of the orbits of the sun and moon, while the investigations of Delaunay include the sixth power of these quantities. The general agreement of my work with the results of Delaunay's calculation is, on the whole, quite satisfactory, but there are a few cases in which the results are entirely at variance, even in terms of the third and fourth orders. In this discussion I shall restrict myself to the comparison of those terms in which the agreement is almost perfect, and also to those in which they are most widely different.

I will first give the value of that part of the co-efficient of the inequality which is known by the name of *variation*, which is independent of the eccentricities and inclinations of the orbits. According to my method of development this coefficient is composed of the following terms:

2111″·841 − 5″·562 − 0″·030—0″·0007=2106″·248.

According to Delaunay's development, this coefficient is made up of the following terms:

1586″·888+424″·447+80″·091+12″·769+1″·809+0″·223+0″·021
=2106″·248.

These two results are identically equal to each other. But a most important distinction between them is the convergency of the series by which they are determined. The four terms of my development are more accurate than seven terms of Delaunay's, since the seventh term of the latter series is thirty times greater than the fourth term of the former.

If we now compare the coefficients of the term whose argument is *twice* the argument of the *variation*, we shall find, according to my development—

8″·789 − 0′·056—0″·0001=8″·733 ;

while Delaunay gives

5″·070+2″·612+0″·813+0″·196+0″·060=8″·751.

These two coefficients, though practically equal to each other, show the same remarkable difference in the convergency of the series, the second term of my development being smaller than the fifth of Delaunay's.

For the equation whose argument is three times argument of the variation, I find 0″·0493 − 0″·0005=0″·0488, while Delaunay gives 0′·0218+0″·0167=0″·0385.

This coefficient of Delaunay's is about one-fourth part too small, since he has not carried the approximation to terms of so high an order as he did for the two former cases. To show, however, that my coefficient is correct, I would observe that the Monthly Notices of the Royal Astronomical Society for November, 1877, contains a paper by Prof. J. C. Adams, which purports to give the coefficients of the equations we have been comparing, with extreme accuracy. If we reduce his coefficient of $\sin 6(nt-n't)$ to seconds of arc, we obtain $0''\cdot0490$ for this coefficient, a value almost identical with my own. For the coefficient of $\sin 8(nt-n't)$ I find $0''\cdot00034$, while according to Prof. Adams it is $0''\cdot00031$.

According to my development the coefficient of the parallactic inequality is composed of the following terms:

$$84''\cdot523+26''\cdot801+10''\cdot280+3''\cdot872=125''\cdot476,$$

while Delaunay gives the following series of terms:

$$74''\cdot023+34''\cdot330+11''\cdot885+4''\cdot428+1''\cdot862+0''\cdot712+0''\cdot381$$
$$=127''\cdot621.$$

The coefficient of this inequality is one of the most troublesome to be determined by the theory, and the four terms above given are all I have yet rigorously computed. If we estimate the sum of the remaining terms, by induction from those already calculated, we should increase the preceding coefficient by $2''\cdot10$, which would make it equal to $127''\cdot58$. Delaunay's coefficient ought also to be increased for the same reason, by about $0''\cdot38$, which would make it about $128''\cdot00$. These coefficients correspond to a solar parallax of $8''\cdot75$. According to my calculations the eccentricity and inclination would diminish this coefficient by $2''\cdot11$; and if we assume the mass of the moon to be *one-eightieth* of the earth's mass the perturbations of the earth by the moon would diminish it by $2''\cdot10$ more. The theoretical coefficient for the above value of the parallax would therefore be $123''\cdot37$. Were the exact value of the coefficient of this inequality determined from observation, we might, by comparing it with the theoretical coefficient, determine the correction to our assumed solar parallax.

The preceding inequalities are the principal ones in which the coefficients of different theories are directly comparable with each other. For those inequalities in which the eccentricity and inclination enter as factors, the value of the coefficient depends, to a certain extent, on the manner in which the arguments of the different equations are measured. In most of the lunar theories the anomalies are measured on the plane of the orbit, while the longitudes are measured on the plane of the ecliptic;—a needless complication, which I have carefully avoided. However, in order to show the rapid convergency of the series which determine the principal periodic inequalities depending on the eccentricity and inclination of the orbit, I here give the two terms of the coefficient of the evection which I have computed. The first two terms depending on the first power of the eccentricity are as follows:

$$4280''\cdot 9 + 122''\cdot 0,$$

while Delaunay gives the following terms:

$$3176''\cdot 4 + 1041''\cdot 5 + 297''\cdot 5 + 72''\cdot 3.$$

It is evident that the first series converges about ten times as rapidly as the second.

The preceding comparison is sufficient to show the correctness and value of the method which I have employed in the problem of the moon's motion; and I shall now mention a few cases in which my results are wholly different from what other calculators have found for the same inequalities.

Before doing so, however, I would observe that there are certain fundamental and axiomatic conditions which ought to be satisfied by the results arrived at, whatever be the method of analysis which we may employ. In the present case the condition to be satisfied is simply, *That all the terms introduced into the expressions of the coördinates by the disturbing function ought to disappear when the disturbing function is put equal to nothing.* It is, however, a remarkable fact in connection with the lunar theory, that, among the *four hundred and seventy-nine* equations of the longitude given by Delaunay, there are *five*, arising from the sun's attraction, which do not disappear when the disturbing function is put equal to nothing. From this circumstance it is easy to conclude that there must be something seriously wrong in his development, notwithstanding its intricacy and refinement. The same remark is also applicable to the lunar theories of LaPlace, Plana and Pontécoulant.

The most important of these equations are those having the arguments, $2F - l$, and $D + l'$, in Delaunay's theory; or, *twice the moon's distance from the node minus the mean anomaly*, and *the moon's longitude minus the longitude of the sun's perigee.* The first of these is an inequality of pure elliptic motion, with a coefficient of $+45''\cdot 4$, while the coefficient arising from perturbation amounts to $-84''\cdot 8$, $28''$ only of which disappears when the disturbing function is put equal to nothing. According to my analysis, the coefficient of this inequality arising from perturbation amounts to only $0''\cdot 18$, a quantity less than a *four hundredth part* of Delaunay's coefficient arising from the same cause.

The coefficient of the second equation, mentioned above, depends entirely on perturbation, and has a value of about 17″ according to Delaunay, while I find a coefficient of only 0″·03. These two equations present the most remarkable differences which I have found among the equations of short period in the moon's motion.

The inequalities of long period, or those which depend wholly on the variation of the elements of elliptical motion are also very easily computed by my method. The values of the inequalities of this kind are subject to very simple and precise laws; so that if we have computed the coefficient of an inequality arising from a given force and having a given period, we may deduce the coefficient of any other inequality arising from a different force and having a different period, directly from it. For convenience we may divide the inequalities of long period into two classes, according to the nature of the forces which produce them. We shall therefore designate the inequalities arising from the variation of the central force as class (A), and those arising from the tangential force as class (B). Then *first*, the inequalities arising from forces of class (A) are to each other as the products of the forces by the periods of their respective arguments; and *second*, the inequalities produced by forces of class (B) are to each other as the products of the forces by the squares of the periods of their arguments.

We may also easily obtain the inequalities produced by either class of forces from the inequalities produced by the other class. For example, suppose the inequalities of the central force f having a period α, is found by calculation to produce an inequality m, in the moon's longitude, and we wish to obtain the inequality produced by a tangential force f', having a period α'. If we call this second inequality m', I find the following relation exists between the two inequalities:

$$3m\,f'\alpha'^2 = -2m'f\alpha n.$$

This gives $m' = -\frac{3}{2}m\,\frac{f'}{f}\,\frac{\alpha'^2}{\alpha n}$, n here denoting the moon's period of revolution. If $f = f'$ and $\alpha = \alpha' = 118{\cdot}3n$, which corresponds nearly to the period of the moon's perigee, we find

$$m' = -178m,$$

whence it follows that for equal central and tangential forces having a period of about nine years, the tangential force would diminish the moon's longitude *one hundred and seventy-eight* times as much as the central force would increase it, and *vice versa.*

There are two inequalities of long period in the moon's motion which have been much discussed by astronomers. They have for arguments, *twice the difference of longitude of perigee* *and node of the lunar orbit*, and *the difference of longitudes of perigee of sun and moon*, respectively. Plana was the first to give a correct approximate solution of the problem of the first of these inequalities, which is produced wholly by the variations of the central force. By means of a laborious investigation, occupying about fifty pages of his Theory of the Moon's Motion, he has obtained a tolerably correct approximation to the value of the inequality. He obtains $+1''\cdot405$ for the sum or the elliptic and perturbed coefficient; but the elliptic coefficient is equal to $-0''\cdot932$; whence it follows that the coefficient due to perturbation amounts to about $+2''\cdot34$. I obtain, almost without labor, $+2''\cdot54$ for the value of this coefficient.

The second inequality is produced by both classes of forces, and the determination of its coefficient is more complicated than that of the inequality just mentioned. The value of the force of class (A), which produces the inequality, is about *one-fifth* of the former, but it has a period about *three times* as long. The inequality produced by this force ought to be about *three-fifths* of the former inequality, which would make it equal to $1''\cdot52$. But the tangential force is far more effective, since the inequalities produced are proportional to the squares of the periods of the arguments. I find, however, by an exact calculation that the part of the coefficient of this inequality which arises from the central force amounts to $+1''\cdot45$; while the part of it which arises from tangential force amounts to $+107''\cdot08$; thus making the coefficient of the inequality equal to $108''\cdot53$. The solutions of Plana, Pontécoulant and Delaunay, all make the coefficient equal to about $0''\cdot4$, when quantities of the same order only are included.

It is remarkable that the inequalities of long period arising from the two classes of forces which produce them should follow the same law as the acquired velocity, and space passed over, by falling bodies at the surface of the earth, the one being proportional to the time and the other to the square of the time.

If we extend the comparison to the variation of the elements, we shall find that the method which I have employed possesses the advantage of more rapid convergency. For example, I find for the first two terms of the mean motion of the perigee the following value:

$$0\cdot00419643 + 0\cdot00395575 = 0\cdot00815218,$$

while the first three terms of Delaunay's series are

$$0\cdot00419643 + 0\cdot00294279 + 0\cdot00099570 = 0\cdot00813492.$$

This comparison shows that two terms of my series are considerably more accurate than three terms of Delaunay's.

The preceding comparisons are sufficient to establish two points in regard to the lunar theory. The first is, that the general methods of computation are undoubtedly correct; and the second is, that one or more of the methods have been incorrectly applied to the investigation of particular inequalities. Now, without claiming that there are no mistakes, either systematic or accidental, in my work on the lunar theory, there are some reasons for believing that it is correct in the cases to which I have called attention. One of these reasons is the fact that all the inequalities produced by perturbation would disappear from the formulas by simply putting the disturbing function equal to nothing; whereas there are a number of inequalities which do not disappear from the formulas of previous investigators by means of the same conditions.

It might seem, however, that such large changes in the values of the coefficients of some of the equations of the moon's longitude, as my researches seem to indicate, would have a tendency to make the theory less accordant with observations than it is at present, since the present lunar tables represent the moon's place within tolerably narrow limits. But a little consideration will show that such a conclusion would not necessarily follow. In order to illustrate this point, let us suppose that we have a perfect system of elements of the moon's orbit together with a perfect theory of the perturbations. It would necessarily follow that the moon's place could be perfectly predicted, and there would be no discordances between theory and observation. Suppose, now, that we omit a number of small though important equations from the computation of our ephemeris, it would follow that there would be a series of residuals between theory and observation. It is evident that these residuals would be perfectly represented by the omitted equations; but if the equations were considered as wholly lost, the theory would be in the same condition as though they had never been found; and we might seek to make up for the imperfect theory by finding certain corrections to the elements by means of equations of condition between the variations of the elements and the observed residuals. In this way we might perhaps obtain a very good agreement between theory and observations which extend over a limited interval of time,—the errors of the theory being partially compensated by the errors of the elements. But this close agreement between theory and observation would soon cease to take place, since the corrections applied to the elements would vitiate the remaining part of the theory. The imperfect ephemeris, computed by means of the changed elements and theory, would gradually depart more and more widely from the observed place of the moon, but the residuals would furnish no information in regard to the nature of the equations to be applied in order to correct them, since the calculated places were based on imperfect elements and an imperfect theory of the perturbations.

Now it seems to me that the actual history of the lunar theory indicates a passage through just such conditions and changes. It is true, however, that it has never possessed the advantages of perfection assumed above; but through the efforts of astronomers to improve the accuracy of the elements and tables, it has been subjected to the same process of correction. Beginning with Tycho Brahe, in modern times, the elements and theory of the moon's motion were so imperfect that the observed discordances forced him to recognize the existence of two considerable inequalities which were at the time unknown to the science of Europe. The discovery of these inequalities, which have received the names of *variation* and *annual equation*, was the last great step towards the perfection of the lunar theory, which preceded the discovery of the physical cause of the inequalities. Since that memorable epoch, the researches of mathematicians have instructed observers in regard to the magnitude and laws of numerous inequalities which must necessarily affect the moon's motion. The labors of Newton and Halley reduced the errors of the theory to about the *eighth* part of a degree; while Mayer, by the aid of theory and more accurate observations, succeeded in reducing the errors to less than the *thirtieth* part of a degree. Later still, the researches of Mason and Burg, according to the authority of LaPlace, reduced the errors of the theory to less than *one-quarter of a minute of arc!* If this last degree of precision was at any time really attained, it must have been owing to the partial compensation of errors of theory by the errors of the elements; because the theory very soon began to depart more and more widely from the observations; and astronomers have been obliged to suspect that the moon's motion was affected by one or more equations of very long period, which theory is hopelessly unable to point out.

About the middle of the present century, new tables of the moon's motion were constructed by Hansen; and, considering the broad basis of observation and the elaborately developed theory of her motion, the hope was justified that the elements and theory were so perfectly known, that they would permanently represent the observations. But this hope seems to have been ill founded. In a very few years the observations unmistakably indicated a growing discordance, which has continued till the present time; and notwithstanding the laborious investigations which have been made in order to detect the laws and the cause, no satisfactory explanation has yet been attained. If we consider the nature and magnitude of the discordances which now pertain to the best tables of the moon's motion, we can hardly avoid the conclusion that they are not due to the terms of a higher order of magnitude which have been neglected in the development of the theory. They must therefore result from some systematic error among terms of more importance in the lunar theory.

In bringing to a close this account of my researches, I would repeat that my only object has been to discover if possible, by means of a new method of investigation, any false steps which may have been committed by previous investigators in the mathematical development of the lunar theory. The history of philosophy affords numerous examples of the advantages of independent methods of investigation over independent calculations by the same method. It often happens that for particular values of the known quantities of a problem some terms of the solution become infinite or indeterminate, when certain general methods of investigation are employed; whereas other methods would not be subject to complications from such a cause. It is therefore evident that the comparison of the results of different methods would serve to call attention to the particular terms affected by any such critical conditions, and by thus narrowing the field of investigation, enable astronomers to concentrate their efforts on those particular terms where further research would seem to be necessary or desirable; and it is believed that the terms to which I have called attention afford the means of a much needed improvement in the lunar theory.

Cleveland, May 25, 1880.

ART. XIII.—*Aqueous Vapor in Relation to Perpetual Snow;* by JAMES CROLL, LL.D., F.R.S.*

SOME twelve years ago I gave (Phil. Mag., March, 1867, Climate and Time, p. 548) what appears to be the true explanation of that apparently paradoxical fact observed by Mr. Glaisher that the difference of reading, between a thermometer exposed to direct sunshine and one shaded, *diminishes* instead of increases, as we ascend in the atmosphere. This led me to an important conclusion in regard to the influence of aqueous vapor on the melting of snow, but recent objections to some of my views convince me that I have not given to that conclusion the prominence it deserves. I shall now state in a few words the conclusion to which I refer.

The reason why snow at great elevations does not melt but remains permanent, is owing to the fact that the heat received from the sun is thrown off into stellar space so rapidly by radi-

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* Communicated to this Journal by the author.

ation and reflection that the sun fails to raise the temperature of the snow to the melting point; the snow evaporates but it does not melt. The summits of the Himalayas, for example, must receive more than ten times the amount of heat necessary to melt all the snow that falls on them, notwithstanding which the snow is not melted. And in spite of the strength of the sun and the dryness of the air at these altitudes, evaporation is insufficient to remove the snow. At low elevations, where the snow-fall is probably greater, and the amount of heat received even less than at the summits the snow melts and disappears. This, I believe, we must attribute to the influence of aqueous vapor. At high elevations the air is dry and allows the heat radiated from the snow to pass into space, but at low elevations a very considerable amount of the heat radiated from the snow is absorbed by the aqueous vapor which it encounters in passing through the atmosphere. A considerable portion of the heat thus absorbed by the vapor is radiated back on the snow, but the heat thus radiated being of the same quality as that which the snow itself radiates, is on this account absorbed by the snow. Little or none of it is reflected like that received from the sun. The consequence is that the heat thus absorbed accumulates in the snow till melting takes place. Were the amount of aqueous vapor possessed by the atmosphere sufficiently diminished, perpetual snow would cover our globe down to the sea-shore. It is true that the air is warmer at the lower level than at the higher level and by contact with the snow must tend to melt it more at the former than at the latter position. But we must remember that the air is warmer mainly in consequence of the influence of aqueous vapor, and that were the quantity of vapor reduced to the amount in question, the difference of temperature at the two positions would not be great.

But it may be urged as a further objection to the foregoing conclusion, that as a matter of fact on great mountain-chains, the snow-line reaches to a lower level on the side where the air is moist than on the opposite side where it is dry and arid. As, for example, on the southern side of the Himalayas and on the eastern side of the Andes where the snow-line descends some 2,000 or 3,000 feet below that of the opposite, or dry side. But this is owing to the fact that it is on the moist side that by far the greatest amount of snow is precipitated. The moist winds of the S. W. monsoon deposit their snow almost wholly on the southern side of the Himalayas, and the S. E. trades, the snow on the east side of the Andes. Were the conditions in every respect the same on both sides of the mountain ranges with the exception only that the air on one side was perfectly dry, allowing radiation from the snow to pass without interruption into stellar space, while on the other side the air was moist and full of aqueous vapor, absorbing the heat radiated from the snow, the snow-line would, in this case, undoubtedly descend to a lower level on the dry than on the moist side. No doubt more snow would be evaporated off the dry than off the moist side, but melting would certainly take place at a greater elevation on the moist than on the dry side, and this is what would mainly determine the position of the snow line.

In like manner the dryness of the air will, in a great measure, account for the present accumulation of snow and ice on Greenland and on the Antarctic continent. I have shown on former occasions that those regions are completely covered with perpetual snow and ice, not because the quantity of snow falling on them is great, but because the quantity melted is small. And the reason why the snow does not melt is not because the amount of heat received during the year is not equivalent to the work of melting the ice, but mainly because of the dryness of the air, the snow is prevented from rising to the melting point.

There is little doubt but that the cold of the glacial epoch would produce an analogous effect on temperate regions to that experienced at present on Arctic and Antarctic regions. The cold, although it might, to some extent, diminish the snow fall, would dry the air and prevent the temperature of the snow rising to the melting point. It would not prevent evaporation taking place over the ocean by the sun's heat, but the reverse, but it would prevent the melting of the snow on the land during the greater part of the year.

In places like Fuego and South Georgia, where the snow fall is considerable, perennial snow and ice are produced by diametrically opposite means, as I have elsewhere shown, viz: by the sun's heat being cut off by clouds and dense fogs. In the first place the upper surfaces of the clouds act as reflectors, throwing back the sun's rays into stellar space, and in the second place, of the heat which the clouds and fogs absorb, more than one-half is not radiated downward on the snow, but upward into space. And the comparatively small portion of heat which manages to reach the ground and be available in melting the snow is insufficient to clear off the winter's accumulation.

ART. XIV.—*Perihelion and Eccentricity;* by R. W. McFARLAND. With Plate III.

THE following table gives the longitude of the perihelion and the eccentricity of the earth's orbit for a period of 4,520,000 years, of which 3,260,000 are before 1850, and 1,260,000 after 1850. It is computed by the formulæ of LeVerrier, as quoted in Mr. Croll's "Climate and Time," and also by those given in Mr. Stockwell's pamphlet on the "Secular Equations of the Moon's Mean Motion." The constants of the latter formulæ differ slightly from those found for the sun's increased parallax in the xviiith vol. of the Smithsonian Contributions.

An inspection of the table shows that the motion of the perihelion is exceedingly irregular, and occasionally retrograde.

The intervals between the maximum and minimum points in the curve of eccentricity also vary greatly, as a glance at the chart will show. The initial periods, 1800 and 1850, for the two sets of formulæ, differ so little from each other that the ordinates to the curves practically coincide.

One object of the table is a comparison of the results reached by these two sets of formulæ. It is obvious that great changes in the eccentricity will occur, unless the elements of disturbance reduce more nearly to zero than is probable, or perhaps possible.

The chart also shows that the *time*, rather than the value of the maximum eccentricity varies; but even this variation of the time, as shown by the two series of values, is not great when long periods are considered.

Mr. Stockwell's formulæ are deemed the more accurate, yet the two curves exhibit a general conformity throughout their whole extent. Whether a period of high eccentricity occurred about 800,000 years ago, or 700,000, is a small matter:—the chief point of interest is, that such a period has actually been found in the past. For about 70,000 years, partly on each side of 1850, the curves differ but slightly.

It is regretted that it has been necessary to draw the curves on so small a scale. When drawn large they move on with a generous sweep, so to speak, and make no sharp turns.

The computations having been made in the small intervals of leisure amid the press of onerous duties, errors may have been made and remained undetected; but it is thought that there are none of sufficient magnitude to vary the general results to any considerable amount.

The computations were originally begun at the instance of President Orton, of the Ohio State University, and were continued, I may be permitted to say, on the suggestion of Mr. James Croll, of the Geological Survey of Scotland.

It is scarcely necessary to add that if any one wishes to determine the difference between the greatest and least distance of the sun, it is only necessary to multiply the sun's mean distance by twice the eccentricity.

Ohio State University, June 3, 1880.

Table *showing the Longitude of the Perihelion and the Eccentricity of the Earth's Orbit for* 4,520,000 *years, according to the Formulas of Stockwell and of Le Verrier.*

Year.	Stockwell.			LeVerrier.			Year.	Stockwell.			LeVerrier.		
Before 1850.	Long.		Ecc.	Long.		Ecc.	Before 1850.	Long.		Ecc.	Long.		Ecc.
	°	'		°	'			°	'		°	'	
3,260,000	130	48	0·0098	235	7	0·0408	2,800,000	270	13	0·0329	339	16	0·0353
3,250,000	187	18	0·0136	261	22	0·0446	2,790,000	313	35	0·0407	13	19	0·0440
3,240,000	226	22	0·0153	284	34	0·0454	2,780,000	351	58	0·0460	47	40	0·0477
3,230,000	261	39	0·0152	308	13	0·0435	2,770,000	27	39	0·0474	81	13	0·0466
3,220,000	295	49	0·0112	329	26	0·0388	2,760,000	61	48	0·0445	120	4	0·0409
3,210,000	336	10	0·0072	336	38	0·0340	2,750,000	95	3	0·0373	161	22	0·0326
3,200,000	104	18	0·0023	356	34	0·0251	2,740,000	128	5	0·0266	211	32	0·0243
3,190,000	198	8	0·0121	353	48	0·0220	2,730,000	163	8	0·0181	274	41	0·0203
3,180,000	225	37	0·0225	350	24	0·0256	2,720,000	335	32	0·0020	335	0	0·0234
3,170,000	258	39	0·0330	0	35	0·0332	2,710,000	32	44	0·0165	25	30	0·0286
3,160,000	290	33	0·0416	21	1	0·0422	2,700,000	111	34	0·0299	65	35	0·0329
3,150,000	321	57	0·0469	45	34	0·0499	2,690,000	97	48	0·0420	101	36	0·0342
3,140,000	352	46	0·0477	74	17	0·0528	2,680,000	128	58	0·0504	136	1	0·0315
3,130,000	22	23	0·0435	103	13	0·0518	2,670,000	161	29	0·0537	171	12	0·0254
3,120,000	49	47	0·0346	134	22	0·0462	2,660,000	193	57	0·0537	211	36	0·0142
3,110,000	70	38	0·0222	166	45	0·0370	2,650,000	227	53	0·0479	318	37	0·0053
3,100,000	50	12	0·0120	200	38	0·0253	2,640,000	263	45	0·0385	54	24	0·0173
3,090,000	17	29	0·0173	237	50	0·0124	2,630,000	304	46	0·0264	93	36	0·0331
3,081,000	----		----	319	39	0·0018	2,620,000	3	15	0·0143	127	6	0·0478
3,080,000	30	28	0·0319	5	34	0·0015	2,610,000	104	16	0·0136	158	59	0·0592
3,079,000	----		----	43	6	0·0021	2,600,000	172	4	0·0221	190	3	0·0660
3,070,000	55	19	0·0450	113	29	0·0115	2,590,000	215	14	0·0342	220	29	0·0666
3,060,000	82	45	0·0524	153	41	0·0202	2,580,000	257	22	0·0383	249	56	0·0609
3,050,000	101	54	0·0560	192	57	0·0264	2,570,000	297	34	0·0411	277	29	0·0492
3,040,000	140	3	0·0580	233	17	0·0303	2,560,000	339	17	0·0397	299	44	0·0330
3,030,000	168	16	0·0523	274	50	0·0326	2,550,000	24	15	0·0369	298	34	0·0167
3,020,000	194	49	0·0427	316	55	0·0341	2,540,000	74	21	0·0323	253	58	0·0192
3,010,000	218	35	0·0302	359	0	0·0355	2,530,000	78	17	0·0252	259	26	0·0368
3,000,000	241	23	0·0151	39	29	0·0365	2,520,000	181	2	0·0321	283	4	0·0535
2,990,000	198	18	0·0095	77	59	0·0365	2,510,000	226	46	0·0344	310	17	0·0657
2,980,000	175	47	0·0181	114	16	0·0351	2,500,000	268	54	0·0352	338	37	0·0721
2,970,000	167	19	0·0295	148	37	0·0315	2,490,000	307	39	0·0331	7	18	0·0722
2,960,000	218	8	0·0387	181	1	0·0260	2,480,000	345	17	0·0275	35	46	0·0662
2,950,000	246	23	0·0439	210	39	0·0170	2,470,000	23	59	0·0189	63	26	0·0553
2,940,000	277	31	0·0467	247	45	0·0033	2,460,000	81	48	0·0083	88	42	0·0414
2,935,000	----		----	178	9	0·0027	2,450,000	212	16	0·0091	109	34	0·0252
2,930,000	310	28	0·0443	125	28	0·0067	2,440,000	266	21	0·0217	97	19	0·0114
2,920,000	345	49	0·0386	142	5	0·0198	2,430,000	302	25	0·0343	57	27	0·0138
2,910,000	26	14	0·0320	170	58	0·0343	2,420,000	334	51	0·0455	64	45	0·0253
2,900,000	80	3	0·0220	200	50	0·0443	2,410,000	353	37	0·0537	88	41	0·0351
2,890,000	150	12	0·0194	231	52	0·0529	2,400,000	36	3	0·0571	116	40	0·0415
2,880,000	214	49	0·0219	263	28	0·0574	2,390,000	65	41	0·0560	147	43	0·0441
2,870,000	266	36	0·0278	295	22	0·0599	2,380,000	95	31	0·0499	181	21	0·0431
2,860,000	313	3	0·0317	327	37	0·0518	2,370,000	128	32	0·0423	218	32	0·0388
2,850,000	353	45	0·0319	0	18	0·0416	2,360,000	143	3	0·0243	260	0	0·0334
2,840,000	38	42	0·0293	30	16	0·0265	2,350,000	130	24	0·0106	308	22	0·0281
2,830,000	4	16	0·0247	71	24	0·0110	2,340,000	78	26	0·0179	2	30	0·0254
2,825,000	----		----	114	24	0·0028	2,330,000	95	38	0·0342	57	16	0·0257
2,824,000	----		----	154	20	0·0017	2,320,000	121	34	0·0485	106	9	0·0270
2,822,500	----		----	215	56	0·0033	2,310,000	150	25	0·0585	151	18	0·0268
2,820,000	154	24	0·0216	261	28	0·0065	2,300,000	179	52	0·0620	195	27	0·0238
2,810,000	217	32	0·0253	305	41	0·0226	2,290,000	201	24	0·0611	295	49	0·0181

Table continued—Perihelion and Eccentricity.

Year.	Stockwell.		LeVerrier.		Year.	Stockwell.		LeVerrier.	
Before 1850.	Long.	Ecc.	Long.	Ecc.	Before 1850.	Long.	Ecc.	Long.	Ecc.
2,280,000	239° 47′	0·0528	311° 19′	0·0125	1,730,000	340° 35′	0·0140	110° 43′	0·0246
2,270,000	269 45	0·0401	37 55	0·0142	1,720,000	340 0	0·0180	128 20	0·0163
2,260,000	306 38	0·0187	98 1	0·0231	1,710,000	352 37	0·0250	126 44	0·0090
2,250,000	308 17	0·0093	141 18	0·0328	1,700,000	13 5	0·0318	94 40	0·0095
2,240,000	220 25	0·0088	178 39	0·0406	1,690,000	36 31	0·0366	73 31	0·0132
2,230,000	232 54	0·0210	213 22	0·0448	1,680,000	60 33	0·0383	114 59	0·0152
2,220,000	259 19	0·0305	245 55	0·0457	1,670,000	87 53	0·0365	138 51	0·0144
2,210,000	288 41	0·0357	277 20	0·0421	1,660,000	101 41	0·0328	161 51	0·0099
2,200,000	325 37	0·0425	307 7	0·0352	1,650,000	113 45	0·0283	167 54	0·0034
2,190,000	351 5	0·0343	334 20	0·0259	1,640,000	118 32	0·0264	67 45	0·0060
2,180,000	25 2	0·0288	355 28	0·0153	1,630,000	123 11	0·0291	94 30	0·0146
2,170,000	63 45	0·0218	344 38	0·0067	1,620,000	134 45	0·0344	109 4	0·0223
2,160,000	113 23	0·0152	295 35	0·0096	1,610,000	152 16	0·0397	134 23	0·0277
2,150,000	180 38	0·0126	305 22	0·0191	1,600,000	172 52	0·0430	158 42	0·0305
2,140,000	296 41	0·0155	331 51	0·0255	1,590,000	194 36	0·0438	180 56	0·0305
2,130,000	289 22	0·0200	0 5	0·0304	1,580,000	216 8	0·0419	199 43	0·0284
2,120,000	327 5	0·0227	30 37	0·0329	1,570,000	236 26	0·0379	213 12	0·0256
2,110,000	2 48	0·0231	61 37	0·0333	1,560,000	254 20	0·0325	225 26	0·0217
2,100,000	37 42	0·0199	98 54	0·0298	1,550,000	268 17	0·0269	225 47	0·0239
2,090,000	74 40	0·0136	137 46	0·0266	1,540,000	277 2	0·0197	233 17	0·0270
2,080,000	133 32	0·0048	182 4	0·0223	1,530,000	278 26	0·0203	245 34	0·0316
2,070,000	282 13	0·0081	232 10	0·0191	1,520,000	281 28	0·0216	262 9	0·0364
2,060,000	326 55	0·0190	284 54	0·0175	1,510,000	294 19	0·0265	281 54	0·0399
2,050,000	2 1	0·0291	334 45	0·0169	1,500,000	309 16	0·0288	303 28	0·0430
2,040,000	34 8	0·0366	20 50	0·0155	1,490,000	331 51	0·0310	326 52	0·0434
2,030,000	64 56	0·0405	63 11	0·0116	1,480,000	348 5	0·0314	351 32	0·0422
2,020,000	95 46	0·0400	113 0	0·0066	1,470,000	29 6	0·0277	16 1	0·0361
2,013,000	----	----	214 46	0·0030	1,460,000	64 31	0·0224	39 23	0·0285
2,010,000	123 8	0·0352	263 1	0·0045	1,450,000	110 50	0·0152	57 12	0·0195
2,000,000	147 16	0·0273	323 44	0·0139	1,440,000	178 7	0·0097	56 58	0·0119
1,990,000	162 0	0·0182	1 30	0·0249	1,430,000	264 46	0·0117	34 7	0·0130
1,980,000	149 53	0·0126	34 44	0·0328	1,420,000	313 50	0·0175	41 32	0·0200
1,970,000	135 1	0·0165	65 33	0·0363	1,410,000	355 46	0·0215	64 12	0·0248
1,960,000	146 6	0·0236	94 18	0·0427	1,400,000	34 49	0·0222	97 35	0·0315
1,950,000	167 23	0·0299	120 32	0·0427	1,390,000	82 31	0·0188	130 43	0·0325
1,940,000	196 46	0·0331	144 21	0·0399	1,380,000	124 10	0·0134	171 11	0·0336
1,930,000	216 49	0·0326	161 18	0·0356	1,370,000	202 27	0·0089	212 0	0·0323
1,920,000	241 27	0·0311	173 10	0·0320	1,360,000	288 47	0·0138	254 51	0·0309
1,910,000	263 47	0·0268	180 31	0·0311	1,350,000	338 48	0·0233	297 10	0·0283
1,900,000	285 42	0·0215	186 29	0·0335	1,340,000	16 58	0·0322	338 37	0·0255
1,890,000	303 28	0·0162	200 34	0·0381	1,330,000	51 10	0·0383	17 42	0·0216
1,880,000	314 34	0·0114	216 11	0·0428	1,320,000	83 11	0·0412	53 59	0·0159
1,870,000	315 24	0·0082	234 1	0·0465	1,310,000	111 27	0·0434	83 22	0·0082
1,860,000	307 49	0·0074	252 51	0·0490	1,300,000	142 12	0·0347	0 37	0·0025
1,850,000	310 11	0·0084	272 15	0·0500	1,290,000	168 15	0·0266	346 20	0·0123
1,840,000	326 26	0·0095	291 44	0·0492	1,280,000	187 17	0·0164	18 27	0·0226
1,830,000	351 46	0·0095	310 47	0·0466	1,270,000	171 4	0·0069	47 42	0·0327
1,820,000	28 24	0·0082	328 36	0·0425	1,260,000	126 50	0·0127	76 55	0·0412
1,810,000	90 35	0·0069	343 38	0·0377	1,250,000	138 21	0·0233	105 34	0·0474
1,800,000	151 0	0·0078	354 49	0·0334	1,240,000	162 37	0·0339	134 24	0·0508
1,790,000	204 17	0·0110	2 53	0·0314	1,230,000	189 52	0·0419	162 36	0·0508
1,780,000	244 36	0·0150	11 37	0·0331	1,220,000	218 54	0.0465	190 9	0·0473
1,770,000	278 57	0·0179	25 31	0·0346	1,210,000	249 17	0·0472	216 35	0·0395
1,760.000	306 35	0·0188	43 37	0·0363	1,200,000	281 5	0·0439	239 34	0·0289
1,750,000	329 29	0·0175	65 25	0·0352	1,190,000	314 51	0·0366	249 54	0·0168
1,740,000	342 17	0·0149	88 21	0·0312	1,180,000	352 16	0·0257	216 1	0·0121

Table continued—Perihelion and Eccentricity.

Year.	Stockwell.		LeVerrier.		Year.	Stockwell.		LeVerrier.	
Before 1850.	Long.	Ecc.	Long.	Ecc.	Before 1850.	Long.	Ecc.	Long.	Ecc.
1,170,000	42° 34′	0·0145	204° 24′	0·0228	610,000	359° 20′	0·0224	348° 54′	0·0353
1,160,000	140 15	0·0088	217 5	0·0325	600,000	44 9	0·0353	32 43	0·0418
1,150,000	222 12	0·0167	250 27	0·0473	590,000	81 44	0·0437	72 46	0·0451
1,140,000	269 14	0·0259	280 5	0·0541	580,000	114 53	0·0509	109 42	0·0478
1,130,000	310 0	0·0323	311 18	0·0558	570,000	151 44	0·0535	145 47	0·0450
1,120,000	350 23	0·0376	343 52	0·0522	560,000	185 16	0·0496	179 9	0·0368
1,110,000	32 58	0·0342	17 59	0·0434	550,000	218 19	0·0409	216 47	0·0262
1,100,000	79 32	0·0315	55 21	0·0311	540,000	251 0	0·0283	267 19	0·0126
1,090,000	131 24	0·0293	103 7	0·0177	531,500	----	---	350 27	0·0019
1,080,000	185 42	0·0297	195 34	0·0099	531,000	----	----	18 21	0·0015
1,070,000	236 27	0·0326	279 57	0·0173	530,800	----	----	29 39	0·0016
1,060,000	281 17	0·0360	322 16	0·0243	530,500	----	----	37 31	0·0018
1,050,000	321 18	0·0375	4 10	0·0346	530,000	283 0	0·0133	61 33	0·0024
1,040,000	358 41	0·0366	40 23	0·0340	520,000	136 52	0·0023	126 41	0·0165
1,030,000	34 10	0·0303	76 40	0·0311	510,000	167 44	0·0169	162 49	0·0315
1,020,000	70 11	0·0214	118 17	0·0246	500,000	199 31	0·0287	193 59	0·0388
1,010,000	111 41	0·0096	171 42	0·0172	490,000	228 9	0·0395	226 12	0·0446
1,000,000	271 11	0·0056	248 26	0·0151	480,000	266 20	0·0425	257 51	0·0470
990,000	326 55	0·0197	313 42	0·0224	470,000	294 4	0·0437	290 35	0·0443
980.000	1 14	0·0338	357 59	0·0330	460,600	326 7	0·0410	322 46	0·0387
970,000	32 19	0·0461	34 3	0·0424	450,000	359 48	0·0353	356 51	0·0308
960,000	62 57	0·0535	66 46	0·0491	440,000	35 21	0·0276	34 44	0·0218
950,000	96 23	0·0605	97 47	0·0517	430,000	77 4	0·0191	101 31	0·0132
940,000	125 7	0·0616	127 42	0·0495	420,000	134 45	0·0119	164 17	0·0087
930,000	152 57	0·0548	156 7	0·0423	410,000	215 12	0·0103	240 38	0·0121
920,000	181 54	0·0440	181 41	0·0305	400,000	279 21	0·0145	289 30	0·0167
910,000	210 42	0·0296	194 15	0·0156	390,000	327 5	0·0182	332 14	0·0199
900,000	218 35	0·0115	135 7	0·0109	380,000	10 42	0·0199	14 11	0·0202
890,000	134 27	0·0124	129 36	0·0277	370,000	55 29	0·0206	62 23	0·0185
880,000	146 56	0·0308	152 33	0·0457	360,000	133 37	0·0188	120 14	0·0171
870,000	174 21	0·0472	180 23	0·0608	350,000	164 15	0·0190	182 50	0·0195
860.000	204 33	0·0592	209 41	0·0709	340,000	222 8	0·0222	236 22	0·0260
850,000	234 52	0·0625	239 28	0·0747	330,000	272 6	0·0278	279 56	0·0337
840,000	267 33	0·0649	269 15	0·0717	320,000	314 55	0·0334	317 31	0·0399
830.000	299 43	0·0582	298 27	0·0623	310,000	352 23	0·0370	5 14	0·0430
820,000	333 10	0·0464	325 45	0·0471	300,000	27 08	0·0373	23 26	0·0424
810,000	8 12	0·0309	348 27	0·0297	290,000	58 14	0·0337	47 16	0·0342
800,000	51 25	0·0140	343 48	0·0132	280,000	86 44	0·0262	74 6	0·0286
790,000	193 20	0·0062	293 27	0·0171	270,000	104 43	0·0163	82 35	0·0214
780,000	261 50	0·0196	303 43	0·0325	260,000	83 2	0·0093	63 27	0·0171
770,000	299 45	0·0310	328 40	0·0455	250,000	56 44	0·0161	58 40	0·0260
760,000	334 47	0·0382	357 14	0·0540	240,000	71 51	0·0271	76 53	0·0362
750,000	9 21	0·0410	28 13	0·0580	230,000	94 20	0·0370	96 37	0·0477
740,000	45 54	0·0391	58 31	0·0562	220,000	119 35	0·0437	120 43	0·0545
730,000	84 47	0·0350	90 56	0·0505	210,000	144 46	0·0471	138 16	0·0567
720,000	127 6	0·0290	125 5	0·0419	200,000	169 0	0·0470	168 18	0·0569
710.000	179 16	0·0240	164 5	0·0342	190,000	191 30	0·0442	187 56	0·0529
700,000	238 3	0·0232	208 26	0·0227	180,000	215 35	0·0395	209 30	0·0477
690,000	292 26	0·0268	269 18	0·0150	170,000	227 38	0·0334	225 8	0·0413
680,000	339 56	0·0312	342 15	0·0141	160,000	238 13	0·0283	236 13	0·0359
670,000	18 56	0·0348	43 10	0·0178	150,000	242 27	0·0254	242 51	0·0332
660,000	57 28	0·0348	93 6	0·0221	140,000	245 45	0·0266	249 6	0·0341
650,000	96 8	0·0310	141 41	0·0227	130,000	254 23	0·0307	259 25	0·0385
640,000	138 28	0·0237	192 38	0·0233	120,000	269 35	0·0356	274 31	0·0426
630,000	195 30	0·0147	247 9	0·0249	110,000	289 28	0·0394	294 7	0·0462
620,000	289 44	0·0127	301 2	0·0287	100,000	312 6	0·0408	316 18	0·0473

Table continued—Perihelion and Eccentricity.

Year.	Stockwell.		LeVerrier.	
Before 1850.	Long.	Ecc.	Long.	Ecc.
90,000	336° 15′	0·0392	340° 3′	0·0452
80,000	0 41	0·0343	4 13	0·0398
70,000	23 36	0·0269	27 22	0·0316
60,000	40 43	0·0181	46 8	0·0218
50,000	38 42	0·0110	51 44	0·0129
40,000	16 31	0·0110	28 36	0·0109
30,000	20 56	0·0157	25 50	0·0151
20,000	41 57	0·0192	44 0	0·0188
10,000	69 28	0·0195	69 47	0·0195
A. D. 1850	100 21	0·0168	100 21	0·0168
10,000	136 1	0·0115	131 43	0·0149
20,000	191 53	0·0055	192 13	0·0059
24,000	----	----	247 18	0·0034
25,000	----	----	263 25	0·0035
30,000	305 49	0·0049	318 38	0·0059
40,000	325 25	0·0077	6 24	0·0124
50,000	37 22	0·0134	38 3	0·0173
60,000	64 38	0·0145	64 30	0·0199
70,000	84 58	0·0134	86 14	0·0200
80,000	93 40	0·0113	101 41	0·0188
90,000	88 46	0·0110	109 31	0·0181
100,000	87 58	0·0143	114 45	0·0192
110,000	106 26	0·0197	123 30	0·0225
120,000	117 11	0·0237	137 40	0·0264
130,000	135 23	0·0261	154 44	0·0299
140,000	156 54	0·0285	175 35	0·0333
150,000	176 0	0·0288	192 27	0·0336
160,000	194 6	0·0280	211 44	0·0336
170.000	209 47	0·0264	230 4	0·0325
180,000	223 31	0·0243	248 21	0·0304
190,000	233 48	0·0226	265 31	0·0279
200,000	241 21	0·0219	280 28	0·0248
210,000	248 39	0·0232	289 46	0·0223
220,000	260 14	0·0264	297 39	0·0219
230,000	277 29	0·0300	307 56	0·0235
240,000	299 19	0·0323	326 47	0·0266
250,000	334 18	0·0325	350 37	0·0286
260,000	351 20	0·0297	19 40	0·0299
270,000	20 21	0·0238	51 39	0·0275
280,000	50 11	0·0159	90 10	0·0242
290,000	79 52	0·0066	128 0	0·0200
295,000	88 27	0·0018	----	----
296,000	81 6	0·0009	----	----
297,000	0 9	0·0003	----	----
300,000	301 25	0·0028	172 32	0·0162
310,000	330 0	0·0108	219 47	0·0120
320,000	4 17	0·0163	244 50	0·0092
330,000	41 18	0·0188	317 55	0·0039
335,000	----	----	3 8	0·0012
337,000	----	----	82 54	0·0007
337,500	----	----	105 0	0·0009
340,000	82 35	0·0188	150 5	0·0023
350,000	131 1	0·0167	202 47	0·0097
360,000	189 5	0·0158	239 17	0·0184
370,000	247 35	0·0181	273 45	0·0270

Year.	Stockwell.		LeVerrier.	
After 1850.	Long.	Ecc.	Long.	Ecc.
380,000	299° 29′	0·0232	306° 9′	0·0346
390,000	336 54	0·0271	336 57	0·0403
400,000	11 57	0·0296	6 7	0·0429
410,000	43 58	0·0289	33 10	0·0439
420,000	71 8	0·0259	58 13	0·0395
430,000	93 25	0·0200	79 17	0·0341
440,000	102 25	0·0129	94 0	0·0278
450,000	77 9	0 0101	98 28	0·0231
460,000	63 40	0·0172	95 51	0·0235
470,000	77 23	0·0275	99 5	0·0293
480,000	98 48	0·0377	121 2	0·0383
490,000	124 0	0·0462	133 3	0·0460
500,000	150 10	0·0518	156 26	0·0523
510,000	176 54	0·0536	181 52	0·0553
520,000	203 46	0·0510	208 31	0·0543
530,000	229 47	0·0438	235 46	0·0488
540,000	253 6	0·0326	262 49	0·0390
550,000	264 17	0·0247	287 31	0·0259
560,000	234 6	0·0133	293 9	0·0134
570,000	186 8	0·0186	229 40	0·0093
580,000	239 48	0·0376	232 38	0·0221
590,000	264 17	0·0497	258 21	0·0332
600,000	293 13	0·0566	288 23	0·0401
610,000	323 42	0·0577	322 49	0·0439
620,000	355 2	0·0532	10 54	0·0396
630,000	27 9	0·0439	40 39	0·0272
640,000	60 45	0·0311	80 5	0·0230
650,000	98 42	0·0157	145 19	0·0167
655,000	126 28	0·0083	----	----
660,000	204 53	0·0038	217 58	0·0192
670,000	315 52	0·0142	270 43	0·0265
680,000	354 26	0·0248	310 37	0·0330
690,000	29 10	0·0320	345 14	0·0364
700,000	63 50	0·0349	17 8	0·0357
710,000	99 50	0·0343	45 43	0·0316
720,000	138 30	0·0306	74 52	0·0223
730,000	181 1	0·0257	94 48	0·0105
737,500	----	----	36 6	0·0033
740,000	236 30	0·0220	359 44	0·0053
750,000	295 6	0·0225	0 52	0·0197
760,000	347 37	0·0262	26 21	0·0335
770,000	32 18	0 0321	53 47	0·0476
780,000	71 53	0·0358	81 26	0·0578
790,000	109 25	0·0364	111 29	0·0635
800,000	146 44	0·0330	137 4	0·0644
810,000	189 1	0·0261	169 27	0·0588
820.000	231 53	0·0148	204 32	0·0506
830,000	330 17	0·0106	221 14	0·0329
840,000	52 47	0·0202	228 10	0·0164
850,000	99 36	0·0335	176 21	0·0145
860,000	138 0	0·0454	177 3	0·0307
870,000	173 46	0·0535	201 11	0·0467
880,000	208 28	0·0568	229 31	0·0589
890,000	242 44	0·0545	260 2	0·0654
900,000	277 0	0·0469	291 17	0·0659
910,000	310 13	0·0350	323 10	0·0608

Table continued—Perihelion and Eccentricity.

Year.	Stockwell.		LeVerrier.	
After 1850.	Long.	Ecc.	Long.	Ecc.
920,000	351° 31′	0·0200	355° 44′	0·0513
930,000	50 16	0·0038	28 55	0·0376
940,000	154 55	0·0134	65 22	0·0230
950,000	248 33	0·0232	114 16	0·0086
955,000	----	----	184 44	0·0040
956,000	----	----	208 11	0·0034
960,000	282 15	0·0378	267 21	0·0070
970,000	316 11	0·0447	322 11	0·0174
980,000	350 4	0·0478	0 46	0·0255
990,000	24 25	0·0461	38 32	0·0307
1,000,000	60 20	0·0414	77 27	0·0334
1,010,000	99 10	0·0345	118 45	0·0341
1,020,000	144 9	0·0268	161 53	0·0350
1,030,000	199 0	0·0209	206 14	0·0360
1,040,000	262 6	0·0195	254 13	0·0371
1,050,000	320 33	0·0220	292 29	0·0397
1,060,000	10 11	0·0254	332 48	0·0403
1,070,000	56 18	0·0272	11 43	0·0384
1,080,000	103 14	0·0267	50 13	0·0331
1,090,000	153 50	0·0253	90 18	0·0244
1,100,000	212 48	0·0248	140 43	0·0132
1,105,000	----	----	185 14	0·0080
1,107,500	----	----	222 19	0·0068
1,110,000	271 9	0·0285	270 16	0·0075
1,120,000	322° 21′	0·0355	337° 1′	0·0201
1,130,000	6 46	0·0429	19 11	0·0342
1,140,000	46 32	0·0484	55 44	0·0462
1,150,000	83 26	0·0502	90 29	0·0543
1,160,000	118 47	0·0472	124 24	0·0575
1,170,000	152 38	0·0392	157 52	0·0554
1,180,000	185 3	0·0269	191 13	0·0484
1,190,000	213 22	0·0113	224 49	0·0373
1,195,000	210 32	0·0032	----	----
1,196,500	160 32	0·0014	----	----
1,197,500	104 16	0·0021	----	----
1,200,000	86 7	0·0060	259 51	0·0236
1,210,000	107 35	0 0229	301 7	0·0100
1,215,000	----	----	8 19	0·0034
1,220,000	138 6	0·0374	85 15	0·0061
1,230,000	166 56	0·0500	157 52	0·0184
1,240,000	196 24	0·0576	193 14	0·0274
1,250,000	225 21	0·0604	221 49	0·0368
1,260,000	253 36	0·0583	260 54	0·0367

ART. XV. — *On Crystallized Danburite from Russell, St. Lawrence County, New York;* by GEO. J. BRUSH and EDWARD S. DANA.

Historical Note.—In December last (1879) we received a box of minerals from Mr. C. D. Nims, the well-known mineral collector of Northern New York, containing several specimens labelled "unknown." Among these were a few prismatic white weathered crystals that had been considered to be feldspar, to which our attention was specially called by Mr. Nims. On a pyrognostic examination this substance proved to be an anhydrous boro-silicate, corresponding in physical characters with the rare species *danburite.* Mr. Nims at that time generously placed at our disposal all of the small amount of this material he had in his possession, for scientific examination. These specimens we investigated as thoroughly as they allowed both chemically and crystallographically, and the conclusions reached were identical with those described in this paper. Upon learning further from Mr. Nims that there was a probability of his being able to obtain, in the following spring, more abundant material and of better quality, we deferred publication. Our expectations and those of Mr. Nims have been fully realized, and the material which he has forwarded to us, as the result of his recent active explorations, is all that could be desired both as to quantity and quality. We take pleasure in acknowledging here our indebtedness to him for his promptness and liberality.

Method of occurrence.—The mineral occurs both crystallized and massive, imbedded in what Mr. Nims calls a granitic rock; the points at which it is found extend along the brow of a hill for a considerable distance, say half a mile. The crystals line cavities or seams, sometimes of very considerable size, in the massive mineral or the enclosing rock. The associated minerals are a pale green pyroxene, a dark brown tourmaline, and also some mica, quartz and pyrite. Of these species, the danburite often encloses the crystals of pyroxene and tourmaline and is itself imbedded in the quartz, which is a point of interest in connection with its time of formation. These cavities were doubtless all filled originally with calcite, as the facts observed conclusively prove. A few perfectly fresh specimens were found with the crystals imbedded in pink calcite and Mr. Nims believes that when the explorations are carried deeper that larger quantities may be obtained. This is much to be desired, for the perfectly clear and transparent crystals found in the calcite are of rare beauty. The specimens here spoken of were actually obtained from some loose bowlders found on the surface.

The most of the specimens are now nearly or quite free from calcite, that mineral evidently having been removed by slow solution. The crystals are thus left in their original position projecting into the cavities. This natural removal of the calcite is in some aspects of the case an advantage, and in others quite the reverse. In no other way could the crystals have been freed from the calcite so perfectly and with so little injury to themselves; for the mechanical removal is out of the question owing to the brittleness of the mineral, and the removal by chemical means in the laboratory would not leave the crystals so nearly in their original condition. On the other hand, the specimens as found are somewhat destitute of freshness of aspect, the crystals being much rifted internally and more or less covered with oxide of iron which cannot be entirely removed. It is to be stated, however, that, while the mineral has thus lost something of its original beauty, it is, in most cases, very little if at all altered chemically, even the luster of the crystalline faces having suffered but little. On some few of the specimens, on the other hand, the crystals are quite opaque and have little luster.

General crystallographic and physical characters.—The danburite from Russell, as has been stated, is in part crystallized and in part massive. The crystals vary from those which are very minute to others which are of considerable size. The largest isolated crystal has a length of 4 and a width (macrodiagonal) of 2½ inches; some of the groups are really grand in their proportions. The massive mineral can be obtained in large blocks; it shows brilliant luster, is quite unaltered, and almost entirely free from admixed species. The most striking point in regard to the crystals is their similarity to crystals of topaz; so close is this resemblance that the specimens, if not examined too critically, might be handled many times without a suspicion that they did not belong to that species. It will be shown below that this resemblance extends beyond the mere external habit, involving a true homœomorphic relation. The cleavage is basal, as in topaz, but not very distinct.

The hardness of the danburite is 7 to 7·25, and the specific gravity 2·986 to 3·021. The luster on the polished crystalline surfaces is very brilliant; on the fracture and in the massive mineral it is vitreous to greasy; in this form it has much the aspect of common varieties of quartz. The color in the freshest crystals imbedded in calcite is pale wine-yellow, and in others from yellowish-white to honey yellow, dark wine-yellow, and yellowish-brown. The streak is white. The freshest crystals are perfectly transparent, the massive mineral translucent. The fracture is uneven to sub-conchoidal.

Description of crystalline form.—The crystals are uniformly prismatic in habit. They are commonly attached by one extremity of the prism so that only the other end is terminated; occasional crystals, however, have been observed with terminations alike at both extremities, and hence it is not hemimorphic. The general range of form in the crystals will be gathered from the accompanying figures; figures 1, 2, 3 and 4 show some of the more common and simple forms, and figures 5, 6 and 7 are others more highly modified. It will be noticed that the forms shown in figures 4 and 5 have the appearance of a square prism ($l \wedge l = 94° 52'$). The variety in habit is, as will be seen, very considerable, though the most constantly recurring form is that where the fundamental prism I predominates (fig. 1); the form represented in figure 7 is rather rare.

The crystals belong to the ORTHORHOMBIC SYSTEM; this is proved by the optical examination, since the three axes of elasticity correspond in position to the three crystallographic axes. The measured angles and the general symmetry of the form also correspond to this system.

Notwithstanding the number of the occurring planes the crystals are not often favorable for exact measurement. The planes forming the extremities of the crystals, even of those taken directly from the surrounding calcite, are, with the occasional exception of the domes *d* and *w*, uniformly unpolished and often much rounded. They show, moreover, many partially developed planes which do not admit of determination.

Fig. 1.

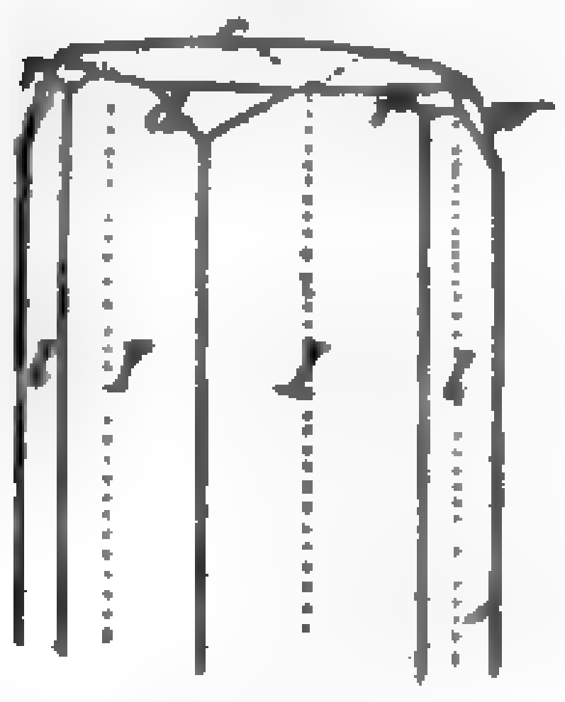


Fig. 2.

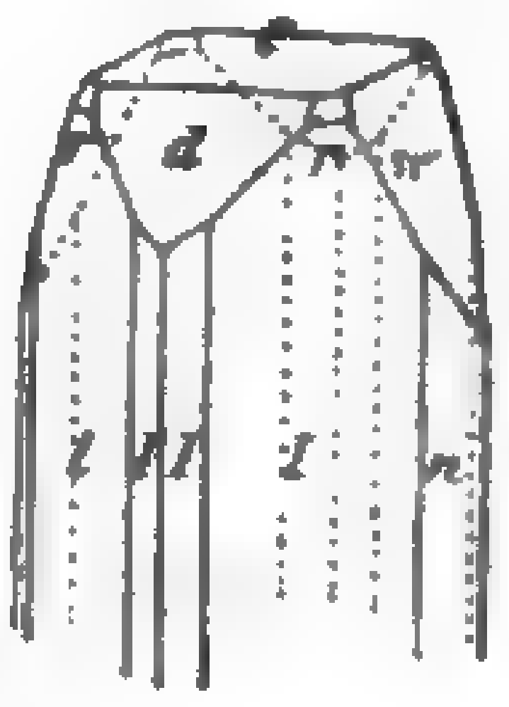


Fig. 3

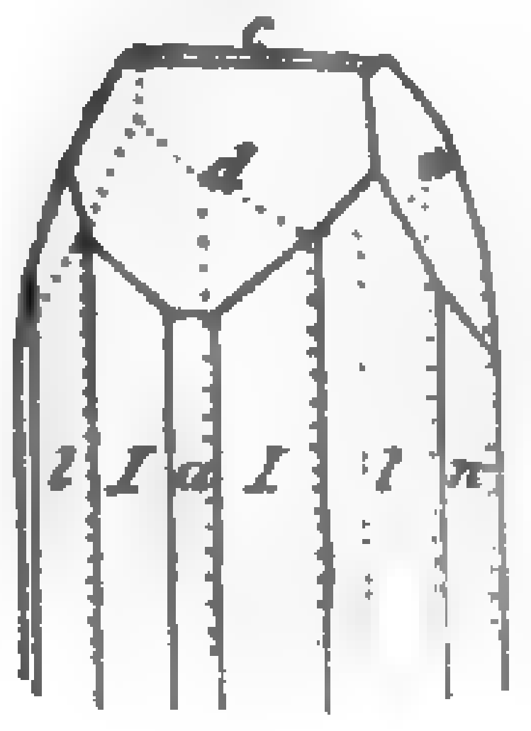
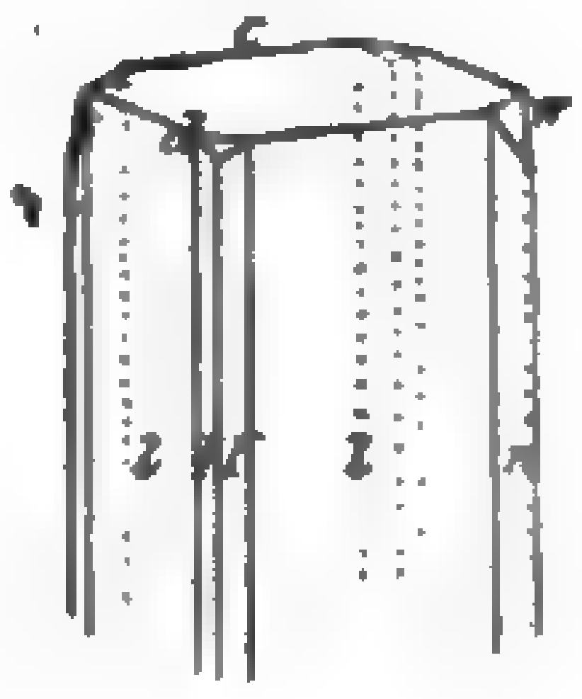


Fig. 4.



In these latter respects they resemble crystals of other species found in a similar situation (e. g. pyroxene in calcite). The determination of the symbols of the various planes was accomplished without difficulty with the aid of the zonal relations and with approximate angles, but only very few exact measurements were possible. The prismatic planes *I* and *l*, are, however, quite commonly smooth and highly polished. As fundamental angles* the following, as the mean of many single measurements, were accepted :

Fig. 5.

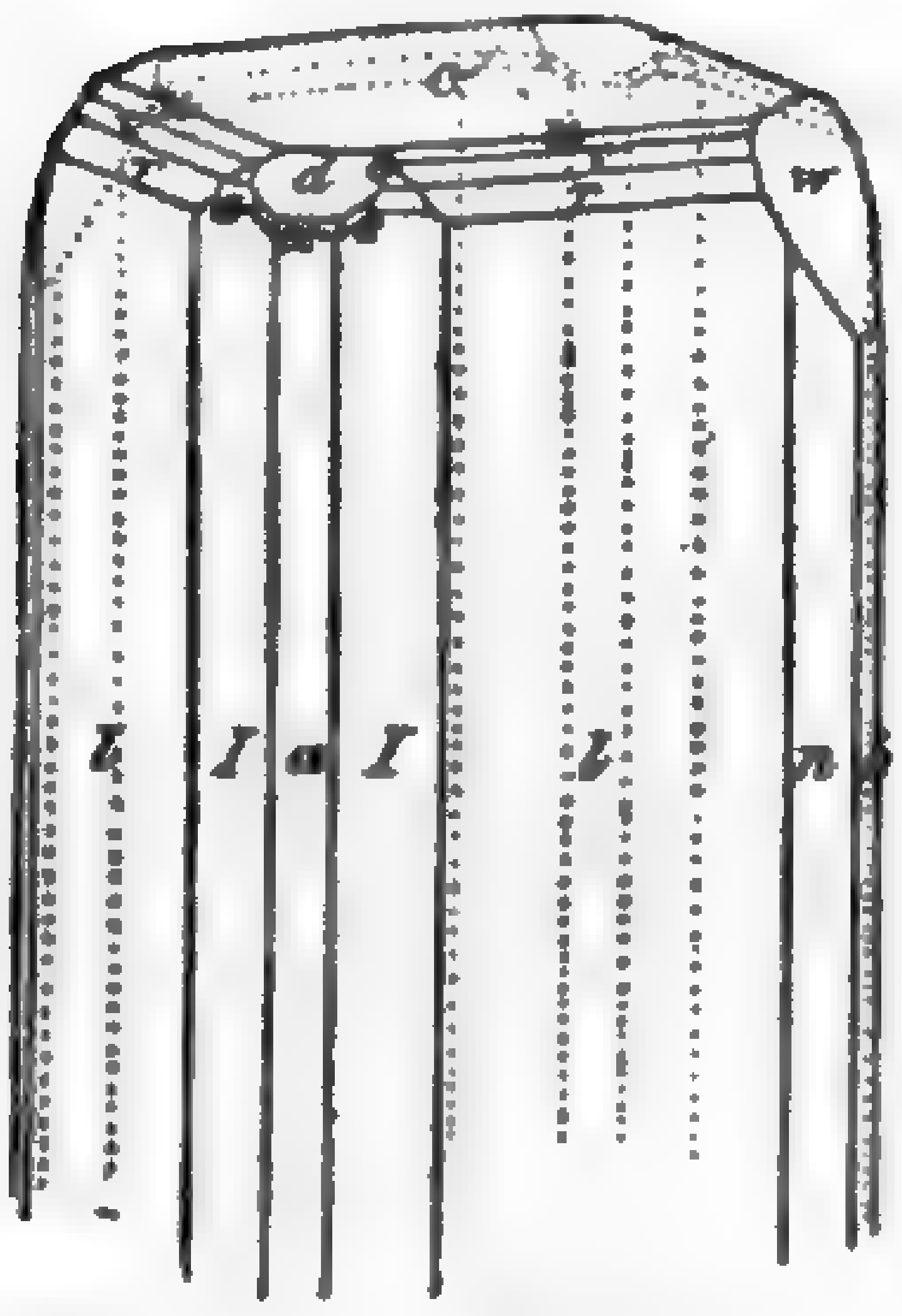


Fig. 6.

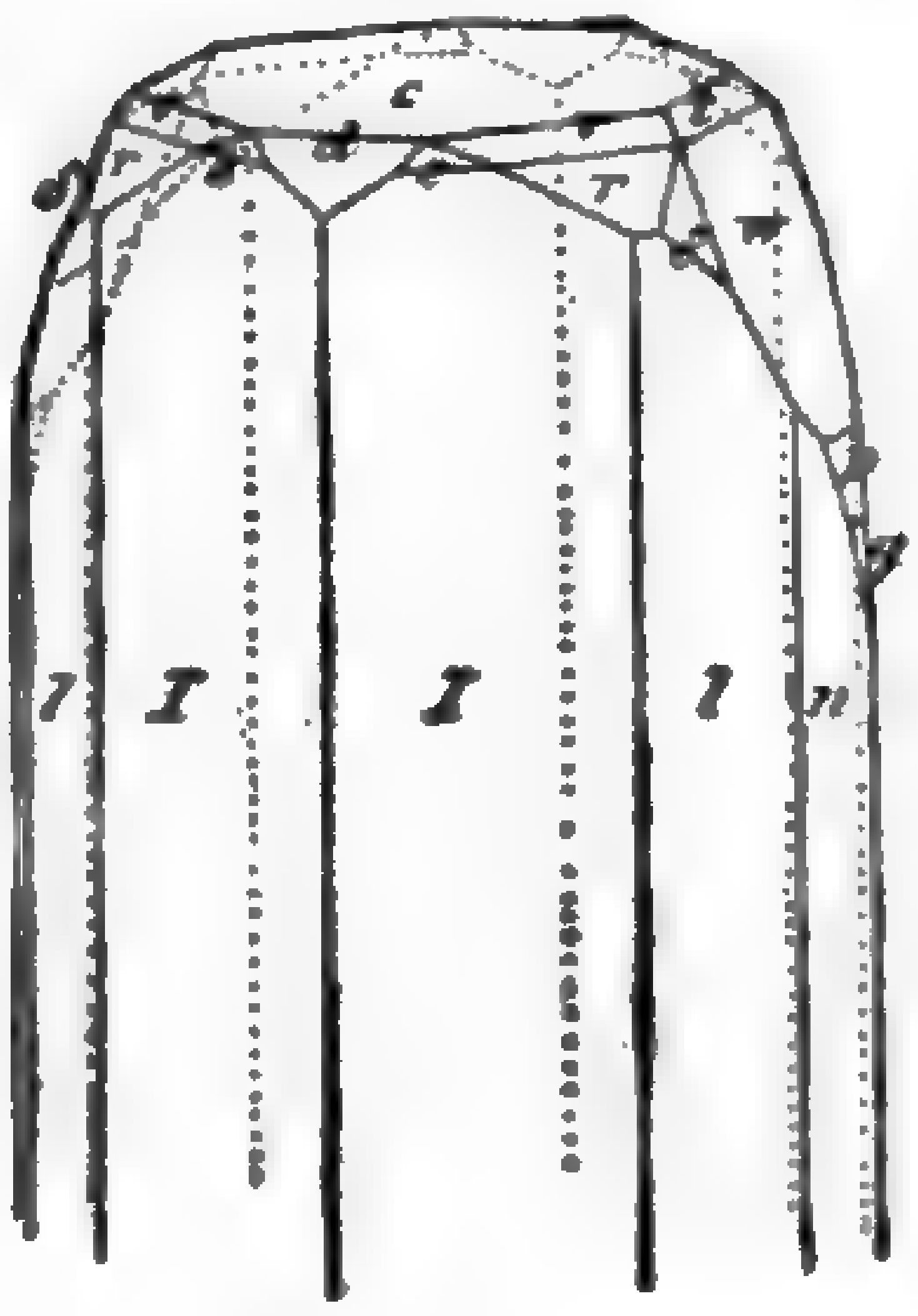
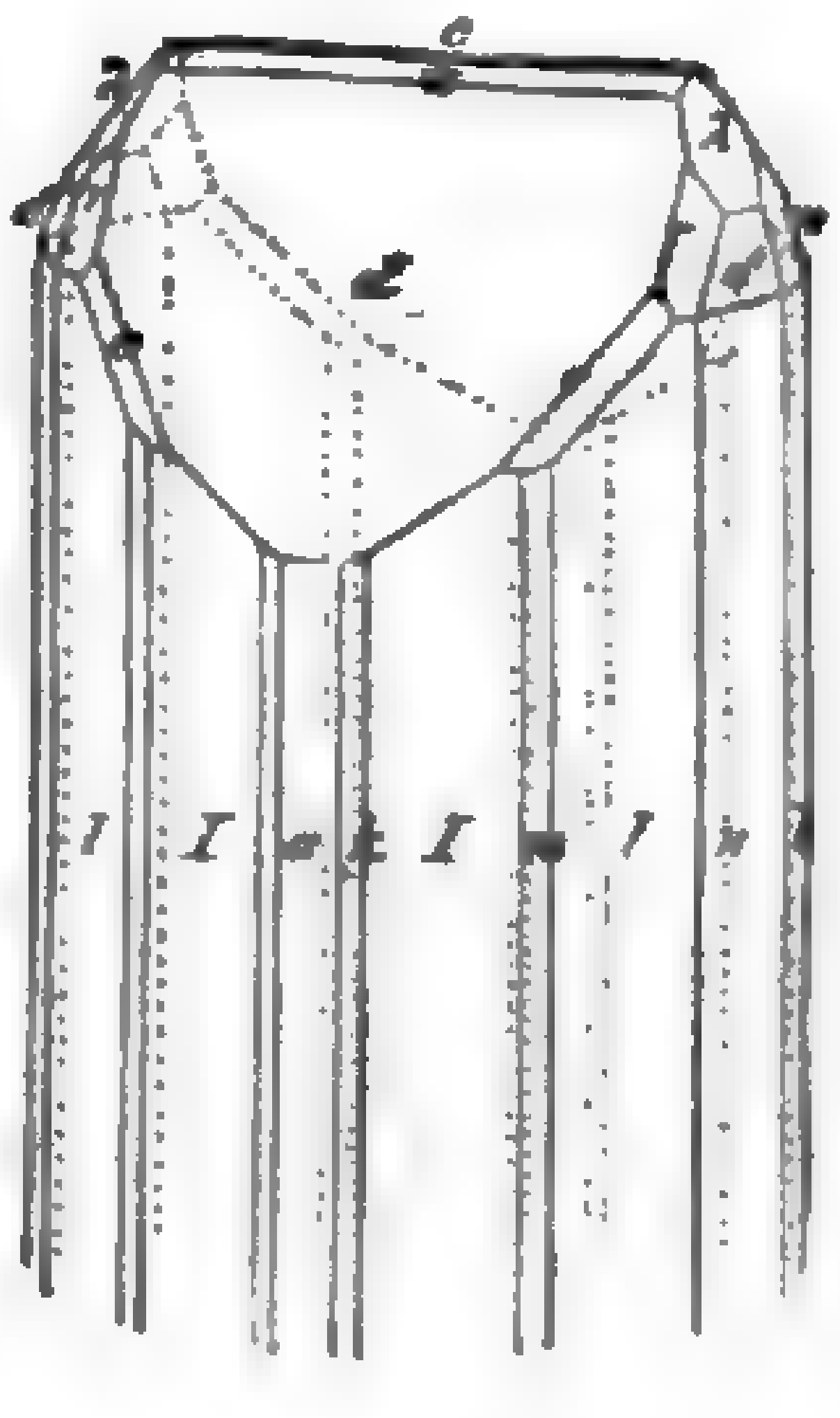


Fig. 7.



$I \wedge I'$ $110 \wedge \bar{1}10 = 57° \; 7' \; 54''$
$d \wedge d'$ $101 \wedge \bar{1}01 = 82° \; 53' \; 18''$

From these the following axial ratio is obtained :—

c (vert.)	$\bar{b}$	$\breve{a}$
0·8830	1·8367	1·0000

The observed planes are, as follows :—

c	*O*	001	*s*	$3\text{-}\bar{\frac{3}{2}}$	321
a	$i\text{-}\bar{i}$	100			
b	$i\text{-}\breve{i}$	010	*o*	1	111
			e	2	221
k	$i\text{-}\bar{\frac{3}{2}}$	320			
I	*I*	110	*u*	$\frac{1}{2}\text{-}\breve{2}$	124
m	$i\text{-}\breve{\frac{3}{2}}$	230	*v*	$1\text{-}\breve{2}$	122
l	$i\text{-}\breve{2}$	120	*r*	$2\text{-}\breve{2}$	121
n	$i\text{-}\breve{4}$	140			

---

* The angles given are all the supplement angles.

z	$\frac{1}{3}$-$\bar{i}$	103	λ	2-$\breve{4}$	142
d	1-$\bar{i}$	101	δ	4-$\breve{4}$	141
x	3-$\bar{i}$	301			
t	2-$\breve{i}$	021			
w	4-$\breve{i}$	041			
p	8-$\breve{i}$	081			
q	16-$\breve{i}$	0 16 1			

The following is a list of the most important angles for these planes, calculated from the axial ratio given above:—

		on *c* (001)	on *a* (100)	on *b* (010)
k	320	90° 0′	19° 57′	70° 3′
I	110	"	28° 34′	61° 26′
m	230	"	39° 14′	50° 46′
l	120	"	47° 26′	42° 34′
n	140	"	65° 20′	24° 40′
z	103	16° 24′	73° 36′	90° 0′
d	101	41° 27′	48° 33′	"
x	301	69° 19′	20° 41′	"
t	021	43° 52′	90° 0′	46° 8′
w	041	62° 31′	"	27° 29′
p	081	75° 25′	"	14° 35′
q	0161	82° 36′	"	7° 24′
s	321	70° 28′	27° 38′	71° 15′
o	111	45° 9′	51° 29′	70° 11′
e	221	63° 33′	38° 9′	64° 39′
u	124	18° 4′	77° 54′	76° 48′
v	122	33° 8′	68° 18′	66° 16′
r	121	52° 33′	57° 31′	54° 13′
λ	142	46° 37′	72° 21′	48° 40′
δ	141	64° 42′	67° 50′	34° 45′

The angle of the fundamental prism $(I \wedge I')$ as measured on several crystals was 57° 7, 57° 7′, 57° 7, 57° 8, 57° 12′; also for $l \wedge l'$ 94° 53, 94° 52′, 94° 55, 94° 56′ (required 94° 52′). The measured angle $c \wedge w$ (001∧041) = 62° 33′ (required 62° 31′). The measured angle $I \wedge d$ = 54° 22′ (required 54° 27′).

The similarity in general habit between the crystals of danburite and those of topaz has already been remarked. In fact the commonly occurring planes of the danburite crystals are all common planes on crystals of topaz, and of the few planes in the above list which do not belong to topaz all are rare in danburite. A comparison of the angles of the two species shows that the relation in form is really a close one. This will be seen from the following angles in the chief zones.

			Danburite.	Topaz.
$I \wedge I'$	$110 \wedge \bar{1}10$	=	57° 8′	55° 43′
$l \wedge l'$	$021 \wedge 0\bar{2}1$	=	94° 52′	93° 11′
$d \wedge d'$	$101 \wedge \bar{1}01$	=	82° 53′	83° 54′
$w \wedge w'$	$041 \wedge 0\bar{4}1$	=	125° 2′	124° 40′
$c \wedge o$	$001 \wedge 111$	=	45° 9′	45° 35′
$c \wedge e$	$001 \wedge 221$	=	63° 33′	63° 54′

The axial ratios for the two species are:—

	c (vert.)	$\bar{b}$	$\breve{a}$
Danburite	0·8830	1·8367	1·0000
Topaz	0·9024	1·8920	1·0000

The above values show that the two species are closely homœomorphous.

Optical properties.—The transparent crystals of danburite offered very good material for the determination of the optical properties of the species, and they prove to be of rather unusual interest. The first point established was the position of the axes of elasticity, which were found to coincide, as stated above, with the crystallographic axes. The optic axes lie in the basal plane, and the axial angles are so large that it was necessary to measure both of them in oil. By this measurement the interesting result was reached that the acute bisectrix for the lower end of the spectrum (red and yellow rays) is normal to the brachypinacoid, and for the upper end of the spectrum (blue rays) normal to the macropinacoid.

From a section cut parallel to the brachypinacoid the following angles were obtained, each being the mean of a large number of measurements:

Red (Lithia flame).	Yellow (Sodium flame).	Blue ($CuSO_4$ solution).
100° 33′	101° 30′	104° 36′

From a section parallel to the macropinacoid the angles obtained in the same manner were:

Red (Li).	Yellow (Na).	Blue ($CuSO_4$).
106° 35′	105° 36′	102° 13′

From these angles the true internal axial angle was calculated by the usual method; the results are:

	Bisectrix normal to b (010).	Bisectrix normal to a (100).
Red (Li)	87° 37′	92° 23′
Yellow (Na)	88° 23′	91° 37′
Blue ($CuSO_4$)	90° 56′	89° 4′

The bisectrix normal to the brachypinacoid is negative, and that normal to the macropinacoid is positive.

The index of refraction of the oil employed was found to be for

Red (Li) = 1·4706; Yellow (Na) = 1·4735; Blue ($CuSO_4$) = 1·483

For obvious reasons the last value is less accurate than the other two. Making use of these values in the usual formulas, the mean index of refraction (β) for danburite is obtained, viz:

β = 1·634, Red (Li)
= 1·637, Yellow (Na)
= 1·646, Blue ($CuSO_4$)

It is obvious from the values of the axial angles for the different colors given above, that for certain rays, those falling in the lower end of the blue, the axial angle must be for the ordinary temperature *exactly* 90°. It would be easy to calculate the wave-length of the rays answering this condition, but since the sections employed were not faultless the angles are not very accurate and hence the calculation would have but little value.

Optically danburite does not agree very closely with topaz, for with the latter species the axes lie in the brachydiagonal, the vertical axis coinciding with the acute bisectrix; the axial angle is also quite different. It is interesting to note, however, that the mean indices of refraction are not far apart; thus for the D line in the spectrum, we have

β, Danburite = 1·637
Topaz = 1·6138

Chemical composition.—The quantitative chemical examination of the mineral was made by Mr. W. J. Comstock, of the Sheffield Laboratory, to whom we wish here to express our grateful acknowledgments for the following analyses:

	I.	II.	III.	IV.	Mean.
Silica	48·16	48·30	----	----	48·23
Boron trioxide	----	----	26·67	27·18	26·93
Lime	23·26	23·22	----	----	23·24
Alumina*	0·48	0·46	----	----	·47
Ignition	0·64	0·63	----	----	·63
					99·50

* With trace Fe_2O_3.

The mineral was decomposed by fusion with sodium carbonate for the silica and bases in Nos. I and II, and the boric acid in Nos. III and IV was obtained by Stromeyer's method as potassium boro-fluoride. A further decomposition was effected with fluohydric acid to make special examination for alkalies, which gave a negative result.

In view of the close homœomorphism of our mineral with topaz, we requested Mr. Comstock to make special examination for fluorine, but the result proved the absence of this and allied elements.

Mr. Comstock's analyses offer a remarkable confirmation of the analyses of Smith and Brush* of the Danbury mineral, the mean of which gave

SiO_2	B_2O_3	Al_2O_3, Fe_2O_3	Mn_2O_3	CaO	MgO	ign.
48·15	27·15	0·30	0·56	22·37	0·40	0·50 = 99·43

The quantivalents ratio from the mean of Comstock's analyses gives for $SiO_2 : B_2O_3 : CaO = 8·04 : : 3·88 : : 4·14$ and that from the analyses of Smith and Brush is 8·02 : : 3·89 : : 4·10. There can be no question that the true theoretical ratio is 2 : 1 : 1. This leads to the formula previously accepted, that

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* This Journal, II, xvi, 365, 1853.

is, $CaB_2Si_2O_8$, or $Ca_2SiO_4+B_4Si_3O_{12}$. The formula requires: Silica, 48·78, boron trioxide, 28·46, lime, 22·76=100. These results set at rest any further question as to the chemical composition of danburite. It does not appear, however, that there is any immediate relation between danburite and topaz in chemical composition, which, considering the similarity in crystalline form, is rather remarkable.

Pyrognostic characters.—The pyrognostic characters of this species are sufficiently important to be here repeated. B. B. the mineral glows, fuses gently at 3·5 to a colorless glass, imparting to the flame the characteristic green color due to boron. On cooling, the assay loses its transparency and becomes milk-white. In the closed tube it phosphoresces brilliantly with a reddish yellow light. The mineral is slightly acted upon by hydrochloric acid, sufficiently so to give the reaction for boric acid with turmeric paper. When previously ignited to the point of fusion the mineral gelatinizes with acid.

Comparison with the original danburite.—A comparison between the characters of the danburite from Russell, N. Y., and those of the same species from the original locality at Danbury, Conn., shows a very close agreement in all essential respects, which removes all doubt as to the real identity of the mineral now described. In crystalline form alone is there apparent divergence. In regard to this there is only to be said that the earlier determinations upon the Danbury mineral were made on imbedded fragments in feldspar where apparent planes, at best of a problematical nature, certainly did not represent the true crystalline form of the species.

ART. XVI.—*On a Photograph of Jupiter's Spectrum, showing Evidence of Intrinsic Light from that Planet;* by Professor HENRY DRAPER, M.D.

[Read before the Royal Astronomical Society, May 14th, 1880, and extracted from the Monthly Notices.]

THERE has been for some years a discussion as to whether the planet Jupiter shone to any perceptible extent by his own intrinsic light, or whether the illumination was altogether derived from the sun. Some facts seem to point to the conclusion that it is not improbable that Jupiter is still hot enough to give out light, though perhaps only in a periodic or eruptive manner.

It is obvious that spectroscopic investigation may be usefully employed in the examination of this question and I have incidentally, in the progress of an allied inquiry,* made a photo-

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* See paper "On Photographing the Spectra of the Stars and Planets," read before the National Academy of Sciences, Oct. 28, 1879, and published in this Journal, Dec., 1879, and in Nature, Nov. 27, 1879.

graph which has sufficient interest to be submitted to the inspection of the Astronomical Society.

If the light of Jupiter be in large part the result of his own incandescence, it is certain that the spectrum must differ from that of the sun, unless the improbable hypothesis be advanced that the same elements, in the same proportions and under the same physical conditions, are present in both bodies. Most of the photographs I have made of the spectrum of Jupiter, answer this question decidedly, and from their close resemblance to the spectrum of the sun indicate that, under the average circumstances of observation, almost all the light coming to the earth from Jupiter must be merely reflected light originating in the sun. For this reason I have used the spectrum of Jupiter as a reference spectrum on many of my stellar spectrum photographs.

But on one occasion, viz: on September 27, 1879, a spectrum of Jupiter with a comparison spectrum of the moon was obtained which shows a different state of things. Fortunately, owing to the assiduous assistance of my wife, I have a good record of the circumstances under which this photograph was taken, and this will make it possible to connect the aspect of Jupiter at the time, with the spectrum photograph, though I did not examine Jupiter with any care through the telescope that night, and indeed did not have my attention attracted to this photograph till some time afterwards.

I send herewith to the Astronomical Society for examination, the original negative which is just as it was produced, except that it has been cemented with Canada balsam to another piece of glass for protection. Attached to the photograph is an explanatory diagram, intended to point out the peculiarities which are of interest. It will be noticed at once that the main difference is not due to a change in the number or arrangement of the Fraunhofer lines, but rather to a variation in the strength of the background. In the case of the moon the background is uniform across the width of the spectrum in any region, but in the case of Jupiter the background is fainter in the middle of the width of the spectrum in the region above the line *h*, and stronger in the middle in the region below *h*, especially toward F. The observer must not be confused by the dark portion where the two spectra overlap along the middle of the combined photograph.

In order to interpret this photograph it must be understood that the spectrum of Jupiter was produced from an image of the planet thrown upon the slit of the spectroscope, by a telescope of 183 inches focal length, the slit being placed approximately in the direction of a line joining the poles of the planet. The spectroscope did not, therefore, integrate the light of the whole disk, but analyzed a band at right angles to the equator and extending across the disk. If either absorption or production of light were taking place on that portion of Jupiter's surface there might be a modification in the intensity of the general background of the photographed spectrum.

A casual inspection will satisfy any one that such modifications in the intensity of the background are readily perceptible in the original negative. They seem to me to point out two things that are occurring: first, an absorption of solar light in the equatorial regions of the planet; and second, a production of intrinsic light at the same place. We can reconcile these apparently opposing statements by the hypothesis that the temperature of the incandescent substances producing light at the equatorial regions of Jupiter did not suffice for the emission of the more refrangible rays, and that there were present materials which absorbed those rays from the sunlight falling on the planet.

If the spectrum photograph exhibited only the absorption phenomenon above *h*, the interest attached to it would not be great because a physicist will readily admit from theoretical considerations that such might be the case owing to the colored belts of the planet. But the strengthening of the spectrum between *h* and F in the portions answering to the vicinity of the equatorial regions of Jupiter bears so directly on the problem of the physical condition of the planet as to incandescence that its importance cannot be overrated.

The circumstances under which this photograph was taken were as follows: Longitude of observatory $4^h\ 55^m\ 29^s{\cdot}7$ west of Greenwich. Night not very steady. Jupiter and the moon differed but little in altitude. Jupiter's spectrum was exposed to the photographic plate for fifty minutes, the moon was exposed for ten minutes. Jupiter was near the meridian. The photograph of Jupiter's spectrum was taken between $9^h\ 55^m$ and $10^h\ 45^m$, New York mean time, September 27, 1879.

I have suspected that perhaps there may have been an influence produced by the great colored patch on Jupiter which has made itself felt in this photograph. It may be that eruptions of heated gases and vapors of various composition, color, and intensity of incandescence are taking place on the great planet, and a spot which would not be especially conspicuous from its tint to the eye might readily modify the spectrum in the manner spoken of above.

ART. XVII.—*On the Spectrum of the Flame of Hydrogen;* by WILLIAM HUGGINS, D.C.L., LL.D., F.R.S.

Received June 16, 1880.

MESSRS. Liveing and Dewar state, in a paper read before the Royal Society on June 10, that they have obtained a photograph of the ultra-violet part of the spectrum of coal gas burning in oxygen, and in a note dated June 8th they add that they have reason to believe that this remarkable spectrum is not due to any carbon compound but to water.

Under these circumstances I think it is desirable that I should give an account of some experiments which I made on this subject some months since, without waiting until the investigation is more complete.

On December 27, 1879, I took a photograph of the flame of hydrogen burning in air. As is well known, the flame of hydrogen possesses but little luminosity, and shows no lines or bands in the visible part of the spectrum, except that due to sodium as an impurity.

Professor Stokes, in his paper "On the Change of Refrangibility of Light,"* has stated that "the flame of hydrogen produces a very strong effect. The invisible rays in which it so much abounds, taken as a whole, appear to be even more refrangible than those which come from the flame of a spirit lamp." I was not, however, prepared for the strong group of lines in the ultra-violet which, after an exposure of one minute and a half, came out upon the plate.

Two or three weeks later, about the middle of January, 1880, I showed this spectrum to Professor Stokes, and we considered it probable that this remarkable group was the spectrum of water. Professor Stokes permits me to mention that, in a letter addressed to me on January 30, he speaks of "this novel and interesting result," and makes some suggestions as to the disputed question of the carbon spectrum.

I have since that date taken a large number of photographs of the spectra of different flames, in the hope of being able to present the results to the Royal Society, when the research was more complete. I think now that it is desirable that I should describe the spectrum of the flame of hydrogen, but I shall reserve for the present the experiments which relate to the presence of carbon and its compounds.

The spectrum of the flame of hydrogen burning in air (No. 1) consists of a group of lines which terminates at the more refrangible limit in a pair of strong lines, λ 3062 and λ 3068. At a short distance, in the less refrangible direction, what may

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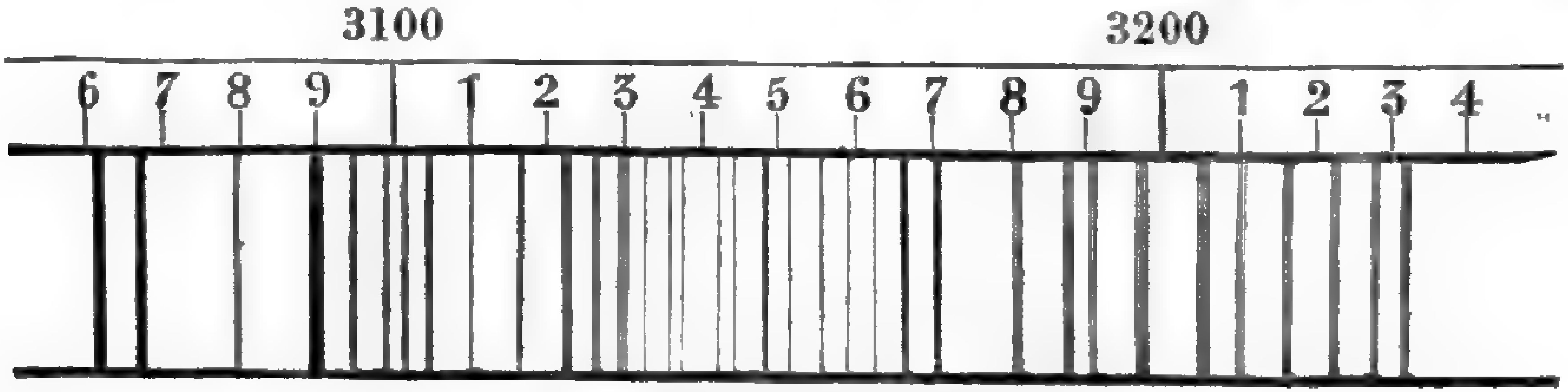
* Phil. Trans., 1852, p. 539.

perhaps be regarded as the group proper, commences with a strong line, λ 3090. Between the strong line λ 3068 and the line λ 3090 there is a line less bright, λ 3080. Less refrangible than the line λ 3090 are finer lines at about equal distances. The lines are then fine and near each other, and appear to be arranged in very close pairs. There is a pair of fine, but very distinct lines, λ 3171 and λ 3167. In this photograph the group can be traced to about λ 3290. This group constitutes the whole spectrum, which is due probably to the vapor of water (see fig.)



Spectrum of Water.

I then introduced oxygen into the flame, leaving a small excess of hydrogen. A spectrum in all respects similar came out upon the plate. I repeated the experiment, taking both spectra on the same plate. Through one-half of the slit the spectrum of the oxyhydrogen flame was taken. This flame was about seven inches long, and the spectrum taken of a part of the flame two inches from the jet. The oxygen was then turned off, and the quantity of hydrogen allowed to remain unaltered. A second spectrum with an exposure of the same duration was then taken through the second half of the slit. On the plate the two spectra are in every respect similar, and have so exactly the same intensity, that they appear as one broad spectrum.

In all these experiments a platinum jet which had been carefully cleaned was used.

In these experiments the two gases met within the blowpipe and issued in a mixed state.

The jet was removed, and a flame of hydrogen was surrounded with oxygen. The spectrum (No. 2) shows some additional lines, In this case the jet was brass, and in this or some other way impurities may have been introduced; and I should, at present, incline to the view that the additional lines about λ 3429 and λ 3473, and the groups more refrangible than λ 3062, do not belong to the water spectrum, but to impurities.

Coal-gas was substituted for hydrogen in the oxyhydrogen blowpipe, and oxygen admitted in as large a proportion as possible. The inner blue flame rising about two inches above the jet showed in the visible part of the spectrum the usual "five-fingered spectrum." The light from this part of the flame was projected upon the slit. The spectrum, (No. 3), contains the water group already described, and in addition a very strong line close to G, and two lines, λ 3872 and λ 3890; this latter line is seen to be the more refrangible limit of a group of fine lines shading off towards K.

The ultra-violet group when carefully compared with the group in the spectrum of pure hydrogen, shows several small differences. I am inclined to believe that there is the superposition of a second fainter group. There is strong evidence of this in some spectra of hydrogen taken under other conditions. There is also a broad band less refrangible than the strong line at G, and the light extends from this line on its more refrangible side.

A double Bunsen burner (Fletcher's form) with a strong blast of air was then fitted up. The spectrum was taken of the intense blue flame. It resembles the one last described. All the distinctive features are intensified and a continuous spectrum and groupings of very fine lines fill up all the intervals between the groups already described, so that there is an unbroken strong spectrum throughout the whole region which falls upon the plate.

A spirit lamp was arranged before the slit. The spectrum is essentially the same as No. 3, but as it is less intense only the strongest lines are seen. The water group, the strong line at G, and the pair of lines rather more refrangible than K, are seen. Probably with a longer exposure the finer lines would also show themselves.

The distinctive features of spectrum No. 3 appear to be connected with the presence of carbon.

Table of Wave-lengths of the Principal Lines of the Spectrum of Water.—No. 1.

3062
3068
3073
3074
3077·5
3080
3082
3085
3090
3094
3095
3099
3102
3105
3111
3117
3122·5
3127
3130
3133
3135
3139
3142·5
3145
3149·5
3152·5
3156
3159·5
3163
3167
3171
3175
3180
3184
3189
3192·5
3198
3201
3207·5
3211
3217·5
3223
3228
3232
3242·5
3252.5
3256
3262
3266
3276

Wave-lengths of other Lines in Spectrum.—No. 2.

2869·5
2872.5
2876
2880
2883
2887·5
2892
2895
2897
2904
2907·5
2910
2913
2917·5
2922·5
2925·5
2929
2932·5
2935·5
2940
2943
2947
2951
2955
2959
2966
2967·5
2970·5
2975·5
2981
2989
2991
2994
2999
3002
3005
3010
3013
3017
3019·5
3029
3031
3039
3042
3046
3051
3057·5
3246
3271
3429·5
3473

Wave-lengths of other Lines in Spectrum.—No. 3.

3872
3890
4310

ART. XVIII.—*Determination of the Acceleration due to the Force of Gravity, at Tokio, Japan;* by T. C. MENDENHALL.

THE following series of determinations of the value of the acceleration due to the force of gravity at this place was begun in the month of February of the present year and continued throughout the succeeding two or three months. A considerable time was devoted to preliminary experiments, and there was some delay on account of the non-arrival of one of the pendulums used, from the maker in Europe. Throughout the whole series and in all of the labor connected with it I have had the intelligent and faithful assistance of Messrs. Tanaka and Tanakadate, two special students in the department of Physics of the Imperial University of Japan.

There is probably nothing new in the method employed, except, perhaps, the mode of determining the time of vibration of the pendulum. As far as I am aware this method has not been previously described, and it seems to possess many advantages over the ordinary method of coincidences. It simply involves the use of a good chronograph and a break-circuit clock or chronometer, together with an arrangement by means of which the experimental pendulum can be made to record its own beats upon the chronograph at any time. In the beginning the whole number of vibrations which the pendulum will make in a given time may be determined by letting it break the circuit at every vibration, or, better, at every sixtieth or hundredth vibration, which can easily be accomplished by counting and raising the break-circuit apparatus to its proper position underneath the pendulum at the right moment. In our arrangement this apparatus consisted of a very small and light "trip-hammer" made of fine wire, which was so adjusted that by pressing upon a button it was brought up to such a point that it would be just "thrown" by the pendulum in its passage through the lowest point of its arc. Although the resistance offered to the pendulum can be made extremely small, yet it is so great as to interfere quite perceptibly with its motion if the pendulum is obliged to operate the break-circuit at each beat, as experiment has proved. But it may be rejected after the first two or three trials, not only on account of the resistance which it introduces but also because it is not necessary to continue its use. The whole number of seconds required for a given number of vibrations being known, it only remains to determine the fractional part of a second as accurately as possible. It is therefore only necessary to cause the pendulum to break the circuit twice, once at the beginning of the period and once again at the end. By this means all objection to the process on account of resistance is removed. Indeed it is in the possibility of determining these fractional parts of a second at the beginning and at the end, that the merit of this method consists. The chronograph used in these determinations is by Alvan Clark and Sons, and for uniformity of speed it is everything that could be desired. The line made by the pen is sharp and clear. The length of one second on the sheet is about 8 mm., so that it can be easily measured with a microscope of low power with a micrometer eye piece. It will easily be seen that even if the total time during which the pendulum is made to swing be not great, its value can be ascertained within a very small fraction of itself. By this process, therefore, it becomes possible to make the duration of the experiment extremely short compared with that required in the method of coincidences and yet to reach the same degree of accuracy. As a proof of this it may be stated that in numerous instances in which the duration of the experiment was only twenty minutes, three independent measurements of the total time, made from the chronograph sheet, did not differ among themselves by more than one sixty-thousandth part of the whole. The advantages in thus reducing the whole duration of the experiment from hours to minutes are many. All of the conditions may be maintained nearly constant during the whole time of the swing, and this is especially important in regard to temperature and arc of vibration, the latter being also made much smaller to begin with than would otherwise be possible. Again, the method eliminates "judgment" to a great extent as the pendulum marks for itself the beginning and the end of the period of time. Another important gain is that the use of the clock may be dispensed with, and, without loss of accuracy, the break-circuit chronometer substituted, thus rendering the whole apparatus for such a determination easily portable.

The first series of experiments undertaken was with a Kater's pendulum. The adjustment of the sliding weights, for the purpose of making the times of vibration when suspended from either knife edges equal to each other, is a matter of considerable difficulty and involves much labor. In the present instance no attempt was made to secure a closer agreement between the two periods than that of those recorded below, for the reason that the difficulties in the way of obtaining the exact length of the pendulum were such as to make any greater degree of accuracy as far as time is concerned unnecessary. There being at that time no standard of length in the possession of the University, recourse was had to a standard bar three meters in length, made by Troughton, belonging to the Department of Public works. As the pendulum was approximately one meter long it was necessary to "triplicate" it in order to compare it with this bar. The latter is provided with reading microscopes, and by repeating the comparison two or three times the result given below was obtained and it is believed to be not more than a few hundredths of a millimeter from the truth. The results of six determinations of the time of vibration are given below in columns A and B, the first set being made upon one of the knife edges, and the second upon the other. The values of "*g*" corresponding to these are also given.

Length of pendulum at 0°	1·00069 meters.
" " at 11°·5 (vibrating temp.)	1·00090

Time of vibration, corrected for arc and chronometer.

A.	B.
1·00410	1·00412
1·00412	1·00417
1·00410	1·00417

Values "*g*."

A.	B.
9·7980	9·7976
9·7976	9·7966
9·7980	9·7966

These give a mean value of 9·7974.

It must be remembered, however, that these results are not corrected for buoyancy, in other words they are still to be reduced to a vacuum. This correction has not been applied for two reasons: first, because the result cannot be considered as anything more than a first approximation, and, second, because I am by no means certain as to just what it ought to be. There is no doubt but the correction must be different in the two cases of suspension, when the heavy ball of the pendulum is above the knife edge and when it is below, as was experimentally demonstrated by Sabine many years ago. I believe Sabine also investigated the actual correction to be applied to Kater's pendulum, but owing to the very limited library facilities afforded residents of this country I am unable to refer to his results. When corrected, the above mean will undoubtedly somewhat exceed the true value, but no great degree of accuracy was attempted either in the adjustment of the pendulum or in the measurement of its length.

A "Borda's Pendulum," made by Salleron, was received soon after the conclusion of the above experiments, and as it was accompanied by a standard measuring apparatus it was determined to undertake a more accurate and a more extended series of observations for the determination of the value of "*g*."

The pendulum was of the well known form used by Borda and by many others since his time. The ball was of brass, and upon examination was found to be very closely spherical and homogeneous. It could be suspended by means of a small concave cup to which the ball would cling when it was rubbed with a little tallow. To this cup a suspending wire was fastened, the other end of which was secured to the end of a small cylinder projecting down from the knife edge. In a line with this and above the knife edge was a set of adjusting screws, by means of which this part of the apparatus, independent of the wire and ball, was made to vibrate in approximately the same period as that of the pendulum. Experiment proved that this adjustment might be very considerably disturbed without sensibly affecting the time of vibration of the pendulum, but it was, nevertheless, carefully attended to. After a number of trials the cup was rejected as a useless and somewhat uncertain part of the apparatus, and in its stead, in the final series of experiments, the wire was securely fastened to the ball by means of a small drop of solder which was fused on the end of the wire and afterward brought in contact with the ball while the latter was heated. The rejection of the cup greatly simplifies the calculation of the reduced length of the pendulum and lessens the probability of error in the measurements. A number of trials were made to determine the most desirable suspending wire. Theoretically an exceedingly fine wire is best, but practically it was found that much trouble was occasioned by the almost constant stretching and final breaking of very fine wires, so that it was found best to employ a wire of sufficient strength to assure, after a few days' suspension, a pendulum of invariable length during the time of the experiment, subject, of course, to slight changes due to variable temperature. The wire used at last was of platinum, which is desirable on account of its low coefficient of expansion. The measuring apparatus was similar to that used by Borda. The great advantage of this method is that the pendulum can be measured *in place*, or at least it must only be removed to give place to the measuring rod, the actual adjustment for length having been made before. This pendulum, as in the previous case, was suspended from a strong iron support secured to the top of a stone pier about six feet in height and two feet square. The knife edge of the pendulum rested on a pair of agate plates which were accurately leveled by means of four leveling screws and then firmly secured, so that motion was impossible. At the base of the stone pier and firmly secured to it was a strong wooden beam, upon which could be placed the apparatus for breaking the circuit, and also the small circular plane table which was elevated by means of a screw until it was tangent to the sphere at its lowest point. The measuring rod which could be substituted for the pendulum was of iron, and the length of the rod was read by means of a vernier and microscope to hundredths of a millimeter. There was also a metallic thermometer attached for giving the temperature of the bar. The reading of the length of the rod was always taken while the rod was in position upon the agate plates, and its temperature was read at the same time. The deflection of the support of the pendulum due to the addition of the weight of the measuring rod was determined to be about ·02 mm. and correction was made for it. As the apparatus was arranged it was very easy to make a measurement of the length of the pendulum, and measures were taken at very short intervals, always both before and after a series of vibrations. It was found, however, that when the temperature was constant the length remains sensibly the same. A number of comparisons were made between the meter upon the measuring rod and a standard meter from the Finance Department, made by Deleuil, both of which ought to be correct at 0°. The result of these comparisons was such that a correction of − ·04 mm. was made upon the length of the measuring rod at 0°. The pendulum was suspended in a small room favorably situated as regards all disturbances from air currents and sudden changes in temperature. From this room wires were carried to the chronograph, which was in a room near by. The time was taken from a break-circuit chronometer in the transit room of the Astronomical Observatory. The chronometer was not moved from its place, the observatory being connected with the physical laboratory, from which it is distant nearly two miles, by a telegraph line, so that the beats of the chronometer were recorded upon the chronograph in the laboratory. The rate of the chronometer was determined by star transits observed for several nights in succession before and after the date of the observations recorded below. The results given are the periods of vibration in mean solar time, corrected for chronometer rate and also for arc of vibration, the latter being observed by means of a scale and a telescope about fifteen feet away. The mean arcs varied, in the different experiments, from 40′ to 70′.

After having found the total length of the pendulum, as well as the dimensions and masses of its various parts, the "reduced length," or the length of the equivalent simple pendulum, is computed by means of a well-known formula. This with the time of vibration gives the value of "g" in air, and to this must be added the correction for "buoyancy." In most of the earlier determinations by this method this correction was found by simply comparing the density of the pendulum with that of the air in which it vibrated. Although it was shown, before Borda made his experiments, that this correction was too small, he seems to have been ignorant of the fact, and not until Bessel again investigated the question a good many years later, was general attention called to the fact. About the year 1830, Baily made an extensive series of experiments with a variety of pendulums, for the purpose of determining the true value of this correction. Unfortunately I am unable to refer to his results directly, but I believe that his conclusion was that for such a pendulum as was used in these determinations the ordinary correction should be multiplied by 1·5, and this factor has been used in correcting the results given.

Below will be found the results of eleven different determinations, the first five of which were made on May 26, and the others on May 27. On both days during the time of vibration, all of the conditions were sensibly constant and the same, and in addition to this the nights were favorable for the determination of the chronometer rate. Each of the results is based upon an experiment of twenty minutes' duration, the time of vibration in each case being the mean of two or three independent measurements of the chronograph record made by different persons.

The value of "*g*" is calculated for each time of vibration determined, and each is corrected for buoyancy. These include all of the determinations made upon those two days, none having been rejected.

Determination of the value of "*g*" at Tokio, Japan.

Latitude N. 35° 41′, long. E. 139° 44′. Ht. above sea level, 5 meters.

Total length of pendulum,	1014·18	mm.
Distance from knife edge to wire,	46·50	"
Length of wire,	931·62	"
Radius of ball,	18·03	"
Weight of ball,	198·951	grm.
" wire,	1·913	"
Density of ball,	8·0	

Length of equivalent simple pendulum, 994·59 mm.

Time of vibration.	Corresponding value of "*g*."	
1·00103	9·7982	meters.
1·00100	9·7988	"
1·00103	9·7982	"
1·00104	9·7980	"
1·00103	9·7982	"
1·00101	9·7986	"
1·00102	9·7984	"
1·00101	9·7986	"
1·00103	9·7982	"
1·00101	9.7986	"
1·00100	9·7988	"

Mean of all results, $g=9{\cdot}7984$.

This result is slightly greater than that given by many of the formulas for computing the value of "g" in any latitude.

An excellent opportunity is offered in Japan for measuring the force of gravity at a considerable height above the sea level, in the great extinct volcano, Fujiyama, which reaches a height of between 12,000 and 13,000 feet. An excursion is being arranged for the purpose of making this determination during the coming summer. For this purpose what may be called an "invariable" pendulum is now being vibrated in the place at which the above result was obtained. Its period will be carefully ascertained here before carrying it to the mountain, then on the top of the mountain, and again here after it has been brought back.

Nearly all of the labor of the above determination had been concluded when the April number of the Philosophical Magazine reached Japan. It was found to contain a paper by Messrs. Ayrton and Perry, on a "Determination of the Acceleration of Gravity for Tokio, Japan," which was based on experiments made by the authors, at the College of Engineering in this city, in 1878. Before beginning the series of experiments described above, I had learned that some work in the same direction had been done in the College of Engineering. Messrs. Ayrton and Perry being no longer in Japan, I was unable to ascertain, although inquiry was made, anything very definite concerning their methods or results. I was led to believe, however, that they had made no attempt at a very precise determination. Their paper, as now published, puts the matter in a somewhat different light, and, as their result differs from that deduced above, I desire to call attention to some points in connection with their method and their calculation. The data furnished in the paper are by no means as complete as would be desirable for a thorough discussion of its value, but much may be learned by an examination of what it does contain.

The pendulum used by Messrs. Ayrton and Perry was nearly ten meters in length. There are serious objections to the use of a long pendulum. Borda, in his celebrated determinations made at Paris, used a pendulum about four meters long, but one which approximates in length to a seconds pendulum has been almost universally made use of since. The great objection to the use of a long pendulum is the difficulty of measuring it *in place.* Messrs. Ayrton and Perry measured their pendulum by placing it in a horizontal position, and stretching it by allowing the end near the ball to hang over a wheel with very little friction. The length was obtained by comparison with a bar one meter long, and as this bar must be placed ten times to cover the whole length, it is plain that any great degree of accuracy must have been difficult to obtain, and this is especially true when the measurement of that portion of the wire which hangs over the wheel is considered. Their 26th experiment was made on the 25th of January, and the 53d on the 21st of February, from which we may infer that the entire time of suspension was at least two months. As only one measurement is spoken of, it is probable that it was measured at the conclusion of the series of experiments, and it seems hardly likely that its length would have remained constant during that length of time. In getting the time of vibration the first method used was what might be termed the method of coincidences by electricity, and which, so far as I know, was first described by Professor Pickering, in his excellent "Physical Manipulations." This was afterward rejected, however, and the vibrations were counted by means of a Morse instrument. The authors speak of measuring the fraction of a vibration, but evidently this could not be done with accuracy by the use of such an arrangement, and there is also the objection that the pendulum was obliged to do the work of breaking the circuit at every vibration. Messrs. Ayrton and Perry give the time of vibration of their pendulum for only three experiments, and it is a little difficult to understand exactly how these were obtained. The time, taken from the chronometer, is given and also the number of vibrations. Any one who will take the trouble to divide one by the other, will obtain results differing very materially from those given in the paper. The only way out of this difficulty that occurs to me, is to consider the times given as the apparent times corrected for clock error, and this I shall do, although it involves the somewhat violent assumption that the chronometer employed had, in the first experiment, a "losing rate" of about 1 minute and 15 seconds per day, which, at the time of the second experiment had changed to a slight "gaining rate," and had fallen again to a "losing rate" at the third. Supposing, however, that this was the case, it will be observed that the periodic time used in the calculation is considerably greater than that of either of the three experiments given. This time, 3·0748 seconds, is doubtless the mean time, and in the absence of the other results it may be fairly assumed that there was at least one result which was as much greater than the mean as the least of those quoted in the paper is less. On this supposition, the extreme times of vibration of their pendulum will be 3·0741 seconds and 3·0755 seconds. Substituting these numbers in their formula, the values of "g" obtained would be, respectively, 9·7997 meters and 9·7907 meters. These results are not corrected for buoyancy, but the same wide range would exist after that correction is made. But as nothing is known concerning the experiments not quoted, the most favorable case imaginable may be assumed. Suppose that in addition to the three results given, they were in possession of an infinite number of others, all agreeing exactly with that which is used in their computation. The extreme results would still cover a wide range, from 9·7997 to 9·7952. Instead of the latter number they give 9·7958, but they have made a miscalculation in reducing the formula, the true value being as given above.

Although making some elaborate calculations concerning corrections which may be rejected, they reject, apparently without calculation, the correction for the arc of vibration. The arc through which their pendulum swung was nearly 2°, and if a correction for this be applied it will materially alter the last figure of their result. In applying the correction for buoyancy they seem to have corrected only for the ordinary density of the ball and not for its "vibrating density." The correction which they apply is ·0016 meters, and if this be multiplied by 1·5 and the correction for arc also made, their result will be 9·7979 instead of 9·7974, as given in their paper. They refer to the close agreement of their result with that deduced from Clairault's formula, which they make to be 9·797. But they have misquoted Clairault's formula, putting γ where there should be 2γ. This is doubtless a typographical error, but they have also miscalculated it, for it gives 9·7980 meters as the value of "g" at this latitude, and not 9·797 meters, as stated in their paper.

Taking all of these facts into consideration, it does not seem that great weight can be attached to their result, notwithstanding its close agreement with the calculated value for this place, and it is doubtful whether the "bounds of existing knowledge" have been advanced, in any great degree, by this investigation.

Tokio, Japan, June 2, 1880.*

ART. XIX.—*On a new species of Pterichthys, allied to Bothriolepis ornata* Eichwald, *from the Devonian rocks of the North side of the Baie des Chaleurs;* by J. F. WHITEAVES.

THE nomenclature of some of the Devonian Placoderms of the sub-order Ostracostei of Huxley is still in a state of great confusion. Thus, *Pterichthys* Agassiz and *Bothriolepis* Eichwald, are both quoted by Pander as synonyms of *Asterolepis* Eichwald, while the *Asterolepis* of Agassiz and Hugh Miller is regarded by the same authority as synonymous in part with

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* Received at New Haven, Ct., June 29, 1880.

Homostius Asmuss, and in part with *Heterostius*. On the other hand, Prof. R. Owen claims* that *Pterichthys* should be retained in preference to *Asterolepis* and *Bothriolepis* Eichwald, on the ground that "no recognizable generic characters were associated" with the latter names; and, as this view has been very generally accepted by paleontologists, it will be adopted provisionally in these notes.

The only remains of fossil fishes yet recorded as occurring in the Paleozoic rocks of North America which may prove to be referable to the genus *Pterichthys*, are some isolated scales from the Catskill group of Tioga County, Pennsylvania, described by Prof. Hall in 1843 as *Sauripteris Taylori*, but which Dr. Newberry thinks have the characteristic sculpture of *Bothriolepis*. The name *Pterichthys Norwoodensis*, although inadvertently cited by Mr. S. A. Miller, on page 238 of his "American Palæozoic Fossils," should have been rejected long ago, for in the first volume of the Second Series of this Journal, dated 1846, Drs. Norwood and Owen showed that the specimen for which it was suggested is the type of their genus *Macropetalicthys*, and of a species which they described as *M. rapheidolabis*.

In the summer of 1879, Mr. R. W. Ells, M.A., of the Geological Survey of Canada, had the good fortune to find, in a concretionary nodule of argillite from the north side of the Baie des Chaleurs immediately opposite Dalhousie, a mould of the plastron or ventral surface of a true *Pterichthys* (as defined by Prof. Owen) with one of the pectoral spines in situ. At the earliest practicable opportunity, Mr. Ells revisited the locality, and in the first week of June last obtained three exquisitely preserved specimens of the buckler of the same species and several fragments; also some isolated scales of a *Glyptolepis*. The finest example of the Canadian *Pterichthys* collected by Mr. Ells had a large piece broken off the left margin when it was found, but with this exception the whole of the upper surface of the helmet and buckler is finely exposed (the plastron being partly covered by the matrix), and the outline of the orbital opening is clearly defined. A few weeks later, Mr. T. C. Weston, also of the Canadian Survey, collected an additional number of fine specimens of the *Pterichthys* from this locality, some of which illustrate admirably the shape, sculpture and mode of articulation of the pectoral spines. Associated with these there are, in Mr. Weston's collection, a nearly perfect but badly distorted specimen of a *Glyptolepis* fully seven inches in length, some fragments of *Psilophyton*, and a spore case of a *Lepidodendron*.

Taken collectively, the specimens thus far obtained of the

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* Palæontology, Second Edition, page 141.

Canadian *Ptericthys* show nearly all the characters of the helmet, buckler, plastron and pectoral spines, in the most satisfactory manner, but no vestiges of the tail have yet been detected, nor of any of the fins other than the two pectoral spines. The nature of the mouth and of its dentition, if it had any teeth, are unknown, and the small isolated plate in the orbital cavity (the "os dubium," of Pander, the "median" plate of Owen) has not yet been observed. In the number, outlines and disposition of the plates on the upper and lower surface of the head and body, and in the shape and mode of articulation of the pectoral spines, the Canadian fish agrees, in every essential point, with Pander's well known figures of a typical *Ptericthys*, but the sculpture of the entire surface of the former is precisely like that of *Bothriolepis ornata* Eichwald, which is thus described by Agassiz:* "Les ornemens de cette espèce consistent en petits enfoncemens circulaires placés les uns à côté des autres et séparés par des carènes qui, par leur juxta-position, paraissent hexagonales, à-peu-près comme les vitraux ronds des anciennes fenêtres, avec l'entourage en plomb qui les réunit. Les creux ont à-peu-près la grandeur d'une bonne tête d'épingle, et ils sont placés en séries linéaires plus ou moins régulières, formant des lignes ondulées sur la surface de l'écaille. Pour la plupart, ces creux sont isolés les uns des autres, quelquefois aussi plusieurs se confondent en formant un sillon plus ou moins long. Les carènes intermédiaires sont tranchantes et minces, mais elles se maintiennent au même niveau; l'on ne pourrait donner une meilleure image de cette sculpture des plaques, qu'en enfonçant des epingles, la tête la première, sur du gyps encore frais, car il en résulterait le même dessin. En examinant ces plaques à la loupe, on voit au fond de chaque cellule osseuse un petit trou central, qui mène dans un canal médullaire de l'intérieur de l'écaille. Evidemment ces trous étaient destinés à donner passage aux fins vaisseaux sanguins qui montaient à travers l'écaille pour se ramifier dans l'epiderme qui couvrait la plaque." All the markings so carefully described in the above passage, even to the minute perforations through the plate in the center of each pit, can be made out with perfect ease in most of the specimens collected by Messrs. Ells and Weston.

The Canadian Ptericthys is so closely allied to the *Bothriolepis ornata* that it is by no means certain whether the two are specifically distinct or not. Apart from its peculiar sculpture, the specific characters of *B. ornata* are very imperfectly ascertained, the species having been founded exclusively on a few large isolated plates of a placoderm, from the Devonian rocks of Russia and Scotland. Until more perfect examples of *B.*

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* **Monographie des Poissons Fossiles du Vieux Grès Rouge, &c., page 99.**

ornata shall have been described and figured, it will be impossible to institute an accurate comparison between it and the nearly related Canadian form. There are, however, good reasons for supposing that the European species attained a much larger size than the Canadian, for Agassiz says that the plates of *B. ornata* are from three to six inches in length, and, judging by this, the approximate length of its helmet and buckler together may be roughly estimated at from six to twelve inches at least. The largest isolated plate of the *Pterichthys* from the Baie des Chaleurs yet obtained (one of the ventro-laterals) is only two inches and a half long, while the smallest of two perfect specimens of the united helmet and buckler from the same locality is a little over two inches in length, and the largest (the fine specimen collected by Mr. Ells) is just six inches.

Under the circumstances, the writer thinks it most prudent to give to the Canadian *Pterichthys* a local and provisional name, with a brief diagnosis of its most salient characters, as follows: premising that a more detailed description of the species, accompanied with figures, will appear at an early date in one of the publications of the Canadian Geological Survey.

PTERICHTHYS (BOTHRIOLEPIS) CANADENSIS, Nov. Sp.—Plastron nearly flat. Helmet moderately arched above, most prominent immediately behind the orbital cavity where it rises into a ridge or blunt keel, which is continued, at intervals, with greater or less distinctness, along the median line of the buckler. Buckler slightly arched, median keel strongest in the center of the dorsomedian plate, and in the posterior half of the post-dorsomedian. General outline of the helmet and buckler combined elliptic-ovate, their united length being nearly, but not quite, twice the maximum breadth of the buckler. Dorsomedian plate large, hexagonal, apparently rather wider than long; its upper margin slightly concave on both sides and somewhat pointed in the middle, its lower margin being concave. Orbital cavity situated nearly in the center of the helmet, transversely reniform or bean-shaped in outline, much wider than high. Upper margin of the orbital cavity broadly, regularly and very shallowly concave, the lower being correspondingly convex, while the two lateral extremities are symmetrically and rather narrowly rounded.

Pectoral spines extending nearly to the posterior end of the buckler, thin and compressed vertically; moderately broad laterally where they are articulated to the ventro-lateral plate, and widening to about their mid-length, where they exceed the breadth at their articulation by about one line. From this widest point the breadth of the spines is again gradually reduced up to the joint separating the two segments of which they are composed, from whence they taper gradually to an acute point. The two segments are divided, nearly transversely, by a ball and socket joint, the ball being in the anterior and the socket in the posterior or terminal segment. The anterior end of each spine seems also to be furnished with a ball and socket joint, as there is a strongly inflected cavity in the ventro-lateral plate to receive the anterior end of the spine, which latter terminates in a rounded protuberance. On the inner and outer lateral margin of the pectorals there is a single row of crowded, nearly erect, conical, tooth-like, hollow spines. These are directed towards the articulation of the spine with the ventro-lateral plate up to about the mid-length of the anterior segment, and from thence they begin to point towards the posterior termination of the spine.

Sculpture of the helmet, buckler, plastron and pectoral spines very closely resembling that of the plates of *Bothriolepis ornata*, but much finer and more delicate.

Montreal, July 6, 1880.

Art. XX.—*A new Meteoric Mineral* (*Peckhamite*), *and some additional facts in connection with the fall of Meteorites in Iowa, May 10th*, 1879; by J. Lawrence Smith, Louisville, Ky.

The mineral now named Peckhamite was referred to in a former paper on the Emmet Co. Meteorite.* Having since been furnished with additional material, I have been enabled to make a more positive determination as to its distinctive characters. It is decidedly different from any mineral I have seen associated with meteorites. In two or three specimens it projected above the outer surface, having a dingy yellow color and a fused surface. When broken it has a greasy aspect with a more or less perfect cleavage, and the yellow color has a greenish hue. In structure it differs widely from olivine, as may be seen under the microscope. Not being furnished with the proper instrument, I have not been able to study all its optical characters. Small rounded nodules, several millimeters in size, are found in the interior of the mass, sometimes of irregular form, from which fragments nearly pure can be detached. Its specific gravity, taken with about 300 milligrams of fragments, is 3·23. Chemical analyses from two specimens gave:

	1	2	Oxygen ratio from No. 2.
Silica	49·50	49·59	25·73
Ferrous oxide	15·88	17·01	3·77
Magnesia	33·01	32·51	12·76
	98·29	99·11	

No. 1 was made with 100 milligrams detached by myself; and No. 2 with 350, sent to me by a friend. The oxygen ratio gives very closely the formula $\ddot{\mathrm{Si}}\mathrm{R}+\frac{1}{2}(\ddot{\mathrm{Si}}\mathrm{R}_2)$ or perhaps more correctly

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* This Journal, June, 1880.

$2\overset{\cdots}{\mathrm{Si}}\mathrm{R}+\overset{\cdots}{\mathrm{Si}}\dot{\mathrm{R}}_2$, being two atoms of enstatite or bronzite plus one atom of olivine. There was a slight inaccuracy in the statement of the formula in the former paper.

I have thought proper to call the mineral Peckhamite in honor of Professor Peckham, who has been industrious in collecting the minerals of our Lake region, and to whom I am indebted for every facility in prosecuting my researches in connection with this meteorite.

In a supplementary note published in the June number of this Journal, on page 495, I have given a brief account of the discovery, near the border of Dickinson County (the county west of Emmet) and about five or six miles southwest from where the larger masses fell, of evidence that the fall of the meteorite was attended by a shower of fragments, as of hailstones, falling upon the water of a lake near by. The search which has been made over the region by men, women and children for a distance of eight miles, and one half mile in width, has resulted in the collection of thousands of pieces of this meteorite from the size of a pea to 500 grams, but mostly quite small. The number found has been estimated at 5000, weighing in all about 30 kilograms. All the smaller pieces are little lumps of nickeliferous iron, and even the larger ones have but little stony material attached. Those familiar with the numerous small stones that were collected after the Pultusk fall, have but to imagine these stones to be all metal, and some idea may be formed of what these fragments are like; they are, however, more irregular than the Pultusk stones. These lumps of iron were on the wet prairie for nearly one year, and yet they are not in the least rusted, many parts being bright, some looking like nuggets of platinum. It may be that they are protected by an invisible coat of melted silicate.

It is clear that the rapid passage of the meteorite through the air disintegrated the surface very rapidly, pulverizing the stony part completely; and the nodules of iron not undergoing this disintegration fell in the track of the meteorite for many miles, and the greater number of them will never be found.

I must state that we are indebted to Mr. Charles F. Birge, of Keokuk, Iowa, for collecting these facts, as well as many others in connection with this most remarkable meteoric shower.

In conclusion, I would state that this last discovery enables us to fix more positively the direction of the meteorite. In former descriptions, including my own, the course of the meteorite is given as from northwest to southeast. But its general direction was from south-of-west to north-of-east; the meteorite came from south of an easterly course in Davidson County, and going north of that line in Emmet County, dropped the smaller fragments over the surface of the latter.

ART. XXI.—*The Earth as a Conductor of Electricity*; by JOHN TROWBRIDGE.

THE Observatory of Harvard University transmits time signals from Cambridge to Boston, a distance of about four miles. The regular recurrence of the beats of the clock affords a good means of studying the spreading of the electrical current from the terminal of the battery, which is grounded at the observatory; and the establishment of the Telephone Dispatch Companies in Cambridge, with their various ground connections, gave me a means of studying this spreading. In all the telephone circuits between Boston and Cambridge, in the neighborhood of the direct line between these places, the ticking of the observatory clock could be heard. The ticking heard in the telephones at the various stations has been attributed to the proximity of the telephone circuit wires to the time wires from the observatory. This is evidently an erroneous conclusion, as will be evident from a short mathematical consideration:

The expression for the induction produced in one wire by making and breaking a current in a parallel wire, is

$$R_2 y_2 = \pm M y_1,^*$$

in which y_2 represents the induced current, R_2 the resistance of the circuit which conveys this induced current, M the coefficient of induction between the parallel circuits, and y_1 the current in the primary circuit; the interruption of which produces the induced currents. Now $M = \iint \frac{ds\, ds'}{r}$, in which ds and ds' are elements of the parallel wires, and r is the perpendicular distance between them. The value of M in the case we are considering is $M = \frac{R_1^2}{r}$, in which R_1 represents the length of the parallel wires along which the induction takes place and r is the distance between the wires.

We shall therefore have $R_2 y_2 = \pm \frac{R_1^2}{r} y_1$, eq. (1). Now the electromotive force in the induced current y_2 is very much greater than that of the inducing current y_1, and in order that the current strength y_2 should be able to develop even a small electro magnetic effect in the receiving telephone, the coefficient of induction must be increased, or the distance along which the conductors are parallel, the distance between them remaining the same. An arithmetical consideration of eq. (1) will convince one that with telephones of the resistance usually employed, no inductive effect will be perceived by the employ-

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* Maxwell's Electricity and Magnetism, vol. ii, p. 209.

ment of even ten-quart Bunsen cells between wires which run parallel to each other a foot apart for the distance of thirty or forty feet. In order to detect an inductive effect under these conditions, a telephone of three or four units of resistance must be employed. The ordinary Bell Telephone has a resistance from thirty to sixty units. For still stronger reasons it is impossible to hear telephonic messages by induction from one wire to another, unless the two wires between which induction is produced run parallel to each and very near to each other a long distance. This distance generally exceeds the distance at which the ordinary Bell Telephone ceases to transmit articulate speech. The effects which have usually been attributed to induction on telephone circuits are due to the earth connections and to imperfect insulation. There would be no trouble from induction if telephone wires were enclosed in a cable; for a consideration of eq. (1) will make it evident that the telephonic message transmitted over one wire would have no practical effect upon the neighboring wires enclosed with it.

Since the transmission of the time signal service of Harvard College Observatory through all the telephone circuits in Boston and Cambridge is evidently not due to induction, but to tapping, so to speak, the earth at points which are not at the same potential, it was an interesting question to study the extent of the equipotential surfaces formed by the ground of the time signal service circuit at Cambridge and in Boston. I speedily discovered that the time signals could be easily heard in a field an eighth of a mile from the observatory, where one ground of the time circuit is located. The method of exploration was to run a wire five or six hundred feet, to ground it at its two ends in moist earth, and to include a telephone of fifty or sixty ohms resistance in the circuit. On completing the circuit through the telephone and the ground, the evidence of an electrical current was plainly apparent from the ticking which the making and breaking of the circuit produced in the telephone; and the time signals of the observatory clock were distinctly heard. At the distance of a mile from the observatory and not in the direct line between the observatory and the Boston office, the time signals were obtained by tapping the earth at points only fifty feet apart. At a distance of five hundred feet directly behind the observatory, no points five hundred feet apart could be found which were not practically at the same potential. The survey was carried to a distance of a mile behind the observatory ground, with negative results. At points one mile from the central line between the observatory and the Boston office, the time signals could not be heard on the trial wire of six hundred feet. This was to be expected, since the trial wire should have its length increased as the distance from the grounds of the battery increases, in order to permit of one end of the wire touching a point of higher potential than the other.

The theoretical possibility of telegraphing across the Atlantic without a cable is evident from this survey which I have undertaken. The practical possibility is another question.

At no point in our survey did we find an absence of earth currents. The peculiar crackling noises heard in telephones are due to earth currents and not to fluctuations in the batteries employed on telephone circuits; for they were characteristic of the circuits employed by us in which the earth was used as a part of the circuit, and were absent when a battery circuit was closed without the intervention of the earth. The tick produced in the exploring telephone, whenever the circuit was closed, through the ground was due to earth currents and not to polarization between the copper wire and the moisture of the ground, for it was many hundred times stronger than the polarization effect produced by dipping the copper terminals of the telephone wire in acidulated water. This crackling noise produced by the earth currents in a telephone is a curious phenomenon, and shows that the earth currents have a rapidly intermittent character, which escapes observation by any other instrument than the telephone. A delicate electro-dynamometer, for the registration and observation of these intermittent earth currents, is much to be desired. In some cases the pulsatory effect of these earth currents was very marked. At no point which we explored, were evidences of earth currents absent. They seemed to be more pronounced along water courses.

In a discussion of the earth as a conductor, Steinheil says: "We cannot conjure up gnomes at will, to convey our thoughts through the earth. Nature has prevented this. The spreading of the galvanic effect is proportional not to the distance from the point of excitation, but to the square of this distance; so that at the distance of fifty meters only exceedingly small effects can be produced by the most powerful electrical effects at the point of excitation. Had we means which could stand in the same relation to electricity that the eye stands to light, nothing would prevent our telegraphing through the earth without telegraph conductors. But it is not probable that we shall ever attain this end."*

Theoretically, however, it is possible to-day to telegraph across the Atlantic Ocean without a cable. Powerful dynamo-electric machines could be placed at some point in Nova Scotia, having one end of their circuit grounded near them and the other end grounded in Florida, the conducting wire con-

* Die Anwendung des Elektromagnetismus, p. 172, 2d ed., 1873.

sisting of a wire of great conductivity and carefully insulated from the earth, except at the two grounds. By exploring the coast of France, two points on two surface lines not at the same potential could be found; and by means of a telephone of low resistance, the Morse signals sent from Nova Scotia to Florida could be heard in France. Theoretically this is possible; but practically, with the light of our present knowledge, the expenditure of energy on the dynamo-electric engines would seem to be enormous.

The points made in this paper are as follows:

1. Disturbances in telephonic circuits usually attributed to effects of induction are, in general, due to contiguous grounds of battery circuits. A return wire is the only way to obviate these disturbances.

2. The well-defined equipotential surfaces in the neighborhood of battery grounds shows the theoretical possibility of telegraphing across large bodies of water without the employment of a cable, and leads us to greatly extend the practical limit set by Steinheil.

3. Earth currents have an intermittent character, with periods of maxima and minima which may occur several times a minute during the entire day. This intermittent character is seldom absent.

Physical Laboratory, Harvard University.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Chemical Curves as Lecture-Illustrations.*—The growing importance of chemical dynamics renders it very desirable to use the graphical method in class instruction. In order to make clear the significance of these curves, especially to those who grasp graphic methods difficultly, Mills has contrived an apparatus for lecture use in which a chemical process constructs its own curve under the eyes of the observer. It consists of a series of glass cylinders, filled with water and inverted each in a circular glass trough, also containing water. Behind these cylinders is a corresponding series of glass tubulated retorts, of 100 c. c. capacity, each beak opening beneath the mouth of a cylinder. Provision is made for leading off the overflowed water. The frame of the author's apparatus is 289 cm. long and 51 high, the capacity of each cylinder being about 270 c. c. To show the effect of dilution upon the action of hydrogen sulphate upon zinc, the sheet metal 0·55 mm. thick was cut into pieces 14 mm. square exactly, and rolled into a cylinder. The sulphuric acid, of specific gravity 1·843, was diluted to strengths varying progressively by 3 per

cent in volume and 50 c. c. of each portion was placed in each retort in order. The retorts and the pieces of zinc must be carefully cleansed. The experiment may be conducted to give either the effect of mass of the acid, or of the time of contact; yielding in the first place a quantity-curve and in the second a time-curve; the quantity of hydrogen gas collected in the successive cylinders giving the required curve, the height of the water column being the ordinate in each case. The time-curve is but a single curve, usually of a logarithmic form. The quantity-curve has points of inflection and consists generally of one or more consecutive hyperbolas, showing (1) that the progress of the reaction is not proportional to the acid-strength; (2) that there is a maximum with 27 per cent H_2SO_4, a minimum with 33 per cent and a second maximum with 36 per cent; very weak and very strong solutions being without effect; (3) that the effect of weakening the solution is more rapid than an equal strengthening of it; (4) that the entire process is accomplished in three stages represented by three curves; and (5) that, if the weight of zinc has been such as exactly to fill the cylinder with hydrogen, the water remaining represents the remaining chemical energy of the zinc. By the simultaneous use of blackboard or lantern curves exactly drawn the significance of the method may be clearly proved. For the time-curve, the author prefers the action of acid on zinc and for the quantity-curve of the action of sodium hydrate upon aluminum. —*J. Chem. Soc.*, xxxvii, 453, June, 1880. G. F. B.

2. *On the Estimation of Zinc and Zinc-dust.*—BEILSTEIN and JAWEIN have suggested a new and simple apparatus for the determination of the purity of zinc and zinc-dust by means of the hydrogen which they evolve by the action of acids. The sample to be examined is weighed into a tube which is then placed in a glass bottle. Hydrochloric acid of specific gravity 1·10 is then poured in beneath the tube in the proportion of 11 c. c. to one gram of zinc, and the mouth of the bottle is closed with a rubber cork through which passes a delivery tube. To this a rubber tube is attached connecting it with a similar tube just passing through the cork of a larger bottle of two liters or more capacity. Through a second hole in this latter cork passes another tube nearly to the bottom of the bottle, this tube being divided into cubic centimeters, and its upper and outer end being turned over so as to deliver the water clear of the bottle. At the bottom of the large bottle is an opening by which the water may be drawn off. Both bottles are placed in water to keep them cool. The large bottle being filled with water and the corks inserted in both bottles, the level of the water within and without the graduated tube is made the same, and then the acid is brought into contact with the zinc by inclining the small bottle. Immediately the hydrogen evolved forces the water out of the large bottle through the graduated tube, into a tared flask in which it is collected, together with the water drawn off from below in order to make again the level the same within and without the graduated tube.

The barometer is now noted, the temperature of the water surrounding the receiving-bottle is observed and the overflowed water is weighed. The water contained in the graduated tube between its first and second level, must be subtracted from that collected in the flask. A sample of commercial zinc which gave 99·80 per cent zinc by Fresenius's method, gave 99·89 per cent by this. A lot of zinc-dust which gave by this method 80·59 per cent of zinc, yielded 80·10 by the method of Fresenius.—*Ber. Berl. Chem. Ges.*, xiii, 947, May, 1880. G. F. B.

3. *On a Reflection Cuprimeter.*—Bayley showed in 1878 that the light transmitted by dilute solutions of cupric salts is deficient in those rays which the spectrum of light reflected from metallic copper has in excess, and hence that if we look at a copper surface through a sufficient thickness of copper sulphate solution, the metal appears silver white, the solution absorbing the excessive rays which make the copper red. He has now perfected an instrument for the estimation of copper, founded upon this principle, which he calls a reflection-cuprimeter. A copper mirror movable about a horizontal axis reflects the direct light of the sky vertically upward through two tubes of glass closed at bottom by glass plates and having at top convex lenses by which the light is concentrated upon two paper discs made translucent by glycerin. The whole is surrounded by a wooden case to shut out extraneous light. By means of lateral openings near the lower ends of the tubes, these are put in communication with reservoirs, one containing a standard solution of copper, the other the solution to be tested. The former is made by dissolving one gram of pure copper in nitric acid, adding a slight excess of sulphurous acid and diluting to a liter at 15° C. Covering one-half the mirror with silver, the other half was looked at through a varying depth of the solution until both disks were equally white. The length of the column required was then noted, the tubes being graduated for this purpose. In the author's instrument it was 8·01 cm. Since the length of the column required to produce white light is inversely as the quantity of copper present and since a solution of copper containing 0·1 per cent required a length of 8·01 cm., a solution of copper containing 100 per cent of metal, i. e., pure copper, would require a thickness of 0·0801 mm. This length the author calls a "cuper;" and hence 1000 cupers of the standard solution produces a white disc and this solution represents copper 1000 times diluted. If c is the number of cupers thick the solution is when the disc is white, c will also represent the volume of liquid in c. c. which contains one gram of copper and $\frac{1000}{c}$ the amount of copper in grams contained in one liter of solution. With a solution containing 0·801 gram of copper per liter six readings of the cuprimeter gave ·806, ·803, ·800, ·793, ·793 and ·813; or ·803 as a mean. Iron, in the ferrous condition, is not injurious. The substance to be analyzed, in such quantity as is supposed to give a gram of copper, is dissolved in nitric acid,

treated with sulphurous acid in excess, boiled, cooled, made up to a liter, and examined in the cuprimeter.—*J. Chem. Soc.*, xxxvii, 418, June, 1880. G. F. B.

4. *On a Method of producing Acetal.*—In the hope of producing in larger quantity, a crystalline substance which they had observed, ENGEL and DE GIRARD dissolved aldehyde in about its own volume of absolute alcohol and passed into it a current of hydrogen phosphide gas for three days, the mixture being at first cooled to — 40°, then to — 21°. No crystals were formed; but on adding water a liquid separated, which gave on fractioning a liquid boiling at 104°, having an ethereal odor, a specific gravity of 0·829 at 13°, and a vapor density of 4·3. Moreover, it possessed in other respects the characters of acetal. The yield is considerable. The authors are now investigating the conditions of maximum production.—*Bull. Soc. Ch.*, II, xxxiii, 457, May, 1880. G. F. B.

5. *On Phlobaphen and Oak-red, and their Relation to Tannin.*—BÖTTINGER has proved that, under the influence of sulphuric acid, quercitannin splits into sugar and oak-red, and that this latter body is identical with the phlobaphen of Stähelin and Hofstetter. To prepare phlobaphen 22 kilos. of oak tan was extracted, first with ether to remove fat, wax, chlorophyll and gallic acid, then with alcohol. The clear brown solution was evaporated on the water-bath, and left a semi-solid mass having a strong odor of tan. After a second extraction with ether, the lumpy residue consisted essentially of two constituents — tannin, soluble in water and phlobaphen, insoluble in it. Their complete separation was extremely difficult, however, owing to the fact that the latter is soluble in a solution of tannin. By repeated extractions with water or alcohol, both of these bodies were finally obtained pure. The quercitannin, treated in concentrated solution with cold dilute sulphuric acid, becomes a thick mass which liquefies on gentle heating. At higher temperatures decomposition takes place, a compact brownish mass of oak-red is deposited and sugar remains in solution. Oak-red and phlobaphen are identical in their physical properties and in their behavior to oxidizing agents, zinc dust, fused potash, acetic oxide, benzoyl chloride, fuming hydrochloric acid, etc. As purified it is a reddish-brown powder, extremely insoluble in the ordinary solvents, but soluble in a tannin solution. It is blackened by ferric chloride, oxidized readily to carbon dioxide and water, gives no result on boiling or heating with zinc-dust, gives protocatechuric acid when fused with potash, and affords the formula $C_{14}H_{10}O_6$. Acetic oxide produces a triacetyl derivative, benzoyl chloride a tribenzoyl compound. By the action of fuming hydrochloric acid carbon dioxide and water separate, and a brilliant black body results apparently identical with that obtained by similar treatment from pyrogallol. The author concludes that while quercitannin and phlobaphen both act efficiently in the tanning process, yet that it is to the latter substance that the peculiar result is essentially due.—*Liebig Ann.*, ccii, 269, May, 1880. G. F. B.

6. *On the Occurrence of Globulin in Potatoes.*—**Zöller** has called attention to the existence in potatoes of one of the albuminoid substances called globulins by Hoppe Seyler. The finely divided potatoes are rapidly washed free from starch and soluble matters, the pulp is pressed, and treated with a ten per cent solution of common salt. In the solution, made neutral with a few drops of a one per cent solution of Na_2CO_3, a lump of rock salt is hung, and the globulin separates in white flocks. It contains 14·2 per cent of nitrogen and its properties prove it to be quite similar to one of the myosins of muscular tissue.—*Ber. Berl. Chem. Ges.*, xiii, 1064, June, 1880. G. F. B.

7. *On the behavior of Carbonic Acid in relation to Pressure, Volume and Temperature.*—Professor R. **Clausius** discusses the bearing of recent observations upon the departure of gases from the law of Marriotte and Gay Lussac, and advances a theory to account for these departures of a gas from the perfect state. In a perfect gaseous state the molecules rush together and separate completely after the collision. When the gas is condensed to a liquid the molecules are generally held together by their mutual attraction, and separate only under certain favorable conditions. Between these extreme conditions one can imagine an intermediate state in which the molecules do not completely separate, but oscillate about one another while moving onward as a whole until they are separated by further collisions. The number of these pairs of attached molecules would be greater the lower the temperature, and hence the less the mean *vis viva* of the motion; on a further fall of temperature more than two molecules might collect together and execute the progressive movement in common. On the above assumption the mean strength of the mutual attraction of the molecules would be increased since the united molecules on account of their greater nearness would attract each other more strongly. "*Hence it would not be allowable to regard the quantity which represents in the formula the mutual attraction of the molecules as independent of the temperature, but one would be obliged to admit that it becomes greater with falling temperature.*" Clausius gives a formula which embodies the above ideas and finds a satisfactory agreement between the values calculated from the formula and those obtained by experiment. At the close of his paper Clausius discusses the pressure curve given by Andrews and James Thomson for the temperature 13°·1, and discovers a reversible cyclical process, and states "that when the theoretical pressure-curve corresponding to the homogeneous state is given, the position of the horizontal straight line answering to the actual processes of vaporization and condensation is also determined. The point made by Clausius has an important bearing upon the subject of thermodynamics and can be fully understood only by reference to his diagrams.—*Wied. Ann.*, vol. ix, p. 337, 1880; *Phil. Mag.*, vol. lviii, p. 393, June, 1880. J. T.

8. *Kerr's experiments on the relation between Light and Electricity.*—H. W. C. **Röntgen** repeats the experiments of Dr. Kerr

with more perfect apparatus than that used by the latter and employs Nichols' prisms, which gave a much larger field than those used by Dr. Kerr. The results of the latter are confirmed and amplified. Glycerine, sulphuric ether and distilled water show an influence of electricity upon the light transmitted through them. Some interesting diagrams are given which show the appearance presented when the liquid under examination is experimented upon. The liquid was also set in movement and the author states that the movement of the particles of the fluid have a marked influence upon the conditions of the directions of the vibrations of the light.— *Wied. Ann.*, No. 5, p. 77, 1880. J. T.

9. *Contributions to Molecular Physics in High Vacua.*—In a paper which is a continuation of the Bakerian Lecture on the illumination of lines of molecular pressure, read before the Royal Society, December 5, 1878, Mr. CROOKES describes some new and remarkable experiments which confirm the theory that the phenomena described by him are due to the repulsion of the molecules of the residual gases after they had obtained a negative charge by striking upon the negative pole. The negative pole not only gives the initial charge but continues to act upon the molecules and causes them to move with an accelerating velocity. It is shown that an idle pole placed between the points of discharge in the exhausted tube is charged positively by the impact of the molecules driven from the negative pole. In order to prove that the action between two streams of molecules is due to the mutual repulsion between the electrified molecules and not to the electrical action between the electrical current carried by the molecules, an exhausted tube was provided with two negative poles and one positive pole. The two molecular streams, instead of converging strongly upon the positive pole under the influence of the mutual attractions of the electrical currents, diverge under the influence of the molecular repulsions. Experiments are described which prove that external magnetic influences act upon the electrified molecules differently in low exhaustions and high exhaustions. The magnetic rotations are fainter in low vacua and depend as much upon the direction of the induction spark as upon the pole of the magnet presented to the discharge.

The phosphorescent effects of the molecular impacts constitute the most beautiful effects obtained by Mr. Crookes. The molecular rays in high vacua possess remarkable powers of causing bodies upon which they fall to phosphoresce. A deadening effect produced upon glass by long continued phosphorescence is confirmed by various experiments. The image of a cross was stencilled by phosphorescence on the end of a large bulb and the bulb was afterward melted and drawn out at the end and afterward blown again into shape. The cross which had produced the image was displaced, and on passing a discharge through the bulb the ghost of the first image reappeared, showing that it had survived the melting of the glass.—*Nature*, June 3 and June 10, 1880. J. T.

10. *On the law of fatigue in the work done by men or animals.* —The Rev. Dr. Haughton, of Trinity College, Dublin, has recently brought to a conclusion a series of papers on Animal Mechanics published in the *Proceedings* of the Royal Society. The ninth of these papers was appointed the Croonian Lecture for the present year, and the tenth paper closes the series.

The most important subject involved in these papers is the experimental determination of the law that regulates fatigue in men and animals, when work is done, so as to bring on fatigue.

Many writers, such as Bougeur, Euler, and others, have laid down mathematical formulæ, connecting the force overcome with the velocity of the movement; but these theoretical speculations have never received the assent of practical engineers.

Venturoli points a method of observations and experiments which would serve to determine the form of the function which expresses the force in terms of the velocity, after which a few carefully planned experiments would determine the constant coefficients; and he adds that "such a discovery would be of the greatest usefulness to the science of mechanics, upon which it depends, how to employ, to the greatest possible advantage, the force of animal agents."

Dr. Haughton believes that he has found the proper form of this function, by means of experiments, and sums it up in what he calls the *Law of Fatigue*, which he thus expresses:—

The product of the total work done by the rate of work is constant, at the time when fatigue stops the work.

If W denote the total work done, the law of fatigue gives us—

$$W\frac{dW}{dt} = \text{const.}$$

or

$$\frac{W^2}{T} = \text{const.} \tag{1}$$

The experiments made by Dr. Haughton from 1875 to 1880 consisted chiefly in lifting or holding various weights by means of the arms; the law of fatigue giving, in each case, an appropriate equation, with which the results of the experiments were compared. When the experiments consisted in raising weights on the outstretched arms, at fixed rates, the law of fatigue gave the following expression—

$$(w + \alpha)^2 n = A \tag{2}$$

where w, n, are the weight held in the hand, and the number of times it is lifted, A is a constant to be determined by experiment, and α another constant depending on the weight of the limb and its appendages.

The equation (2) represents a cubical hyperbola.

The *useful work* done is represented by the equation—

$$w\,n = \frac{A\,w}{(w + \alpha)^2} \tag{3}$$

This denotes a cuspidal cubic, and the *useful* work is a maximum, when $w = \alpha$, or the weight used is equal to the constant depending on the weight of the limb and its appendages.

When the weights were lowered as well as raised at fixed rates, and no rest at all permitted, the law of fatigue became—

$$\frac{n\,(1 + \beta^2 t^2)}{t} = A \qquad (4)$$

where n, t, are the number and time of lift, A is a constant depending on experiment, and β is a constant involving the time of lift (τ) at which the *maximum* work is done.

Equation (4) denotes a cuspidal cubic.

When the weights are held on the palms of the outstretched hands, until the experiment is stopped by fatigue, the law becomes—

$$(w + \alpha)^2 t = A \qquad (5)$$

where t is the whole time of holding out.

This equation denotes a cubical hyperbola.

The *Law of Fatigue* seems, in itself, probable enough, but of course its real value depends on its agreement with the results of experiment.

If W denote the total work done and R the rate of work, the law becomes, simply—

$$W \times R = \text{const.} \qquad (6)$$

If different limbs, or animals were used, each working in its own way, and under its own conditions, the *Law of Fatigue* would become—

$$WR = W_1 R_1 + W_2 R_2 + W_3 R_3 + \&\text{c.} \qquad (7)$$

and the problem for the engineer would be, so to arrange the work and rate of work of each agent employed, as to make the *useful work* a maximum, the work both useful and not useful, in all its parts, remaining subject to the conditions imposed by equation (7).

In using equation (5) in his concluding paper, detailing the results of experiments made on Dr. Alexander Macalister, Dr. Haughton treats α as an unknown quantity, and finds from all the observations its most probable value to be—

$$\alpha = 5{\cdot}68 \text{ lbs.}$$

This result was compared with that of direct measurements made on Dr. Macalister himself, and indirect measurements made on the dead subject, from all of which Dr. Haughton concluded the value of α to be—

$$\alpha = 5{\cdot}56 \text{ lbs.} \pm 0{\cdot}125 \text{ (possible error).}$$

This result agrees closely with that calculated from the law of fatigue.

It should be added that a proposal was made by Dr. Haughton to Dr. Macalister to make the experiment conclusive by direct amputation of his scapula, a course which he, unreasonably, objected to, as he draws the line of "vivisection" at frogs.—*Nature*, xxii, 554.

11. *Acceleration of Gravity at Tokio, Japan.*—The paper by Messrs. Ayrton and Perry on a "Determination of the Acceleration of Gravity for Tokio, Japan," published in the April number of the Philosophical Magazine and alluded to on page 130 of this number, has been severely criticized by Major Herschel (l. c. June, 1880, p. 446). A reply to this criticism is given by the authors in the July number of the same journal, p. 43.

12. *Winchester Observatory of Yale College: Circular of the Horological and Thermometrical Bureaus*, June, 1880.—These bureaus have been established by the corporation of Yale College, at the recommendation of the Board of Managers of the Winchester Observatory. The former is designed to encourage the higher development of the horological industries, and to pursue researches calculated to aid in the construction of refined apparatus for the measurement of time. This circular gives detailed information in regard to the tests to which time pieces are subjected; the regulations of the distribution of the time service from the observatory, a list of the standard instruments employed in rating time pieces, and those used in testing thermometers. Watches and chronometers are submitted to well considered tests during varying times, and certificates are given which embody the performances of the time pieces and the conditions of the tests. In the work of the thermometrical bureau, thermometers are carefully compared with the air thermometer and with Kew standards. The circular also contains a synopsis of the constants of the Kew, Fastré and Casella primary (mercurial) standards. The details connected with these bureaus have evidently been carefully considered and ably carried out. A field of great usefulness is open to this department of the Winchester Observatory.

Physical Science in America, also, cannot fail to be indebted to it. The late report of the Astronomer Royal, Airy, speaks of the time service as an important feature in the work of the observatory of which he is director, and the French Astronomers in many recent articles have directed public attention to the importance of work similar to that undertaken by the Horological Bureau of Yale College. The thermometrical bureau promises to afford valuable assistance to the United States Signal Service and to meteorology in general, also to medico-physiological investigations and to many departments in the arts. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *Odontornithes; a Monograph on the Extinct Toothed Birds of North America;* by Professor O. C. MARSH, pp. i–x, 201, 4to, thirty-four plates, with Appendix containing a Synopsis of American Cretaceous Birds. 1880. Advance copy, issued with the permission of the Chief of Engineers.—This most valuable and original memoir, which forms volume VII of the Survey of the 40th Parallel, will receive the notice which its importance demands in a future number of this Journal.

2. *Mucorini announced as the chief source of Mineral Coal.*—Professor P. F. Reinsch, of Erlangen, Bavaria, has announced, as the result of some recent investigations of mineral coal by means of thin transparent slices, the view that in the formation of coal only certain low forms of plant-life took part; and that these forms are so well preserved in some cases that almost no difference can be observed in their most intimate structure from similar forms still living. They are long fibrous forms of cellular structure, united to strong stems; and in the fibrous net-work, other forms, spherical in shape are imbedded, organically connected with the net-work. The fibers in the coal, which, according to the author's conclusions, constitute the chief part of it, consist, as a general rule, of opake coaly material, but in the finer ramifications a micro-granular structure can be distinguished. The spherical bodies, which sometimes adhere together with flattened sides, have a diameter of from 0·13 to 0·24 millimeter. The structure is somewhat more sharply defined after heating the section with caustic potash. In polarized light these forms behave precisely like starch. In revolving the Nichols the revolving dark cross appears very plainly in all the spherical bodies. There is generally at the center a rhombohedral kernel of a somewhat more transparent substance than the rest; and the substance in them which becomes somewhat more transparent on treatment with caustic potash has a radiated structure. The forms are declared to be gigantic Mucorini.

These conclusions of Professor Reinsch are wholly opposed to those of other investigators, and to the facts presented by all the ordinary kinds of mineral coal. The author has evidently misunderstood the objects under examination, and his supposed facts are not likely to find acceptance in science.

3. *A New American locality of Fergusonite;* by W. E. Hidden (communicated). Besides other results of my search for platinum, in the auriferous gravels of the Southern States, is the discovery, in July, 1879, of the mineral fergusonite at Brindletown, Burke Co., N. C. A few of the crystals were sent by me lately to Dr. J. Lawrence Smith, who answers as follows: "I received the fergusonite safely and have made an examination of it. It is beyond all doubt that mineral; its specific gravity is 5·87.

Metallic acids, principally columbic acid,	49·83	
Yttria earths,	47·01	
Oxide of iron and uranium,	·42	
Water,	1·01	
		98·27

This analysis corresponds perfectly with fergusonite. I intend of course, to make a more thorough examination on well selected pieces. It also possesses the property of glowing in an eminent degree." A more particular description with figures of crystals and complete analysis will be given later.

4. *DeCandolle's Phytography. La Phytographie, ou l'Art de decrire les Végétaux considérés sous différents points de vue, par* Alph. DeCandolle, etc. Paris, Masson, 1880. pp. 484, 8vo.—Valuable as the present volume is, it may very probably not be

translated into English. So we propose to give a running account of its contents, adding here and there some brief comments, critical or otherwise. Treatises like this can be written only by botanists of long experience; and long experience, founded upon good training and accompanied by good judgment, gives the right to speak with a certain authority, particularly upon writing and publication in systematic botany, in which rules and method are most important. DeCandolle is now one of our oldest systematists, one who as editor as well as author has had to consider every sort of phytographical question; and the volume he has here produced is a needful supplement to the Philosophia Botanica of Linnæus and the Théorie Élémentaire of the elder DeCandolle, the two classical books which the serious botanical student should early and thoroughly master. Phytography has to do with form and method in botanical works; and natural history is nothing if not methodical. Its advancement by research and its educational value—which will be more and more appreciated as it is better taught—both depend upon correct morphology and upon well-settled method. Those who will not use its proper language and respect its customs, must not expect to be listened to, any more than is unavoidable. Observation and interpretation must go together, if either is to be of value; the naturalist must not only observe that he may describe, but describe if he would observe. In his preface DeCandolle remarks upon the peculiar advantage of natural-history study in the combination of observation with judgment, and upon the importance to a student of acquiring a clear idea of what natural groups are, what a natural classification and the subordination of groups really mean, and how a naturalist arranges, names, and with precision defines the immensely numerous objects of his study. Men who have distinguished themselves in various professions and lines of life, have owned the advantage they have derived from this kind of training in youth, even though they never became naturalists.

DeCandolle's book is in thirty chapters, many of them short and somewhat discursive, and generally abounding in recommendation and advice, rather than laying down positive rules.

The first chapter glances at "the evolution of botanical works" from Cesalpino, with whom scientific botany began in the middle of the 16th century, to Linnæus, whose rules and spirit still govern, and to our own times,—noting the gradually increasing importance of herbaria as compared with botanic gardens. The second chapter touches upon the moral and intellectual dispositions necessary in botanical work, and asks the question what manner of men botanists are or ought to be. As their pursuits do not lead to fortune, and professorships are neither numerous nor well paid, he concludes that botany is just the science for disinterested people to prosecute from pure love of knowledge and the pleasure of discovering something new; that it does not deal with questions of a very high order, nor require very difficult or absolutely rigorous reasoning. The faculties which it brings into requisition are the spirit of observation and of order, sagacity, and a certain good sense in the appreciation of facts; that, if it does shine with great éclat, at least the faults of its cultivators are not likely to harm any one; that, equally with the other sciences, it tends to elevation of character in that it requires an ardent love of truth, reposing as it does upon the idea that the veracity of its cultivators is absolutely complete. He concludes, "Les sciences jouent dans le monde le rôle d'une école practique de bonne foi. D'apres ces réflexions, il est permis de penser que les botanistes sont ordinairement et devrait être toujours des hommes paisibles, inoffensifs, indulgent pour les erreurs de leur confrères, et occupès bien plus de l'avancement de la science que de leurs intérèts ou de leurs petites glorioles. . . . Ne nous arrêtons pas cependant sur de rares exceptions. La presque totalitè des botanistes est pénétrée du sentiment de la justice et des convenances. On en trouverait difficilement un seul qui ne reconnût le principe fondamental de ne pas faire à autrui ce qu'on ne voudrait pas qui vous fût fait."

Still—our author continues—sometimes the perfectly honest and right-minded botanist may have failings. He may, for example, neglect to cite his predecessors, or cite them inexactly, either from negligence (not to speak of calculated omissions, which show want of honesty and soon bring down reprobation), or from the want of literary resources. The latter case may be deemed a misfortune, and no fault. But, our author rejoins, if he has not the necessary books within his reach, why not go where they are and consult them? Or if unable to do that, why need he publish?

Some good advice follows about polemics and captious criticism; which we pass over, as seemingly superfluous, so long as the botanists are almost without exception such peaceable and good people. Something is said of the need of a right appreciation of the extent of the science; of the danger of exclusive devotion to a single branch of botany, in which one may lose all just perspective; and, finally, of what accuracy means in natural history as distinguished from mathematical exactness. Everywhere the naturalist has to judge as well as to measure.

The third chapter discourses upon the manner of preparing and editing botanical works, and the most advantageous modes of publication, considers the different degrees of publicity:—for instance, complete and durable publicity is attained when a monograph of an order or genus, a flora, a Species or a Genera Plantarum is published and placed on sale by the booksellers; or when an article or memoir is contributed to any leading and well-known botanical journal, or to the bulletin of a purely botanical society, which publishes with some regularity and indexes its volumes; or when printed in the transactions or bulletins of any scientific society, if separate copies in sufficient number are printed and fairly distributed or placed on sale. The usage in some learned societies of paging each memoir separately and placing it separately on sale is referred to, with implied commendation. Let us add that in all such separate issues, the original pagination of the volume should be scrupulously preserved; and it were better that there should be no other. Less complete, but durable publication is that of *ouvrages de luxe*, so limited in number of copies, and so high in price that only a few libraries can possess them; also articles in journals without full indexes, or with indexes only to a series of volumes.

Incomplete publicity is given when papers upon botany are inserted in the voluminous transactions of general learned societies, of which few individuals can possess the series or find room for them; also articles in reviews, encyclopædias, and the like, treating of many or of all sciences. Even journals of natural history alone fall under the ban, unless divided into separate parts for zoology and botany,—as is the long-continued Annales des Sciences Naturelles of Paris, and the Journal of the Linnean Society of London. A remedy or alleviation of these obstacles to publicity, and of others like them, is supplied by the catalogue of papers published by the Royal Society of London; which noble work was instigated by the late Professor Henry; yet, as this embraces all sciences and fills a goodly series of volumes, it can seldom be in the library of botanists.

In speaking of the obstacles to scientific publicity which are interposed by too limited editions, high prices caused by undue luxury in plates, and inopportune or inappropriate media of publication, DeCandolle refers to customs in the book trade and in government patronage which need reform; and mentions incidentally what a botanical library costs. He says there should be by the side of every great herbarium and every considerable botanic garden, a special botanical library, without which it is impossible to determine exactly the plants of the one or the other, or to write any good monograph or flora. Such a library costs fifty or sixty thousand francs (ten or twelve thousand dollars), and needs about 12,000 francs for annual purchases. He asks how many such establishments there are in the world, and concludes that there may perhaps be between ten and twenty.

The section on the comparative superiority of certain kinds of works, sets forth the greater value of *books* or systematic works as compared with memoirs or articles.

The language to be employed in botanical publications is the topic of a special article. For descriptions, Latin, and the Latin of Linnæus. "Le Latin des botanistes n'est pas cette language obscure et à rèticences de Tacite, obscure et à periodes pompeuses de Ciceron, obscure et à grâces tortillées d'Horace, qu'on nous fait apprendre au collège. Ce n'est pas même le langage plus sobre et plus clair d'un naturaliste tel que Pline. C'est le Latin arrangé par Linné à l'usage des descriptions et, j'oserai dire, à l'usage de ceux qui n'aiment ni les complicationes grammaticales, ni les phrases disposées sens dessus dessous, ni les parenthèses enchâssées dans les phrases."

This for descriptions, except in local floras, where popular use demands the vernacular; and we interpose the remark that English botanical language, freely incorporating as it does all Latin and Greek terms, comes next to Latin in convenience, compactness, and facility to all foreign botanists, who, being familiar with Latin, can seldom be at a loss. For discussions and reasonings, the botanists of each nation prefer their vernacular tongue; but DeCandolle would restrict them to the four modern languages, one or two of which, beside his native tongue, every naturalist is now-a-days supposed to be able fairly to read; English, German, French, and Italian. Indeed, DeCandolle recommends Latin and the technically descriptive style even for *generalia*, on the ground of brevity; and he aptly suggests that the less capable botanists are of handling other than Linnæan Latin, the more brief, sententious, and strictly to the point their exposition will be.

Hints are given as to the best mode of collecting literary material, making and preserving notes (each upon separate slips of paper), upon the importance of adding clear explanations of drawings at the time they are made; and upon the desirability of refraining from publication until the work is thoroughly completed, but of then publishing as soon as possible. A manuscript work is said to have its maximum value at the moment of completion. Our author declares that second and third editions are seldom equal to the first. That depends. He objects also to posthumous publication, citing Roxburgh's Flora Indica, published by Wallich, Plumier's plates published by Burmann, and the wretched figures of Velloso; and he might have referred to the ill-advised printing of Griffith's rough notes and comments. But all depends upon the character of the manuscript and the length of time which has elapsed.

Chapters IV–XI traverse the whole subject of descriptions, under various aspects and a rather minute division of topics. As even a brief analysis would overpass available space, we will merely touch here and there upon certain points.

As to the relation of varieties to species, there are two modes of presentation, both of which have been followed by Linnæus, and by most systematists, upon different occasions. Varieties are commonly designated by the small letters of the Greek alphabet, α, β, γ, etc., and also by names when they are pretty distinctly marked. Either the varieties, one or more, may be appended to the species (that is, to the form taken as the type, which usually must be the form originally described under the name), and therefore be treated as aberrant forms; or else the species is characterized as a group of forms, which forms are classified and defined just as species are under their genus. For instance, *Mentha Canadensis* is held to comprehend both a hairy and a smooth form, the two differing also somewhat in other respects. Linnæus founded the species on the former; and it is pretty well agreed that we are to refer the species back to him, however it be limited. Now we may either give a common character to the species, and then distinguish var. *α. villosa*, and var. *β. glabrata;* or we may characterize the species in general upon the originally named form, and append the variety *β. glabrata.* Either mode has its advantages and is likely to be employed in certain cases. The former classifies the varieties under the species, perhaps more naturally, and exhibits the polymorphous character of what we call a variable species; and DeCandolle considers that it will prevail in proportion as the forms of a species come to be well known; the latter holds closer to the bibliography. There is danger of some misunderstanding when the two modes are used in the same work. In the Synoptical Flora of North America, the former mode is invariably adopted, partly on the score of brevity. Either the originally described form, or a medium or common form is taken as the type, and the varieties are treated as departures from this. Even when the specific character is drawn so as generally to cover the varieties (as should be done as far as possible), some form, and the history of the species generally indicates what form, is kept in view as the norm or alpha. Of course, except for cultivated plants, there is no knowing and no pretence of determining which was the parent form, or in what order the several varieties may have diverged from a pristine stock.

As DeCandolle points out, there is much ambiguity and looseness in the use of this word *type,* which it would be well to avoid. Properly the type of a species *is* the species or genus, or the full idea of it, which no one individual or species may embody, which in the case of a group no single representative or member can fully exemplify. To apply the term to a form which well exemplifies the essential characters of the species or genus is quite natural, and hardly involves any confusion. But the term is also used in a historical sense, as referring to the particular form on which a species was founded, or the species on which the genus was characterized or which its founder had mainly in view, but which very often proves not to be the best representative of the group, sometimes not even a fair one. Finally a particular specimen which the original author described, or an authentic specimen, is said to be a type, or a typical specimen; and this DeCandolle objects to. But after all, such terms can hardly be held to a single sense in technical any more than in ordinary language. Something must be left for the context to determine.

In drawing up the characters of groups, such especially as orders and genera, are exceptions or what we call exceptions to be indicated in the character, or shall this express only what is generally true? DeCandolle discusses the question, but leaves it, as must needs be, for practical judgment to determine. On the one hand the point or the usefulness of a character is blunted or dissipated by the intercalation of alternatives and exceptions, yet characters must be somehow made to correspond with the facts. The method of Bentham and Hooker, of a separate specification of the principal known exceptions, is commended.

Should outlying or anomalous groups be incorporated with the orders they most resemble, or be merely appended as "genera affinia," and the like? The latter was inevitable in the earlier days of the natural system; but increasing knowledge, as well as considerations of symmetry and convenience, more and more fixes the place of these floating groups; so that their general incorporation into the orders by Bentham and Hooker in the Genera Plantarum of our day is in the natural course of things. But botanists have to remember that many of them are still riddles.

DeCandolle classes descriptions under the two general heads of *developed* and *abridged.* A developed description is a detailed account of the whole conformation, without regard to *differentiæ.* The type of an abridged description is the diagnosis, such as the specific phrase, or as Linnæus called it, the *nomen specificum;* what we now universally term the specific name being his *nomen triviale.* In the course of phytography both these have become rare or of special use as regards species, and a hybrid between the two has been engendered which is more serviceable than either. The long and independent descriptions of the olden time are now seldom written. Except for special cases, the development of the natural system in its subordination of groups in ever increasing numbers and definiteness, has rendered them superfluous. What was once stated in the developed description of a species in one formula, and a vast deal more, is now parceled out among the ordinal, tribal, generic, sub-generic or sectional, sub-sectional and other characters, each of which deals primarily, if not wholly, with *differentiæ.* The characters of each grade, being diagnostic, may be comparatively short; but taken together they become almost exhaustive. But to avoid going again over the same ground, subsidiary matters not diagnostical, yet needful or useful, are not rarely intercalated among the more essential points, instead of being collected in a separate paragraph. Consequently the specific diagnosis may be prolonged and get to partake of the nature of a developed description. The remedy for over length is to multiply divisions and sub-divisions between the genus and the species. To do this well, to arrange the species group within group most definably as well as most naturally, tasks the powers and the patience of a systematic botanist, and tests his aptitude for discerning affinities, and solving practical difficulties.

Developed descriptions are in place in such general works as DeCandolle's *Systema* (which was soon overweighted and crushed by them), and above all in monographs of orders or genera. In his sixth chapter, devoted to this topic, the author cites, in order of date, the principal monographs of orders or tribes (excluding those of a single genus) which may be taken as models (about two dozen only), and points out some of their merits or defects. The subject of abridged descriptions is taken up in chapter VII; and this connects itself with a great number of subsidiary questions and particular details, running on through twenty chapters more (individually short), and forming the most practically useful part of the book. There are so many points which it were well to call attention to, or sometimes to comment upon, for which space is now wanting, that we must defer the remainder of this critical notice to the next issue of the Journal.

It is to be regretted that, for the completeness of this work the author did not comprehend in it the subject of nomenclature of groups—an important part of phytography—and reprint in it his opuscula, entitled *Lois de la Nomenclature Botanique*, along with some further commentaries, such as his experience and some adverse criticisms from an opposing school may have suggested. This may still be desired, although the little treatise has already been widely disseminated in three languages, and although, as the author incidentally remarks, his own view is shared by an immense majority of descriptive botanists. A. G.

5. *The Ferns of North America: Colored Figures and Descriptions with Synonymy and Geographical Distribution, etc.;* by DANIEL CADY EATON, Professor of Botany in Yale College, 1879, 1880. 71 plates. Published by S. E. Cassino, 299 Washington street, Boston.—From time to time we have noticed this truly classical work, and have now only to congratulate author, artists, and publisher, also the botanical public and the numerous amateur fern-people, upon its happy completion. The author's part has been well sustained throughout. The illustrations began well, and went on better and better. The author adds to the second volume a complete Synopsis of the Genera and Species contained in the work, in systematic order, with diagnostic characters, a most convenient and useful addition. Would that our other Cryptogamia, or any of them, were similarly provided for. A. G.

6. *Index perfectus ad Caroli Linnæi Species Plantarum, nempe earum Primam Editionem* (*anno* 1753), *Collatore*, FERD. DE MUELLER. Melbourne, 1880. pp. 40, 8vo.—Baron von Mueller some time ago called attention to the fact, that most botanists cite the second edition of the Species Plantarum of Linnæus instead of the first, thus not really beginning at the beginning. Attributing this practice to the scarcity of the first edition, he now prints an index to that edition, for the use of those who possess only the second, or its equivalent, the third or Vienna reprint. We agree that it is most proper to cite the *editio princeps* for the species the names of which originate there; and, taught by Robert Brown forty years ago, we have uniformly done so. But we suspect that the prevalent habit of citing only the second edition did not grow so much out of the scarcity of the first as from the idea that the revised edition was the properest to use. Still the only safe and true way is to begin at the beginning; and it sometimes happens that the accretions in the subsequent edition are misleading. A. G.

7. *Catalogue of North American Musci;* arranged by EUGENE A. RAU and A. B. HERVEY. Taunton, 1879. pp. 52, 1880.—The species are arranged after Schimper's Synopsis; gen-

eral habitat or geographical range is given; the printing and proof-reading appear to be well done; and "the compilers [may well] believe that they are supplying a want which has long been felt by American botanists." We hope and may expect that we shall have something more than a compiled catalogue before long, although the death of Mr. Sullivant has greviously postponed the desired consummation. A catalogue like this is always useful.

A. G.

8. *Botanical Exploration of the little-known West India Islands.*—Baron Eggers, the commander of the Danish forces in the Danish West Indies, resident at St. Thomas, has issued a circular inviting subscribers for sets of botanical specimens, sections of woods, fruits, etc., in view of a complete investigation of the botany of those West India Islands which have been very little explored, at least in the present century, and which doubtless contain much that is new to science. Hayti and Dominica are particularly in view, also Porto Rico. It is intended that the specimens shall be well studied before distribution, named, and made up into uniform sets. As announced in the circular, the price of botanical specimens was fixed at $12.50 the hundred for Phænogams, and $10 for Cryptogams. But we understand that if encouragement is offered for the making of a considerable number of sets, the price of phænogamous plants will be reduced to the customary $10 the century. Botanists should communicate promptly with Baron Eggers, St. Thomas, Danish West Indies. A. G.

9. *Note to Dr. C. A. White's paper in volume* XX *of this Journal;* by R. ELLSWORTH CALL. (Communicated.)—In Dr. C. A. White's interesting communication to this Journal, vol. xx, July, 1880, pp. 44–49, "On the Antiquity of certain Subordinate Types of Fresh-water and Land Mollusca," occur two slight errors which may be misleading to future students pursuing the same line of research. On page 47 he lists seven species of fossil *Unionidæ* from the Laramie strata of Wyoming and Utah, together with a second series of seven recent Uniones "as their respective congeners." Congeneric with the *U. Couesi* White is written *Unio complanatus* Solander. Since the doctor gives a list of *Unionidæ* inhabiting the "*waters of the Mississippi basin*" as congeneric with the fossil forms, *U. complanatus* Sol. is out of place in such a list, being an inhabitant *solely* of the Atlantic slope, together with the numerous other species of which it is a type. This species is *not* found west of the Alleghanies. This fact is important in the matter of the geographical distribution of the recent *Unionidæ*. A slight error in the determination, or the nomenclature, of the species placed as congeneric with *U. Endlichi* White occurs. Doctor White evidently means *Unio gibbosus* Barnes. *Unio gibbus* was described by Spengler in "Skrivter af Naturhistorie Selskabet," vol. iii (1792,) and the habitat given is Tranquebar.

Dexter, Iowa, July 6, 1880.

10. *Packard's Zoology.*—A letter has been received from Professor Packard in reply to Professor Wilder's criticism of his work, as regards the accounts of the brains of vertebrates, on a former page of this volume. We cite from it a single sentence: "The book was not designed to give a monographic or even tolerably complete account of the brains of the Vertebrates; this would be out of place in such a work."

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The Seismological Society of Japan.*—A society under this name has been formed in Tokio, Japan, with the purpose of encouraging the study of earthquake and volcanic phenomena in that country. Its officers are I. Z. Hattori, President; Prof. John Milne, Vice-President, and Prof. W. S. Chaplin, Secretary. These names are already familiar to students of Seismology and are sufficient guarantee that the new society will be a valuable acquisition to the science. At a general meeting held April 26, 1880, a paper was read by Prof. Milne,* which he summarizes as follows: "What I have attempted has been to show the position which the study of earthquakes and volcanoes occupies in the scheme, waiting to be worked out, for the elucidation of the natural laws upon which all terrestrial things appear to be dependent. After this I give a condensed summary of the work which has been done in this country toward carrying out this scheme."

The paper, which is of considerable length, is printed in full in the account of the meeting in the Japan Gazette of May 1, 1880. One item of general interest is the actual horizontal movement of an earth particle during an earthquake shock, which Prof. Milne and his associates have succeeded in measuring instrumentally. The movement in seven cases, reported from his own and Mr. E. Knipping's observations, varied from 1·7 mm. to "4 or 5 mm.," with a mean of 2·9 mm. Prof. Milne described briefly several modifications of existing seismometers and at the close of his paper, Prof. J. A. Ewing exhibited a new form of seismograph. We quote the description of it somewhat condensed.

"The principle on which it is based is the well known one that the bob of a long pendulum may be assumed to be sensibly stationary during most shocks. Two levers at right angles to each other have their short arms kept in continuous contact with the very massive bob of a pendulum twenty feet long. The levers are joined to their supports so that each is affected only by the component of the movement resolved in its own direction. They are also unaffected by torsion of the pendulum or any other kind of relative motion of its parts. The long ends of the levers press gently against two smoked glass plates which are kept revolving continuously and uniformly by clockwork. So long as no earthquake occurs each lever traces one and the same circle over and over again on its revolving plate. The earthquake causes the

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* Professor Milne has given some of his results in a letter to *Nature*, vol. xxii, p. 208, July 1, 1880.

lever to move across this line, and so records an undulating line on each plate. These lines enable the movements to be measured and their relation to the time, from which the amplitude, velocity and direction of the horizontal motion of a point on the earth's surface are determined at every instant throughout the whole disturbance. The pendulum is not suspended from the roof of the house but from a separate rigid frame; and the levers with their recording discs are attached firmly to a wooden post stuck in the ground and cut off a few inches above the surface."

The new society is well located for effective work, as earthquake shocks seem to occur in Japan *almost daily.* A letter from Prof. Milne (June 12) speaks of "*over fifty* during the last two months," one night five, and another night three. C. G. R.

2. *Science: A weekly Record of Scientific Progress;* JOHN MICHELS, editor. Vol. I, No. 1 and 2, New York, July 3 and 10, 1880. The aim of this new Journal is stated to be "to afford scientific workers in the United States the opportunity of promptly recording the fruits of their researches and facilities for communication between one another," etc. It aspires "to take the position which 'Nature' so ably occupies in England." The necessity of the existence of such a Journal may perhaps be questioned, in view of the prompt and wide distribution of "Nature" in this country, although it would certainly be of value if it could maintain the position suggested in the prospectus, which it certainly has not done thus far.

The author of the ingenious story about the "diaphote" will be amused to see a column in "Science" devoted to the subject, in which the remarkable invention of the supposed "Dr. H. E. Licks" (=*helix*) is described in full detail. The original account, from which this quotation was made, is so clearly worked out in all the minor points and so ingeniously plausible that it is, perhaps, not strange that so many have been deceived. It deserves to take a place beside the famous "moon hoax" of years ago.

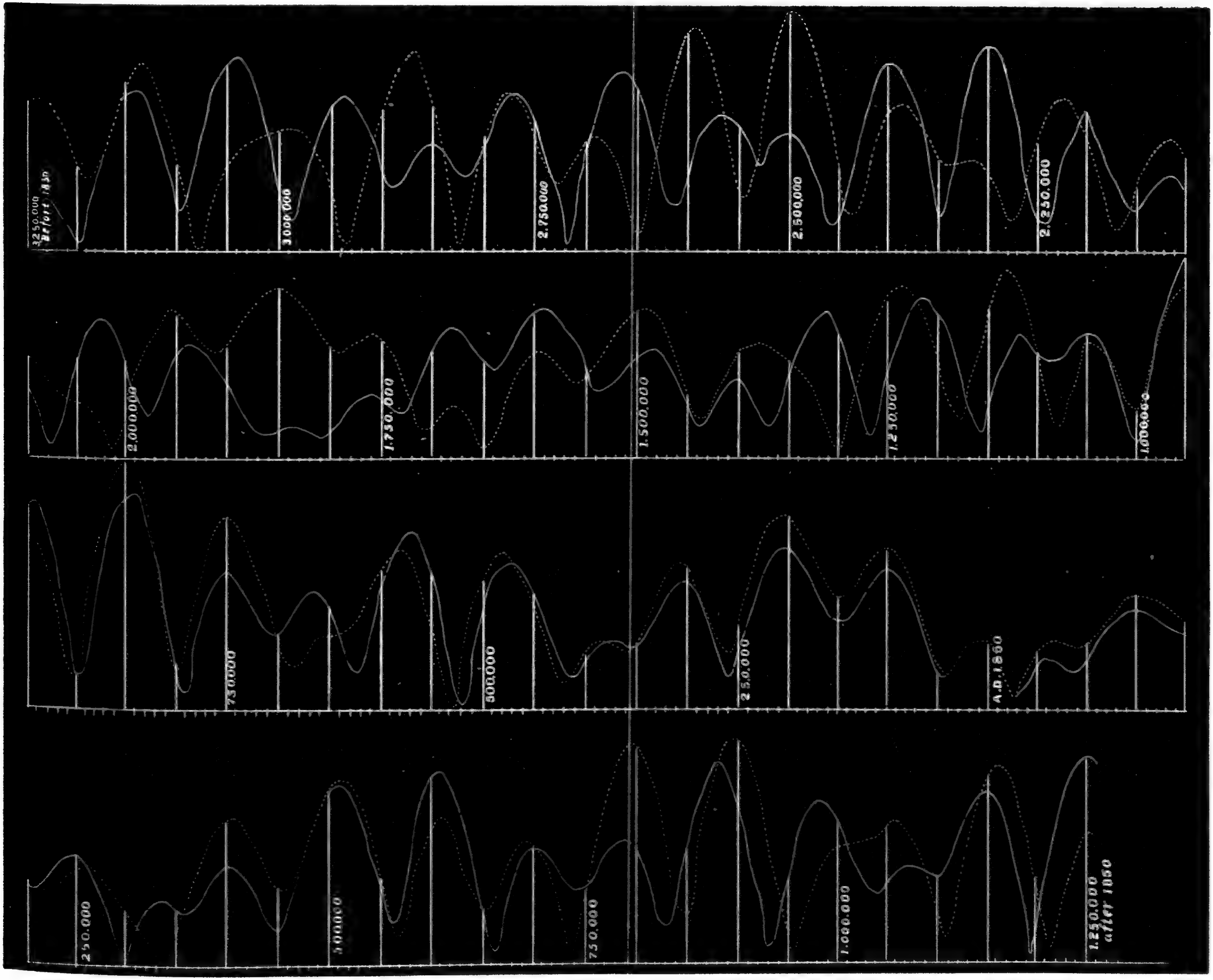
3. *Science Record:* A Monthly Bulletin of Scientific Researches, Discoveries and Reports on the Pacific Coast. San Francisco, Cal. (Dewey & Co.). The "Science Record" was commenced in February, 1879. The number recently received (vol. ii, No. 3) contains an article on the Origin of Lakes, by Prof. John LeConte, the first of a series to be published in future numbers; it also contains an account of the monthly meeting of the California Academy of Sciences, an article on the U. S. Fish Commission on the Pacific Coast, and other interesting matter. This Journal promises to fill a valuable place as a medium of publication of scientific observation in the western part of the United States.

OBITUARY.

COUNT LOUIS FRANÇOIS DE POURTALES, the well-known pupil and companion of Agassiz, Keeper of the Museum of Comparative Zoology at Cambridge, Mass., died July 18, in the fifty-eighth year of his age. A notice will be given in a subsequent number of the Journal.

Professor EDUARD GRUBE, of Breslau, died June 23, 1880, at the age of sixty-eight years.

Chart showing the Eccentricity of the Earth's Orbit for 3,250,000 years before and 1,260,000 years after A. D. 1850.



[illegible] intervals of 50,000 years; full curve, Stockw[illegible]

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

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ART. XXII. — *On the New Action of Magnetism on a Permanent Electric Current;*[*] by E. H. HALL, Assistant in Physics at the Johns Hopkins University.

IN the early part of last winter there was published in the American Journal of Mathematics[†] an account of some experiments which prove that an electric current, as distinguished from the conductor bearing the current, is acted upon by magnetic force in a manner altogether different from that in which ordinary induction is known to take place. The new phenomenon was in short the action of a permanent magnetic force on a permanent electric current. Up to the time when the above-mentioned article was written this new action had been observed in only one conducting material, gold. In the present article will be given the results of observations with several other conductors; but first it seems worth while to give some account of various closely related experiments which, though resulting negatively, are not entirely devoid of interest.

In the previous article the fact was mentioned that a form of apparatus had been devised which, it was thought, might reveal the new action in the shape of an increase of resistance in the conductor. The plan, as modified in accordance with a suggestion of Professor Rowland, was to employ as the conductor to be experimented upon a circular disk of gold leaf, in which the current entering at the center would radiate to a thick ring at the edge and so pass off by a wire attached to the ring. In such an apparatus under ordinary conditions the electromotive force, and so the flow of electricity, would be

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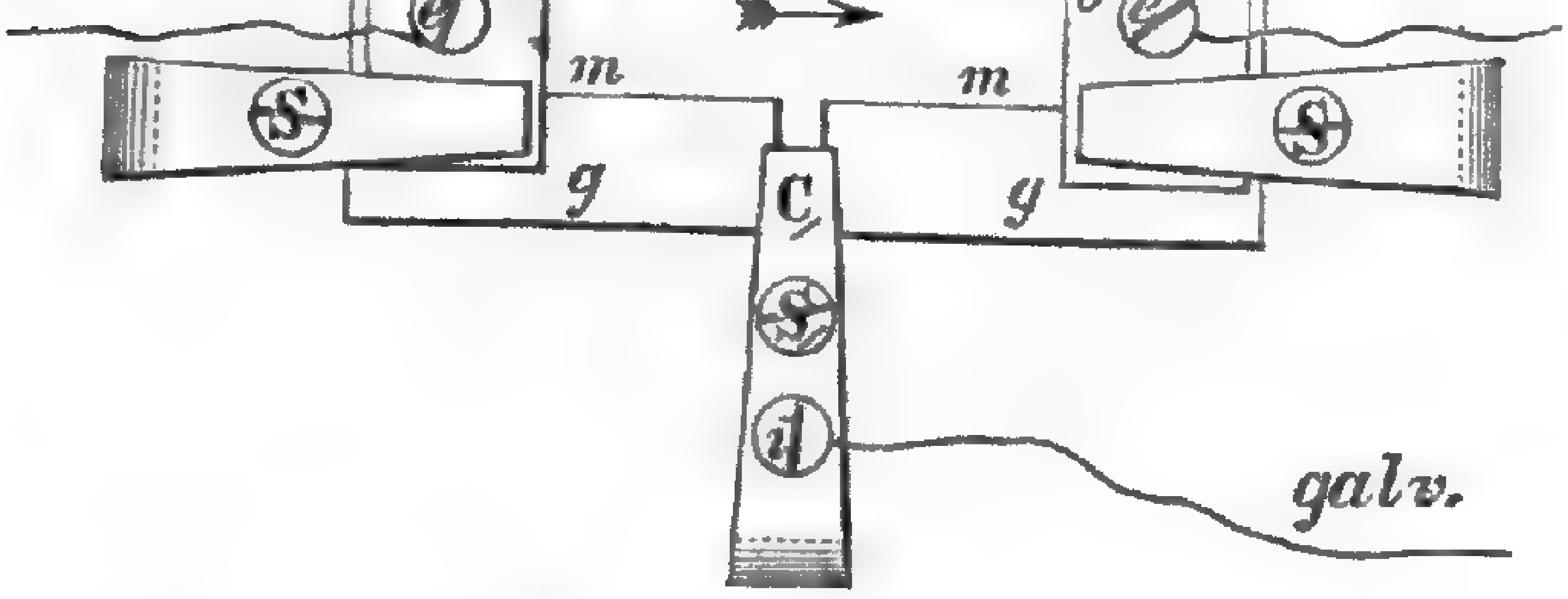
[*] In its original form this article was a thesis for the degree of Doctor of Philosophy. Some alterations have been made in preparing it for publication.

[†] Vol. II, page 287, 1879; republished in this Journal, March, 1880.

along the radii of the disk, but if a strong magnetic force were made to act perpendicularly to the face of the disk a new electromotive force would be set up, which would be always perpendicular to the direction of the magnetic force and to the actual direction of flow of the electricity at any instant in every part of the disk. The actual electromotive force therefore, under which the electricity would flow, would be compounded of two, one of which would in general have the direction of the radii of the disk, while the other would be nearly at right angles to this, though changing its direction constantly as the flow of electricity continually veered from its normal course under the resultant action of the two electromotive forces. The resulting path of the electricity from the center to the circumference of the disk would be, not a straight line as under normal conditions, but a spiral. This path being longer than the straight line, we should expect an increase of electrical resistance in the disk of gold leaf. Before any very extended experiments had been made with this apparatus, however, it was pointed out by Professor Rowland that the increase of resistance which might be looked for in this case would be exceedingly small, too small probably to be detected. This experiment was therefore abandoned for the time at least.

The next experiment to be described was a very simple variation upon the main one, and before going farther it may be well to give a drawing of such a plate as has been used in making most of the observations to be hereafter recorded.

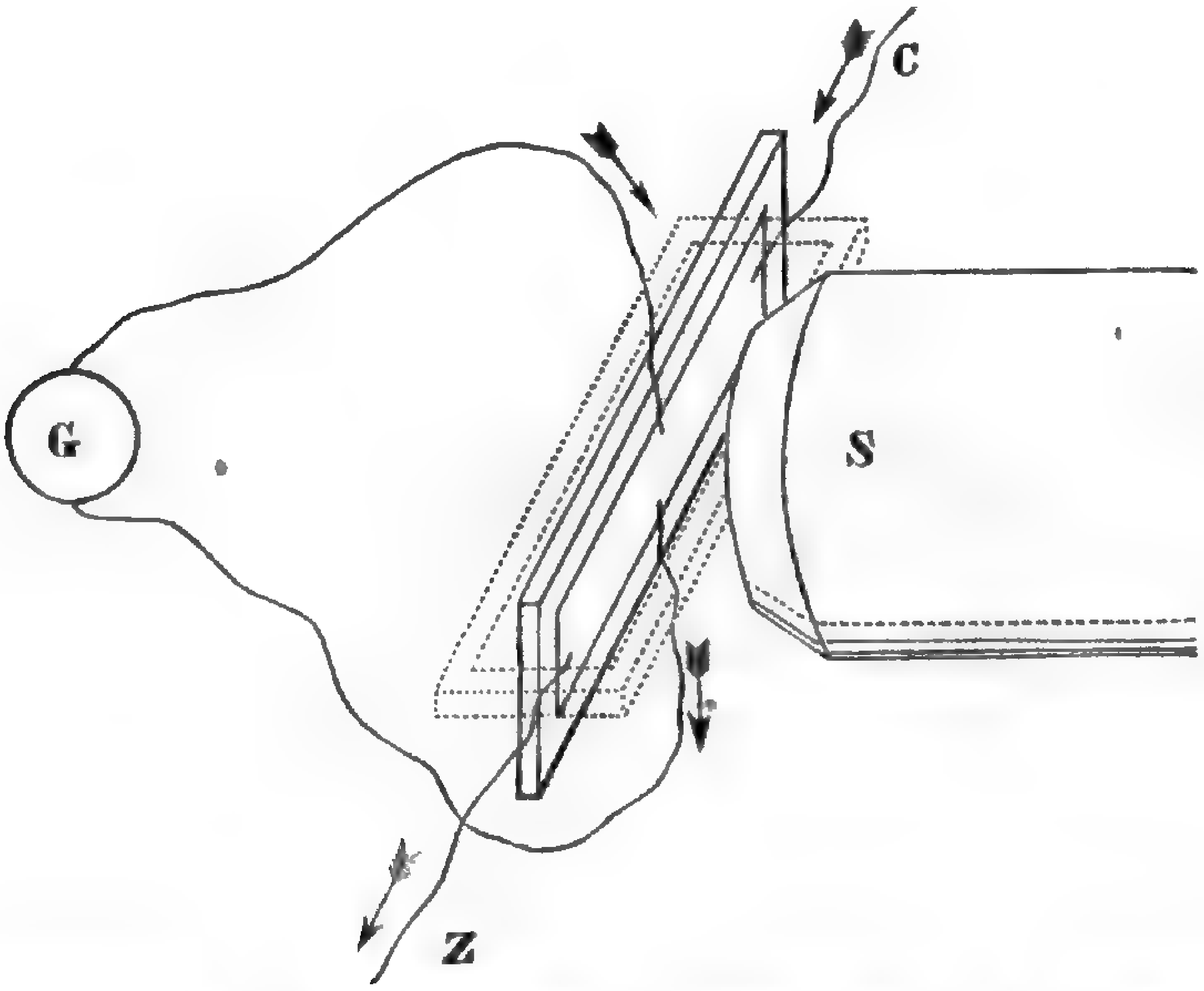
1.



In fig. 1, which is about one-half the actual size of an ordinary plate, *g g g g* represents the plate of glass upon which the metal strip *m m m m* is mounted. Contact with this strip is made at the ends by the two thick blocks of brass *b*, *b*, which are held firmly in place by the four brass clamps worked by means of the screws *S*, *S*, *S*, *S*. The main current of electricity enters and leaves the metal strip by means of the binding screws *e*, *e*. Running out from the middle of this strip are two projections which make contact with the clamps $C_{\prime\prime}$, $C_{\prime\prime}$, worked by the screws $S_{\prime\prime}$, $S_{\prime\prime}$. From the screws *i*, *i*, wires lead to the Thomson galvanometer. The projections from the metal strip just alluded to make the apparatus very easy to adjust, for by scraping off little particles from the proper part of the projections, while the current is allowed to run through the metal strip, the current through the Thomson galvanometer may be reduced to the extent desired.

In ordinary experiments such a plate as that just described is placed between the poles of the magnet in such a position that the direction of magnetic force would be represented by a perpendicular to the plane of the paper in the above drawing.

2.



In the variation upon the main experiment a plate was employed similar to the above, but narrower and with very short side clamps. This plate was first placed between the poles of the magnet in the usual position as shown by the heavy lines in fig. 2.

With this arrangement a permanent deflection of about 30 cm. on the scale before the Thomson galvanometer could be obtained by reversal of the magnet current. Leaving now the distance between the poles very nearly the same as before and using, both in the magnet and the gold strip, as nearly as possible the same strength of current which had just been employed in the previous trial, the plate was turned into the position indicated by the dotted lines in fig. 2. With this second arrangement no action of the kind previously seen was detected, or at least none that could with certainty be distinguished from the direct action of the magnet on the Thomson galvanometer. This latter effect produced a deflection of only a few mm. and could not have masked any considerable action of the kind looked for.

The first part of this experiment then shows our main fact, viz: that in a conductor subjected to the given conditions a permanent electromotive force is at once established which has a direction perpendicular to the direction of magnetic force and perpendicular to the direction of the primary current in the conductor. The second part of the experiment shows that under similar conditions no electromotive force is set up in the direction of the magnetic force, or at least none of the same order of magnitude as that described above.

The third experiment to be described was made at the suggestion and desire of Professor Rowland. It was to test for an action of the magnet on the lines of static induction in glass. A thick piece of plate glass about four cm. square was taken and a hole about four mm. in diameter was drilled through each of the four lateral faces. These four holes were all directed toward the center of the glass and each extended to within about seven mm. of this point. If the holes had met they would have formed two cylindrical channels at right angles to each other and extending straight through the glass from lateral face to lateral face. In each hole a loosely fitting plug of brass several mm. long was placed and securely fastened with a cement of insulating material. Leading out from each plug was a wire which was insulated for some cm. by being surrounded with a glass tube. The piece of plate glass thus prepared was placed between the poles of the magnet, precisely as a plate bearing a strip of gold would be. One of the brass plugs was placed in connection with the inner coating of a battery of Leyden jars charged by means of a Holtz machine, the opposite plug being in connection with the outer coating of the jars and with the earth. The other two plugs were placed in connection with separate quadrants of a Thomson electrometer. The quadrants were both insulated from the earth. The electrometer was sufficiently sensitive to deflect the spot of light about 170 mm. for the electromotive force of a Bunsen cell, or 340 mm. on reversing the connections with such a cell. The battery of Leyden jars was charged to a potential sufficient to give a spark of two or three mm. The connections being thus made, the position of the spot of light was observed and the magnet then operated with the purpose of discovering, if possible, any consequent change of position of the spot of light which would indicate an action of the magnet on the lines of static induction in the glass. The observation failed to establish the existence of any such action. The electrometer being in a very sensitive condition the spot of light was rather unsteady, so that any very slight effect of the kind looked for would not have been detected, though it is probable that if a reversal of the magnet had caused a change of four mm. in the position of the spot of light, this effect would have been apparent.

We may therefore conclude that any change of relative potential on the quadrants of the electrometer caused by reversal of the magnet was probably less than $\frac{1}{80}$ of that caused by reversing the connections of the electrometer with a Bunsen cell, as mentioned above. If now we estimate the difference of potential between the plugs A and B, connected with the Leyden jars, to have been, as indicated by the length of the spark, equal to that which would be produced by 10,000 Bunsen cells in series, we may conclude that any difference of potential between the other plugs C and D which was caused by the action of the magnet, must have been less than $\frac{1}{800000}$ of the difference of potential between A and B. We must remember, however, that any change of potential on C and D had to be extended as well over the comparatively large area of the electrometer quadrants. Professor Rowland has roughly estimated the capacity of the quadrants as twenty times that of the plugs C and D. If, therefore, these plugs had not been attached to the electrometer, any difference of potential between them due to the action of the magnet would have been twenty times as great as in the actual case, so that instead of $\frac{1}{800000}$ we have $\frac{1}{40000}$ of the difference of potential of A and B as the superior limit of the difference of potential of C and D which the magnet might possibly have produced, if C and D had not been connected with the electrometer. Representing the former difference of potential by E, the latter by E′, and the strength of the magnetic field, about 4000 (cm.-grm.-sec.), by M, we have for this case of static induction in glass $\frac{E'}{E \times M}$, if not zero, is less than $\frac{1}{1600000000}$.

Turning to the analogous case of current electricity in the various metals and representing now by E the difference of potential of two points a centimeter apart in the direction of the current, and by E′ the difference of potential of two points a centimeter apart in a direction at right angles to that of the current, while M has the same signification as before, we may write, as a very rough estimate for the case of iron, $\frac{E'}{E \times M} = \frac{1}{10000000}$, while for tin the value of this ratio may be as small as $\frac{1}{600000000}$. We may therefore conclude that the equipotential lines in the case of static induction in glass, if affected at all by the magnet, are affected much less than the equipotential lines in the case of a current in iron, but we can not say that any such possible action in glass has been shown to be smaller than the analogous action in the case of a current in tin.

I now go on with an account of further investigation of the phenomenon actually discovered and already in some measure described in my previous article. When writing that article it seemed to me instructive to deduce the ratio, $\frac{E}{E'}$, of the difference of potential per cm. on the longitudinal axis of the gold leaf strip to that per cm. on the transverse axis. There were thus obtained for the experiments made values of $\frac{E}{E'}$, ranging from 3,000 to 6,500 according to the strength of the magnetic field.*

At that time I supposed that the ratio $\frac{E \times M}{E'}$ would prove to be a constant, not only for different strips of one metal, but for all conductors. Subsequent experiments showed that this was not the case, and in this article the results obtained will be expressed by the ratio $\frac{M \times V}{E'}$, where E′ has the same signification as before, while M now expresses the strength of the magnetic field in cm.-grm.-sec. units and $V = \frac{C}{S}$†, the strength of the primary current divided by the area of section of the conductor. This ratio does not prove to be the same constant for different metals but for any particular metal it seems much more nearly a constant than the ratio $\frac{E \times M}{E'}$ given above would be.

It may seem to those who read the following pages that an unnecessary amount of study has been devoted to gold. It must be remembered, however, that many readers of my previous article were not fully convinced by the evidence there adduced that any really new principle had been discovered, thinking that the explanation of the phenomenon described was possibly to be found in some such fact as the state of mechanical strain, into which the strip of gold leaf would be thrown in its endeavor to move across the lines of magnetic force in obedience to the perfectly well known laws of the

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* In obtaining this latter quantity, which was called M, a serious error was made and the value given was probably not much more than half what it should have been. This fact was mentioned in a note when the article in question was republished in this Journal, Mar., 1880, p. 200, and p. 235.

† This quantity V may be said to bear an intimate relation to the absolute velocity of the electricity, for if we were to take as the unit velocity of electricity that of a unit current flowing through a conductor of unit cross-section, the velocity in any particular case would be a quantity $\frac{C}{S}$.

action of magnets on conductors bearing currents. This being the case, it seemed desirable to make experiments with several strips of the same metal and determine whether the ratio $\frac{M \times V}{E'}$ would prove to be a constant for all. The dimensions of many of the strips used, of whatever metal, are given below, and in order that the conditions to which they were variously subjected may be more fully understood, there will be given in many cases the strength of the magnetic field in absolute units and the strength of the primary current through the strip, the latter being expressed in terms of the constant, k, of the tangent galvanometer used to measure it. This constant there has been no occasion to determine exactly, but it is about ·07.

It will probably be readily admitted that the results obtained cannot be accounted for without admitting substantially all that was really claimed in the previous article. Even if no such quantitative investigation had been made, however, there would still be one fact inexplicable on the theory of an accidental cause for the phenomenon under consideration. The arrows in fig. 2 show the direction of the transverse current relatively to the direct current in gold, the magnet pole, S, being a south pole, i. e., the pole attracting the north pointing end of a needle. This relation between the directions of the two currents and the magnetic force is the same in all of the four gold plates which have been examined in this particular. The same uniformity is observed in the four silver plates, and the three iron plates, which have been tested in the same way. With the two plates of tin which have been examined there has been a trifle of uncertainty upon this point, as the effect in this metal is at best very small, but this uncertainty is hardly sufficient to cast doubt upon the correctness of the rule that, so far as observation has gone, the relative direction of the transverse current is always the same for any particular metal. This uniformity in so many cases could hardly be accidental.

This matter of direction is evidently one of fundamental importance. The direction was found to be the same for silver as for gold, these being the two metals first examined. Professor Rowland, however, predicted that the direction would be reversed in iron and experiment verified the prediction. Prof. Rowland's comments upon the significance of this discovery are already before the public*. It is a seemingly awkward fact that in nickel, next to iron and cobalt the most strongly magnetic substance, the direction of the transverse current is the same as in gold. This fact will be discussed further on. The conductors which have, up to this date, been subjected to ex-

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* Am. Journ. Math., vol. ii, p. 355.

periment are gold, silver, iron, tin, nickel and platinum. The direction is the same in all except iron.

The extreme irregularity in the results obtained in the early part of this course of experiments was due to various causes, only one of which is worth mentioning here. This source of error was the shape of the magnet poles, which, being intended for the study of the magnetic rotation of polarized light, were perforated axially by a hole several mm. in diameter. With these poles the magnetic force was found to vary many per cent in different parts of the field. These poles were subsequently replaced by solid ones, and a sufficiently uniform field was thus secured. It will, however, be noticed that even after this change the results obtained on the same day and with the same plate often vary by several per cent. Probably quite a part of this irregularity was due to the faulty manner in which the tangent galvanometer, which measured the strength of the primary current through the strip, was introduced. This source of error can probably be avoided in future measurements. Again it is to be remembered that the strength of the transverse current was determined by a delicate Thomson galvanometer, an instrument far more sensitive than accurate. In using comparatively thick strips of metal there is especial liability to error from this source, as a low resistance galvanometer must then be employed, which may easily change in sensitiveness several per cent within an hour.

Much of the disagreement to be observed in the results obtained with different plates of the same metal, is no doubt to be explained by the difficulty of determining with anything like accuracy the thickness of the various strips employed. I have tried to determine approximately the thickness of the thinnest films used by measuring the electrical resistance, but this method, as will be seen, is exceedingly faulty. The thicker strips have been weighed before being placed on the glass, but even this method fails to determine the effective thickness accurately. Even if the specific gravity were the same for all the strips, and it probably is not, the value thus obtained for the thickness would give only the average thickness, and this is by no means the effective thickness. It will be remembered that the connections leading to the Thomson galvanometer are placed opposite to each other with the width of the metal strip between them. The effective thickness is the average thickness along the line joining these two side connections. Gold foil is obtained in sheets ten or twelve cm. square. It will be seen further on, that in one case two strips cut from similar positions in the same sheet differed in average thickness about seven per cent. This being the case it seemed quite possible that the effective thickness of any strip, as defined above, may differ many per cent from the mean thickness indicated by the weight.

All these sources of error being considered, the discrepancies which will be observed in the results to be given, will not be surprising.

A single complete series of observations consisted of the following parts:

1st. A determination of the extent to which the indicator of the Thomson galvanometer was affected by the direct influence of the magnet and the magnetizing current.—All that it was necessary to ascertain in this case was the change in position of the galvanometer indicator caused by reversing the current through the magnet. This usually amounted to one or two mm. and subsequent readings of the Thomson galvanometer were, when it was necessary, corrected accordingly.

2nd. A determination of the strength of the magnetic field.—This was done by withdrawing suddenly from the field a small coil consisting of a few turns of wire and observing the effect of this action on a delicate galvanometer placed in circuit with the coil.* The galvanometer was used with a mirror and scale and the readings actually obtained were reduced by the formula

$$\sin\frac{\Phi}{2}=\frac{n}{4r}\left(1-\frac{11}{2}\left(\frac{n}{4r}\right)^2\right)$$

where n is the actual reading and r the distance from the mirror to the scale. The constant of the galvanometer not being known, its sensitiveness, that is the significance of its readings in absolute measure, was determined whenever the strength of the magnetic field was to be found. This was effected by means of an earth inductor placed in circuit with the galvanometer and the test coil used with the magnet. The determination of the strength of the magnetic field therefore involves two series of observations, one with the earth inductor and one with the test coil.

3d. A determination of the sensitiveness of the Thomson galvanometer.—This was done by sending through it a current of known strength obtained by shunting the current from a Bunsen cell, the main current being measured with a tangent galvanometer.

4th. The main experiment.—The primary current through the metal strip measured with the tangent galvanometer just spoken of, and the effect of reversing the magnet observed on the scale of the Thomson galvanometer.

5th. Another determination of the sensitiveness of the Thomson galvanometer.—Method as described above.

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* Rowland, "On a Magnetic Proof Plane," this Journal, vol. x, p. 14, 1875.

6th. Another series of observations with the test coil.

7th. Another series of observations with the earth inductor.

8th. Another determination of the direct action of the magnet on the Thomson galvanometer.

If, as was usually the case, several series were to be made with the same plate in one day, for the purpose of using primary currents of various strengths, the sensitiveness of the Thomson galvanometer was tested before each main series of observations and after the last.

The mean of two values found for the sensitiveness of the Thomson galvanometer was of course taken to be the sensitiveness during the series of observations intervening. It was not found necessary to determine the strength of the magnetic field more than twice during a half day's observations.

In working up these observations the following formula applies:

$$\frac{\mathrm{M}\times\mathrm{V}}{\mathrm{E}'}=\frac{7460\,\mathrm{H}\,\dfrac{\sin\dfrac{\Phi}{2}}{\sin\dfrac{\Phi'}{2}}\,\dfrac{k\tan\alpha}{wt}}{\dfrac{dk\tan\Theta\,pr}{d'w}}$$

M, V, and E' have been already defined.

7460 = twice the integral area of the earth inductor divided by the integral area of the test coil. Twice the simple ratio of these two areas is taken, for the reason that the earth inductor coils are turned through 180° when used.

H = horizontal intensity of earth's magnetism at position of earth inductor.

$\sin\dfrac{\Phi}{2}$ = a quantity relating to effect on the galvanometer used with test coil, produced by withdrawing the latter from the magnetic field.

$\sin\dfrac{\Phi'}{2}$ = a similar quantity relating to the galvanometer and the earth inductor.

k = constant of tangent galvanometer.

α = reading of tangent galvanometer when measuring primary current through the metal strip.

w = effective width of metal strip.

t = effective thickness of metal strip.

d = difference in readings on the Thomson galvanometer scale caused by reversing magnet in the main experiment.

d' = difference in readings on same scale caused by reversing current in determining sensitiveness of the Thomson galvanometer.

Θ = reading of tangent galvanometer when measuring current used to determine sensitiveness of Thomson galvanometer.

p = proportion of above current which passes through the Thomson galvanometer.
r = total resistance of circuit containing Thomson galvanometer during main experiment.

The above formula reduces to the form

$$\frac{M \times V}{E'} = \frac{7460 \sin \frac{\Phi}{2} \tan \alpha \, d' \, H}{t \, d \, p \, r \tan \Theta \sin \frac{\Phi'}{2}}$$

It will be seen that k and w have disappeared. The elimination of w is a very important fact as this would be an exceedingly difficult quantity to determine with accuracy. As the case stands, it is not at all important to preserve the form of the metal strip after its thickness has been determined. This makes the adjustments of the side connections (see fig. 1), leading to the Thomson galvanometer, a matter of considerable ease.

The following pages give some details of the study of the various metals examined.

GOLD.

The experiments which furnished the results already published, were made with gold leaf so thin as to be transparent. In order to reduce those results to the form since adopted, it would be necessary to know the thickness of the gold strip. This thickness might be determined roughly, if we knew the the specific resistance of the material and the actual resistance of the strip, which is now destroyed. The latter value is known approximately, and, by assuming the specific resistance to have been that of pure gold, we might arrive at a value of the ratio $\frac{M \times V}{E'}$. This value, however, would be very much larger than that obtained when thicker strips of metal are used, and facts to be hereafter mentioned make it appear quite probable that the thickness of the strip, as above arrived at, is several times smaller than the true thickness.*

Without attempting therefore any accurate determination of the constant of this first strip (A), I pass on to

Gold Leaf, Plate (B).

This plate also is of very thin metal, and in general I shall use the term gold *leaf*, when speaking of the metal in this shape, and use the term gold *foil* to denote the strips of considerable thickness.

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* See also Albert v. Ettingshausen, "Bestimmung der Absoluten Geschwindigkeit," etc. Sitzungsberichte Akad. Wien, vol. lxxxi, p. 446, 1880. He found the value of the thickness indicated by the weight in similar cases, to be from four to ten times as great as that indicated by the resistance.

This second plate of gold leaf was not constructed until after several thick plates had been tried and found to give very different results from those obtained with the first thin plate in the manner described above. Thinking that some experimental error in the first measurements might account for the discrepancy, and the first plate being destroyed, I constructed the second one. In making observations with this plate I first used the high resistance Thomson galvanometer, whereas the low resistance instrument had been used with the thick plates. Thinking that I might in changing instruments have fallen into some error, I afterward made another series of observations with the same plate, but using the low resistance galvanometer. The results were, the thickness here also being estimated as above described,

March 18, with high resist. galv., $\frac{M \times V}{E'} = 622 \times 10^{10}$
" " " " " $= 637 \ldots\ldots$
" 19, " low " " $= 681 \ldots\ldots$
Mean " $= 647 \times 10^{10}$

This result is about four times as large as those found with thicker plates. Arguing from these facts alone, it would appear that the transverse effect in thin leaf gold is relatively much smaller than the effect in strips of sensible thickness, but this is hardly a safe conclusion. Three objections to the above method of determining the thickness by means of the resistance are evident; 1st, gold leaf so thin as to be transparent is by no means continuous, but is perforated by a multitude of small holes, so that the electricity is, as it were, obliged to wind or zigzag its way through the strip, thereby having a longer path and meeting a greater resistance, than if it could pursue a direct course: 2d, gold leaf is an alloy about twenty-three carats fine, and the resistance of such alloys is often much larger than that of either of the pure metals: 3d, it is difficult to secure good contact at the ends of the strip. In the plate under consideration this contact was probably very bad, and may have been many per cent of the whole resistance of the plate as measured.

All these sources of error affect the result in the same way. To compensate, it would be necessary to diminish the resistance as measured and then, in deducing the thickness, use a specific resistance higher than that belonging to gold. In using thin silver plates I have in a rough way made a correction for the error due to contact resistance, but the gold *leaf* is in several respects so unsuitable for anything like accurate work, that it does not seem worth while to spend any more time upon it at present. In fact I would in the present article dismiss the subject of gold *leaf* strips with a very few words, were it not the case that, in a matter of this kind, it seems proper that the public should be informed of any facts that have the slightest suspicious appearance.

The gold plates which are now to be described, were of comparatively thick metal, such as is used by dentists. The metal in this shape is said to be very pure, and the thickness was so considerable as to make it possible to weigh the strips with sufficient accuracy. The determination of the thickness in this way involves the assumption that the specific gravity is that given by the tables, but the error from this source must be very much smaller than the sum of those introduced by employing the resistance method.

Gold used by dentists is classed under various heads according to the manner of tempering. The kinds I have used are, I think, "soft," or possibly "semi-cohesive," and "hard," or "cohesive." I noted the varieties, thinking that specific peculiarities might possibly appear in their behavior. The number attached to each plate is the commercial number of the specimen and indicates approximately the number of grains in a sheet about ten cm. square. The letters attached are intended to distinguish different plates constructed from gold of the same number.

Gold Foil, No. 6 (*A*).

This strip was, I believe, of the kind called by dentists "hard," or "cohesive." To determine the thickness it was weighed before being attached to the glass. Previous experiment having shown the great variation in thickness between different parts of a sheet of gold foil, this strip was cut before weighing into nearly the same shape and size that it was to have on the glass.

The strip was in general shape a parallelogram with a projection from the middle of each of its longer sides. The use of these projections, which were much reduced in size before making the observations, has been already explained.

Length of strip when weighed = 8·50 cm.
Width " " = 2·14 "
Area including projections =20·5 " sq.
Weight = .0848 grms.

Taking the specific gravity of gold at 19·36, the value given by Ganot for "gold stamped," we find

Thickness = ·000214 cm.

With this plate many series of experiments were made, yielding most of the time results which were very discordant, owing to various disturbing causes, some known and others perhaps unknown, to which allusion has already been made. The results obtained every day, except the last of my working with this plate, are so discordant, that in preparing them for publication it does not seem worth while to go over again the great mass of figures involved, for the purpose of correcting any small errors of calculation. The results obtained were

February 20th $\frac{M \times V}{E'} = 134 \times 10^{10}$
" " " $= 136 \ldots\ldots$
" 23d " $= 163 \ldots\ldots$
" " " $= 159 \ldots\ldots$
" " " $= 166 \ldots\ldots$
" 25th " $= 160 \ldots\ldots$
" " " $= 149 \ldots\ldots$
" " " $= 157 \ldots\ldots$
" 27th " $= 152 \ldots\ldots$
" " " $= 147 \ldots\ldots$
Mean " $= 152 \times 10^{10}$

Replacing now the old perforated poles of the electro-magnet by solid new ones and removing one or two other sources of error, I found

March 5th $\frac{M \times V}{E'} = 150 \times 10^{10}$
" " " $= 150 \ldots\ldots$
" " " $= 154 \ldots\ldots$
Mean " $= 1513 \times 10^{9}$

The strength of the magnetic field was, as usual, determined twice on March 5th, once before and once after the other observations. The two values varied by something more than one per cent. The mean of the two is taken as the uniform strength for the day. The strength of the primary current sent through the gold strip was much varied for the different series of observations.

Thus we may write as corresponding to the above three values

Strength of Field. M.	Strength of Primary Current. C.
6400	$k \times \tan 23° \ 44'$
"	" " $42° \ 14'$
"	" " $49° \ 28'$

when k is the constant of the tangent galvanometer $= \cdot 07$ nearly.

The agreement between the mean of the various results previously obtained and the mean of those found March 5th, was considered satisfactory, and the next measurements were made with

Gold Foil, No. 5.

The metal in this plate was, I believe, either "soft," or "semi-cohesive."

Length of strip when weighed = 8·49 cm.
Width " " = about 3·28 "
Area including projections = 30·0 " sq.
Weight = ·1122 grm.
Thickness = ·000188 cm.

This strip after being placed on the glass was trimmed down to a width of about 2·32 cm., and the mean thickness of this strip was no doubt quite different from the value above obtained. This strip was reduced in width after being weighed more than any other that has been used, and this fact may account for the discrepancy between the results obtained with it and those obtained with the strips of No. 6, already described, and of No. 4, which is to be described next.

With No. 5 were made four series of observations, resulting thus:

	M.	C.	$\frac{M \times V}{E'}$
Mar. 8th,	6400	$k \times \tan 42° \ 26'$	161×10^{10}
" "	6330	" " $26° \ 2'$	163 . . . . .
" 10th,	6440	" " $22° \ 48'$	162 . . . . .
" "	6440	" " $43° \ 0'$	164 . . . . .
		Mean	$= 1625 \times 10^{9}$

The next plate used was

Gold Foil, No. 4 (*soft*).

Length when weighed = 7·64 cm.
Width " = 2·13 "
Area including projections = 18·46 " sq.
Weight = ·0478 grm.
Thickness = ·000134 cm.

With this plate four series of observations were made in one day.

The results obtained March 12th were

M.	C.	$\frac{M \times V}{E'}$
6480	$k \times \tan 22° \ 21'$	155×10^{10}
"	" " $26° \ 25'$	155 . . . . .
"	" " $42° \ 16'$	154 . . . . .
"	" " $28° \ 43'$	154 . . . . .
	Mean	$= 1545 \times 10^{9}$

Measurements had now been made with three plates of gold foil, and, considering the irregularity likely to be produced by the impossibility of determining accurately the effective thickness of the strips, the results seemed to agree satisfactorily, indicating $\frac{M \times V}{E'}$ to be a constant for this metal. If the experiments in gold had begun with these particular plates, they would probably have ended with them for the present. Owing, however, to the great discrepancy observed between these results and those obtained with the very thin plates it seemed desirable to go further, and I therefore constructed a plate using

Gold Foil, No. 30 (A), (*semi-cohesive ?*).

Length of strip when weighed = 5·76 cm.
Width " " = 1·085 "
Area including projections = 7·36 " sq.
Weight = ·161 grm.
∴ Thickness = ·001129 cm.

With this plate

	M.	C.	$\frac{M \times V}{E'}$
Apr. 20th,	6520	$k \times \tan 48° 38'$	123×10^{10}
" 23d,	6600	" " 31° 30′	124 . . . . .
" "	"	" " 40° 39′	128 . . . . .
		Mean	= 1250×10^{9}

This value is about twenty per cent lower than the mean of those obtained with the three plates, Nos. 4, 5, and 6, previously used. The discrepancy was so great, that another plate was made with a strip cut from the same sheet as No. 30 (A).

Gold Foil, No. 30 (B), (*semi-cohesive ?*).

Length of strip when weighed = 5·69 cm.
Width " " = 1·08 "
Area including projections = 7.33 " sq.
Weight = ·149 grm.
∴ Thickness = ·00105 cm.

It will be seen that the strips (A) and (B), cut from similar positions in the same sheet of metal, differ about seven per cent in mean thickness. The importance of this fact has already been pointed out. The difference in thickness thus found was so great, that I at first supposed a mistake must have been made in weighing the first strip, thereby giving too large a value for the weight. I therefore removed the strip from the glass plate and weighed it again. The result confirmed the original value obtained.

With the new plate, No. 30 (B), I found

	M.	C.	$\frac{M \times V}{E'}$
Apr. 26th,	6760	$k \times \tan 68° 0$	139×10^{10}
"	"	" " 39° 26′	141 . . . . .
		Mean	= 1400×10^{9}

This value is much nearer those obtained with the plates 4, 5, and 6, but even now there is a discrepancy of eight or ten per cent. Without discussing this matter any further at present, I pass on to tell what has been observed with

SILVER.

Measurements have been made with four separate plates of this metal. The thickness of the strip was estimated in one case by weighing, in the three others by measuring the electrical resistance. I will give first the results obtained with the thick strip.

Silver Foil, No. 10.

Length of strip when weighed = 7·98 cm.
Width " " = 1·07 "
Area including projections = 9·23 " sq.
Weight = ·0474 grm.
∴ Thickness (taking sp. gr. to be 10·47) = ·000491 cm.

With this plate

	M.	C.	$\frac{M \times V}{E'}$
Apr. 21st,	6580	$k \times \tan 49° 17'$	114×10^{10}
"	"	" " 32° 20′	118 . . . . .
		Mean	$= 1160 \times 10^{9}$

Two of the other plates were prepared, not by fastening silver leaf to glass with shellac, but by depositing from a solution the silver directly upon the glass. The process made use of for this purpose was Böettger's, as detailed in this Journal for 1867. The two plates were cut from the same piece of glass after coating.

Silver Film (A).

Length between the contact blocks = 6·05 cm.
Width = 2·46 cm.
Electrical resistance, as measured, = 1·45 ohms.

Knowing that the contact resistance must be quite a part of this value, I endeavored to determine its amount roughly in the following manner. Having obtained the above value, 1·45 ohms, and measured the distance between the blocks, I shortened the strip by placing the blocks nearer together, then measured the length and again determined the resistance of the whole. This process was repeated, thus giving three values of the resistance corresponding to the three lengths of the strip employed. From these values the contact resistance is readily determined, though of course very roughly. It appeared to be equal to the resistance of about 2·7 cm. of the strip itself, and therefore in estimating the thickness of the strip from the electrical resistance, the effective length of the strip was taken to be not 6·05 cm., but 8·8 cm. Assuming the specific resistance of the silver in this plate to be ·00000165 ohms, the value given by Jenkin for "hard drawn" silver, we obtain as the thickness of the strip ·00000407 cm. It will be shown below that this value is probably very much too small, but I will for the moment give the results obtained on the basis of this estimation of the thickness.

Passing over a result obtained at quite an early period of the experiments, and which there are excellent reasons for rejecting, we have

	M.	C.	$\frac{M \times V}{E'}$
Jan. 30th,	7120	$k \times \tan 43^\circ\ 33'$	487×10^{10}
"	"	" " $19^\circ\ 32'$	499×10^{10}
		Mean	493×10^{10}

The discrepancy between this result and that obtained with the thicker strip of silver was so great, that I determined to try

Silver Film (B).

I have assumed the thickness of (B) to be the same as that of (A). The other dimensions are about the same, and the result is

	M.	C.	$\frac{M \times V}{E'}$
May 4th,	6640	$k \times \tan 47^\circ\ 39'$	491×10^{10}

The agreement of this result with the mean of those just preceding is entirely satisfactory, and the discrepancy above mentioned, as existing between the results with plates of different kinds, is confirmed. This disagreement was so large as to be difficult to account for, without the hypothesis of a specific difference exhibited by different forms of the same metal, under the conditions of the experiment. To be sure the method of estimating the thickness from the electrical resistance was open to suspicion. Among other probable sources of error there was the possibility of having assumed a wrong value for the specific resistance of the silver in this condition. It did not appear to me probable that an error of about 400 per cent could be accounted for in this way, but it seemed worth while to attempt a determination of the thickness of the films by another method.

Plate (A) was taken and cleaned with alcohol to remove the particles of cement adhering to the glass and metal. The area of the silver film was roughly determined, and the plate was dried and, when cool, carefully weighed. The silver was then removed by dissolving in nitric acid, after which the glass was again dried and weighed. In addition to this the solution of silver was filtered and treated with hydrochloric acid. The precipitate was filtered off, and the silver reduced by burning with the filter paper. The amount of silver on the glass was thus estimated in two ways. According to the weight lost by the plate the amount of silver appeared to be 4·3 mgr., while the amount obtained by the chemical process was only about 2·5 mgr. There are good reasons for thinking the former value too great and some reasons for thinking the latter too small. Giving the latter double weight in taking the mean we get $\frac{4{\cdot}3+2\times 2{\cdot}5}{3}=3{\cdot}1$ mgr. for the amount of silver in the film. The area covered by this on the glass was about 20 sq. cm. Taking the specific gravity of silver to be 10·5, we get for the thickness of the film

$$t=\frac{{\cdot}0031}{20\times 10{\cdot}5}={\cdot}0000148 \text{ cm.}$$

This value is more than 3·6 times as large as that obtained by the resistance method. In order to make perfect accord between the results obtained with the two kinds of silver plates, the thickness would need to be rather more than four times as great as that obtained by the resistance method, but considering all the difficulties of the case, it seems to me that the large discrepancy still existing is within the limits of experimental error. In presenting the results of all the experiments in tabular form further on I shall give the results obtained with these silver films as calculated on the basis of the larger value, i. e., ·0000148 cm., found for the thickness.

Mention is made above of a fourth plate of silver. This was also of a very thin film, but the silver was fastened to the glass with shellac instead of being deposited from a solution. The silver was in the same state as that of the thickest plate, and the results of measurements with it accord sufficiently well with those obtained with that plate. As the resistance method was employed in estimating the thickness, it does not seem worth while to publish the results obtained.

IRON.

Measurements have been made with three separate plates of iron. The first two plates were made early in the research and the quantitative results, like all others obtained at that time, are hardly reliable enough to be worth publishing.

The dimensions of the third strip were as follows:

Length as weighed = 5·68 cm.
Width " = 1·08 "
Area including projections = 7·15 " sq.
Weight = ·193 grm.
.·. Thickness (taking sp. gr. = 7·79) = ·00347 cm.[*]

With this plate the following results were obtained:

	M.	C.	$\frac{M \times V}{E'}$[†]
Apr. 29th,	6680	$k \times \tan 38° \; 37'$	-127×10^9
"	"	" " $49° \; 13'$	-130 . . . .
		Mean	$= -1285 \times 10^8$

PLATINUM.

One strip of this metal has been used.

Length as weighed = 6·32 cm.
Width " = 1·078 "
Area including projections = 7·57 " sq.
Weight = ·457 grm.
.·. Thickness (taking sp. gr. = 22·1) = ·00274 cm.

With this strip only one series of observations was made and that was rather a hasty one; I found

	M.	C.	$\frac{M \times V}{E'}$
Apr. 28th,	6830	$k \times \tan 66° \; 2'$	417×10^{10}

NICKEL.

There was some difficulty in obtaining a strip of this metal of proper shape for the experiment. The piece used was obtained by stripping off the nickel plating from a piece of brass, upon which the deposit had been purposely laid in such a manner as to make it easy to remove. The strip thus obtained was narrow and irregular in shape and its thickness cannot readily be determined at present, so that I do not attempt to give numerical results for this metal. The main object in using it was to determine the direction of the new effect therein, nickel being, next to iron and cobalt, the most strongly magnetic substance. As already stated, this direction was found to be oppo-

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[*] The plates of very thin rolled iron used were furnished me by Prof. Rowland, who is indebted for a supply of the same to the courtesy of Prof. Langley of Allegheny Observatory.

[†] It is evident that the values of this ratio thus obtained for iron are to some extent, perhaps to a great extent, fictitious, for of course the strength of the magnetic field within the iron plate itself is the effective strength in the experiment, and this is probably very different from the value of M as determined by means of the test coil. It seems best, however, for the present, to employ this latter value of M, which must bear an intimate relation to the true value, and which has the great advantage of being easily determinable. Nickel has hardly been examined quantitatively as yet, and platinum is not sufficiently magnetic to present any difficulty of this sort.

site to that in iron. The action in nickel, though not really measured, was seen to be very decided, and may possibly prove to be as strong as that in iron.

TIN.

The action in this metal is very small and has not been measured with any accuracy. Its magnitude may be $\frac{1}{30}$ that of the action in gold.

No other conductors have been tested in such a manner as to warrant an expectation of detecting an action.

In the following table the results obtained with the different metals are brought together. Those obtained with very thin strips will be marked thus (?) for reasons which must be evident to any one who has read the preceding pages:

Metal Plate.	M.	C.	$\frac{M \times V}{E'}$	
Gold, No. 6 [“ hard”]			152×10^{10}	1515×10^{9}
“ “ “	6400	*k* × tan 23° 44′	150×10^{10}	
“ “	6400	“ “ 42° 14′	150×10^{10}	
“ “	6400	“ “ 49° 28′	154×10^{10}	
“ No. 5 [soft or semi-cohes.]	6400	“ “ 42° 26′	161×10^{10}	1625×10^{9}
“ “	6330	“ “ 26° 2′	163×10^{10}	
“ “	6440	“ “ 22° 48′	162×10^{10}	
“ “	6440	“ “ 43° 0′	164×10^{10}	
“ No. 4 [“ soft”]	6480	“ “ 22° 21′	155×10^{10}	1545×10^{9}
“ “	6480	“ “ 26° 25′	155×10^{10}	
“ “	6480	“ “ 42° 16′	154×10^{10}	
“ “	6480	“ “ 28° 43′	154×10^{10}	
“ No. 30 (A) [semi-cohes. ?]	6520	“ “ 48° 38′	123×10^{10}	1250×10^{9}
“ “ “	6600	“ “ 31° 30′	124×10^{10}	
“ “ “	6600	“ “ 40° 39′	128×10^{10}	
“ “ (B) [semi-cohes. ?]	6760	“ “ 68° 0′	139×10^{10}	1400×10^{9}
“ “ “	6760	“ “ 39° 26′	141×10^{10}	
Silver, No. 10	6580	“ “ 49° 17′	114×10^{10}	1160×10^{9}
“ “	6580	“ “ 32° 20′	118×10^{10}	
“ [deposited] (A)	7120	“ “ 43° 33′	134×10^{10}	1355×10^{9} ?
“ “ “	7120	“ “ 19° 32′	137×10^{10}	
“ “ (B)	6640	“ “ 47° 39′		1350×10^{9} ?
Iron (C)	6680	“ “ 38° 37′	-127×10^{9}	1285×10^{8}
“ “	6680	“ “ 46° 13′	-130	
Platinum	6830	“ “ 66° 2′		4170×10^{9}

Nickel—effect large, possibly as strong as in iron.
Tin—effect probably much smaller than in platinum.

This table enables us to arrange the metals so far examined, excepting nickel, in order with respect to the magnitude of the action observed in them. Opposite each metal in the following list is placed a number representative of this magnitude. In the case of gold this number is a quantity inversely proportional to the mean of the results obtained with the five different plates named above. In finding the corresponding number for silver, I have, for obvious reasons, used only the result obtained with the plate of No. 10. The representative number given for tin has been very roughly estimated and may be one or two hundred per cent larger or smaller than the true number. All the numbers given must of course be taken as at best only rough approximations to the true representative numbers.

We find then

Iron	— 78·	Platinum	2·4
Silver	8·6	Tin	·2 (?)
Gold	6·8		

This arrangement is made on the basis of defining the magnitude of the action studied as a quantity inversely proportional to $\frac{M \times V}{E'}$. If on the other hand we were to define the same as inversely proportional to $\frac{M \times E}{E'}$, rather, E being the difference of potential of two points a centimeter apart on the longitudinal axis of the metal strip, the representative numbers would be relatively changed. The representative numbers on this new basis may be found by simply dividing each of the representative numbers given above by a quantity proportional to the specific electrical resistance of the metal to which the number is attached.

We thus obtain

Iron	— 80·	Platinum	2·6
Silver	57·	Tin	·15 (?)
Gold	32·		

It will be observed that the order of arrangement remains unchanged.

Platinum and tin are carried still farther from gold and silver than before, so that the range of the representative numbers is increased. It is plain, therefore, that by this second arrangement no progress has been made toward finding a constant representative quantity for all the metals. In dealing with the results obtained with different metals, it seems to be of little importance whether we take as our basis $\frac{M \times V}{E'}$ or $\frac{M \times E}{E'}$. When, however, we have to do with different plates of the same metal, we see from the experiments on both gold and silver that the basis $\frac{M \times V}{E'}$ is by far the better one. We may sum up the matter by saying that according to present appearances:

1st, there is no constant representative quantity for all metals;

2nd, the basis $\frac{M \times E}{E'}$ does not give a constant representative quantity for different plates of the same metal;

3rd, the basis $\frac{M \times V}{E'}$ gives for different plates of the same metal a representative quantity which is approximately a constant.

It is evident, upon consideration, that this ratio $\frac{M \times V}{E'}$ could not be expected to give the same result for all metals. We get the quantity V by dividing the nominal cross section of our conductor by the strength of the current. We must, however, think of a metal as not strictly continuous, but consisting of metallic particles more or less compactly aggregated in the space occupied by the body as a whole. Evidently, therefore, the cross-section effective in conduction would vary in different conductors of the same nominal cross-section. It may, therefore, be found that different specimens, of the same metal but of different densities, will give quite different values for $\frac{M \times V}{E'}$.

Of course the magnitude of the new action in the different metals may be considered in connection with various other physical properties of the metal beside the specific electrical resistance. One might for instance expect to find some striking relation by comparing in this connection the known magnetic or diamagnetic properties of the metals. It is indeed to be observed that the most strongly magnetic substance, iron, does show the new action in a more marked degree than the other metals, and possibly nickel will come next in the list. Here the clue is entirely lost however, for the relative magnitude of the action in gold, silver, etc., is entirely out of proportion to the magnetic capacities of these metals.

On the whole we cannot be sure that any relation has yet been detected between the magnitude of the new action in the various metals and any known physical property of these metals. It is of course possible, however, that when more data shall have been obtained, analogies and relations at present unsuspected will appear. It can hardly be doubted that the action we have been considering, placing at our command, as it does, a new point of view from which to study the interior workings of the substances examined, is destined to teach us a good deal in regard to the molecular structure of bodies, while helping us toward an understanding of the physical nature of electricity and magnetism.

We return now to the remarkable anomaly presented by the direction of the action in iron. That the direction in this metal, a magnetic substance, should be different from that in gold, a diamagnetic substance, is remarkable, but not perhaps surprising. We find, however, that nickel and platinum, both magnetic substances, resemble in the particular above mentioned, not iron, but gold, and the other diamagnetic substances. This fact has to be taken into account in endeavoring to apply the newly discovered action to explain the magnetic rotation of the plane of polarization in accordance with the principles of Maxwell's electro-magnetic theory of light. Professor Rowland, therefore, in view of this difference of behavior of iron and nickel with respect to electricity, was very desirous to know whether these two metals would manifest a similar disagreement in their action upon light. I have, therefore, at his suggestion, repeated Kerr's experiment on the rotation of the plane of polarization of light by reflection from the pole of a magnet, using nickel for the latter instead of iron. The reflecting surface used was the nickel plating on one of the disks of Professor Rowland's absolute electrometer. This disk for the purpose of the experiment was placed between the poles of the electro-magnet. The action upon the plane of polarization, though apparently much weaker than in iron, has, in the plate used, unmistakably the same direction. This nickel plating, however, was executed in Germany, and Professor Rowland thinks that, as the nickel of that country is very impure, this specimen may possibly contain iron enough to mask the true action of the nickel.

I have already spoken of the fact that, when a strongly magnetic substance is experimented upon, complications are introduced by the influence of the induced magnetism which affects the condition of the magnetic field through which the current flows, making the value of M different from that determined by means of the test coil. It does not seem probable that in this fact can be found an explanation of the anomalous behavior of iron, but there is no doubt that an interesting research is here suggested. For instance, it might be profitable to subject to experiment a thin plate of hard steel and determine to what extent the permanent magnetization induced therein by the electro-magnet would be accompanied by a permanent change in the equipotential lines after the electro-magnet had ceased to act.

It is perhaps idle to speculate as to the exact manner in which the action between the magnet and the current takes place in any of the preceding experiments, but it may be worth while to remark a seeming analogy, somewhat strained perhaps, between this action and a familiar mechanical phenomenon, the theory of which has of late attracted considerable attention. It is well known that a base ball projected swiftly through the air and having at the same time a rapid motion of rotation about its vertical axis does not throughout its course continue in its original vertical plane of its motion, but follows a path curving sensibly to one side. Imagine now an electrical current to consist of particles analogous to the base ball, moving through a metallic conductor the electrical resistance of which will correspond to the mechanical resistance offered by the air. Suppose, further, the particles of electricity, on coming within the influence of the magnet, to acquire a motion of rotation about an axis parallel to the axis of the magnet.* Under all these supposed conditions we might perhaps expect to find the action which is actually detected. To account for the reversal of the action in iron, we might suppose the particles of electricity to acquire in this metal a rotation about the same axis as in the other metals, but in the opposite direction. Even after all these generous concessions in favor of our hypothesis, however, it fails to account for the behavior of nickel, as different from that of iron. The analogy, such as it is, which has been pointed out, is perhaps curious rather than significant.

Historical.

I am not aware that investigators, during the first part of the century, made any attempt to discover the phenomenon which has been the subject of the observations described in the preceding article. Wiedemann,† however, mentions two investigators who have at different times given the subject their attention. The first of these in point of time was Feilitzsch.‡ He made use of two flat spirals of wire, through each of which an electric current was made to pass. These currents, passing in opposite directions through the coils of a differential galvanometer, were so adjusted that their combined action produced no effect upon the needle. A third spiral, similar to the others and itself bearing a current, was now brought near one of these and the galvanometer was observed. No permanent deflection of the needle was detected, and therefore no permanent action of one current on the other was discovered. I have not had access to the original article and cannot say what the author's theory of the experiment may have been. The method of attacking the problem seems however to have been similar in principle, to that which I at first adopted, viz: an endeavor to increase the resistance experienced by an electrical current by diverting it from its normal course through the conductor.

Another research in this direction mentioned by Wiedemann was that of Mach.§ This investigator covered a circular disk of silver leaf with wax and applied the poles of a battery to points diametrically opposite each other on the circumference of the disk. The silver leaf becoming heated by the cur-

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* Maxwell (Electricity and Magnetism, vol. ii, p. 416) says, "I think we have good evidence for the opinion that some phenomenon of rotation is going on in the magnetic field, that this rotation is performed by a great number of very small portions of matter, each rotating on its own axis, this axis being parallel to the direction of the magnetic force," etc.

† Galvanismus, vol. ii, p. 174.

‡ Berichte der Naturforscher in Karlsruhe, 1858, p. 151, etc.

§ Carl's Repertorium, vol. vi, p. 10, 1870.

rent, the wax began to melt and melted most rapidly where the current was strongest, thus roughly showing the distribution of the stream. The plate still bearing the current was now subjected to the action of an electro-magnet, but no change could be detected in the behavior of the melting wax, the current remaining apparently unchanged in its course through the disk. This experiment therefore, like the preceding, was negative in its indications.

A recent number of the "Beiblätter zu Wiedemann's Annalen" mentions, in connection with the researches of Feilitzch and Mach, another by Gore.* The latter took a wire bifurcated throughout a part of its length and passed through it a current sufficiently strong to raise both branches to a white heat. He then endeavored by means of a magnet to divert the current somewhat from one branch of the wire and draw into the other branch more than its normal share. It was thought that an unequal division of the current might show itself by a change in the appearance of the white hot branches. No change of this kind could be detected, and the investigator therefore concluded that the action known to take place between conductors bearing currents, was not an action between the electric currents as such. Gore expressly states that he undertook this experiment not knowing that any previous investigations with the same aim had ever been made.

On the same page of the "Galvanismus" which treats of the research of Mach, as mentioned above, Wiedemann describes, as a means of showing that no action takes place between permanent electric currents as such, almost the exact arrangement of apparatus with which the discovery was finally made. Who first used this apparatus for this purpose I cannot say, unless it may have been Wiedemann himself. The same plan was hit upon by Professor Rowland,† quite independently I believe, and he experimented to some extent in this direction about the year 1876. The same arrangement was finally adopted by me after another method of attacking the problem had been unsuccessfully tried.

I desire to express my sense of obligation to the professors and students of the physical department of the Johns Hopkins University, for the generous assistance which they have rendered me during the progress of this research.

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* "On the Attraction of Magnets and Electric Currents."—Phil. Mag. (4th series), vol. 48, p. 393, 1874.

† Amer. Jour. of Math., vol. ii, p. 289.

ART. XXIII. — *The Colors of Thin Blowpipe Deposits;* by C. H. KOYL, B.A., Student of Physics in Johns Hopkins University.

SOME examples of the action of very fine particles of matter upon light, having lately come to my notice, it may be interesting to make them public, as they have heretofore, I believe, been unexplained.

Those who are familiar with the methods of blowpipe analysis have observed faint borders occasionally surrounding some of the colored charcoal coatings, the colors of these borders seemingly bearing no relation to the characteristic colors of the adjoining oxides. For instance, the white coating of antimony is generally accompanied with a blue border, the brownish oxide of cadmium occasionally with a green, while the lead and bismuth yellows not unfrequently have a whitish ring inclosing them. As these occur only and always where the coating is very thin they have a significance different from that of the ordinary colors, and as they may be produced at pleasure from the purest specimens they cannot be due to mixtures of the metals. A possible analogy with the antimony blue was suggested by a consideration of the colors of the sky, and to prove the connection it was simply necessary to show the similarity of attendant phenomena. As is well known, it is believed that the blue of the sky is due to the presence in the atmosphere of suspended particles, so fine that they are unable to reflect the longer rays of the spectrum which accordingly are transmitted and the union of the remainder gives to the sky its blueness. At evening, the sky is red because we get the rays of the sun directly transmitted or reflected from the clouds. Thirdly, the light of the sky, reflected at an angle of 90° with the sun, is plane polarized.

When an antimony coating had been produced which gave, beyond the white oxide, a blue well defined and full, the whole was illuminated in a dark room by a sodium flame and that the blueness was no psychical or physiological effect as distinguished from ordinary vision was proved by the fact that here it almost completely vanished while the white presented the usual ghastly appearance. A blue book-cover, treated in the same manner, gave more reflection than did the blue coating.

Experiments with the polariscope were at first inconclusive from the fact that though the light from the blue coating was largely polarized, so, to some extent, was also that irregularly reflected from the charcoal, and it was found necessary to cover the block with a thin layer of carbon from a gas-flame. The repetition of the test then showed that the proportion of light polarized by the layer of carbon, at the given angle, was almost nothing; that by the thick white coating, small; while on the blue the phenomenon was almost complete. What light here was not polarized was evidently reflected from the larger particles mixed with the fine, for the analyzer, while it did not totally extinguish the light, yet excluded nearly all appearance of blueness.

In order to determine the character of the transmitted light, a microscope covering-glass was inlaid in the charcoal and the oxidation so executed that the glass was in the center of a small area all of which was blue. On removing the glass, the light which passed through, proved to be of the expected yellow, though less brilliant than anticipated. The color might be seen either by transmitting the direct light of the sun or by placing the glass at such an angle that total reflection was produced and thus in the passage of the rays through the layer to the glass and out through the layer to the eye the blue was principally lost and only the mixture of longer rays appeared. Viewed through a microscope, the result was the same. I have since, however, improved upon this plan by the more convenient method of covering with carbon a piece of ordinary window-glass, three inches by two, and then projecting the oxide upon the *opposite* surface of the plate. There is thus no difficulty in distinguishing a very slight amount of color in the coating and for transmitted light, any portion of the carbon may be easily removed.

This case, a type of all charcoal coatings which shade off to blue in thin layers, appears thus parallel to that of the sky color and the theory which is accepted for the one will also satisfactorily explain the other.

To account for the cadmium green we have only to note that if the substance upon which we are experimenting have the power of absorbing the shorter rays of the spectrum, the reflected light would from a heavy coating be yellowish or reddish, the particular shade depending upon the amount of absorption of violet and blue; and the formation of a layer as thin and of particles as fine as before should result in giving us the color of the shortest rays which the substance is capable of reflecting, viz: in this case, green. The coating of cadmium has exactly this appearance and shows the effect of the gradual transmission of red by shading from the original color (dark red) through yellow into a fine green. As before, the light reflected from the thin layers is highly polarized and the rays which pass through form a deep, dark red. In exceptional cases, it is possible to produce such a thin coating that the extreme edge is fringed with a faint blue.

The other case, lead, is now easily explained. This metal gives a coating of which the color is a beautiful chrome yellow, and regarding this merely as a repetition of the preceding phenomenon and the yellow as compounded of rays from the whole range of the spectrum but not in the proper proportion to form white, the line of thought suggested evidently is, that if the layer be decreased in thickness regularly from the center to the circumference of the charcoal, there ought to be, at some distance from the centre, a zone within which sufficient red should be transmitted to equalize the amount of blue lost by absorption and the reflected rays should form a yellowish white. Beyond this, as the thickness of layer still decreased, the color should be blue for the same reason as in the case of antimony. The white zone is easily produced and the blue border, which always surrounds it, polarizes the light as before and transmits orange colored rays.

The theory, once given, serves to explain nearly all the anomalous colorings of the charcoal coatings;—the bluish borders which occasionally skirt almost any of the metallic oxides, the "peacock-tails" of cadmium, etc., and thus does away with the necessity of supposing the presence of impurities (though, by the way, no impurity would solve the problem in the case of the cadmium green.)

From a physical standpoint, the experiments seem interesting as an extension of our knowledge of the action of these small particles upon light. Had not the subject presented itself in this way, we would scarcely have guessed that such a change in reflecting power could have been produced by so small a change in size and thickness.

Baltimore, Md., July 9, 1880.

ART. XXIV.—*The Periodic Character of Voluntary Nervous Action;* by M. M. GARVER.

IN the June number of this Journal for 1878 (No. 90, vol. xv, pp. 413–422), in an article on Nervous Transmission, I called attention to a peculiar grouping of the answers in experiments requiring a voluntary movement. In concluding that article I suggested an explanation of the grouping by intimating that an individual had to "think twice" before performing the stipulated action, and ended with the following query and statement: "Could not such a periodicity have its origin in the transformation lying between sensation and volition? It is easily conceivable that such might be the case and be of such a nature as to resemble an increment to the judgment."

Further study of the subject has led me to the conclusion that the expression "think twice" is *literally* true, and that the variation *is* entirely cerebral." The matter can probably be best presented in the form of an hypothesis, supporting it by what proofs may be at hand. The hypothesis is this:

The cerebral portion of the nervous system is continually varying in its activity, waxing and waning between certain limits, periods of maximum activity following periods of minimum activity at the rate of 36 to 60 times per second.

The first proof in support of this view is that it offers a satisfactory explanation of the grouping in those experiments to which attention was called in the preceding article. For, if such a condition of things exists it is evident that the purely voluntary movements must also be periodic in character—it being impossible, according to the hypothesis, for a voluntary impulse to originate during a period of minimum activity or rest. The fact that the periods are not more sharply defined is not conclusive proof of the non-existence of such cerebral variations, for there is evidence to show that the periods are somewhat variable in different individuals, and in the same individual under different circumstances. For instance, it is generally conceded that the brain does not work so well after a hearty meal as before. Here are two series of experiments, one of which was taken immediately before dinner, the other soon after.

Garver, "hand to hand."

Before Dinner.

16	17	18	19	20	21	22	23 vib.
16	17	18	19	20	21	22	
16	17	18	19	20	21		
16	17	18	19		21		
	17		19		21		
	17		19		21		
			19		21		

The numbers below the line are the answers to the signals and show the time expressed in vibrations of the tuning-fork,—one vibration being equal to $\frac{1}{128}$ of a second. An evident preference is shown for the numbers 17, 19, 21.

Garver, "hand to hand."

After Dinner.

16	17	18	19	20	21	22	23	24	25	26	27	28	29 vib.
16	17	18	19	20	21	0	23	24	25	26	0	0	29
	17	18	19	20	21		23			26			29
	17	18	19	20			23						
		18	19	20			23						
		18	19	20									
		18	19	20									
			19										
			19										

Besides these numbers there were many failures, in the last series, to answer at all. This last series differs in one respect from many others. The periods are not all of the same length; and if this should prove to be a rule and not an exception a modification of the hypothesis would be necessary. At present I am inclined to regard it as accidental, as it is opposed to so many well-defined examples. The periods after dinner are seen to be lengthened and the whole series drawn out.

That the grouping is not due to the nerves themselves is shown by the fact that the nerves of animals recently killed transmit the motor impulse with perfect regularity; and also by the fact that, in the living subject, nerves excited by artificial means transmit the motor impulse with the same regularity.

2d. The muscles, in order to remain in sound health, must have periods of rest alternating with periods of activity. Even the heart, that keeps the blood in ceaseless motion from the earliest dawn of our independent existence till the last closing act in life's drama, rests about one-half the entire time; and it certainly appears reasonable to suppose that the brain also has its periods of rest. Besides this, it is an established physiological fact that a muscle during contraction is in a state of vibration, giving out a continuous sound like a musical tone. According to Helmholtz* the pitch of the fundamental tone is very difficult to determine, because the rate is such that it lies just at the lower limit of continuous tones. The rate of vibration varies somewhat, but Helmholtz and two other observers working independently agree in finding thirty-six vibrations per second as the rate, although Helmholtz himself found, in some cases, thirty-two to be the number. Foster† states that the sound heard indicates thirty-six to forty vibrations, but that the sound is the first harmonic, and that the real number of vibrations is one-half that number, or eighteen to twenty per second. The period found in our experiments is from thirty-six to sixty. If the muscular system is subject to such pulsations it seems reasonable to suppose that the nervous system is subject to a similar law, if not really the cause of the muscular variations.

3d. All of the simple mental or psychological processes, the time of which has been measured (and many such measurements have been made), require a *longer* interval of time than that shown by experiment to pass between two maxima and minima. This fact is regarded as specially significant, for, if such waxing and waning of nervous activity exists, the sim-

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* Helmholtz, Ueber das Muskelgeräusch; Reichert u. du Bois Raymond's Archiv für Anatomie, 1864, p. 766.

† Foster, Text-book of Physiology, 2d edition, p. 56.

plest possible element of thought would probably require at least one period of maximum activity, while more complex processes would require two, three, or some higher multiple of that number. According to experiments by Burckhardt,* Professor Donders, and many others, the time required by an intelligent person to perceive and to will is about $\frac{1}{10}$ of a second. To illustrate, take an example from Burckhardt.* After allowing for the time required to traverse all of the nerves and for the latent period of the muscles, there still remains about $\frac{1}{10}$ of a second for the cerebral operations. When the signal was given by a bell and the answer required a movement of the hand, the percentage of the time required for the different operations was found to be as follows:

Acoustic nerves	6	per cent.
Brain	62	"
Spinal cord	4	"
Nervous transmission	22	"
Latent period of muscles	6	"

The mean value for the time required from "ear to hand" was 0·169″, of which 0·105″ or sixty-two per cent was taken up by the mental operation involved. From this it will be seen that "quick as thought" is after all not so very quick. Similar results were obtained by Exner.† In our experiments (see this Journal for June, 1878, p. 416), the "reaction period" from ear to hand varied from 0·1327″ to 0·1651″. The latter number is my own "reaction period;" and if sixty per cent of the time was consumed in the cerebral operation it takes $\frac{1}{10}$ of a second for me to perceive and will.

The foregoing results were obtained by answering to an expected and known signal; however, if a dilemma is introduced, offering a choice, the time required is considerably lengthened, and the lengthening is greater as the mental operations are more complex. Professor Donders‡ made some experiments in which the answer was required by the left hand when the signal was given on the right foot, and by the right hand when the signal was given on the left foot. After allowing 0·009 of a second for the less ready use of the left hand, the results agreed exactly in requiring $\frac{1}{15}$ of a second for the increased psychological processes involved. That is, it took $\frac{1}{15}$ of a second longer than if the signal was always given in the same place and required the same answer. By combining three series of observations of different degrees of complexity, Professor Donders found in his own case that the simple percep-

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* Burckhardt: Die physiologische Diagnostik der Nervenkrankheiten, Leipzig, 1875, p. 91.

† See Foster's Physiology, p. 522.

‡ Donders: Die Schnelligkeit psychischer Processe; Reichert und du Bois Raymond's Archiv, 1868, p. 657.

tion of an impression required $\frac{1}{25}$th, and an act of volition $\frac{1}{28}$th of a second. The sum of the two is practically equal to what has been found to be the time required for the cerebral operations in simply answering a signal! But each of these periods is long enough to include *two* periods of maximum activity; and this fact might lead us to infer that the so-called simple operations, perception and volition, are in reality complex, and that the simplest mental operation requires about $\frac{1}{50}$th of a second. However, the fact that from $\frac{1}{20}$th to $\frac{1}{30}$th of a second is necessary for a simple perception may serve to explain our appreciation of continuous sounds, as a musical tone; if the vibrations occur at a less rapid rate than that they are recognized as separate sounds,—if at a higher rate as continuous tones.

4th. It is maintained by some writers upon purely metaphysical grounds that alternating states of consciousness and unconsciousness are necessary to explain some of the phenomena of mind. Dr. Payton Spence* advances some views which in this connection are very interesting. He says in conclusion: "Hence the simplest form of consciousness or mental life must consist in an alternation of a state of consciousness with a state of unconsciousness—a regular rhythmical revelation of the affirmation, consciousness, by its negation unconsciousness, and *vice versa.* We might call it a pulsation or an undulation of the constituent of the mind, provided such an expression did not fasten upon us a premature theory as to the nature of that constituent. Perhaps it would be safer, for the present, to call it a pulsation or an undulation in the brain, or a vibration of the molecules of the brain paralleled in consciousness. This pulsation or vibration is, of course, very rapid; otherwise, we should not have to infer its existence, but would know it by perceiving the alternation of one state with another. We may make it to some extent perceptible, however, by interfering with the regularity of its rhythm, as by making a determined, persistent effort to retain any state of consciousness for any length of time. Thus, if we fix the eye upon any object and try to keep a steady, unbroken consciousness of it, we will find that in spite of our most determined efforts, the mind will alternately flash off and on the object, and we catch ourselves losing our consciousness of it and then returning to it. If the experiment be persevered in it ultimates in a certain bewilderment and confusion of mind as well as of vision, and during brief intervals not only does the object cease to be visible, but the mind seems to go out."

Dr. Spence may object to my "hypothesis" as a "premature theory;" however, his words express quite clearly my views, and seem to accord well with the facts in the case.

Ithaca, N. Y., July 1st, 1880.

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* Dr. Payton Spence: Space and Time considered as Negations. Journal of Speculative Philosophy for October, 1879.

ART. XXV.—*Geological Relations of the Limestone Belts of Westchester County, New York;* by JAMES D. DANA.

[Continued from page 32.]

(4.) *Hornblendic, Augitic, and other associated Rocks not included in the preceding subdivisions.*

THE hornblendic and associated rocks referred to in the above title cover a large part of the township of Cortland—the northwestern of Westchester County — between Croton River on the south, and the parallel of Peekskill on the north, an area of about 25 square miles. They differ widely from the ordinary rocks of the county, and may well be designated the Cortland series. In fact, a series so remarkable in constitution, so diversified in kinds and so full of geological interest is seldom found together within so small an area any where on the globe. They reach the banks of the Hudson just south of the Peekskill railroad station, and at several points beyond; yet considerable portions of the shore region are occupied by narrow strips of common kinds of mica schist and gneiss, and occasionally limestone. Leaving Peekskill by South street, near the river, the first ledges (north and south of Hudson street, *b*, on the following map), consist of one of the rocks of the series; and to the eastward of the village, on the road leading southeast, only half a mile from the Academy grounds (adjoining which, on the street north, an evenly bedded mica schist of the limestone series outcrops), the same rocks occur. The western boundary of the town is passed by the Cortland rocks only south of its middle point (below Mr. Strang's), for a distance of a little over a mile.

South of Verplanck they extend to the Hudson, and are the rocks of Montrose Point and the northern portion of Cruger's Point. Just here the river becomes narrowed to one third of its width through the projection of these points and of an equally prominent headland called Stony Point on the opposite side. This isolated east-and-west ridge consists of rocks related to those of Montrose and Cruger's Points, and there is little doubt that it was once connected with the Montrose region. It is the only locality of the rocks yet observed on the western side of the Hudson.

The accompanying map of the western portion of the town of Cortland, between Peekskill and Cruger's, together with the Hudson River adjoining, contains the places here referred to. Its scale is an inch to a mile.

The occurrence of limestone areas in close proximity to the rocks of the Cortland series is a fact of special interest, as is shown beyond. These areas on the maps are those horizontally lined.

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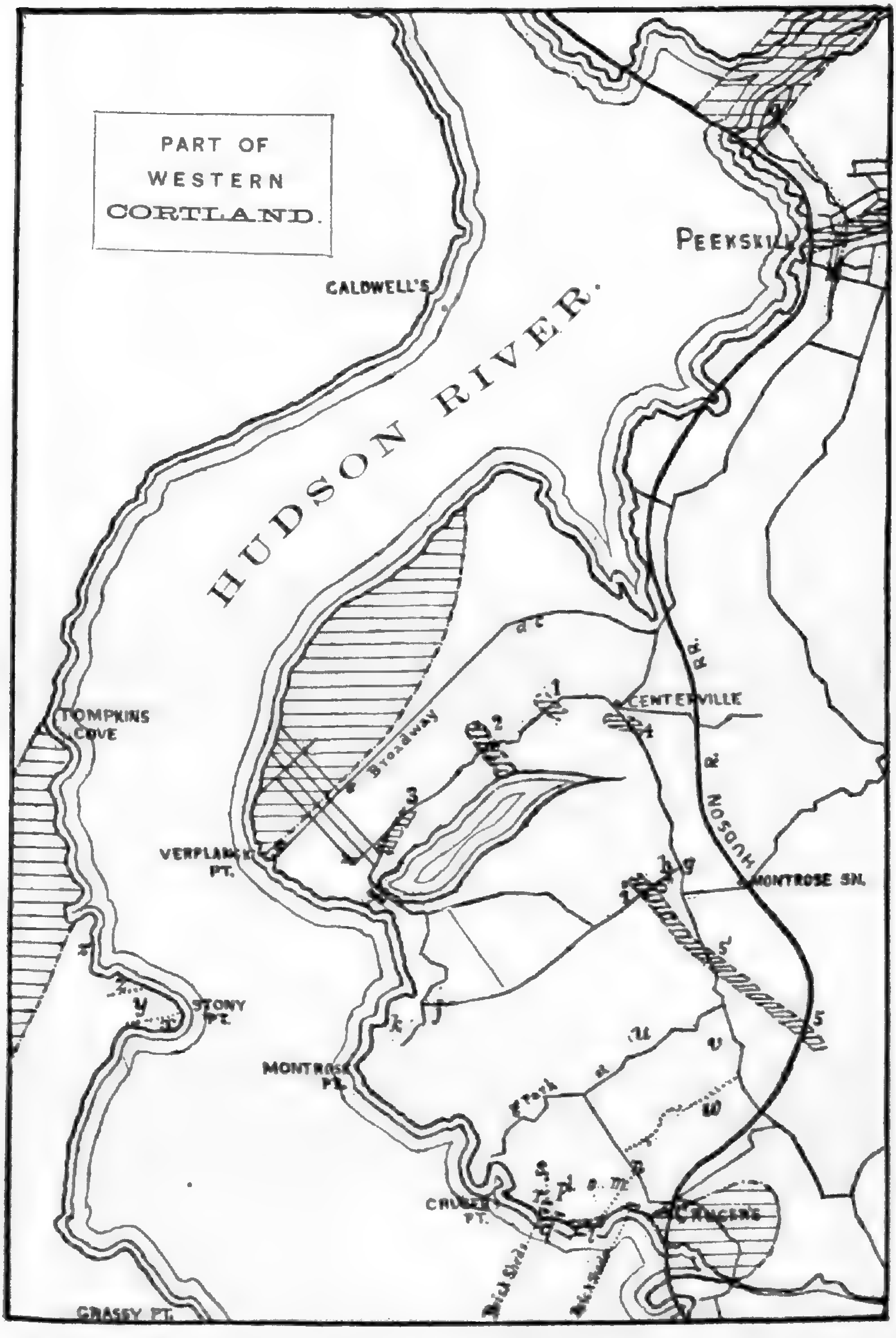

A brief description of the prominent varieties or kinds of these Cortland rocks will prepare the way for a discussion of their relation to the other rocks of Westchester County.

A. KINDS OF ROCKS.

The more prominent peculiarities in the constitution of these rocks, (as learned by the aid of thin slices and microscopic examination,) are as follows:

1. The feldspars are chiefly triclinic species, or soda-lime feldspars, though some orthoclase (potash-feldspar) is also often present. They are therefore distinctively what many would call "*plagioclase*" rocks.

2. One or more of the minerals of the Amphibole group —hornblende, hypersthene, augite—are present in a large part of the rocks; of these, hypersthene is the most widely distributed. Its crystals, which are sometimes quite perfect, have the form of the augite common in volcanic rocks except that they are not oblique; they were ascertained to be true hypersthene through optical methods by Dr. G. W. Hawes.

3. Black mica or biotite is usually present, and sometimes abundantly, and in some of the kinds replaces wholly, or nearly so, the iron-bearing amphibole minerals.

4. Quartz is not a prominent ingredient, and in general is only sparingly present.

5. Chrysolite is a characteristic ingredient of some of the common kinds.

6. Apatite exists in microscopic and sometimes visible crystals in all the varieties; the largest crystal observed has a length of half an inch and diameter of a sixteenth. Magnetite is present in grains, and sometimes constitutes beds. Pyrite also is disseminated through most of the rocks.

These crystalline rocks are commonly massive, that is, without bedding. They are everywhere jointed, and for this reason the ledges are generally piles of large and small blocks. In most places they undergo easy decomposition, making a gray or iron-red soil around; and, as the joints give access to water, the outer blocks in the pile have often become reduced to rounded and half-detached masses.

The rocks may be divided, for the convenience of the stratigraphic discussion beyond, into (1) the *non-chrysolitic*, and (2) the *chrysolitic*. The former include four groups, based on the iron-bearing silicate prominent in the kinds; (A) the *Hornblendic;* (B) the *Hypersthenic;* (C) the *Augitic;* and (D) the *Micaceous* or *Biotitic;* but the groups pass into one another by intermediate varieties. The chrysolite-bearing kinds are either (E) *hornblendic*, or (F) *augitic*, or (G) chiefly chrysolite; but here again intermediate kinds occur.

In the following descriptions I have confined myself to noting only the prominent distinctions so far as necessary to the stratigraphical discussion beyond. I take pleasure in stating that a detailed study of the rocks of the Cortland region has already been begun, at my suggestion, by the accomplished lithologist, Dr. G. W. Hawes.

A. *The Hornblendic.*—The common hornblendic rock resembles syenyte, but contains little orthoclase and much triclinic feldspar. The latter is mostly of the species oligoclase, according to an optical measurement on cleavage slices. In addition, quartz is rather sparingly present. The rock contains more or less black mica and sometimes much of it; and as the mica increases at the expense of the hornblende, the rock passes into soda-granite (mentioned beyond). The quartz-dioryte has the same relation to soda-granite that quartz-syenyte has to potash or common granite. Garnets are rare. The rock is often a very coarsely crystallized rock (*Aa*), having the hornblende crystals large, one-fourth to one-half an inch being a common size, and an inch and larger also common; and not unfrequently the black crystals are as large as the fingers, and occasionally six to eight inches long. A fine-grained variety (*Ab*) has a blackish color; and this variety is sometimes porphyritic (*Ac*). The micaceous is another common variety (*Ad*). Another kind (*Ae*) is exceedingly fine-grained and consists of minute grains of hornblende along with similar feldspar grains, which are partly orthoclase; it looks much like hornblende schist, and in some places is schistose. It sometimes contains an occasional crystal of hypersthene. Another rock of the region is hornblendyte, consisting almost wholly of hornblende. One variety (*Af*) is made up of coarsely crystallized black hornblende; another (*Ag*) of gray hornblende along with an asbestiform mineral. The black hornblendyte graduates into dioryte; and again, it is often chrysolitic.

B. *The Hypersthenic.*—The typical rock of this division (*Ba*) is the most wide-spread of the Cortland series. It consists of triclinic feldspars (and, according to some trials, yet incomplete, by Dr. Hawes, oligoclase is the most abundant), hypersthene in grains or quite small crystals, with frequently more or less biotite, and often some orthoclase. There are also present some magnetite and apatite, frequently traces of quartz, and generally some augite or hornblende. In mineral constitution it approaches one of the kinds of rock that have been called both noryte and hypersthenyte or hyperyte. The name *noryte* is here given it provisionally. It, however, looks more like a coarsish doleryte or diabase than like other hypersthene rocks.

The noryte has commonly a dingy, brownish-red color on a surface of fracture owing to the smoky-red color of the feldspar, but varies from this to pale gray on one side and blackish-gray on the other. It occurs along the railroad between Peekskill and Montrose station, and over the most of the town of Cortland east of this line, and to some extent west.

This rock passes into a feldspathic kind (*Bb*), consisting almost wholly of the feldspars; and into a micaceous kind (*Bc*) containing very much black mica with little hypersthene—a very common variety, often occurring close alongside of the ordinary noryte.

Although the noryte is generally a massive rock, it is occasionally distinctly gneissic in structure, and sometimes contains a few garnets. The schistose variety usually abounds in black mica, or contains more quartz than other varieties, and sometimes more orthoclase.

C. *The Augitic.*—True augitic rocks are less common than hypersthene rocks, although augite is present in most of the massive rocks of the Cortland region. The chief kind (*Ca*) is pyroxenyte—consisting mainly of pyroxene or augite, with sometimes a little hornblende; it varies from a very coarse rock with the augite crystals half an inch across, to a fine granular kind. A greenish-gray granular variety occurs on Stony Point in its chrysolitic region. Another kind (*Cb*) contains much triclinic feldspar with the augite, and is here called *augite-noryte.*[10] A local variety (*Cc*), related to the last, is light gray in color and smooth in fracture; it has a whitish feldspathic base, seemingly almost felsitic, speckled with small spots or points of dark gray-green augite, and only traces of mica. The feldspar in this variety, as slices show, is actually in fine crystalline grains; almost all of it is triclinic, as in other varieties. Chrysolitic kinds are mentioned beyond.

D. *The Micaceous.*—The micaceous rocks are of two prominent kinds. One (*Da*) is like a coarse granite in aspect; but its feldspathic portion is chiefly triclinic, and quartz is sparingly present. It is characteristically a soda-lime granite, although containing some orthoclase, and it is a nearly quartzless variety of it. The mica is almost solely biotite or black mica. It is called beyond *soda-granite.* Some hornblende or augite is usually present; and apatite is common in small or minute disseminated crystals. It is sometimes sparingly garnetiferous. Good examples of this rock occur west of Cruger's railroad station above the brick yards; and also at Stony Point, where it is the prominent rock. At the former locality it graduates into the quartz-dioryte; and at several places the coarsest of the dioryte is found within a few yards of the typical soda-granite.

Another kind (*Db*) is a fine-grained black rock, often small-porphyritic. It owes its color and texture to its having black mica in fine scales as its chief constituent. Like the preceding, it contains little quartz, and the feldspar is almost wholly

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[10] This rock looks like the noryte, but contains augite in place of hypersthene. If its feldspar is chiefly labradorite (a point yet in doubt), it does not differ in mineral constitution from doleryte or diabase, or a prominent part of the so-called gabbro.

triclinic. Hornblende and augite are sparingly present. The rock is therefore a micaceous variety of the soda-granite. But though ordinarily massive, it sometimes has distinct indications of bedding. The rock is most common in the vicinity of limestone belts. It occurs at Centerville, east of limestone number 4 (see map), and also north of this limestone in the field west of the road, where it is conformable with the limestone.

E. *The Chrysolitic rocks.*—The chrysolitic rocks of the region have no resemblance in aspect to ordinary chrysolitic volcanic or igneous rocks. The kinds are (1) *chrysolitic hornblendyte,* (2) *chrysolitic pyroxenyte,* (3) *chrysolitic noryte;* and these graduate not only together but also into a rock in which chrysolite is the chief constituent. They are black or brownish-black rocks, and are mostly coarsely crystallized, the hornblende crystals being often an inch in length or breadth; and the chrysolite is in grains of various irregular forms and sizes, distributed through these crystals as well as among them, and not in well-formed crystals. In general, they contain but little feldspar, and this is triclinic; and a variety intermediate between the hornblendyte and pyroxenyte is common. They contain occasionally black mica, but no quartz. The chrysolite is more or less altered, as is shown (when examined in thin slices) by the bordering and intersecting bands of magnetite and viridite, and in some cases it appears to be changed to serpentine.[11]

These rocks are largely exposed along the western half of the north side of Stony Point, west of the boat pier (the area is lettered $z\, z'$ on the map), and over Montrose Point, as well as in its vicinity; at which places they are associated with noryte and other rocks of the series. They also outcrop in eastern and southern Cortland. The most eastern locality observed is within half a mile of the eastern border of the town, near the middle of the three "emery" mines referred to beyond, and the most southerly, a short distance east of Croton, within half a mile of Croton River.

The chrysolitic rocks are the most decomposable of the series, and wherever the brown-black ledges are crumbling in an extraordinary way and making a profusion of brown sand or brown or red earth, the presence of chrysolite may be suspected.

F. *Iron and Emery Mines.*—This Cortland region has its mines of magnetite, some of which are also mines of emery. The containing rock is either noryte, dioryte, or soda-granite,

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[11] These chrysolitic rocks usually have, on a fresh fracture, the cleavage surfaces of the hornblende or augite spotted with chrysolite; but the presence of chrysolite, however abundant, cannot be made certain without slicing for microscopic examination, since the chrysolite is slightly altered externally, and such spots on hornblende crystals may be due to small imbedded crystals of augite. If the cleavage of the hornblende has an unbroken surface it is probable that the rocks contain no chrysolite. The hornblendyte has much stronger luster than the pyroxenyte.

and even chrysolitic rocks are sometimes near by. The iron ore has been found at several points within a mile north and northeast of Cruger's, and also three or four miles distant in the eastern part of the township of Cortland; but the amount appears to be small and no workings have yet proved profitable. The ore is commonly very chloritic, and contains less magnetite than the appearance and weight seem to indicate.

At a mine three-fourths of a mile north of Cruger's (at *u*, on the map, p. 195), the including rock is a dark reddish-brown noryte. The ore contains much chlorite, as shown by the gray-green tinge of its powder, and the green color of transmitted light when in very thin slices. With it there are also garnet and some fibrolite in minute short needles. Southeast of this locality (at *v* and *w* on the map) other openings have been made. Thin magnetite beds occur also on Cruger's Point, in the soda-granite and quartz-dioryte, half a mile west of the railroad station. The material is fine-grained, nearly black in color, chloritic like the preceding, and is usually associated with black mica. These beds are the subject of special descriptions beyond.

Among the localities in *eastern* Cortland, three are situated in a ridge or mountain running northward from Colabaugh Pond. One is at the southern end of the ridge, just north of the pond; another, near the road crossing it, about a mile farther north; and the third, at the north end of the ridge, nearly three miles from the pond, south of "Summer Hill." The magnetite, at each of these places, contains some disseminated corundum, making it a serviceable emery, and two of these mines have been worked for the emery; much of it also is chloritic. Fibrolite in small needles and divergent tufts is found with the ore at each locality.

B. THE RELATION OF THESE CORTLAND ROCKS TO THE OTHER ROCKS OF WESTCHESTER COUNTY.

The above brief description of the Cortland rocks prepares the way for a consideration of their relation to the other rocks of the county. The following questions arise: Are they one with the latter in system? are they rocks of an earlier system? or are they eruptive rocks, and not metamorphic, and, hence, of no bearing on the general question as to the age of the Westchester limestones and the associated schists? If it can be shown that the second or last supposition is the true one, the subject before us is rid by a stroke of the most serious of its perplexities.

1. Evidences of more or less complete fusion.

The evidences of fusion or plasticity are many; and, taking them collectively, they are decisive. They are exhibited in the following ways: (1) The massive character of the crystalline rocks over so large an area, and a general resemblance in them to igneous rocks; (2) the great size of the hornblende crystals in some of the quartz-dioryte, and the well-defined crystals of hypersthene in part of the noryte, resembling the augite crystals of some volcanic rocks, facts indicating freedom of molecular movement during the process of crystallization; (3) the broken condition of the crystalline individuals in some places, which is evidence of movement while in a pasty state after the beginning of solidification; (4) the occurrence in the massive rocks of included fragments of other rocks, like the inclusions in many trap or basaltic ejections; (5) the existence of dikes or veins of the hornblendic and other rocks, of very various sizes, intersecting the adjoining rocks.

The inclusions are remarkably numerous in some portions of the region, and are often of wonderful magnitude. About Cruger's station, in the soda-granite and quartz-dioryte, they occur from an inch in breadth to many feet; one seen in the face of a bluff on the railroad, between three and four hundred yards northeast of Cruger's station, has a maximum breadth of eighteen feet and a length but little less, and consists of garnetiferous mica schist like that within a fourth of a mile to the east and south; and this is not the largest in that region. They abound also in the chrysolite rocks and noryte of Montrose Point and Stony Point, and in the limestone of Verplanck Point. They usually consist of the various materials which constitute the schist of the vicinity, even to the magnetitic garnet rock, quartzyte, etc.

Figure 3 represents ($\frac{1}{30}$ of the natural size) an example from the soda-granite, half a mile west of Cruger's, where displaced fragments of a thin layer of mica schist occur in the granite. Figure 4 ($\frac{1}{12}$ the natural size) is of an inclusion in the noryte of Montrose Point; the distorted form, the fractures, and the faults appear to be evidence of former free movement in the massive noryte. Figure 5 represents a surface three feet square from a large brecciated pyroxenyte adjoining directly the crystalline limestone on the shores of the Hudson at Verplanck Point. The masses in this strange breccia are contorted fragments of the limestone, one to two feet long, the thin layers of which have been brought out prominently by surface erosion.

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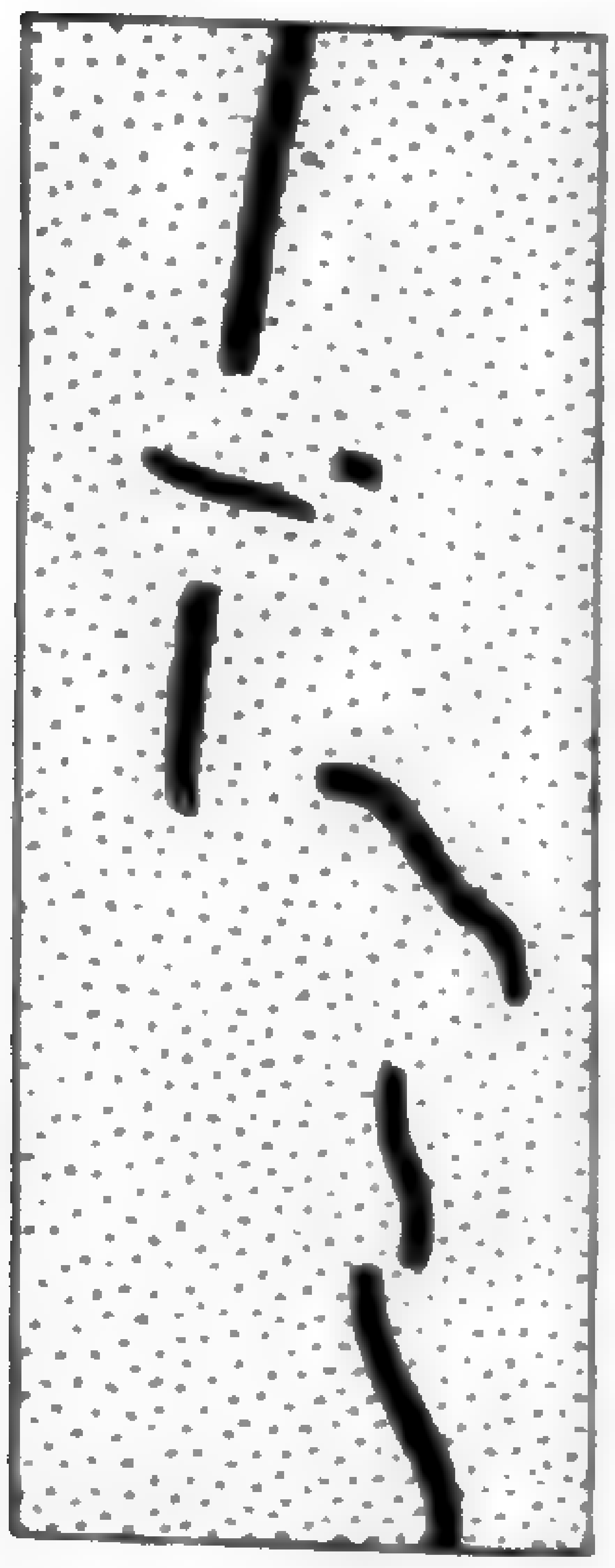

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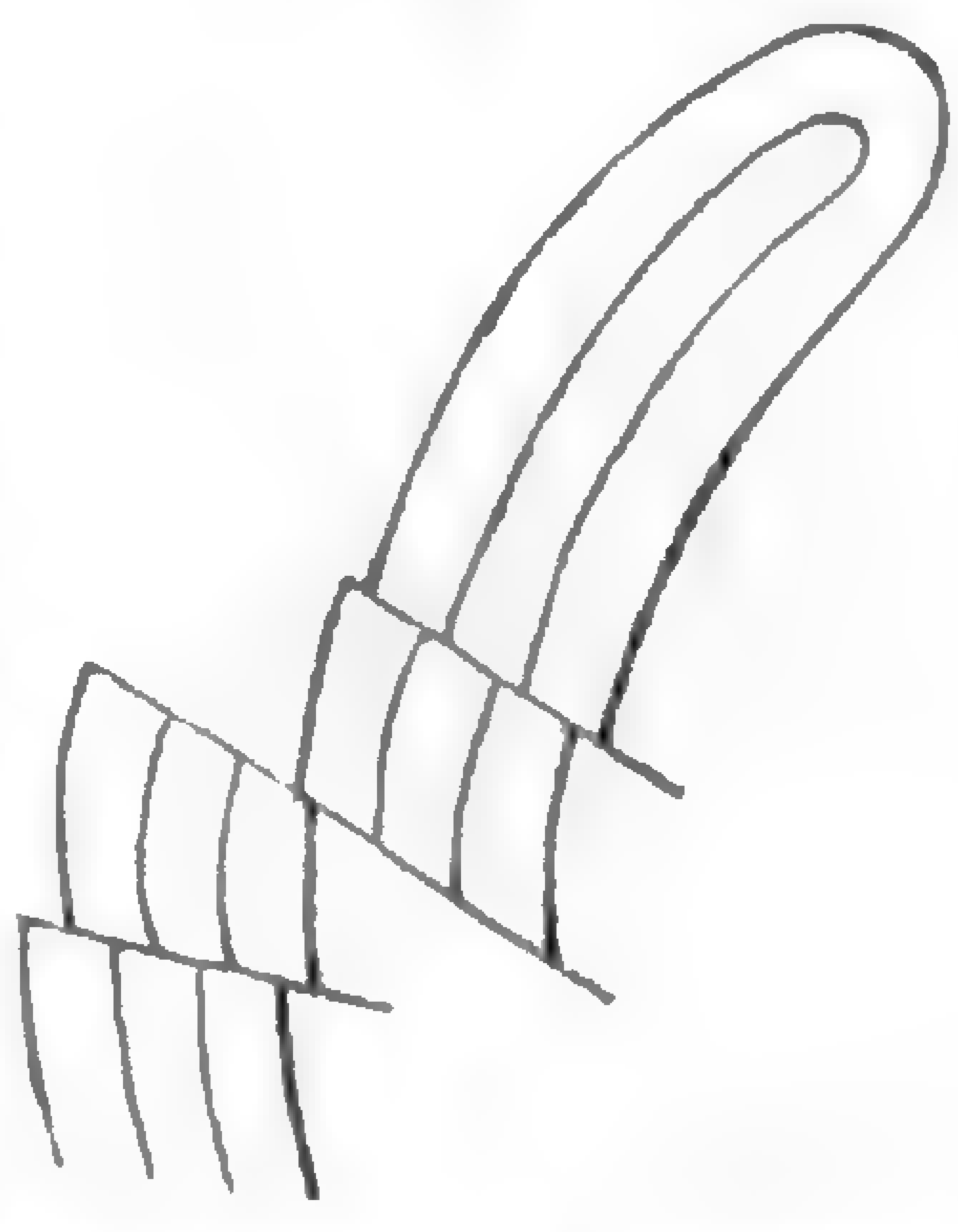

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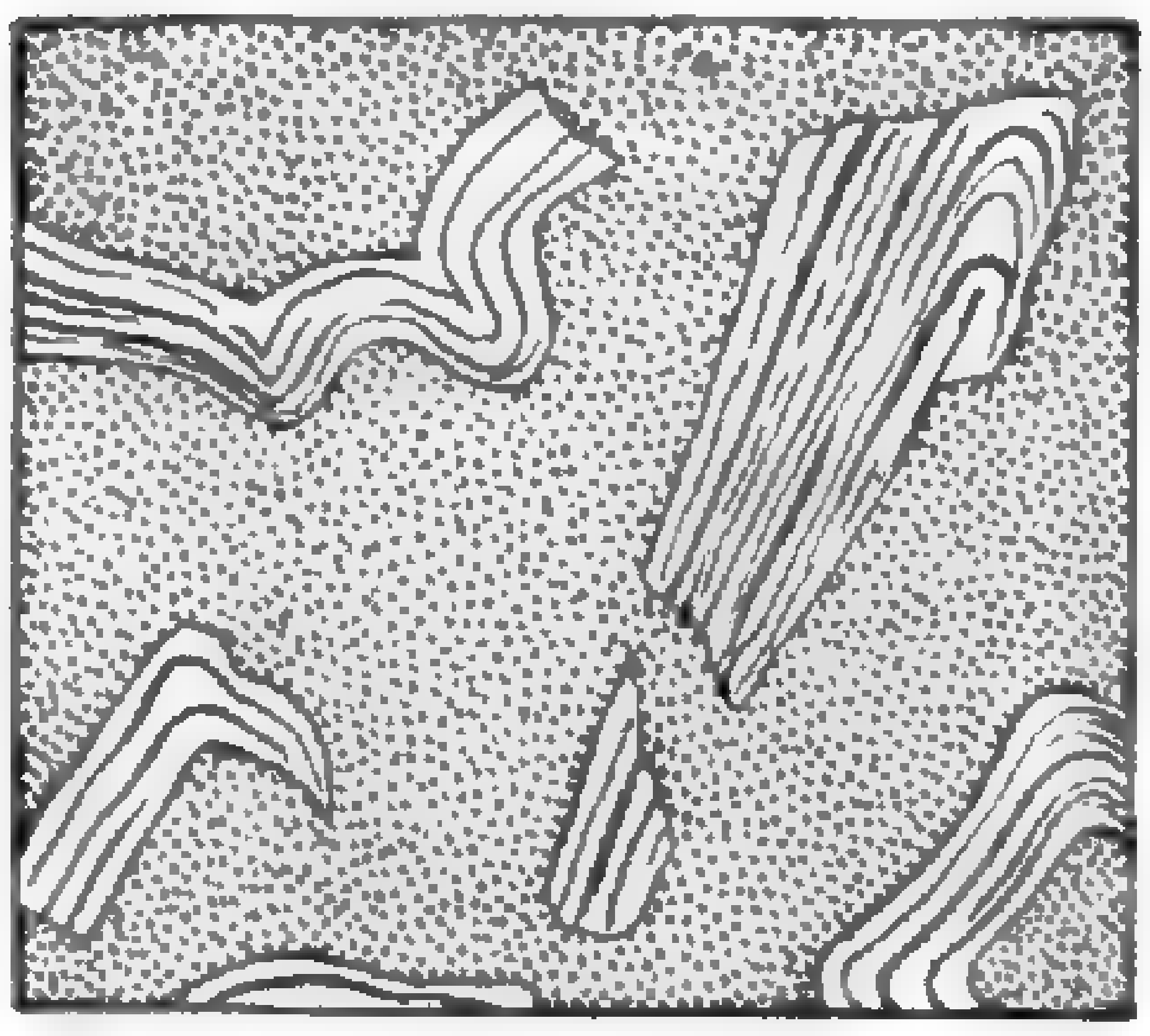

The examples of what appear to be veins or dikes are also numerous. They cut through the chrysolite rock and noryte of Stony Point and Montrose Point, and through the crystalline limestone of Verplanck Point. Those at the last-mentioned place, facing the river (north of the foot of Broadway), vary from an inch in width to over fifty feet. Some are simply faulted bands, like figure 6. Others have more irregular courses, as in figure 7, representing eight feet from a vein at Verplanck Point. Figure 8 shows a crossing of two small veins from the same limestone region. Some, if not all, of such veins must, therefore, be true veins or dikes; and are evidence as to the former fused or plastic condition of the material and its injection into fissures. Veins formed in this way are not veins of infiltration or segregation, that is, they are not due to the filling of fissures by material supplied slowly in solution or vapor; for no difference in coarseness of texture or structure exists between the rock constituting them and that of the massive rock elsewhere; they are just such as have been made by simple injection.

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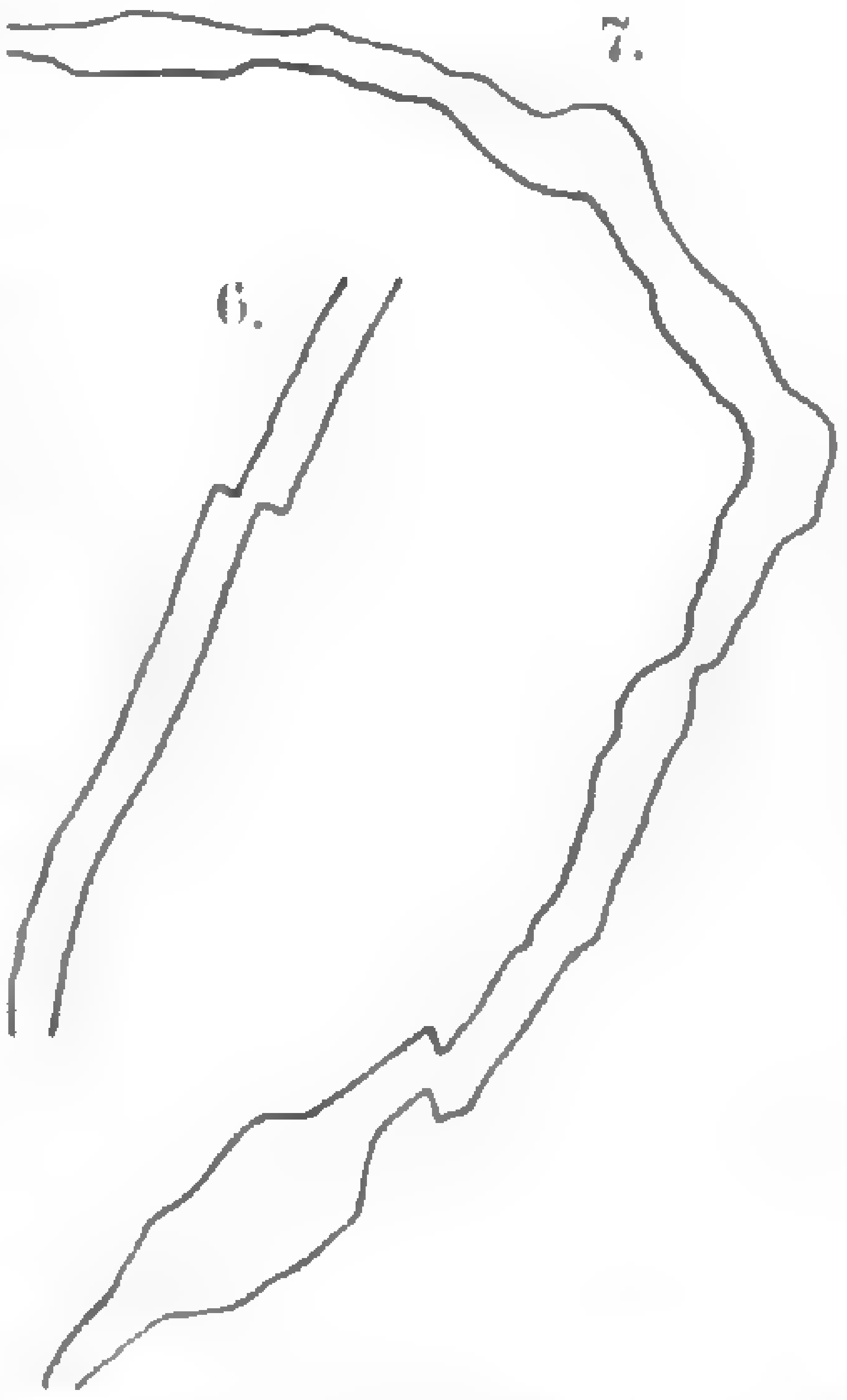

There are also peculiarities in the exterior of inclusions, and in the walls of veins or dikes, in some cases, which favor the idea of fusion. At Verplanck, the limestone of the wall is often discolored for two or three inches, and sometimes penetrated by the material of the vein, or contains minute crystals of hornblende; and in other cases, the limestone is impregnated with the hornblendic or augitic material in irregular lines or bands, so that surface erosion has left a complexity of small curving ridges. The crystallization of the limestone adjoining the vein is sometimes coarser than elsewhere; though, in general, no difference is apparent. On a small point, just north of the region of veins, part of the limestone is of the coarsest kind, the crystalline grains over a fourth of an inch broad, while the larger part is very fine in grain, like the most of the Verplanck limestone—a fact that indicates the local action of escaping heat.

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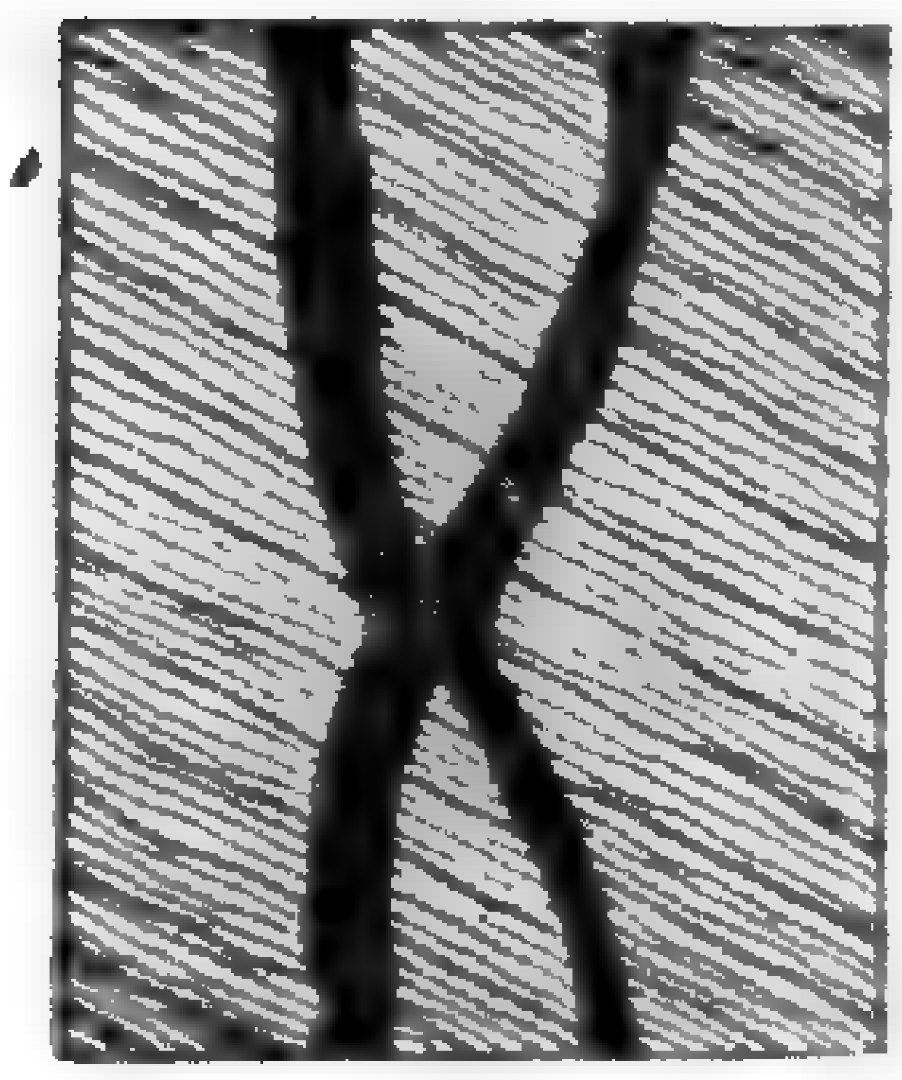

Still more positive evidence, if possible, of fusion are shown at the junction of the schists of Cruger's Point with the soda-granite, where the schist itself bears evidence of partial fusion and exhibits other contact-phenomena.

The proof of the crystallization of the rocks from a more or less perfect state of fusion or plasticity is thus complete.

2. Evidences as to condition of fusion.

But, admitting fusion or a plastic condition, the question still remains:

Were these once-fused rocks fused approximately *in situ*, that is, where, or near where, they now lie; or were they erupted through fissures from great depths below? that is, using Dr. Hunt's terms, are they indigenous, or are they exotic?

a. *The results are partly the same whichever the condition of fusion.*—If they were fused where approximately they now lie, that fusion must have come from accessions of heat, and such accessions may have resulted from the movement and friction connected with an upturning of the rocks; and it may hence have been one of the results, in that region, of metamorphic action at an epoch of general metamorphism; and if so, at the very time that these rocks became fused or plastic through the process, other rocks of the region, owing to less extreme metamorphic action, or to less fusibility, may have been left with their bedding unobliterated; just as much granite in New England and other countries received its crystalline condition in the same process and at the same time with the associated schistose rocks, the gneisses, mica schists, etc.

All the facts as to fusion which have been presented are consistent with either mode of origin, even to the inclusions and the dikes or veins.

(1) The veins or dikes have the same essential characters whether made one way or the other. As has often happened in the case of granitic rocks, and even granular limestone, the fused or plastic material, under the pressure attending the subterranean movements, would have entered and filled all fissures that might have been opened to it, and so have made veins or dikes having the sizes of the fissures were they large or small, and possessing also a uniformity of grain like that of ordinary erupted rocks.[12]

(2) Again, whatever the process of ejection, fragments, large or small, of any rocks adjoining such fissures might have become included in the fused or plastic material.

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[12] In the writer's Manual of Geology (1880), veins of this kind are called veins of plastic injection, an abbreviation of the full statement that they were made by the injection of material rendered plastic or fused during a process of metamorphism. They are better called dike-like veins.

(3) Moreover, the contact-phenomena in the case of veins so formed may be as decided and extensive as in that of any dikes or erupted masses.

(4) Further, the evidences of fluidal movement exhibited in the broken condition of many of the crystalline grains would be the same. Such a fragmenting of grains taking place after the stiffening of incipient solidification requires but a moderate amount of movement, and this is all that such circumstances would admit of. One foot would suffice; thousands would be impossible.

(5) Again, the resulting rocks need not, and generally do not, differ in kinds from erupted rocks of deeper source. In such fusions in the course of a process of metamorphism, the thickness of the rocks undergoing common movement may have a depth of 20,000 feet or more, and the fusion, therefore, would not be superficial. The view that many of the ordinary erupted rocks are nothing but fused sedimentary rocks need not be here discussed. The improbability of the view comes from the improbability of any movements in the earth's crust being sufficient to fuse its own rocks or the overlying sediments. But the epochs of metamorphism are the times not only of the profoundest movements of the crust, but also of the most thorough upturning of sedimentary beds, and if these are ever melted through the friction of upturning, or by its aid, then would be the occasion for it.

(6) Veins made at such an epoch by the injection into fissures of any rock so fused might have any extent, even that of the whole depth of the rocks metamorphosed; for the fissures may be thus deep. And the material filling them, since it might be that of the bottom rocks, might be wholly unlike that of the rock on either side of all the higher parts of the fissure.

But while there may be these resemblances between the effects of metamorphism and those of deep-seated eruption,

b. *The results of fusion of sedimentary beds under metamorphic action may have distinguishing peculiarities.—First:* The kinds of rocks so resulting are likely to vary greatly at comparatively short intervals, because sedimentary beds often vary thus. They should not have that uniformity for scores or hundreds of square miles which often characterizes ejections that have come up from regions beneath the supercrust.[13] Sediments, and therefore sedimentary deposits, are liable to frequent and sudden changes as to material, which igneous outflows cannot imitate. *Secondly*, the rocks are likely to have no

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[13] The term *supercrust* is used for that part of the earth's crust which has been made by sedimentation, the *true crust* being restricted to the part beneath which is a result simply of cooling.

columnar (basaltic) structure; because the fractures to be filled in such cases are fractures in rocks which are participating in the movement and which, therefore, are heated rocks, and not cold.

Again, the phenomena of contact and the facts as to inclusions, structure and superpositions may have distinctive peculiarities.

c. *The condition of fusion or plasticity in the Cortland region.*—To answer the question before us we have, therefore, to consider more closely than has been done the phenomena of contact of the schistose with the massive rocks over the Cortland region, the peculiarities of some of the inclusions, the characteristics of some of the so-called veins or dikes, and the characters of the rocks as to their transitions, structure, and relative positions.

3. Special facts from the Cortland region.

a. *Contact-phenomena between the schistose and massive rocks; facts connected with the inclusions; stratigraphical relations to the limestones.*—The facts with reference to inclusions and all contact-phenomena bear directly, as will appear, upon the question as to any stratigraphical relation in the Cortland rocks to the limestones; and they are, therefore, here taken from the vicinity of particular limestone areas.

(1) *The vicinity of Cruger's limestone area.*—The small limestone area near Cruger's, (see map), lies mostly to the south and east of the station; only a small portion about forty feet in greatest width borders the river west of it, beyond the first brick-yard (*l*), the rest of the westward extension of the limestone being beneath the river. The schistose rocks directly and conformably adjoin it on the north, the average strike of both being N. 70° E. and the dip 75° to the northward. In the southeastern portion of the area there is a twist in the whole to the northwest. The limestone is finely crystalline granular, mostly white in color, and over the hills to the eastward contains crystals of white pyroxene.

The schist north of the limestone has a thickness of about a thousand feet. Toward the limestone, it is a silvery mica schist containing a little black mica and an abundance of very small garnets. A hundred yards or so to the north it is staurolitic, the staurolite occurring in grains of a clear chestnut-brown color and rarely in distinct crystals; and it also in some parts becomes quartzose and consequently thick-bedded. There are, besides, seams containing much magnetite; and at one place an intercalation of a black micaceous rock containing some feldspar which is about equally orthoclase and a soda-lime species. After another hundred to a hundred and fifty yards northward, in the course of which it becomes increasingly staurolitic and garnetiferous, and passes in places into a true gneiss, it comes to its end against soda-granite and quartz-dioryte. Thus within a breadth of only 250 to 350 yards, there is here a passage from a stratum of crystalline limestone through conformable schists, to the massive rocks along which we have to look for contact-phenomena.

The facts here described are mostly from three south-to-north sections: *Section* 1, 300 to 400 yards west of the Station (*l* to *n*, on the map); *section* 2, about 700 yards (*p*); *section* 3, about 900 yards (*q* to *s*).

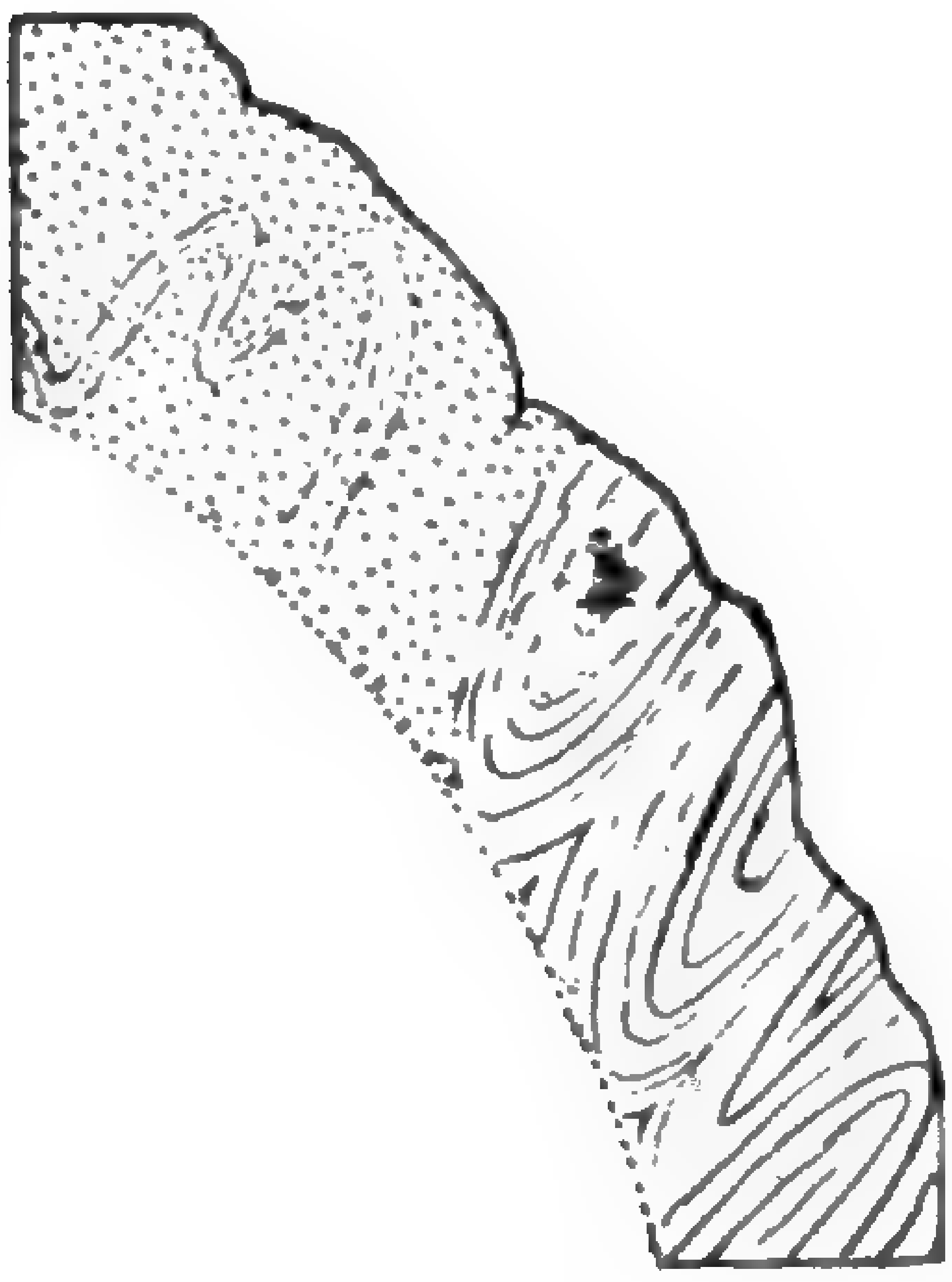
In section 1, *l* to *m* is the schist; at *m* is soda granite, which becomes hornblendic twenty-five feet above, toward the road; and then at *n*, on the north side of the road, the rock is of coarse quartz-dioryte. (The locality *n* is that of the first outcrop of rocks on the road going northwest from the railroad station.) The contact-phenomena in this section are as follows.

In the first place, the mica schist is even in bedding against the limestone; becomes more and more contorted to the northward, or away from it; and is full of flexures of a yard or so in span for the last fifty feet or more south of the junction with the granite.

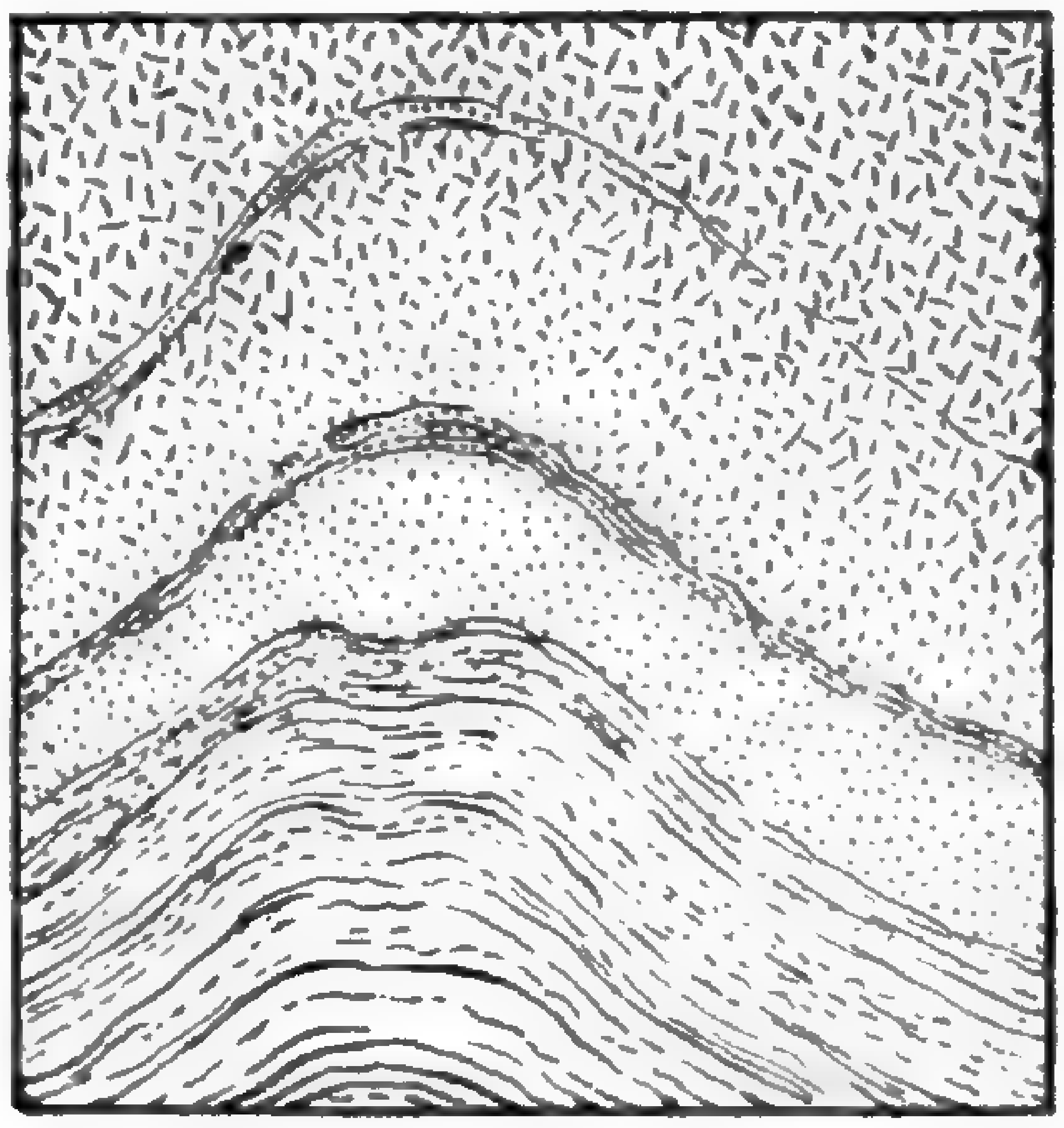
With the increase in the flexures of the layers, the schist becomes interlaminated with nodose-lines of quartz, vein-like in origin; and, besides, the garnets become somewhat larger. At the junction referred to, the schist is mostly a garnet rock containing much fibrolite and staurolite, and the latter is in some places granular-massive in a small way. Just below the granite, the layers are a compact body of flexures, and *in the soda granite* there is another flexed layer rather faintly indicated.

Figure 9 represents the condition here described; it was taken from the west side of a little bluff at *m*; the height is twenty feet. The dotted portion is that of the soda-granite. The garnet rock of the flexures under the granite contains, like the granite, soda-lime (or triclinic) feldspars, with little orthoclase; and the first foot of the granite is strongly garnetiferous;—facts which show a degree of transition in the material of the two rocks. The flexed bed within the soda-granite is gneissoid in character and of darker gray color than the granite; it is quartzose and garnetiferous, strongly micaceous with black mica, and contains magnetite and a little staurolite. The schist is consequently not a schistose portion of the granite, but a distinct bed; it is like the schist in its minerals, but in its more gneissic character indicates that it is intermediate between the schist and the soda-granite. The eastern face of the same ledge is about a dozen feet to the east of the western, and here the junction of the schist with the granite looks more abrupt, but partly in consequence of erosion; above this plane

9.



10.



of junction, in the mass of the granite, distinct though fainter indications of flexed beds exist. The change above *m* from soda-granite to quartz-dioryte is simply a change in the substitution of hornblende for the larger part of the black mica, the feldspars being equally triclinic in the two, and the quartz equally deficient in amount. At a small bluff, 160 yards to the west of *m* (at *o*, see map), the change is more abrupt than between *m* and *n*; in only six feet, the rock passes from soda-granite to the dioryte.

A natural inference from the series of facts presented in this section, those as to the flexures in the schist as well as the changes at the junction of the schist and granite, would be that the heat of metamorphism increased from the limestone northward toward the granite and dioryte region, the heat being a consequence in part, if not chiefly, of the movement and friction attending the flexing, and that consequently there was produced a more and more yielding condition in the material of the schist as the region of complete fusion was approached, and, at the junction, perhaps a fusing and obliteration of portions of some layers of the schist; and that a bed of schist existed in the granite which approached somewhat the granite in character, but which, owing to the nature of its material, was not wholly obliterated.

But, are not these flexed portions of beds fragments that were broken off and carried up by the fused or plastic material as it rose from depths below? They lie so conformably to the flexures of the schist as to suggest a negative reply to this query.

Sections 2 and 3 (at *p*, and *q r s*, on the map) show inclusions on a grander scale.

Section 2 extends up the face of the first high bluff of bare rock west of *m* (a bluff that has by its east foot a path leading up among the trees to a fine spring).

Figure 10 represents a portion of the surface of the bluff about forty feet wide. Below is the hard contorted schist, a well-bedded micaceous schist, becoming in its upper part true gneiss; and above this, as the dotted surface shows, there is soda-granite, and then, after a few yards of this rock, the dioryte or hornblende rock, which is indicated in the diagram by short lines instead of dots. About a yard above the schist, *within the mass of the granite*, a schistose layer, about a foot thick, occurs; and eight to nine feet above this another *in the dioryte*, and *both are conformable to the schist.*

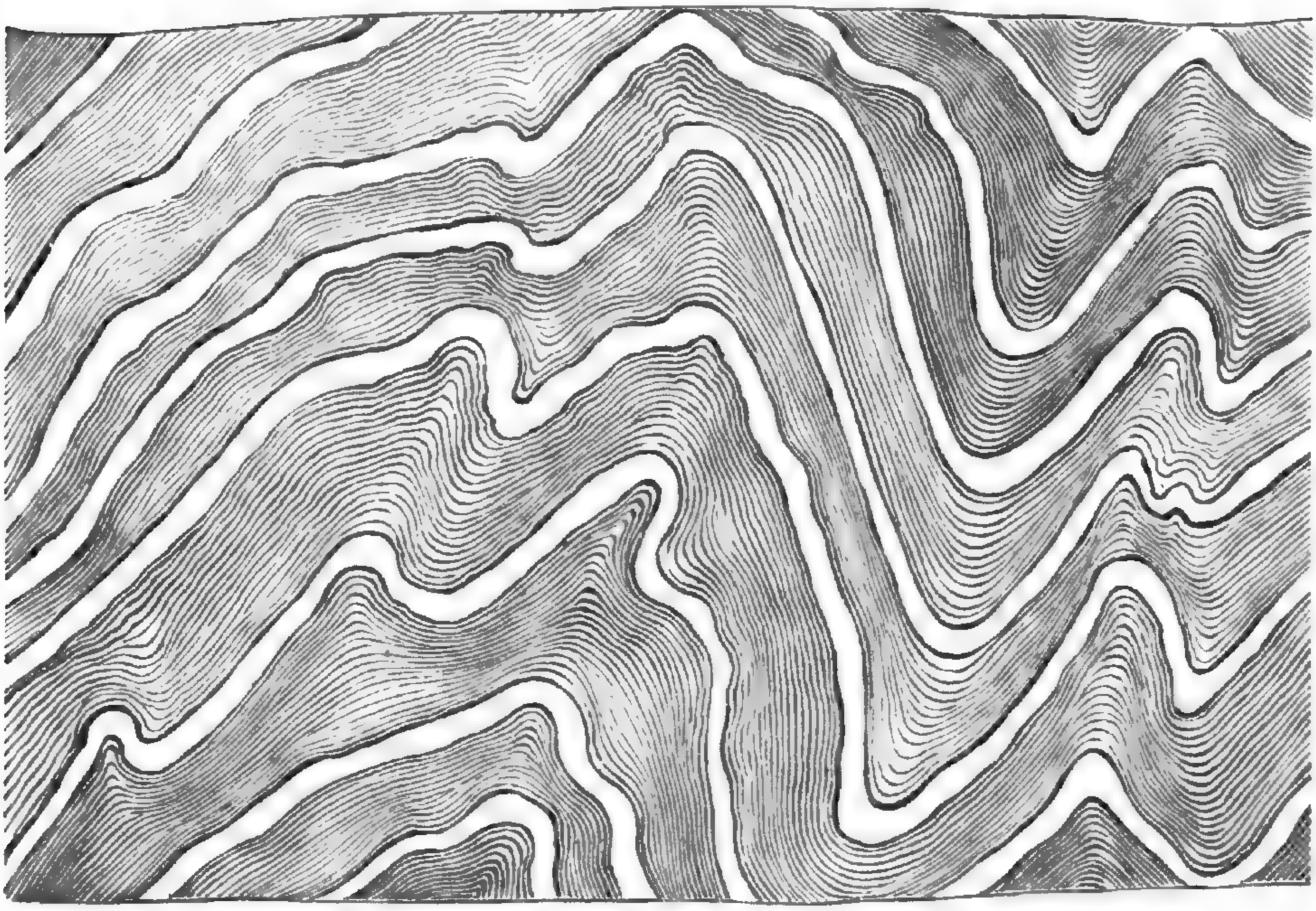
The upper bed of schist shows (in thin slices) that it is a quartzose, dark gray gneiss, containing much black mica and garnet, but also much triclinic feldspar and apatite, and in these two points approaching the soda-granite,—thus evincing a very marked transition in its composition toward that of the soda-granite. The first bed above it, lying in the granite, is similar to the schist in its black mica and quartz, but contains very little garnet; but like the soda-granite, it contains much apatite and more triclinic feldspar than orthoclase. Still other parallel beds are indicated at higher levels; one of them exists at the top of the bluff, twenty-five to thirty yards above the upper bed in the figure.

The facts look toward the same conclusions as those from section 1.

Section 3 was taken along a line about half a mile west of Cruger's Station, commencing on the river at *q* (see map, p. 195) in front of the most western of the brickyard sheds, and passing *r*, a point north of the upper shed, to *s*. For a distance of about 500 feet from the shore, the rock is mica schist; next follows soda-granite for about fifty feet; then, very coarse dioryte (the hornblende crystals in some parts finger-like in size) for 90 to 100 feet; then soda-granite again. At the shore the schist is nearly evenly fissile; 450 feet north, on the line of the section, it is like the six feet square represented in fig. 11. In the next fifty feet, the flexures are distinct but half faded out or nearly obliterated; and this is the last step before the soda-granite, the once plastic or fused rock, begins.

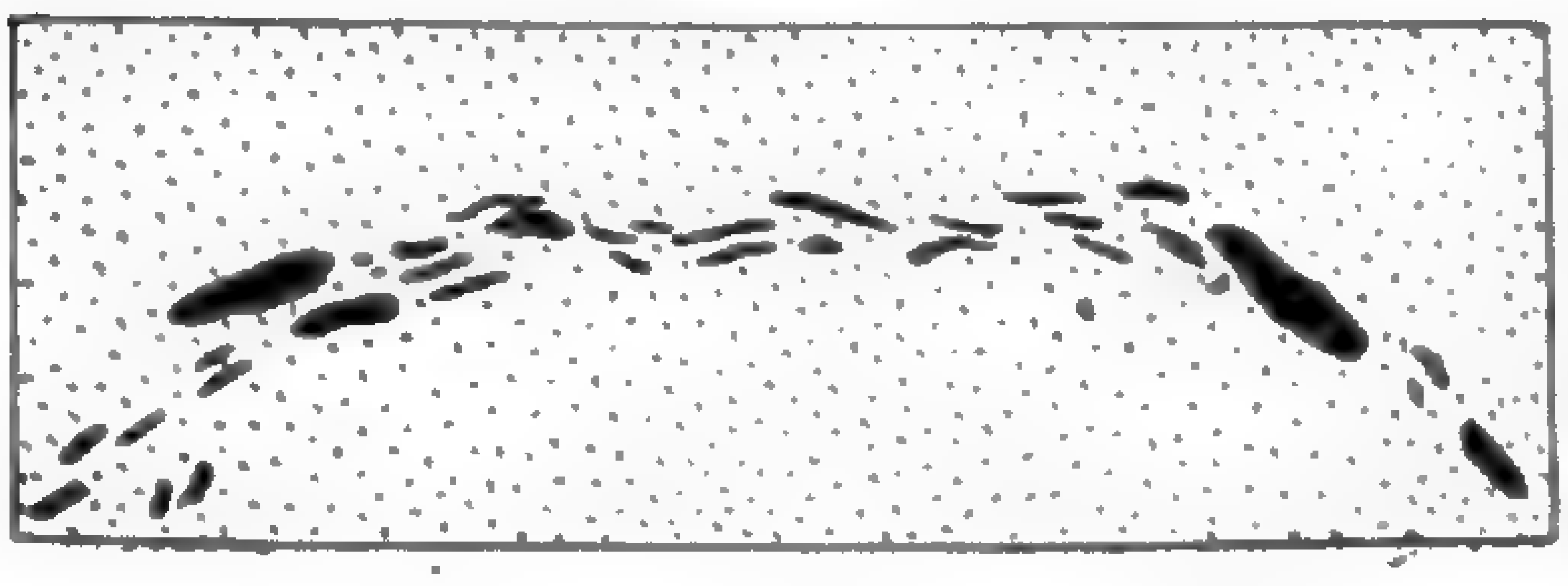
After twenty-five feet of soda-granite the first (*a*) of the ranges of "inclusions" appears; it is on the side of the road which here leads up the slope. Between three and four yards of the band are represented in figure 12. As shown, it is in pieces; yet the pieces are not much displaced, which they would be in an erupted rock. The material is grayish-black, and consists of a very chloritic magnetite, with a little black

11.



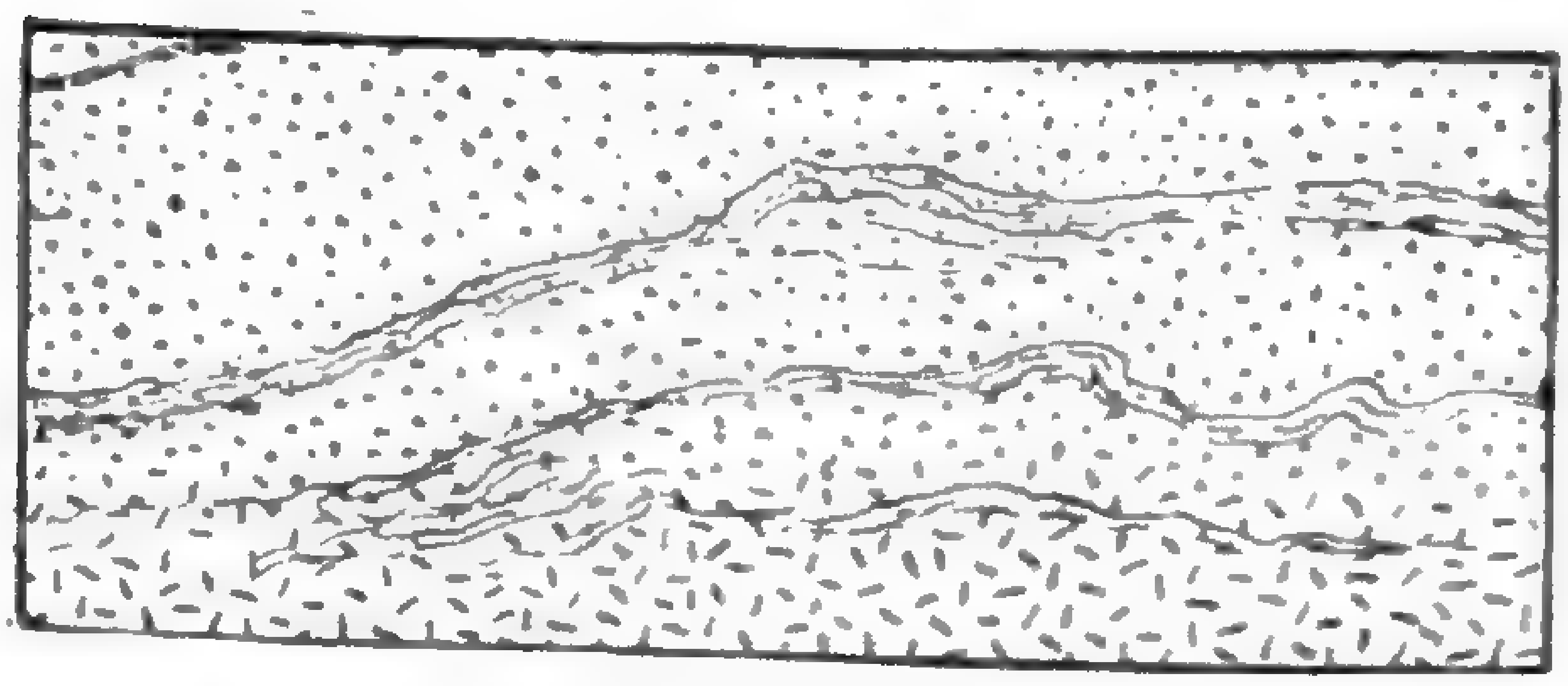
mica, in a feeble amount of base of triclinic feldspar. After an interruption it appears again for a short distance to the westward, where it is much more micaceous and garnetiferous; but the exposure is not as satisfactory as in the case of the other bands. Three feet behind this band, that is to the north, there is another similar one having a parallel position.

12.

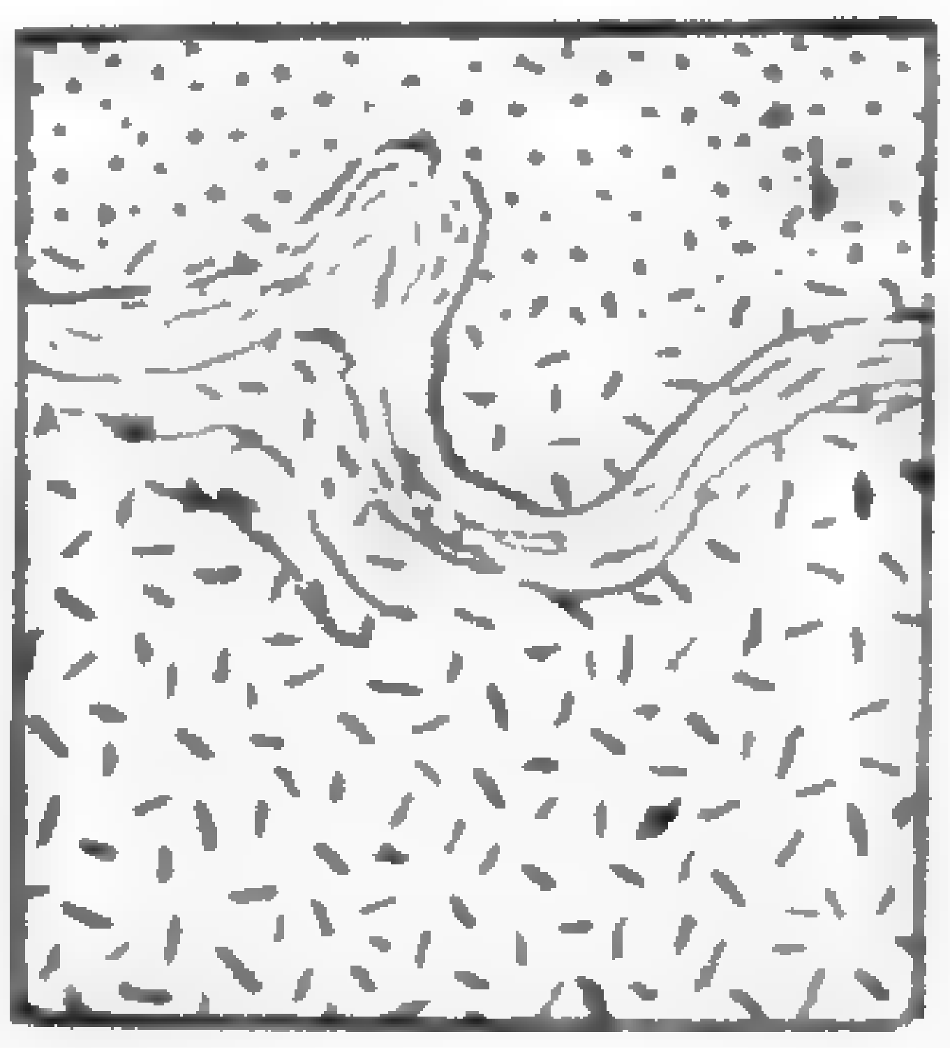


Eight or nine yards north commences the coarse dioryte. At the top of the slope, near the passage of the coarse dioryte to the soda-granite, partly in the dioryte but mostly in the granite, there are three bands (*b*) within three to five feet of one another, gneissic in constitution. Figure 13 represents about a dozen yards of these bands, in the dioryte and granite.

13.



14.



The upper or northern of the three bands (b^3) is exposed with small interruptions for *a length of more than one hundred and* *fifty feet;* and the more eastern portion is shown in figure 14. The strike is the same as that of the schist.

The rock of the middle of these bands (b^2) is a quartzose gneiss, with black mica, many visible grains and octahedrons of magnetite, and some garnet—resembling the gneiss of some of the nearest schist and unlike the enclosing soda-granite in its excess of quartz, magnetite, and its garnets; and that of the others is similar. About three yards north, but a little to the west, is another band (b^4), one to two inches thick, which has a gray color, and consists of small spangles of silvery mica, some scales of black mica and chlorite, and grains of magnetite—a thin layer of the mica schist more magnetitic than usual.

About eight yards north of the third of the bands represented in figure 12, there is another schistose band (*c*) which is short in the line of the section, but appears again to the eastward and also to the westward; the rock is quartzose, garnetiferous, and includes chloritic magnetite with fibrolite, and other materials of the schist.

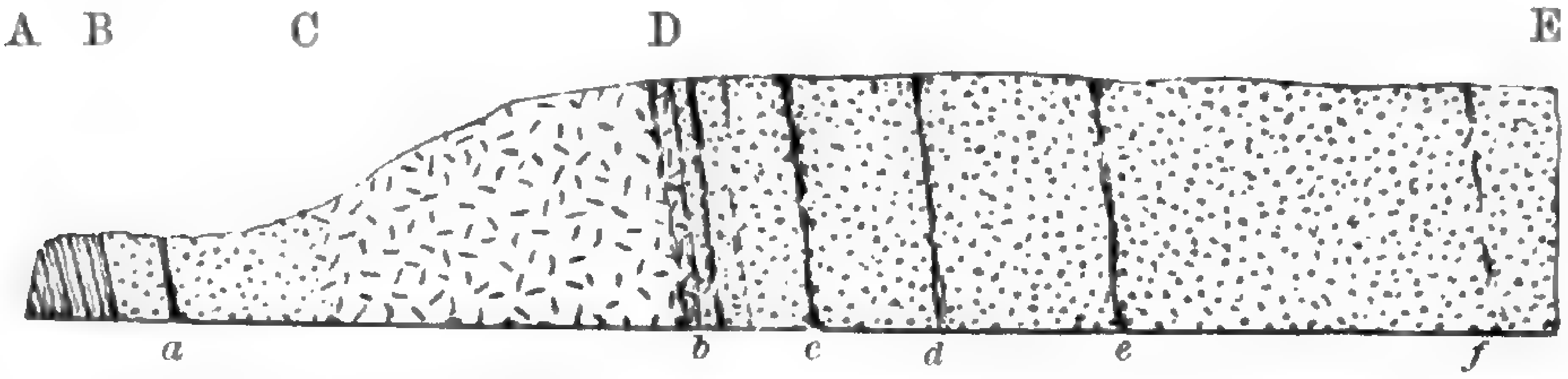
Eight to nine yards farther north, in the soda-granite, another band (*d*) exists, with the same strike—that of the schist—which outcrops for *two hundred feet*, or as far as the rocks in the direction are uncovered. This band is gray, like the last, and sparkles with the same pearly mica, but it is made up largely of brown staurolite in a half-granular form, showing but rarely crystalline faces, and contains also disseminated magnetite and some fibrolite and chlorite; a garnetiferous portion contains much black mica. Eight feet farther north, but to the eastward a few yards, a very silicious schist appears for a short distance. Fifty feet north, in the soda-granite, is still another band (*e*), which contains much chloritic magnetite; and a hundred beyond, another thin, gray, micaceous band resembling closely b^4; the condition of a portion of it is shown in figure 3, on page 203. Farther north, at intervals, other schistose bands exist, and along the north side of Cruger's Point, facing the brick-yards at the foot of Park street, they are more largely displayed.

The extent of these bands, their number, uniformity of direction and apparently of dip, and the identity of the material constituting them with beds of the schist, especially the more northern, are such as to warrant the following section (fig. 15).

A B represents a portion of the schist near the granite; B to C, soda-granite; C to D, coarse syenyte-like dioryte; D to E, soda-granite; *a* to *f*, the bands, which are lettered as in the above descriptions of them.

The depth to which the beds are made to descend downward in the granite (100 feet) is an assumption in this section; but considering that probably 5,000 feet, and more likely over 10,000 feet of these upturned rocks have been removed by erosion, and noting also the number of the bands and their parallelism to the schist, and the effect of pressure to keep them in place, the assumption can be no exaggeration.

15.



Since it is obviously impossible that the inclusions taken in and carried up by rocks erupted through deep fissures should be beds of schist 100 to 200 feet long, and a series of such beds separated by the fused rock retaining together their parallel position, we have to admit that these indications of bedding are of *unobliterated* bedding. The rest of the upturned strata were fused or at least softened; these portions of beds were not fused, though flexed and variously displaced.

There is reason for the resistance to fusion in the mineral nature of the beds; for quartz, staurolite, fibrolite, magnetite, are infusible minerals; muscovite and biotite are but slightly fusible on thin edges; and orthoclase fuses with great difficulty, much greater than the other feldspars, oligoclase, labradorite and albite.

Thus the study of the phenomena of contact becomes in this region a study of "inclusions;" and the larger of the inclusions turn out to be beds of schist, conformable to the schist.

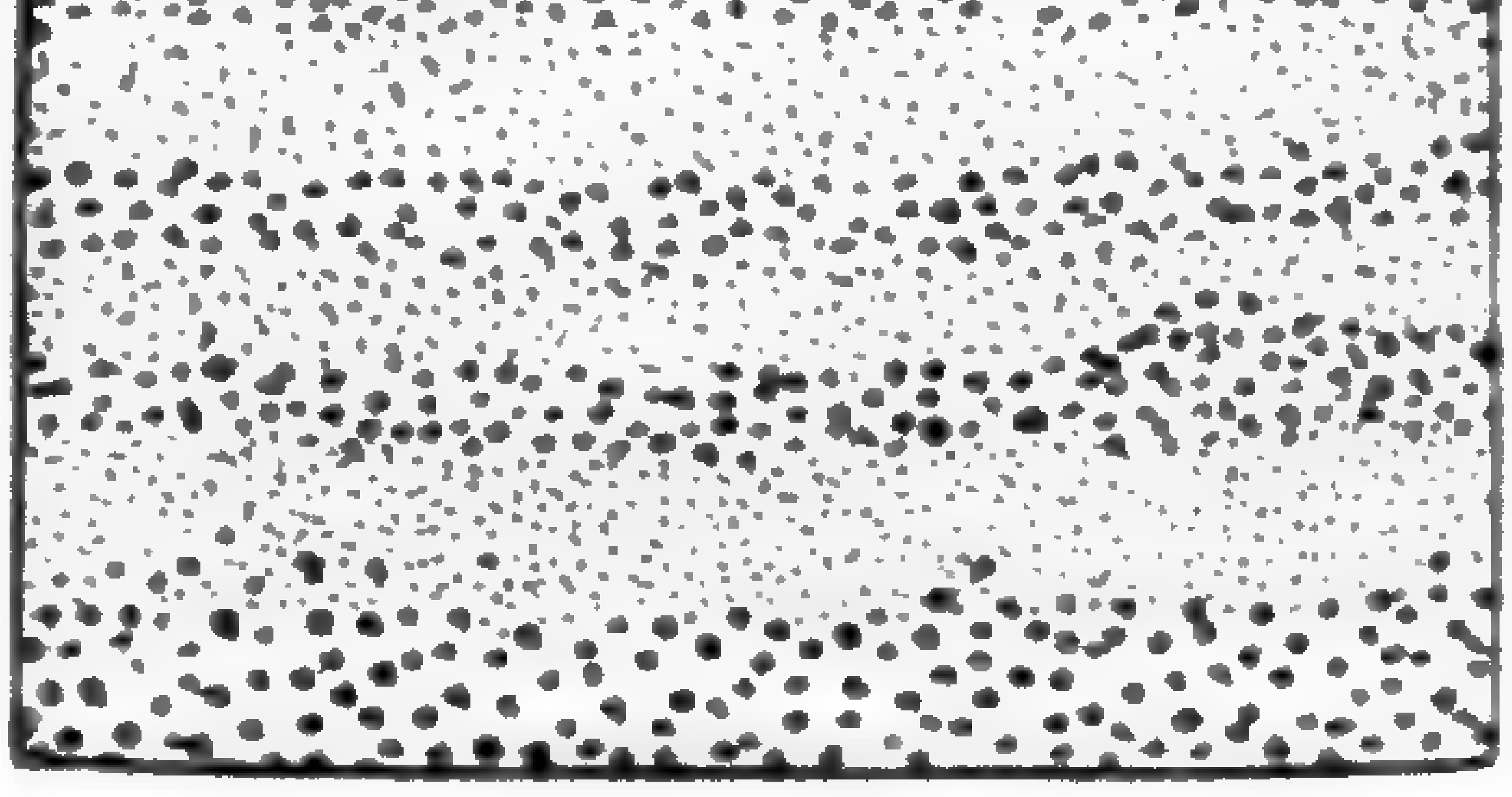
We seem to be thus forced to the conclusion that the soda-granite and the included dioryte were once parts of the same sedimentary strata with the schist, and that all, with the Cruger limestone, were once a continuous stratified formation; and that the plasticity given to the granite-making or dioryte-making portions, because of the heat, occasioned the exceptional geological features of the region.

The region of Cruger's Point is continued northward into that of Montrose Point; the latter is characterized, as has been stated, by chrysolitic rocks for its southern three-fourths, and by noryte with chrysolitic rock for the other fourth; and through the facts there as well as elsewhere afforded, the evidence from inclusions is made to extend also to these other rocks. With the chrysolitic pyroxenyte and chrysolitic hornblendyte, there is also hornblendyte which is not chrysolitic, but more or less augitic and containing some triclinic feldspar. On the south side of Montrose Point facing Cruger's Point (or the brick-yard between the two), in the chrysolitic rock, there is what looks like a vein or dike two to four inches wide, exposed for a length of twenty feet. The material shows it to be no vein or dike, but a bed from the schist; it is a dark-colored quartzose *garnet rock*, heavy with magnetite and containing some staurolite, resembling much a portion of the schist in section 1 (above described), near the soda-granite. The covering of earth prevented a determination of its whole extent. In the same kind of rock, about fifty yards north of the brick-yard which divides Montrose Point (into a North Montrose and a South Montrose Point), a vein-like band, two feet to twenty inches wide descends the bluff, which consists of a light-gray massive argillyte. Examined in thin slices by the microscope, it is found to have a mealy aspect with microlitic points, like an argillyte in the first stages of metamorphism. The band is a bed from the schist, although a different variety of it from any exposed at Cruger's.

Other long vein-like bands are black and of very fine grain; some of them look grayish and minutely arenaceous. The microscope shows, on an examination of thin slices, that some consist of grains of hornblende and feldspar, the latter partly orthoclase, and look like hornblende schist, while others are very fine-grained hornblendic mica schist. One of the latter had a thickness of two feet. These bands are most numerous in the noryte of the northern part of the point. Figure 4, as stated on page 201, represents an "inclusion" in the noryte; but the inclusion is evidently a *bed bent back on itself;* for a vein would not be thus folded double in its enclosing rock. The rock of this *bed* much resembles the noryte, though finer in grain, and consists (as observed by means of a thin slice) of hornblende with much augite and some triclinic feldspar.

On the same part of the point, the noryte and chrysolitic rocks apparently cut through one another, but with the noryte oftener like an inclusion in the chrysolitic rocks. Again, they follow one another, or lie side by side, but without a distinct divisional plane: and in one place the rock consists of bands of noryte and chrysolitic hornblendyte without a trace of any planes of separation. Figure 16 represents an example of this kind, in which the bands are two to three inches wide, noryte bands (the fine-dotted in the figure), alternating with bands of the chrysolitic rock. Difference of material in successive portions might, under some metamorphic conditions, give rise to such a structure, although the bands are so thin; successive outflowings of different eruptive rocks could not produce it.

16.



Going north from the vicinity of Cruger's Station along section 1, instead of section 3, the rocks change from the coarse dioryte at the end of the section to fine-grained; and then, in three-fourths of a mile, the rock is well-characterized noryte. Moreover the noryte contains a band of magnetite, exposed in a working (near Mrs. Murden's) with which occur garnet and fibrolite. The band is bedded, the magnetite is chloritic, and the assemblage of minerals is the same that occurs in the soda-granite, as well as the schist west of Cruger's. Fibrolite is found also with the magnetite of Eastern Cortland.

The noryte and chrysolitic rocks are thus apparently in the same category with the soda-granite and quartz-dioryte.

Stony Point.—This conclusion is further sustained by the facts to be observed at Stony Point, and these facts come into this place although the locality is on the west side of the Hudson; for the Cruger schists make the south border of the region precisely as near Cruger's, and have the same strike and dip, showing a like relation to the Cruger limestone belt and proving its former extension across the river. For further comparison between the geological facts of the east and west sides of the river, it is to be observed that the succession of rocks west of Cruger's, on the line going northward, from the river on the south side of the point to the north side of Montrose Point, is (1) limestone; (2) schist; (3) soda-granite (with some included dioryte); (4) chrysolite rocks; (5) (on Northern Montrose Point) noryte and chrysolitic rocks in complicated combination.

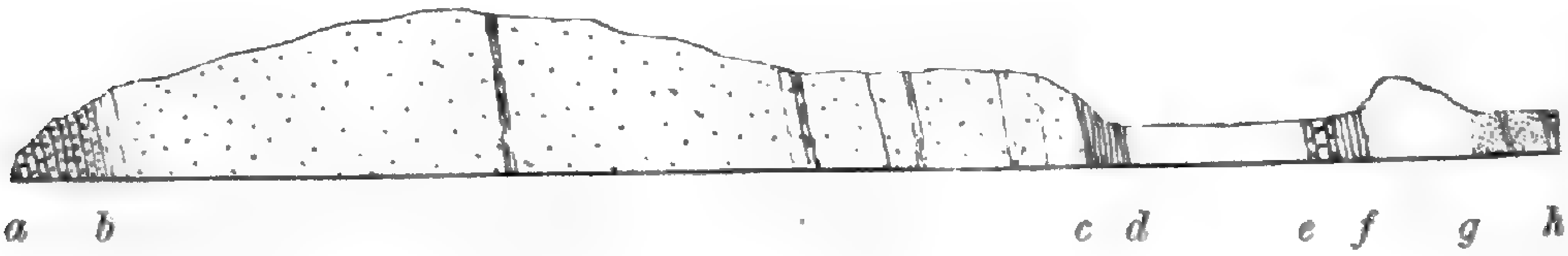
The same is the order on Stony Point, except that the limestone is not in sight (no doubt because submerged); it is: (2) schists; (3) soda-granite; (4) chrysolite rocks, followed by (5) noryte and chrysolite rocks combined. (The dioryte of the Cruger soda-granite is not represented there.) On the map, x is the area of the schists; y, the soda-granite; z, the chrysolitic rocks, and z' the latter with noryte. But besides being the same in order, there is evidence that the soda-granite succeeds the schist *along a plane of bedding* of the schists, as if conformable. This is apparent at the junction of the two on the east-northeast shore of the point. Included beds of schist occur, but the covering of earth prevents a determination of their direction. Further, the chrysolitic rocks succeed to the soda-granite along a plane parallel to the same plane of bedding, as is seen just west of the boat-pier near the middle of the northern shore. Besides these facts, there are included beds of fine-grained hornblende rock (schist?) and other kinds in the noryte and chrysolitic rocks, which are in general conformable to the same plane, or about N. 70° E. in strike, with a dip of 75° to 80° to the northward.

Such facts sustain the inference as to the former connection of the rocks of the east and west sides of the river, and strongly favor the view that the succession in the rocks noted was dependent originally on stratification.

If the thickness of the schists at Cruger's Point may be taken as that at Stony Point, the submerged Cruger limestone is to be found beneath the bottom mud of the river within a few hundred feet of the southeast shore.

(2) *Vicinity of the Peekskill Limestone areas.*—The Peekskill limestone areas have similar stratigraphical relations to the noryte and the other Cortland rocks. One of the two areas extends up Sprout Brook or Canopus Hollow, and the other up the valley in the village of Peekskill along which Center street descends toward the river. The southern extremities of these areas are shown on the map, page 195; the former has the strike N. 52° E. and dip 75° S.; the latter, N. 78° E. dip 75° S. Figure 17 represents a section about 1300 yards in length from north to south, along the line marked *a b c* on the map, starting from the limestone at the mouth of Sprout Brook, near the Iron works. The limestone (*a*) lies against true, whitish, well-bedded, conformable quartzyte (*a* to *b*); this quartzyte changes gradually to jointed massive granitoid and gneissoid quartzyte, with only an occasional bedded band or plane; each such band or plane is conformable in direction to the limestone and the adjoining bedded quartzyte. This quartzyte (the rock referred to on page 24 of this volume) continues southward to the Center street valley, but on the north side of the valley, just back of Hill's Foundry, it is followed by an arenaceous mica schist (*c d*), with the strike varied to N. 78° E. the dip remaining the same; then, on the south side of the valley, 50 yards above Baxter's Iron Works (on Water street), the limestone of the *second* belt outcrops, having the same dip and strike as the mica schist; and behind these iron works, thin-fissile dark-gray mica schist (containing both white and black mica) appears conformable in position to the limestone; then, after an earth-covered interval of about 200 yards, there is an outcrop of massive noryte along South street, north of Hudson street, which is without bedding, but has an extremely micaceous layer—a kind of coarse mica schist—intersecting it near its middle which is *conformable in its strike and dip with the mica schist and limestone of Center street valley*; and it shows conform-

17.



able planes of bedding also near its south extremity. Moreover, this noryte has a lighter-gray color and contains more quartz and orthoclase than in other outcrops more remote from the mica schist and limestone, and thus exhibits an intermediate character corresponding with its intermediate position. This stratification in portions of the noryte is also distinct a mile to the eastward of this locality on the same side of the limestone, at the point mentioned on page 194.

The granitoid and gneissoid quartzyte of Peekskill *looks* much like true granite and gneiss; but its transition to bedded quartzyte shows what it in fact is; and this is confirmed by the examination of thin slices, the quartz in it proving to consist of an aggregation of grains just like a sandstone. (The transition of this granitoid quartzyte to schist or slate has been mentioned on page 24.)

These facts are all in favor of the conclusion that the noryte was once a stratum conformable to the Peekskill limestone areas.

(3) *Vicinity of the Verplanck Limestone belt.*—The Verplanck limestone belt follows the border of the river from a point just north of the foot of Broadway, and has the usual strike for the county, northeastward. Like the Cruger limestone area, it has, on the landward side, with a small exception, a border of ordinary mica schist or micaceous gneiss, a fine-grained arenaceous rock, the feldspar of which is mostly orthoclase. This schist extends to the point marked *d* on the map; at *c* the rock is massive noryte, but no junction of these two rocks is here in sight.

The exception referred to is at the southwest extremity of the belt on the river. Here there lies against the eastern side of the limestone a great mass of grayish or brownish-black rock of the Cortland series. It is mostly pyroxenyte, moderately coarse in grain, but varies to a kind in which the augite individuals are half an inch broad, and, on the other hand, to a fine-grained variety; and it contains, besides augite, a little hornblende, quartz, calcite, and apatite. But portions of the mass consist of coarsish hornblendyte; and a small part of micaceous augite-noryte; and there are also broad and narrow bands of very fine-grained black hornblendic mica schist, not showing well a schistose structure, part of which are conformable in strike and dip with the beds of the limestone, while others are in other positions. All the material is very pyrrhotitic. Besides, it contains the remarkable limestone breccia, of which a portion three feet square is represented on page 202.

This singularly constituted mass shows no appearance that looks like a subdivision into dikes or veins, except in the bands of hornblendic mica schist: one of these bands has a border of the micaceous augite-noryte just mentioned. In the limestone just north of this mass, facing the river, occur the supposed dikes or veins mentioned on page 202. Some of them consist of pyroxenyte; others of coarsish hornblendyte; very fine-grained hornblendic rock looking like hornblende schist (*Ae*); very fine-grained hornblendic mica schist; augite-noryte.

As already admitted, there is here abundant evidence of a former plastic state in at least part of this augitic and hornblendic material. Still, there are strong reasons for questioning the idea of its deep-seated origin. (1.) The variety in the constitution of the mass bordering the limestone and in the supposed dikes or veins is very unlike what is ordinarily found in regions of igneous eruption. (2.) The supposed veins or dikes are for the most part conformable with the bedding of the limestone and partake in its flexures, just as if they had been originally beds alternating with the limestone depositions. (3.) The impregnation of the limestone along the junctions with pyroxenic or hornblendic material, sometimes minute crystals, looks as if it may have been in part at least a result of mixture attending original deposition.

Further (4.), there is the decisive fact that these intercalated masses are represented to the northward by bands ten feet and less to over thirty feet in thickness, of a black fine-grained mica schist, very pyritiferous. Going from the Point, the first outcrops of interstratified schist and limestone occur after an earthy interval of 300 yards, and here the mica schist is *hornblendic*, a feature it loses to the northward. These beds of mica schist have just the positions of most of the supposed "veins," and appear to be their more northern portions; and further, among the more northern "veins" of the Verplanck shore some are *simply mica schist.* Such facts explain also many of the vein-like bands of Montrose and Stony Points. The difference in mineral constitution between such interstratified beds to the northward and on the shore is what should be expected; for the limestone is bordered to the eastward in the one case by true mica schist, and, in the other, by augitic or hornblendic beds; and the associations at Montrose and Stony Points are similar. This view is also sustained by the occurrence in the limestone near the schist, 1000 yards from the Point, of coarse spots of pyroxene with mica and chlorite, rudely in layers, which must be due to the original deposition of impurity and metamorphic action. The augitic rock (pyroxenyte) on the east of the limestone at the Point outcrops (owing to excavations in the drift) for 200 yards from the shore; but its place beyond this continues covered for three-fourths of a mile, and here the rock is arenaceous mica schist; the spots of pyroxene are its only representative.

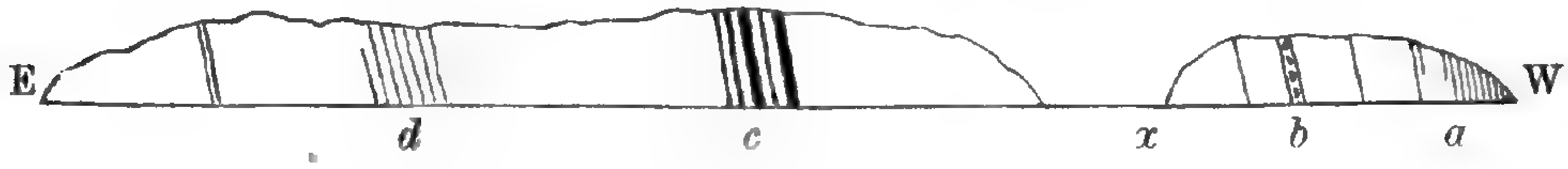
The essential continuity of these intercalated beds of mica schist with the intercalated beds of augitic and hornblendic material along the coast proves identity of origin, and origin by sedimentation. It indicates also a small change of constitution in the beds as they extend in that direction. The plasticity occasioned in part of the latter, during the progress of the metamorphism, accounts for all that looks like eruptive phenomena, even to the broken feldspar grains found in a slice of the pyroxenyte of one of the so-called veins. There is nowhere evidence of injection into or through cold rocks.

(4) *Vicinity of the smaller limestone areas of the Verplanck Peninsula.*—Six small limestone areas occur in the Verplanck peninsula. They are lettered on the map 1 to 5 and *j*. Number 3 has the strike of the large Verplanck belt, and has about it the same arenaceous mica schist. The others are in the midst of, or adjoin, the noryte, dioryte, and chrysolitic rocks, and hence might be put down among the "inclusions" of the region. In addition, they have a *northwest* strike (N. 17°–40° W.) But this is the strike, in part of Cruger's limestone area, and in a portion of the Verplanck belt, so that the twist is not confined to them. And, among so extensive masses of rock that became plastic or fused in the era of upturning, this abnormal position of included strata is not strange. Numbers 2 and 5 are probably parts of one belt; and numbers 1 and 4 may be in the same line, though disconnected by intervening rocks. The following are some of the stratigraphical facts observed among them.

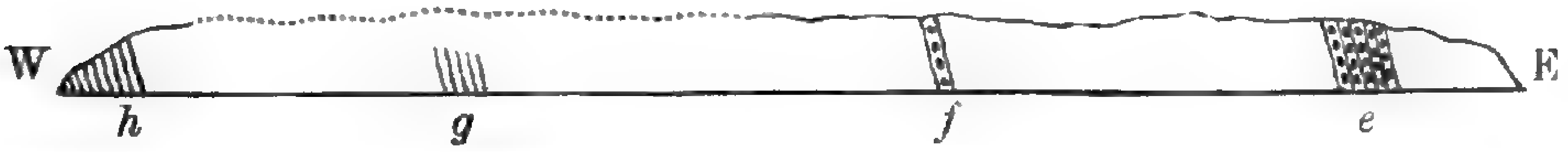
No. 4, at Centerville, has at middle on its east side the compact porphyritic mica rock, *Cb*, which is schistose directly adjoining the limestone in the field west of the road, and has the strike of the limestone N. 47° W. But to the westward in the field (in which the limestone can be traced for 250 yards with a change of strike to N. 62° W.) the mica rock changes to hornblendyte and quartz-dioryte; and to the southeastward along the road, augite-noryte appears within a few feet of the limestone, both the feldspathic fine-grained (almost cryptocrystalline) variety (*Bc*), and the coarser dark variety. Whether this latter change in the bordering rock is due to a fault or not, could not be ascertained: it was not due to an intrusive dike.

No. 5 outcrops on the railroad at 5 (see map) and on two roads at 5′ and 5″, with the strike N. 32° W. Between Montrose Station and this limestone at 5″, the rock is noryte, excepting some grayish augitic rock (*Bc*) at the corner (Munger's), where the road turns west, and an outcrop of *chrysolitic* noryte (hypersthene rock) 135 yards west of Munger's. Eighty yards beyond the chrysolitic rock comes the outcrop of limestone. One hundred and fifty yards west of the small exposure of limestone, on the north side of the road, a ledge commences which extends along for nearly 350 feet, with no dike-like subdivisions. It *consists mainly of noryte and augite-noryte, but with some hornblendyte and noryte-gneiss, and has distinct planes of bedding in several places, all of which are conformable to one another.* The strike of its beds is N. 27° W., or nearly that of the limestone, and the dip 60° to 70° E. Part of the noryte is garnetiferous. Figures 18, 19, represent the stratification observed in the ledge—fig. 18 the eastern portion, and 19 the western; forty feet of earthy interval separates the two. At the east end, at *a*, the rock (as a slice shows) is hornblendyte (with about equal proportions of orthoclase and triclinic feldspar), and it is schistose. It passes at the place to coarsish quartz-dioryte. At *b*, it is well-defined micaceous gneiss or noryte-gneiss, affording perfect observations of the strike and dip. West of this the rock is mainly noryte and augite-noryte. At *c*, for eight feet, black bands (or beds less feldspathic than the rest) alternate with the ordinary gray-black rock, and exemplify the conformability stated, though without divisional planes; at *d*, are divisional planes in the gray-black augite-noryte, having the strike N. 27° W. and dip 70° E. At *e*, is a much decomposed micaceous gneissic layer (noryte-gneiss apparently) conformable in strike, but varying in dip from 40° E. to 60° E.; at *f*, a distinct bed of light-colored very feldspathic augite-noryte, deeply decomposed, having the conformability; at *g*, or the west end, the rock is again micaceous and gneissic, with some garnets, the bedding distinct, and N. 27° W. in strike as at the east end.

18.



19.



This ledge, although made up mainly of massive noryte and augite-noryte, bears thus positive evidence of its having once had bedding throughout, and affords thereby a demonstration that its noryte is of metamorphic origin, and that the associated beds comprised also the limestone of the region.

(5) *A bed of quartzyte in noryte.*—About half a mile east of the limestone number 5, about the Montrose Station, the rock is the ordinary dark-colored noryte. 120 yards up the road going northeastward from the station, a bed of *whitish granitoid quartzyte* outcrops on the roadside for seventy yards, first on the west and then on the east side. This bed of quartzyte *overlies*

noryte. The noryte near the quartzyte is micaceous, quartzose and schistose, and that underneath is of the ordinary massive kind. There is evidence also that the bed of quartzyte has noryte above as well as below it. The quartzyte looks somewhat like a pale quartzose porphyritic granite; but, as observed in thin slices, the quartz consists of aggregated grains like sandstone; showing a resemblance to the Peekskill quartzyte. The feldspar is mainly orthoclase.

C. CONCLUSIONS AS TO THE CORTLAND ROCKS.

Many more observed facts might be here reported. But the above appear to be sufficient to settle the question as to the relations of the rocks of the Cortland series. They appear to sustain fully the following conclusions:

(1) These rocks, although they include soda-granite, noryte, augite-noryte, dioryte, hornblendyte, pyroxenyte, and chrysolitic kinds, are not independent igneous rocks erupted from great depths.

(2) However complete their former state of fusion or plasticity may have in some cases been, they are metamorphic in origin.

(3) The strata that underwent the metamorphism were one in series and conformability with the adjoining schists and limestone, and were part of the Westchester limestone series.

(They are *younger* rocks if of different age, since they contain and intersect portions of the Verplanck limestone.)

(4) These Cortland rocks differ from the other Westchester County rocks because the metamorphic process had to do with sedimentary beds that differed in constitution or were in some respects under different conditions from those that existed elsewhere.

On the view reached, it follows that the limestones, schists, and other rocks of the Cortland region originally constituted together one series of horizontal strata. They underwent an upturning through subterranean movements, and in the course of it, they became metamorphosed; part into mica schist and gneiss, part, by loss of bedding, into the massive rocks. The number of these rocks does not imply widely different ingredients in the original strata. For hornblendyte and pyroxenyte have the same chemical constitution; the chrysolitic rocks contain no ingredient not in them also, and are peculiar mainly in their less proportion of silica. Moreover, the dioryte, noryte and augite-noryte are alike in containing the same bases in nearly the same proportions. The soda-granite differs in chemical constituents only through its mica, which indicates the presence of potash; but the other rocks also are often micaceous and contain in addition more or less orthoclase. Silica, alumina, iron protoxide, magnesia, lime, soda, potash, are all the essential ingredients obtained in analyses of these various rocks (excluding the magnetite, apatite, pyrrhotite* and pyrite); and it is not mysterious, therefore, that such rocks should be among the results of metamorphism.

The title of this paper might, therefore, well have been *Soda-granite, noryte, dioryte, hornblendyte, pyroxenyte, and various chrysolitic rocks made through metamorphic agencies in one metamorphic process.*

The geologist will nowhere on the continent find a more instructive spot for a day's walk than in the western portion of the Cortland region. Starting from Cruger's Station (37 m. from New York City), a walk of half a mile brings him to the western brick-yard shed; going north from here by a wood road carries him along section 3, and in less than a mile in a northerly direction (passing brick-yards at the end of it) he will reach Montrose Point and the chrysolitic rocks; following these around by the shore for about a mile he will then pass a brick-yard on the point, and beyond it find the norytes and chrysolite rocks together; a mile and a half more (passing on the route the large Verplanck ice-house) will take him to Broadway, in the village of Verplanck, near the foot of which street, on the shore, occur the limestone and its associated augitic and hornblendic rocks. Thus, in a distance of seven miles, he will see a wonderful diversity of rocks and facts. Possibly he may be convinced, at the end of the walk, that igneous eruption explains every thing. But let him go over this ground a second time more carefully, then trace the rocks of Verplanck Point northeastward, and afterward extend his walks in other directions over the Cortland region, and he may see enough to satisfy himself finally that, although there has been fusion and some eruption, it was not eruption from the earth's deeper recesses, like that which brought up trap (doleryte) through a series of great fissures for a thousand miles along the Eastern Atlantic border, from the Carolinas to Nova Scotia, all of it rock of one kind essentially, but eruption from less depths, not greater than the lower limits of a series of formations that were subjected together to foldings, fractures, and metamorphic change, and mostly far short of this.

The next subject is the distribution of the limestone areas of the county.

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* Pyrrhotite is the common iron sulphide of the norytes, hornblendyte, pyroxenyte and chrysolitic rocks, and it is abundant also in the mica schist that occurs interstratified with the Verplanck limestone.

[To be continued.]

ART. XXVI.—*The Permian and other Paleozoic Groups of the Kanab Valley, Arizona;* by C. D. WALLCOTT.

[Taken from the report of fieldwork by permission of the Director of the United States Geological Survey.]

THE Kanab Valley heads on the high divide between the Colorado and Salt Lake Basin, and extends southward, seventy miles, through Southern Utah and Northern Arizona to the level of the river in the Grand Cañon of the Colorado. It is somewhat open in its upper portion before entering the terrace Cañons of the White and Vermilion Cliffs. Opening out below the latter into a low broad valley, it breaks through the escarpment of the Shinarump Cliff, and narrowing a few miles to the south, enters the Cañon worn down through the Carboniferous and Silurian formations to the depths of the Grand Cañon.

During the field season of 1879 a detailed section was taken of the strata exposed along its entire course. The section embraces 13,300 feet of bedded rocks ranging in time from the Lower Tertiary to the Upper Primordial.

The strata are conformable by dip, although unconformity by planes of erosion occurs in several instances.

In the present note the Permian and other Paleozoic groups will be spoken of as they were observed south of the Shinarump Cliff and in the lower Cañon of the Kanab Valley.

The accompanying tabulation of the subdivisions of the Paleozoic gives the general stratigraphical features of this portion of the section.

The Permian group terminates above with ripple-marked, banded, reddish-brown, and chocolate-colored arenaceous shales and sandstone. A plane of unconformity by erosion separates it from the overlying Shinarump conglomerate, which is considered as the base of the lowest Mesozoic group. It is undoubtedly of Triassic age, but, as yet, this has not been determined by paleontological evidence in the Colorado Valley.

The chocolate arenaceous shales give way below to drab or lavender-colored arenaceous and gypsiferous marls and shales, that pass, midway of the group, into reddish-brown shales of the same general character. A thin stratum of impure limestone is intercalated in this bed forty-four feet above the summit of the lower division and fifteen feet above a band of impure shaly limestone. This band of limestone is of variable thickness and character, and forms the base of the upper division. Numerous fossils occur in it and the associated arenaceous layers.

The summit of the lower division was slightly eroded antecedent to the deposition of the limestone. The upper bed is a

PERMIAN. 855 feet.		PLANE OF UNCONFORMITY BY EROSION.
	Upper Permian. 710 feet.	Gypsiferous and arenaceous shales and marls, with impure shaly limestones at the base.
		PLANE OF UNCONFORMITY BY EROSION.
	L. P. 145 ft.	Same as upper division with more massive limestone at the base.
		PLANE OF UNCONFORMITY BY EROSION.
CARBONIFEROUS. 3,260 feet.	Upper Aubry. 835 feet.	Massive cherty limestone with arenaceous gypsiferous bed passing down into calciferous sandrock.
	Lower Aubry. 1455 feet.	Friable reddish sandstones passing into more compact and massive beds below. A few filets of impure limestone are intercalated.
	Red Wall Limestone. 970 feet.	Arenaceous and cherty limestone 235 feet, with massive limestone beneath. Cherty layers, coincident with the bedding, in the lower portion.
		PLANE OF UNCONFORMITY BY EROSION.
	Devonian. 100 feet.	Sandstones and impure limestones.
SILURIAN. 785 feet.		PLANE OF UNCONFORMITY BY EROSION.
	? 235 feet.	Massive mottled limestone with 50 feet of sandstone at the base.
	Tonto Primordial. 550 feet.	Thin-bedded mottled limestone in massive layers. Green arenaceous and micaceous shales 100 feet, at the base.

Entire thickness of Paleozoic, 5000 feet.

reddish-brown gypsiferous marl that becomes more arenaceous below, finally passing into a sandstone that rests on the chocolate and cream-colored limestone beneath. This has suffered extensive denudation by erosion and is now found only in patches from ten to twenty feet in thickness over limited areas, the sandstone filling the spaces between. Recent erosion has cut channels down through each to the formation beneath, which is a member of the Upper Aubry group. A slight plane of erosion with an entire change in the character of the rock separates the two groups.

The Permo-carboniferous of Mr. G. K. Gilbert* is the same as my lower division of the Permian. It is placed as a subdivision of the group, now that the beds above are known to be of Permian age.

The stratigraphy of the section shows a group separable into two divisions, defined above and below by planes of unconformity by erosion and a decided change in the character of the beds from those of the subjacent and superjacent formations. There is no physical break in the beds above the Permian limestone of the upper division before the conglomerate is reached. This stratigraphical arrangement is sustained by the evidence of the fauna found in the limestones and associated arenaceous layers in the upper division.

The genera *Myalina*, *Schizodus*, *Nucula*, *Aviculopecten*, *Murchisonia*, *Naticopsis* and *Goniatites* are represented in the lower chocolate-colored limestone. The fauna is distinct in specific character from that of the Carboniferous groups beneath, and more intimately related to that of the fossiliferous beds of the Upper Permian division. Mr. G. K. Gilbert obtained from this same horizon *Pleurophorus*, *Schizodus* and *Bakevellia* a group of shells, as he states, suggesting the Permo-carboniferous of the Mississippi Valley.†

Twenty-three genera represented by thirty-four species comprise the fauna of the upper division. Of these the following have strong Paleozoic relations: *Scolithus* ——*?*, *Lingula mytiloides*, *Discina nitida*, *Orthis* ——*?*, *Rhynchonella Uta*, *Terebratula* ——*?*, *Nucula*, 2 species, *Aviculopecten*, 3 species, *Myalina*, 4 species, *Naticopsis*, 2 species, *Pleurotomaria* ——*?*, *Macrocheilus* ——*?*, *Cyrtoceras* ——*?*, *Goniatites* ——*?*, and *Nautilus* ——*?*.

The Permian character of the fauna is more marked by the presence of *Pleurophorus*, 3 species, *Schizodus* ——*?*, 3 species of *Bakevellia* including *B. parva*, *Pteria* ——*?*, *Mytilus* ——*?*, *Rissoa* ——*?*, and the still more typical Mesozoic genera *Pentacrinus* and *Pileolus* ——*?*.

The Pentacrinus plates were discovered by Mr. Edwin E.

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* Wheeler Survey, West of the 100th Meridian, iii, p. 177, 1875. Also, see Arch. R. Marvin's Report in same, p. 213.

† Ibid. p. 177.

Howell, below the Shinarump conglomerate in Southwestern Utah. They belong to a species distinct from *P. asteriscus* of the Jurassic. Three species are now known to pass from the lower division to the limestone of the upper division.

The Permian character of the fauna, taken with the evidence afforded by the stratigraphy, clearly establishes the Permian as a well-defined and distinct group in the Colorado Valley. It occurs at the same horizon as the Permian determined by Mr. Clarence King in Northern Utah, Western Colorado, and Southern Wyoming, fully corroborating the views advanced by him of the age of the beds resting on the "Bellerophon bed" of the Upper Carboniferous.*

The Permian as found in the Kanab section undoubtedly extends to the west, east and southeast in Arizona and New Mexico.†

Mr. Jules Marcou referred the beds resting on the Carboniferous at the crossing of the Little Colorado to the Permian. He says:‡ "This formation, which is placed between the Carboniferous and the Trias, corresponds without doubt, to the magnesian limestone [Permian] of England." The proof of this was entirely stratigraphical, but Mr. Marvin's discovery of Permo-carboniferous fossils at the same horizon and locality, and on the same horizon of those obtained by Mr. Gilbert, which are known to have come from the lower division of the Permian, as given in the present note, tends to prove that Mr. Marcou was correct in his original reference of the beds he mentioned to the Permian and entitles him to the claim he asserts of adding a new member to the series of secondary rocks in North America, although, elsewhere, he includes a portion of the Upper Aubry group in his Permian.

The Carboniferous formation is divided into three great groups, Upper Aubry and Red Wall limestones with the intermediate Lower Aubry sandstones. The contained fauna is of the Coal-measure type, except near the base, where there is an assemblage of forms uniting a few coal-measure species with a much larger proportion of a Lower Carboniferous character.

The Carboniferous rests on the slightly eroded surface of the Devonian formation. The Devonian beds are very variable in character, and of little vertical range. At their greatest development, when increased by being deposited in a hollow of the limestone beneath, there is but 100 feet of purple and cream-colored limestone and sandstone passing into gray calciferous sandstone above. Over the knolls of Silurian limestone the

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* Exploration of the 40th Parallel, i. pp. 245, 246, and atlas maps of the same.

† Messrs. Marcou, Newberry, Shumard, Gilbert, Marvin and Howell all give information of this horizon.

‡ Pacific R. R. Report III, pt. iv. Resumé, p. 170.

upper beds alone extend with a thickness of from 10 to 30 feet. The purple sandstones deposited in the hollows of the Silurian limestone are characterized by the presence of Placoganoid fishes of a Devonian type. The Silurian limestone was extensively eroded antecedent to the deposition of the superjacent Devonian beds. Hollows 80 feet deep are seen that were worn in the evenly bedded strata. The upper 235 feet may belong to about the time of the Carboniferous group. The 450 feet of mottled limestone and 100 feet of arenaceous, micaceous shales is shown to be of Primordial age by the presence of *Lingulepis prima*, *Conocephalites* and *Bathyurus* in the upper portion, and *Hyolithes primordialis*, *Lingulepis*, *Crepicepalus*, and the species found above in the lower beds.

The missing Silurian groups may not have been deposited in this region, or, what is quite probable, their representatives were removed in the period of erosion that followed the close of the Silurian time, and has left traces of its action in the hollows and irregular surface over which the Devonian beds were spread.

ART. XXVII. — *Preliminary Account of a Speculative and Practical Search for a Trans-neptunian Planet*; by D. P. TODD, M.A., Assistant Nautical Almanac.

Introductory and Historical.

THE suggested probability, on scientific grounds, that there revolves about the sun a second planet exterior to the orbit of Uranus, is not new. So early as 1834, when the foremost astronomers of the day were by no means settled in their convictions that even the greater portion of the then rapidly increasing residuals in the longitude of Uranus was due to the perturbing action of a single exterior planet, Hansen is credited with expression of the opinion, in correspondence with the elder Bouvard, that a single planet would not account for the differences between theory and observation.* Dr. Gould, however, in his *Report on the History of the Discovery of Neptune*,† says, "I have the authority of that eminent astronomer himself [Hansen] for stating, that the assertion must have been founded on some misapprehension, as he is confident of never having expressed or entertained that belief." Professor Peirce's criticism of the investigations of LeVerrier, to the effect that his predicted orbit of Neptune was so widely discordant from its

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* Memoirs Royal Astronomical Society, vol. xvi, p. 388.

† Published by the Smithsonian Institution, 1850.

observed orbit as to indicate that his computations did not pertain to the actual disturbing planet, elicited from him the reply that the perturbations of Uranus due to a possible planet exterior to Neptune might readily cause an uncertainty of 5″ to 7″ in the fundamental data of his research.

In 1866, the Smithsonian Institution published the general tables of Neptune, by Professor Newcomb. In the investigation of its orbit the author proposed: "3. To inquire whether those motions [of Neptune] indicate the action of an extra-Neptunian planet, or throw any light on the question of the existence of such a planet." He concludes (page 73) that it is "almost vain to hope for the detection of an extra-Neptunian planet from the motions of Neptune before the close of the present century."

In 1873, the Smithsonian Institution published the general tables of Uranus, by Professor Newcomb. His success in the treatment of the theory of Uranus was such that astronomers generally may be said to have been satisfied, from the smallness of the longitude-residuals, that there existed no evidence of perturbative action upon Uranus other than that actually taken into account in the construction of the tables. It is well known, however, that since the publication of these tables the error of longitude has been on the negative increase, and the latest observations place the planet increasingly more in advance of its theoretic position.

Sometime in the spring of 1874, the first preliminary outline of the very simple method which I have here employed in the treatment of planetary residuals with reference to exterior perturbation, suggested itself to me. For more than three years, very little opportunity offered for consideration of the problem of a trans-neptunian planet, and I gave it merely desultory attention. In August, 1877, however, I began to devote the larger portion of my leisure time to the theoretic side of the question. It was soon evident that no certain hold upon any possible cause of exterior perturbation could be obtained from the residuals of Newcomb's tables. And I may remark here that I have consequently chosen the term *speculative* rather than *theoretic* as applying more fitly to the investigation which preceded the actual telescopic search.

The Speculative Search.

While the magnificent researches of LeVerrier and Adams on the perturbations of Uranus are masterpieces of analytic skill, I felt that they should not be taken as models in the present investigation—for two reasons:

(1) The residuals of longitude which must form the basis of

the investigation are not sufficiently well marked to justify the execution of so laborious a research, especially if it be found that a simple, rational treatment, unencumbered with the refinements of analysis, may be fairly interpreted as indicating the position of an exterior perturbing body with merely a rough approximation.

(2) Even in the case of Uranus, and the theoretic search for Neptune, where the residuals of longitude were very strongly marked, many of the elements pertaining to the disturbing planet which Adams and LeVerrier sought to determine theoretically, turned out afterward, when their real values became known, to have been indicated with only meagre precision. Much less should we now expect these elements to be given with any certainty in the case of a planet exterior to Neptune.

I was also much impressed by a remark in Sir George Airy's *Account of some Circumstances historically connected with the Discovery of the Planet exterior to Uranus*—"I have always considered the correctness of a distant mathematical result to be a subject rather of moral than of mathematical evidence."*

This provisional treatment of the residuals of Uranus was undertaken, then, as a preliminary to the proposed telescopic search, to determine whether that search was worth undertaking; and, if so, at what point, approximately, it was best to begin. I should remark, also, that this portion of the work, as an investigation to these ends, was never undertaken with reference to publication.

I.—Let us now consider, seriatim, the errors of the elements of the perturbed planet—errors which the very hypothesis of a disturbing body introduces, and which must have entered into the tables of the inferior planet, as constructed independently of unknown exterior perturbation: we consider what the effect of these errors may be, and how far it may be eliminated or subtracted from the residuals of the actual theory of the planet. These residuals are, of course, first corrected for any known error of theory or tables, or erroneous masses of known perturbing planets.

(1) *The error of mean distance of the perturbed planet.*—Any error of radius vector enters very largely into the residuals of heliocentric longitude, if the observations are made at any considerable interval from the planet's opposition. If it is suspected that the error of radius vector will vitiate the residuals of longitude, we may avoid its effect by passing to residuals of geocentric longitude. Or, we may confine our research to the mean residuals of observations near the opposition-points, and symmetrically placed with reference thereto. The effect of erroneous radius vector is thereby eliminated.

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* Memoirs Royal Astronomical Society, vol. xvi, p. 398.

(2) *The error of periodic time of the perturbed planet.*—If the residuals are examined graphically, the eye will readily detect whether any correction to the periodic time is advisable. If, in general, the mean line of the residuals is nearly a right line, and makes a given angle with the line of zero-residual, it may fairly be concluded that the residuals need a correction depending directly on the time, the magnitude of the coëfficient of which is indicated by the divergence of the two residual-lines.

I had considered the problem only thus far when it occurred to me to apply the method, only partially developed, to the determination of an approximate position of Neptune from the residuals of Bouvard's Tables of Uranus, published in 1821. Taking also the residuals from observations up to 1824, and not permitting myself a knowledge of the longitude of Neptune at any epoch, a very little labor gave me an approximate position of the disturbing planet from which, it now appears, Neptune might easily have been found some twenty years in advance of its actual discovery.

When my work had advanced to this stage, a mere chance threw in my way a copy of Sir John Herschel's *Outlines of Astronomy*, (which I had never before examined): I at once observed that my treatment of the residuals of Uranus with reference to a planet exterior to Neptune was quite similar to his "dynamical" exposition of the perturbations of Uranus arising from Neptune itself. And I was further gratified to find that he had given a very full and lucid statement of the effect upon the longitude-residuals caused by errors of the third and fourth elements of the perturbed planet—the error of eccentricity, and the error of longitude of perihelion. I therefore adopted, without hesitation, the continuance of the graphical method therein detailed; and shall do no more here than to refer to the pages of Herschel's treatise where these elements are dealt with.

(3) *The error of eccentricity of the perturbed planet.*—(See Sir John Herschel's *Outlines of Astronomy*, page 536.

(4) *The error of longitude of perihelion of the perturbed planet.*—(Ibid., page 537.)

When the longitude-residuals have been corrected in this manner, we proceed on the assumption that any outstanding residuals are due to unexplained exterior perturbation.

II.—Of the seven elements of the disturbing planet, we must assume a value of one: the values of three others, together with the mass of the disturbing planet, we may consider as theoretically determinable from the longitude-residuals themselves.

(1) *The mean distance of the disturbing planet.*—Regarding

the next order of distance beyond Neptune as occupied by the planet for which we are searching, I assumed, as a first value of mean distance, $a=46{\cdot}0$: this value seemed to be indicated by a fair induction. The periodic time of the planet would then be 312 years, and conjunctions with Uranus would occur nearly at intervals of 115 years.

(2) *The eccentricity of the disturbing planet.*—Even with the large residuals of Uranus employed in the investigations of LeVerrier and Adams, the derived value of the eccentricity of Neptune was entirely illusory. The several values of eccentricity of Neptune resulting from their investigations are as follow:

Adams (*first hypothesis*)	0·16103
LeVerrier	0·10761
Adams (*second hypothesis*)	0·120615

The eccentricity given by investigation of the orbit of Neptune from observations of the planet was:

Newcomb (*Tables of Neptune*)	0·0089903

We should, therefore, expect nothing of any attempt to arrive at the eccentricity of an orbit exterior to that of Neptune.

(3) *The longitude of perihelion of the disturbing planet.*—Much the same remark obtains in reference to this element. The several values of longitude of perihelion of Neptune, resulting from the researches on perturbations of Uranus, are as follow:

Adams (*first hypothesis*)	315° 57′
LeVerrier	284° 45′
Adams (*second hypothesis*)	299° 11′

The longitude of perihelion given by observations of the planet is:

Newcomb (*Tables of Neptune*)	46° 6′ 39″·7

Evidently it would not be wise to include this element in the investigation.

(4) *The epoch of the disturbing planet.*—If we can obtain even a rough approximation to the value of this element, the end of the investigation is fully attained. An inspection of the outstanding residuals, graphically exhibited, will show. without further labor, the epochs of maximum disturbance. The best that can be done will be to prepare an approximate perturbative curve, the epochs of maximum disturbance of which shall be in harmony with the assumption of mean distance of the exterior planet. By applying this to the plot of outstanding residuals, we may decide at what points the appli-

cation of the perturbative curve best accounts for them. The amount of excursion in the several sinuses of the perturbative curve we need not for this purpose attend to with any great care: this will depend upon the mass and distance of the disturbing planet; and, that it will be unavailing to attempt any determination of the mass in the present case will be evident from the fact that the mass of Neptune, from the theoretical investigations of LeVerrier and Adams, was widely discrepant:

Adams (*first hypothesis*)	0·0001656	$\frac{1}{6039}$
LeVerrier	0·0001075	$\frac{1}{9300}$
Adams (*second hypothesis*)	0·00015003	$\frac{1}{6666}$

While the most reliable mass of Neptune from observation is:

Newcomb (*motion of the satellite*)	0.00005160	$\frac{1}{19380}$

We have thus reduced the inverse problem of perturbation to a very simple, rational form. The residuals of longitude of Uranus were next treated in accordance with this method.

In his *Investigation of the Orbit of Uranus*, Newcomb presents three series of residuals: the mass of Neptune finally adopted in the tables, $\frac{1}{19700}$, corresponds very nearly to the mean of the first and third series. But the mass of Neptune which was employed in this investigation is that given by Newcomb's discussion of the motion of the satellite of Neptune, and is $\frac{1}{19380}$. Our first step, then, was to correct these mean residuals into accordance with this adopted mass. The following table presents the date, the mean residuals, the correction for mass, and the corrected mean residuals.

Date.	$\frac{1}{2}(\Delta_1 l + \Delta_3 l)$.	Mass-correction.	Σ.
1691.0	−11″	+3″	−8″
1715.2	− 8.5	+1.9	−6.6
1751.1	+ 2.8	−0.7	+2.1
1769.0	− 1.5	+1.5	0.0
1783.3	− 0.17	+2.58	+2.41
1790.0	+ 0.76	+2.27	+3.03
1795.0	− 0.36	+1.73	+1.37
1802.0	− 1.06	+0·72	−0.34
1806.5	− 0.86	+0.09	−0.77
1810.5	− 0.21	−0.32	−0.53
1814.5	− 0.32	−0.64	−0.96
1819.5	− 0.37	−0.79	−1.16
1824.8	+ 1.45	−0.79	+0.66
1829.7	+ 0.86	−0.76	+0.10
1835.2	− 0.37	−0.77	−1.14
1839.8	− 0.33	−0.82	−1.15
1844.8	− 0.02	−0.93	−0.95
1849.9	− 0.37	−1.08	−1.45
1854.9	− 0.25	−1.20	−1.45
1860.0	− 0.14	−1.27	−1.41
1865.0	+ 0.49	−1.24	−0.75
1870.0	+ 0.12	−1.05	−0.93

The numbers, then, in the column Σ, taken in connection with the corrected residuals given by observations up to 1877, formed the basis of the subsequent investigation. I need only state here that, examining these residuals according to the method just related, in reference to unexplained perturbing action, I concluded that Uranus was in conjunction with an exterior perturbing body between the years 1780 and 1795, and that another conjunction would take place at some time before the close of the present century. The most probable position of the exterior planet I therefore considered to be about 170° of longitude: the probable error of the position I estimated to be, roughly, 10°. This result was reached on the morning of the 10th of October, 1877. During the few days immediately following, I reviewed this examination, as much as possible independently of the previous result, and at the same time varying the assumed mean distance. With a value of $a = 52.0$ (which I finally considered inductively the most probable) I set down the longitude of the exterior planet equal to $162° \pm 6°$: this result was reached on the afternoon of the 14th of October. I now turned my attention toward a similar treatment of the residuals of Neptune, with a slight hope of getting a confirmatory result: two suppositions agreed in fixing the longitude at about 180° and 200°, respectively. I therefore, on some day in the latter part of October, 1877, wrote down as the exposition of all my enquiry, the following results:

EXTERIOR PLANET.—Longitude (1877·84), 170° ± 10°
Mean distance from the sun, 52·0
Period of revolution about the sun, 375 yrs.
Mean daily motion, $9''\cdot46$
Angular diameter, $2''\cdot1$
Stellar magnitude, 13+
Longitude of ascending node, 103°
Inclination of orbit to ecliptic, 1° 24′

To the determination of the four latter results I shall allude presently. I may now add that this result for longitude of the exterior planet is sustained by observations of Uranus up to and including the late opposition. If a new, disturbing planet really exists in the longitude here indicated, nearly a century must elapse before its existence can be asserted at all positively from residuals of Neptune alone.

The Practical Search.

I should never have been able to execute the telescopic search consequent upon the investigation just related, had it not been for the courteous offices of Rear Admiral Rodgers, Superintendent of the Naval Observatory, and Professor Hall, in charge of the great refractor. It was with this instrument—the 26-inch equatorial—that the search was conducted, beginning on the night of the 3d of November, 1877. It seemed to me that I should begin the search at a point about 20° preceding that indicated as the most probable position of the planet, and continue it to a point following by the same distance. But a careful search extending over a zone of this length, and of sufficient width to be certain to contain the supposable planet would be a work of such magnitude that I could not expect its completion under several years. I therefore had recourse to an inductive determination of the inclination and longitude of node of the planet's orbit.

I computed anew the position of the invariable plane of the solar system. A differential comparison of its inclination with the inclinations of the orbits of the major planets gave, with little uncertainty so far as the mere induction was concerned, the inclination of the orbit of the trans-neptunian planet equal to 1° 24′. Similarly I obtained for the longitude of node, though not so certainly, 103°. For the preliminary search, I determined to fix the latitude-limits of the zone at a width of one degree to the north, and one degree to the south of this adopted plane. To these elements I strictly adhered,—with the intention, however, of alternately increasing and decreasing the inclination, and varying the longitude of node, if I should arrive at no successful result from the search of this limited zone.

I may remark that the detailed plan of the instrumental search had been completely digested and written out as early as the 5th of September. To assist in a decision as to what method of search I should employ, I had recourse to an inductive consideration of the real diameters of the known planets of the solar system: I need only mention here that I arrived at the result that a diameter of 50,000 miles might be taken as the minimum value for a planet next beyond Neptune. On this assumption, the mean distance of 52·0 gave for its apparent diameter 2″·1. I did not, therefore, hesitate in adopting the method of search depending upon the detection of the planet by contrast of its disk and light with the appearance of an average star of about the thirteenth magnitude. I considered a magnifying power of 350 diameters sufficient for the detection of a disk of this diameter: in the actual search, a power of 600 was often employed, but most of the search was conducted with a power of 400 diameters.

On thirty clear, moonless nights, between the 3d of November, 1877, and the 5th of March, 1878, this search was carried on after the manner I have indicated.

After the first few nights, I was surprised at the readiness with which my eye detected any variation from the average appearance of a star of a given faint magnitude: as a consequence whereof my observing-book contains a large stock of memoranda of suspected objects. My general plan with these was to observe with a sufficient degree of accuracy all suspected objects. On the succeeding night of observation these objects were re-observed: and, at an interval of several weeks thereafter, the observation was again verified. At 3 A. M., the 6th of March, 1878. the search was discontinued—my observing-book ends with the following note:

"The adopted plane of orbit of trans-neptunian planet is now searched (without break) from

$$v = 146°{\cdot}8$$
$$\text{to } v = 186°{\cdot}1."$$

I have much confidence in this telescopic search—my aim was to sweep the zone so carefully that there should be no pressing need of duplicating it. If a trans-neptunian planet of an apparent diameter so great as 2″ is ever discovered, I shall be much surprised if it is found that it must have eluded my search.

Very soon after the termination of this search, I received the new tables of Uranus, by the late LeVerrier.* I at once instituted a treatment of the residuals of these tables after the method employed with those of Newcomb. I merely mention here that I reached a result entirely confirmatory to that previously obtained. The residuals were first reduced to Newcomb's mass of Neptune.

I ought not to conclude this paper without adverting to the apparently long delay of its publication. From the very beginning, I had approached the entire problem of search for a trans-neptunian planet with resolute direction toward the end which I regarded of the highest scientific import—that of *finding the possible planet at the earliest moment:* if I were successful, observations of its position would then be secured at once, and an accurate determination of its elements would be a matter of earlier realization—it seeming improbable that any prior chance-observation would ever be brought to light. After pursuing the theoretic side of the question for a short time, I saw clearly that many years must elapse before the perturbing action of this body on any interior planet would afford anything like pronounced evidence of its existence: recourse must be had to the practical, telescopic search. So I tarried longer with the residuals of Uranus only in the hope of a possible shortening of the search by some indication that the

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* Annales de l'Observatoire de Paris, Mémoires, vol. xiv.

planet was more probably in one portion of the heavens than in another. After the telescopic search which I was conducting had been temporarily brought to an end, by circumstances beyond my control, I was not without hope of effecting some arrangement whereby I might resume the search at an early day, and carry it to a satisfying conclusion. After much thought upon the apathetic reception with which the magnificent researches of Adams and LeVerrier had met, I reached the conclusion that no competent observer would be led to continue the search through knowledge of the little work of speculation that I had done. And, as the work was undertaken with the end always in view of finding the planet, I saw no good to come from its publication.

It will be remarked that this matter now assumes a very different aspect: the publication of a recent memoir *On Comets and Ultra-Neptunian Planets*, by Professor George Forbes, of Glasgow, assigns, by a method of investigation entirely independent of my own, a position to a possible trans-neptunian planet which may be regarded as in exact coincidence with that which I have deduced. The assumption of a mean distance 100, indicated in Professor Forbes' paper, will not appreciably destroy the representation of the residuals with which I have dealt. I have not yet been able to convince myself that the remarkable harmony of the results of the two investigations is simply a chance agreement; and, with the hope that the accumulated evidence of the existence of a far exterior planet may not fail to incite some observer in possession of sufficiently powerful telescopic means to a vigorous prosecution of the search, I have prepared this preliminary paper in order that attention may be called to the matter in sufficient advance of the now approaching opposition-time. I may add here that, should a careful and protracted search of the region adjacent to the indicated longitude prove unavailing, no more certain test of the existence of a trans-neptunian planet admits of application within the next few years than that of telescopic search of a limited zone extending entirely around the heavens—a search which I have been hoping, for more than two years past, for an opportunity to undertake, but which I see no present prospect of realizing.

Nautical Almanac Office, Washington, August 4, 1880.

ART. XXVIII.—*Notice of Jurassic Mammals representing two New Orders*; by O. C. MARSH.

IN addition to the Mammals from the Jurassic deposits of the Rocky Mountains, already described by the writer,* a number of other specimens have since been discovered. Some of these add materially to our knowledge of those previously found, and others are different from any now known.

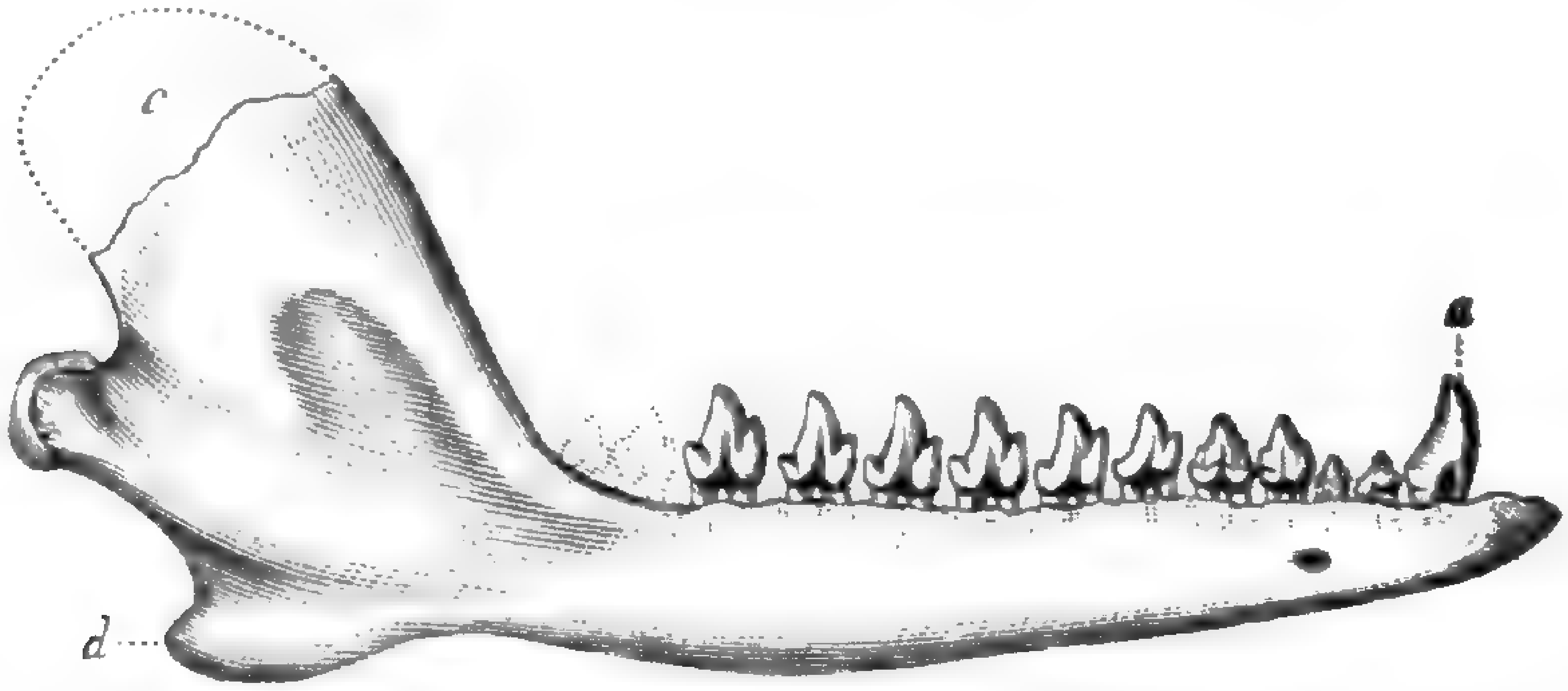
This new material is all from the Atlantosaurus beds, in essentially the same horizon which furnished the earlier specimens. The general resemblance of the American forms to those from the Purbeck of England becomes still more evident in the remains here described.

Diplocynodon victor, gen. et sp. nov.

One of the largest mammals yet discovered in the Jurassic beds of this country or of Europe is represented by various remains of several individuals, found in the same locality. The most characteristic of these specimens is a right lower jaw, with most of the teeth in position, and well preserved.

The general characters of this jaw are well shown in the figure below.

1.



Right lower jaw of *Diplocynodon victor*, Marsh. Outside view; twice natural size. *a*, incisor; *b*, condyle; *c*, coronoid process: *d*, angle.

This jaw is quite distinct from anything hitherto described, and exhibits several characters of special interest. There were at least three incisors, directed well forward. The canine is very large, and is inserted by two fangs. This important fact has suggested the name of the genus. The molar series consists of no less than twelve teeth, all essentially the same in form, and each inserted by two fangs. There are apparently six premolars. The second of these is smaller than the first, and the others gradually increase in size. The last true molar was smaller than the others. The crowns of these teeth are

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* This Journal, vol. xv, p. 459, 1878; vol. xviii, pp. 60, 215 and 396. 1879.

composed of a main external cone, with a small elevated lobe in front, and a lower one behind. This is repeated on a reduced scale on the inner side, except that the posterior small cusp is rudimentary or wanting. The antero-posterior faces of the crown are deeply excavated, and grooved. There is no cingulum.

The jaw is elongate, and gently curved below. The coronoid process is large and elevated. The condyle is placed very low, nearly on a line with the teeth. The angle of the jaw is produced into a distinct process, the lower margin of which bends outward, although the process as a whole has a slight inward direction, which may be due to pressure.

A second specimen, apparently of the present species, is a left upper jaw, with the canine and eight succeeding teeth in excellent preservation. The canine is very large, and has two distinct fangs. The molar teeth have one main external cone, and two lateral cusps, which rise from a strong basal ridge. On the inner side, there is one main cone, with a small posterior heel. The outer face and the sides of the upper molars are deeply sculptured with irregular grooves.

Stylacodon validus, sp. nov.

Since the discovery of the type of this genus,* two other allied specimens have been brought to light, one of which, also a lower jaw, proves to be new. This indicates a species much larger than the one first described, but apparently belonging to the same genus. The molar teeth in this jaw are inserted by a single fang. The anterior premolars preserved have each two fangs. All the molar series in place have elevated conical crowns, raised some distance above the outer margin of the jaw. They have one main external cone and three inner cusps, thus agreeing in general form with the molars of *Dryolestes*. The mylohyoid groove is distinct, and continues forward nearly to the symphysis.

Some of the dimensions of this specimen are as follows:

Space occupied by eight anterior molar teeth,	10·0mm
Depth of jaw below first lower premolar,	3·0
Depth of jaw below fourth premolar,	3·5
Height of crown of fourth premolar,	2·0

Tinodon ferox, sp. nov.

An interesting specimen of the genus *Tinodon*, about twice as large as the type, is a right lower jaw, with most of the teeth in position. There are three premolars of the usual form, and apparently four molars. The premolars have one main cone, pointed and compressed, with a low faint cusp in front, and a high larger one behind. The last premolar is very large. The

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* This Journal, xviii, p. 60, July, 1879.

penultimate molar has four distinct cones instead of three. The canine was large, and directed well forward. The coronoid process is large, and inclined backward. The mylohyoid groove is nearly parallel with the lower margin of the jaw, and extends forward to the symphysis. The latter is large, and elongate.

The main measurements of this specimen are as follows:

Extent of lower molar series,	14·5$^{\text{mm}}$
Space occupied by premolars,	7.0
Depth of jaw below canine,	3.0
Depth of jaw below last premolar,	3·5
Depth of jaw below last molar,	4·0
Antero-posterior diameter of penultimate molar,	3·0
Height of crown,	2·5

Triconodon bisulcus, sp. nov.

Two or three fossil jaws in the Yale Museum agree so closely with the *Triconodon*, of Owen, from the Purbeck of England, that they may be provisionally placed in that genus. One of these specimens is a right lower jaw, with several teeth in good preservation. The molar teeth differ from those of the typical *Triconodon* in having the middle cone larger than the other two. The penultimate molar is the largest of the series. The angle of the jaw is not inflected, but the outer margin of the angle is developed into a rounded ridge. On the inner side, there is a strong sharp ridge running from the inlet of the dental canal backward to the condyle. The mylohyoid groove is well marked, and there is a second deep downward-curved groove beneath it.

The size of this specimen is indicated by the following measurements:

Space occupied by three last molars,	8·0$^{\text{mm}}$
Antero-posterior extent of last molar,	2·0
Depth of jaw below last molar,	4·0
Antero-posterior extent of penultimate molar,	2·5
Height of crown,	2·0
Depth of jaw below last premolar,	3·0

Dryolestes obtusus, sp. nov.

Additional specimens of *Dryolestes* show that this genus possessed a peculiar dentition. There were no less than twelve teeth in the lower jaw behind the canine, and at least eleven in same series above. The upper molars had three external cones and one inner cusp, and this order was reversed in the lower molars. There was no cingulum above or below. The canines were small.

The specimen on which the present species is based is a left upper jaw, with the molar series nearly complete. The crowns of the true molars differ from those in typical specimens of *Dryolestes* in having the cusps blunted, making the crowns unusually short. Another important difference is that the tooth which may be regarded as the last premolar is so much larger than the rest of the series that it projects far beyond them. The line of the true molars is much curved outward.

Some of the dimensions of this upper jaw are as follows:

Space occupied by eleven posterior teeth,	12·0^{mm}
Extent of seven posterior teeth,	8·0
Projection of last upper premolar from jaw,	2·0

Ctenacodon serratus, Marsh.

Additional remains of this interesting form have made clear some points in the structure of the lower jaw which the type specimen did not show.* The left lower jaw, represented in figure 2, agrees so closely with that specimen in size and general features, that it must be referred to the same species. The symphysial portion is very short, and nearly round. The inlet of the dental canal is quite large, and enters the jaw beneath a fold that curves downward, and passes into the inflected lower margin of the angle. The latter is distinct from the condyle, not identical with it as in *Plagiaulax*. The coronoid process is of moderate size, and directed well backward.

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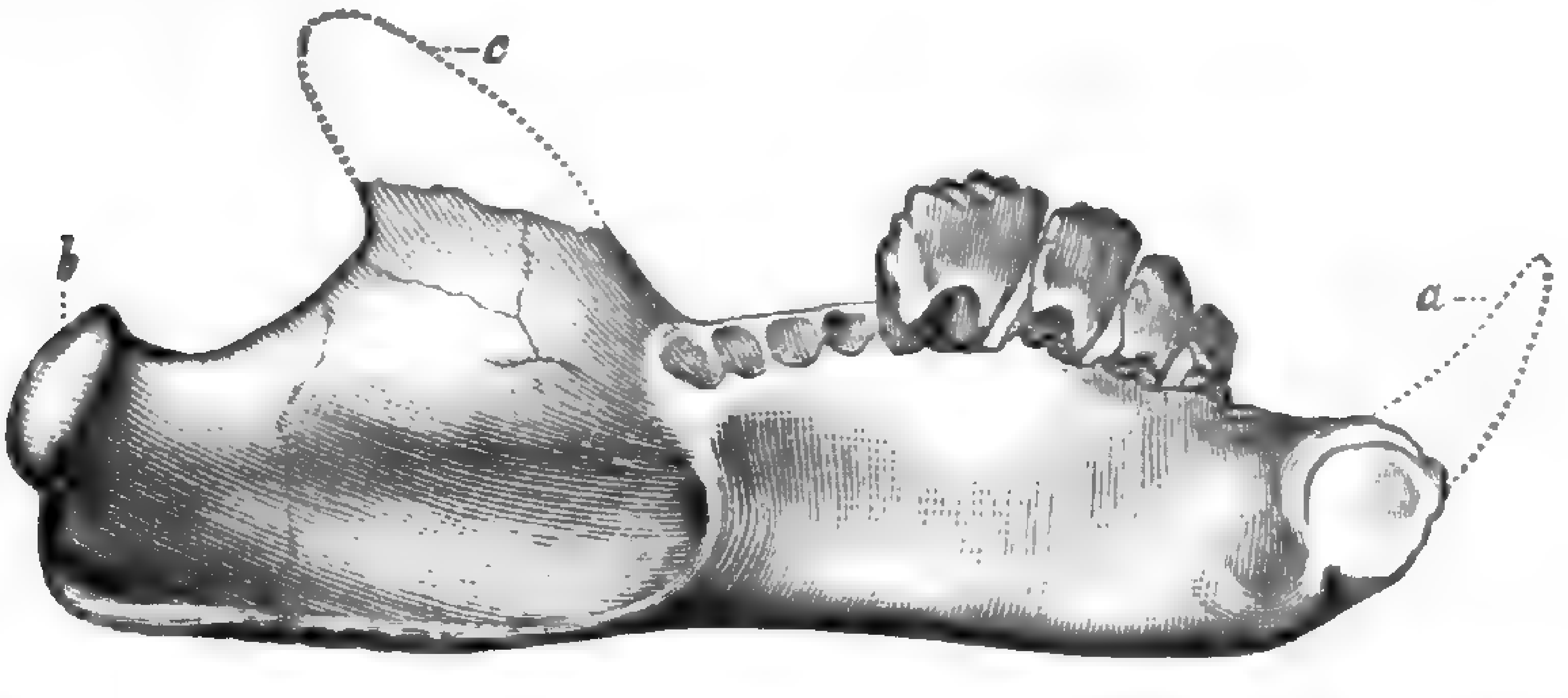

Left lower jaw of *Ctenacodon serratus*, Marsh. Inner view, four times natural size.

Mesozoic Mammals have been very generally referred hitherto to the *Marsupialia*. An examination of all the known remains of American Mesozoic Mammalia, now representing upwards of sixty distinct individuals, has convinced the writer that they cannot be satisfactorily placed in any of the present orders. This appears to be equally true of the European forms which the writer has had the opportunity of examining. With a few possible exceptions, the Mesozoic mammals best preserved are manifestly low generalized forms, without any distinctive Marsupial characters. Not a few of them show

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* This Journal, vol. xviii, p. 396, Nov., 1879.

features that point more directly to Insectivores, and present evidence, based on specimens alone, would transfer them to the latter group, if they are to be retained in any modern order. This, however, has not yet been systematically attempted, and the known facts are against it.

In view of this uncertainty, it seems more in accordance with the present state of science, to recognize the importance of the generalized characters of these early mammals as at least of ordinal value, rather than attempt to measure them by specialized features of modern types, with which they have little real affinity. With the exception of a very few aberrant forms, the known Mesozoic mammals may be placed in a single order, which may appropriately be named *Pantotheria*. Some of the more important characters of this group would be as follows:

(1.) Cerebral hemispheres smooth.
(2.) Teeth exceeding, or equalling, the normal number, 44.
(3.) Premolars and molars imperfectly differentiated.
(4.) Canine teeth with bifid or grooved fangs.
(5.) Rami of lower jaw unankylosed at symphysis.
(6.) Mylohyoid groove distinct on inside of lower jaws.
(7.) Angle of lower jaw without distinct inflection.
(8.) Condyle of lower jaw near or below horizon of teeth.
(9.) Condyle vertical or round, not transverse.

The generalized members of this order were doubtless the forms from which the modern specialized Insectivores and Marsupials, at least, were derived.

Another order of Mesozoic mammals is evidently represented by *Plagiaulax*, the allied genus *Ctenacodon*, and possibly one or two other genera. These are all highly specialized aberrant forms, which apparently have left no descendants. This order, which may be termed the *Allotheria*, can be distinguished from the previous group by the following characters:

(1) Teeth much below the normal number.
(2) Canine teeth wanting.
(3) Premolar and molar teeth specialized.
(4) Angle of lower jaw distinctly inflected.
(5) Mylohyoid groove wanting.

These characters alone do not indeed separate the *Plagiaulacidæ* from some of the Marsupials, and future discoveries may prove them to belong in that group, where they would then represent a well marked sub-order.

Yale College, New Haven, August 7th, 1880.

SCIENTIFIC INTELLIGENCE.

I. Physics.

1. *Terrestrial Magnetism.*—Professor Balfour Stewart, in a letter to Nature, July 1, 1880, discusses the connection between auroras and magnetic storms. Since we have changes produced in stationary strata by a moving magnet, cannot the reverse be true? May we not have discharges produced in moving strata by a stationary magnet? The sun in this case would by convection currents produce changes in the atmospheric strata and the earth as a permanent magnet would cause electric disturbances, which in turn would react upon terrestrial magnetism. Working on this hypothesis Balfour Stewart has been led to the fact "that certain magnetic diurnal changes lag behind corresponding solar changes, just as meteorological changes would do," and he also states that his observations up to the present appear to show that an increase or decrease of solar activity corresponds to an increase or decrease of both magnetic and meteorological activity. The probability of a progress of magnetic phenomena from west to east, corresponding in character to a progress of meteorological phenomena is alluded to. Magnetic weather appears to travel faster, however, than meteorological weather. J. T.

2. *On the Reversal of Photographic Impressions.*—M. J. Janssen has discovered that photographic images can be made to pass from negative to positive by the prolonged action of the same light which produced them originally. At Meudon solar photographs are obtained with an exposure of about $\frac{1}{1000}$ of a second. These photographs show the granulations of the photosphere. With gelatine bromide of silver plates the time of exposure is in the neighborhood of $\frac{1}{20000}$ of a second. If, however, one of these dry plates receives an impression of light during a half a second or one second—that is to say, during a time ten to twenty thousand times longer than that which gave the first impression, the developer reveals a positive image giving the disc of the sun in white and the spots in black. This positive image can be obtained as distinct as the negative image which it replaces. A certain intermediate length of exposure gives an image intermediate between a negative and positive image, and the plate presents a sensibly uniform tint. If one allows the light to act for some time after the positive image is produced, this last image disappears in its turn and the developer causes no metallic deposit to be formed upon the image, which appears uniformly transparent upon the black background of the sky. This dark background disappears under the prolonged action of the light. A complete discussion of the results obtained is promised.—*Comptes Rendus*, No. 25, p. 1447, June 21, 1880. J. T.

3. *Electro-magnetic Rotation of the Plane of Polarization of Light in Gases.*—H. A. Kundt and H. W. C. Röntgen continue their research upon this subject, using a Gramme machine instead

of a battery. They remark that the current from the latter was sufficiently constant. In order to show, however, the fluctuations in current caused by irregularity in the contact of the brushes of the machine, and want of constancy in the speed of rotation, they enclosed a tube filled with bisulphide of carbon in a coil; polarized light was sent through this tube and the light was afterward viewed by means of a spectroscope. The apparatus was so arranged that a dark band appeared in the midst of the spectrum. This band or stripe moved to and fro with the fluctuations of the current. The authors state that this method is very suitable to convince one of the fact of variations in the current which the inertia of the galvanometer needle masks. The telephone has been used in America for the same purpose. It appears from their results that hydrogen, nitrogen and atmospheric air show nearly the same change of polarization. They do not find a simple relation between the rotation of the plane of polarization and the indices of refraction of the gases which were submitted to examination. The expression $\frac{d}{n^2(n^2-1)} =$ a constant, in which d is the rotation, and n the index of refraction, an expression given by Becquerel (Ann. de Chim. et de Phys., (5) 12, 1877), they do not find to be correct, although they believe that the index of refraction has great influence upon the result; of no less importance, however, is the diamagnetic induction constant. The authors find that their later results with hydrogen and carbonic oxide agree with their earlier ones, but they do not find this agreement in the case of oxygen and atmospheric air.—*Wied. Annalen der Physik und Chemie,* No. 6, p. 257, 1880. J. T.

II. GEOLOGY AND NATURAL HISTORY.

1. *Geological relations and fossil remains of the Silurian Iron ores of Pictou, Nova Scotia.*—Dr. J. W. Dawson, in the Canadian Naturalist (vol. ix, No. 6), gives an account of these ore beds with lists of fossils, and reaches the conclusion that the beds probably do not reach as far up as the Oriskany group (his former published view), but correspond in age with the upper beds at Avisaig, which are Upper Silurian. "These deposits of iron ore apparently began locally in an early part of the Upper Silurian period, and were continued into the Lower Helderberg period, while in the western part of Nova Scotia, in the Nictaux district, we have evidence of their continuation into the Oriskany age." There is no representative of the Niagara limestone in the region, a general fact in Nova Scotia, and along the Atlantic margin of North America, though present farther west in Northern New Brunswick, and in Gaspe.

2. *DeCandolle's Phytography.* (Notice continued from the preceding (August) number.)—We proceed with our remarks upon this interesting volume, taking up certain points as they strike attention in turning the pages, but passing over many others of equal or superior importance.

There is a short chapter upon enigmatical descriptions or botanical riddles, and how they come about. The author has taken the pains to collect and tabulate the "species dubiæ" of the last four volumes of the Prodromus, to see who is accountable for them, taking into account only botanical authors no longer living, and excluding those who have contributed no more than three. So good a botanist as Blume heads the list, one so indifferent as Siebold is accountable for the fewest; so not much comes from such a tabulation. The practical point is that Blume, as well as Miquel and Kunth, who stand high on the list, have fallen much into the habit of founding species on fragmentary or quite insufficient herbarium specimens; instead of passing them over without mention, or at least without naming them. One is apt to suppose that a description of an incomplete specimen, say without flowers, may be readily eked out later by another hand supplied with the missing parts. This, as DeCandolle says, is a mistake. The succeeding botanist is hindered more than he is helped by such work. And it is the same with species founded on figures, such, for instance, as those of Moçino and Sesse, upon which the elder DeCandolle established species and some genera in the earlier volumes of the Prodromus. As to "*genera dubia vel non satis nota*," very few can be laid at the door of first class botanists. In the list of names of deceased botanists which are notable for their absence, the name of Torrey is inserted between that of the elder DeCandolle and that of the elder Hooker.

In the chapter on the description of groups superior to species, the author enumerates and sketches the character of the six *Genera Plantarum* which have appeared within the 180 years of modern botany; the immortal works of Tournefort (*Institutiones*, 1700), Linnæus (the first edition of whose *Genera* was published in 1737), A. L. Jussieu (1789), Endlicher (1836–1840), Meisner (1836–43, which is much less known), and finally of Bentham and Hooker, which began in 1862, and is now three-quarters finished. Tournefort fixed the rank and character of genera, Linnæus tersely and clearly defined them, Jussieu arranged them under natural orders, defining these; Endlicher and Lindley developed the hierachy of groups superior to orders, also the tribes inferior to them, and the latter is deservedly praised for his sagacity in discerning affinities, the former for the perfection of his style; and to Bentham and Hooker is justly awarded the crowning merit of having, far beyond their predecessors in this century, verified or developed the characters of the genera by a wide and direct study of the herbarium materials.

Floras, or descriptions of natural groups, not in their entirety but so far only as represented in a particular country or region, are discussed in Chapter X. In floras, as in more general works, abridged descriptions or diagnoses suffice, indeed are preferable in all cases where the region has been pretty well explored, and where the materials can be thoroughly elaborated. Formerly all considerable floras were written in Latin, at least the characters.

So they would continue to be if the convenience of botanists and the advancement of science only were to be considered. But floras are used by many to whom even Linnæan Latin would be a stumbling block. Fortunately the difference between good botanical English and botanical Latin is not wide, and will not seriously trouble a French or German botanist. The converse hardly holds. The greatest flora written in English, we might say the best great flora in any language which has ever been produced and completed, is Bentham's *Flora Australiensis*, in seven octavo volumes. Touching upon works of special illustration, the Botanical Magazine is justly singled out for praise, for sustained botanical correctness under difficulties, and for its great influence upon the science.

DeCandolle insists much on the importance of describing and well classifying the varieties of a species, and of distinguishing them as much as possible into grades, such as subspecies or races, varieties, subvarieties, &c. We suggest that this can be done with great advantage only when the forms are comparatively definite, or have been described as species. We think that only the more salient and definite varieties should be distinguished by names; otherwise the names and the groups will be limitless.

In the eleventh chapter, on partial descriptions of groups from the point of view of organography (a term which our author prefers to morphology), of physiology, botanical geography, &c., our author has some pertinent remarks upon the helps which all such studies are offering to phytography, which will gradually extend its domain over them; and upon the obvious advantage and great need of having results of histological researches expressed descriptively, under something like a common terminology, and with due regard to rules which have governed the more matured branches of botany,—rules and practices which eliminate a deal of verbiage, facilitate comparison of views, and ensure mutual intelligibility. Of botanical descriptions for the purposes of systematic botany, it could be said that whatever is not clear is not botany. May such clearness be hoped for in the future of histological botany?

Chapter XII treats of the unavoidable mixture of artificial with natural grouping. Truly natural groups are often artificially defined, that is, are indicated by single characters; or truly artificial characters are used for the sake of convenience in the division of natural groups. Of the latter sort are the divisions *Polypetalæ*, *Gamopetalæ*, and *Apetalæ* in Dicotyledons; also those founded on the mode of curvature of the embryo in *Cruciferæ*, introduced by Brown, who cautiously used them for genera, but raised to the rank of primary or subordinal characters by DeCandolle. Hypogyny, perigyny and epigyny are in the same category, and probably no one was more sensible of it than Jussieu himself, whose point and forte was the constitution of orders, not their collocation under these artificial heads. DeCandolle suggests that, while to the more natural divisions are appropriated the terms of

Class, Cohort, Orders, Tribes, Genera, and Sections; such names as Division, Subdivision, Series, &c., might be restricted to artificial divisions, and that these should take adjective names not of generic origin, such as *Liguliflorœ*, *Polypetalœ*, and the like.

Chapter XIII relates to difficulties in phytography which have grown out of various methods or absence of method in the nomenclature of organs, and from the want of consideration of the law of priority in such matters. The result of which in some departments, such as histological morphology, is a state of anarchy not unlike that which prevailed in the names of groups before the days of Tournefort and Linnæus. We may hope that order and lucidity will some day dawn upon this chaos and a common language replace this confusion of tongues. Meanwhile DeCandolle offers certain counsels, the utility of which, he says, is not doubtful nor the application very difficult.

(1) Hold fast to common and universally known names, whether in Latin or in modern languages. *Radix*, *caulis*, *folium*, *flos*, &c., with their vernacular equivalents, are not to give place to new-fangled substitutes. This, he thinks, will rid us of "such useless terms as *caulome*, *phyllome*, &c." Now these terms, along with *trichome*, seem to us legitimate and useful, as succinct expressions of a morphological idea; they are annoying only when pedantically ridden as hobbies over ground on which they are not wanted.

(2) Do not entertain the idea that a change in the mode of considering or defining an organ requires a change of name. Although Linnæus did take the leaf-blade for the leaf, and define it accordingly, that did not much hinder the coming in of a truer view, involving merely a change of the definition. But one may intimate that DeCandolle here comes into conflict with another rule he insists on, namely, that terms should have unmistakably one meaning. When we say—as we ever shall—that leaves are ovate, we speak according to the Linnæan definition; when we say that their insertion is alternate, we use the word in a more comprehensive sense; when we have occasion to declare that cotyledons, bracts, petals, &c., are leaves, we use the word in the most comprehensive sense. All this involves considerable ambiguity; and the endeavor to keep the new wine in the old bottles causes no little strain. It is borne because it has been applied gradually. If Linnæus had started with, or even reached our ideas, we should happily have had a nomenclature to match. Now we must be content, for descriptive purposes, to employ some words both in a restricted and in a comprehensive sense, and let the context fix the sense, just as it must in ordinary language. Technical precision is only a matter of degree. But it is clear that the excellent rule here laid down need not forbid the introduction of terms to express our conceptions, such as *rhizome*, *caulome*, *trichome*, and the like. Yet these are ill-chosen terms, except the last. In particular, *rhizoma* has long ago been appropriated for something which is not of root nature, but the contrary.

(3) The third counsel is to change the name of an organ, as we do that of a genus or species, only when it is positively contrary to the truth, or when it has been pre-occupied.

(4) Avoid giving special names for rare or ill-definable cases of structure. An epithet or short periphasis is vastly preferable to a new and strange term, which will be seldom used and may be hardly understood. DeCandolle truly remarks that after a a great multiplication of terms and distinctions generally comes some good generalization, which does away with a crowd of particular names; that what has happened in carpology is likely to occur for microscopic organs; and he adds: "Nous assistons au 'feu d'artifice' d'une trentaine de noms de ces états des cellules" [in our vernacular, we have seen them "go up"]; "il en restera seulement quelques-uns généraux ou fréquents, qui seront toujours nécessaires."

(5) Between two or more names choose, not the most agreeable, or even the most significant, but the one best known and most widely recognized.

(6) Between names equally known and used, adopt the oldest. Which are the older names is not difficult to know in the case of common organs; but is very much so in modern histology.

(7) In this matter of priority or of usage, consider only names taken from [or in conformity with] Latin or Greek. As in systematic botany, scientific and not vulgar names are to be accounted in this regard. Those who like *spaltöffnung* for *stoma* or *stomate*, and *scheitelzelle*, must needs follow their own fashion; but the genius of our own and the French language resists their importation, while it adopts or adapts with ease technical terms from classical sources.

(8) Not to admit names contrary to these rules.

Chapter XIV surveys some difficulties in phytography which arise from the variant, changed, or contradictory use of certain botanical terms, and from the employment of vernacular terms which cannot be latinized. The latter has just been referred to incidentally. Even the French describe the dehiscence of a certain kind of capsule as "*en boîte à savonette.*" In English we do not attempt to say "in soap-box fashion," and should not be understood if we did, but we adopt the Linnæan Latin "circumcissile." In general, DeCandolle concludes that a vernacular term, whether the name of an organ or of a botanical group, which will not enter into a Latin text by a modification of its termination, is not scientific, and may give place to one which is.

A few terms are mentioned which have been more or less changed in meaning since the time of Linnæus; such as *lanceolate*, which has gradually varied more or less, and for a part of the change the present writer is held to account; also *glaucus*, which classically means sea-green in hue, but which has been generally used in botany to designate sometimes a certain whitishness, and sometimes a whitishness caused by a minute waxy exudation in the form of a powder: the latter is the same as *pruinosus*. Others may be as surprised as we were to learn that neither *glaucus* nor *pruinosus* are Linnæan terms.

Among the terms used ambiguously, it is surprising that DeCandolle does not refer to *pistillum*, first introduced into botany by Tournefort, and used in the sense of the modern term *gynœcium*, therefore only one to a flower; modified by Ludwig to denote a female member of the flower (having ovary, stigma, and commonly a style), of which there may be several or many in a flower; and adopted in the latter sense by Linnæus, yet generally with a use that avoids contradicting the sense of Tournefort. Mirbel, Moquin-Tandon, and St. Hilaire among the French, have openly departed from Tournefort's use, and speak freely of pistils in the plural. Brown and DeCandolle have used the word in the manner of Ludwig and Linnæus when they have used it at all, but have generally evaded its use; other botanists, especially British, have gone back to the Tournefortian sense of gynœcium. The present writer has a note on the subject in the new edition of his Structural Botany (1879 and 1880), p. 166.

Sinistrorse and *dextrorse* in the direction of ascent of climbing stems or the overlapping of parts in a bud, &c. DeCandolle had formerly insisted upon the desirability of following what he takes to be the authority and practice of Linnæus in the use of these terms; and he here returns to the subject, reinforcing his former arguments. It is most desirable that these terms should not continue to be employed in contradictory senses, one party calling that sinistrorse which the other calls dextrorse; it is also fitting that the principle of priority should prevail, and that the authority of Linnæus should be respected. Let us, therefore, in the first place give an abstract of the points which DeCandolle here makes.

But first, we take it for granted that a stem or such organ, having no front or back, can have no right or left of its own: so when we say that it twines to the left or right, we can mean nothing else than the right or left of the observer. The contradiction comes from the different position which the observer is conceived to occupy. DeCandolle supposes the observer to be placed within the coil or ascending helix, and that this is the more natural position. The other party supposes the observer to face the object from without; and from this position the Hop twines to the left, i. e., turns in ascending from the observer's right to his left, while the Convolvulus turns from his left to his right; the first is sinistrorse, the second dextrorse; while to DeCandolle, standing within the coil, the first is dextrorse, the second sinistrorse. Now, says DeCandolle, Linnæus in the first edition (1751) of the *Philosophia Botanica*, § 163, page 103, says: "Sinistrorsum hoc est quod respicit sinistrum, si ponas te ipsum in centro constitutum, meridiem adspicere; dextrum itaque contrarium."

DeCandolle remarks that the phrase "*meridiem adspicere*" is of no account [but it indicates a certain confusion in Linnæus's mind], for it matters not in what direction you look. He adds

—what we had all overlooked—that in the errata, on p. 360, Linnæus corrected the word *sinistrum* into *dextram*. But, inasmuch as two editions of the *Phil. Bot.* were printed at Vienna in Linnæus's life-time, and this correction was not introduced into them, he concludes that the correction was canceled by the author of it. And he notes that the expression "sinistrorsum hoc est quod respicit dextram" is a most awkward one for denoting the right-about change which the erratum had in view. Nevertheless the correction was so made in the edition of the *Phil. Bot.* by Gleditsch in 1780, two years after the death of Linnæus, also in that of Willdenow, published ten years later. But DeCandolle the elder, in the *Flore Française* and in all his writings, followed the original text, as also has the present DeCandolle, who cites as maintaining the same view, Braun (who for a time gave way to the opposite), Bischoff, Mohl, Palm, Dutrochet, Nægeli, and even Darwin. But we should say that Darwin, noting the conflict of views, had carefully evaded both, using instead the expression "with the sun, and against the sun." Yet sometimes saying "from left to right," as equivalent to "against the sun" (as on p. 34), showing that he took the external position to be the natural one.

Among those who have used the terms sinistrorse and dextrorse and defined them in the way which supposes the observer to stand outside of the helix, are Aug. St. Hilaire, Duchartre, Bentham and Hooker, Eichler; and the present writer may be added, although our author appears not to be aware of it. While trusting that the younger botanists will follow the example of Linnæus and the majority of authors, DeCandolle recommends that those who depart from it, and even those who adopt it, shall state their point of view by some convenient abbreviation, such as *extus vis.* or *intus vis.;* and thus lessen the danger of a misunderstanding. This is indeed essential.

DeCandolle remarks that he can discover no reason for the *ab extra* point of view except a tacit but perhaps nowhere expressed assumption that it requires some effort to suppose one's self in the center of a helix or spire. He thinks a moderate effort will accomplish this. The reply may be that, in the case of a stem climbing a hop-pole, or of the scales imbricated on the axis of a pine-cone, or of a flower-bud on the stage of a dissecting microscope, the contemplation of the object from without calls for no effort at all! So natural does this extraneous position appear to be that we found ourselves describing these objects from that point of view without thinking of any other,—so natural, as we shall see, that Linnæus fell into it himself, and there remained. Yet, that the opposing view has also its fitness is obvious from the fact that the physicists and mathematicians are divided in usage, no less than the naturalists.

In the actual state of the case, the question which view ought to prevail in botany must be determined on a balance there of considerations: 1. priority and authority, such as that of Linnæus;

2. naturalness; 3. preponderant actual usage. We had maintained in this Journal (for March and for May, 1877) and in Structural Botany (6th ed., note on pp. 51, 52) that the *externe visum* view has decidedly the best case on the second ground, and except in botany on the third also. And now that DeCandolle has drawn our attention to the matter, we are going to claim the remaining ground likewise, and to contend that the contrary usage in botany came in from non-attention to the teaching and practice of Linnæus himself!

On p. 39 of Linnæus's only own edition of the *Philosophia Botanica* he defines and illustrates the directions of twining thus: "*Sinistrorsum*, secundum solem vulgo: *Humulus, Helxine, Lonicera, Tamus. Dextrorsum*, contra motum solis vulgi; *Convolvulus, Basella, Phaseolus, Cynanche, Euphorbia, Eupatorium.*"

Nothing is said about the position of the observer. But in every one of the examples of sinistrorse (*Helxine* being *Polygonum convolvulus*), the stem winds around the support passing from right to left of the observer confronting the coil; and in every one of the dextrorse examples (*Eupatorium* being *Mikania*) it winds in the opposite direction. That is, dextrorse and sinistrorse are used in the *externe visum* sense. On p. 103 the same is repeated, except that reference to the sun's apparent course is omitted and additional examples are added, most (but not all) of them accordant with the preceding. So far, it would seem that Wichura was not mistaken in his statement that DeCandolle had followed a different method from that of Linnæus. And this appears to be the whole case as respects direction of twining.

But on the same page, to "*Corolla sinistrorsum*," is appended the foot-note which has made so much trouble, viz: "Sinistrorsum hoc est, quod respicit sinistrum, si ponas Te ipsum in centro constitutum, meridiem adspicere; *Dextrorsum* itaque contrarium." That is to say, in defining the direction of overlapping of the parts of a perianth, Linnæus took the open flower instead of the bud, and proposed to look down upon it from above or within. Now it may well be that Linnæus subsequently perceived the contradiction between his terminology for overlapping and that for twining; and that his brief erratum, on p. 310, "pro *sinistrum* lege *dextram*," was intended to bring the former into congruity with the latter, which it does, but in an awkward way. Perhaps he saw the incompatibilty of the cited examples; in fact about as many of them accord with the outside as with the inside point of view. Anyway, the erratum is his own; it seems unlikely that he authorized its omission from the Vienna editions; and Gledistch and Willdenow should not be blamed for heeding his behest in their editions. For, so far as it goes, it tends to render their author consistent with himself. If Linnæus had revised the page himself, he would have left out the "*meridiem adspicere*," which has nothing to do with the matter, and doubtless he would have completed his assimilation of the direction of petal-obliquity or overlapping with that of stem-winding; and so the whole confusion from which we are endeavoring to escape would have been avoided.

In adopting the external point of view—now fortified by original authority—it is well to note that we shall be in accord with the modern physicists and mathematicians, and also with common people. The ordinary screw, on which the thread winds from left to right of the confronting observer, and which is driven home by the semi-rotation of the hand and fore-arm from left to right, is everywhere known as the right-handed screw; and this, with the corkscrew, is taken as the norm and exponent of right-handed rotation by Clerk-Maxwell (Treatise on Electricity and Magnetism, i, 23), and by Sir Wm. Thomson.

The analogies which have been adduced in favor of the inside position are mostly drawn from objects which have a right and left of their own; a building, for instance, has a right and left side or wing because it has a front and a rear. The right side of an assembly presided over by an officer who faces the members is quite arbitrarily, but naturally, taken to be that on the right of the chairman. But the right hand figures on a drawing or engraved plate are taken to be those on the right hand of the observer, notwithstanding that the plate, having face and back, has a right and left of its own.

Chapter XV refers to certain difficulties which grow out of ambiguous terms of ordinary language; for example, the various meanings of the word (*fin*) *end* or *purpose*, and the ambiguities in the use of the terms *Nature, natural, supernatural* (which lead off into philosophy, but are here treated rather in reference to style of exposition); also the change which has occurred in the scope of the word *history* in natural science.

Chapter XVI is an interesting and pertinent one, upon the manner in which facts observed under the microscope are described, and on the great saving of space and advantage in clearness which would be gained by the adoption, for all matters perfectly capable of it, of the Linnæan descriptive style, and of Linnæan Latin. Extracts from the German of Schacht, the French of Payer, and the Italian of Gasparrini are given, and by their side a rendering in descriptive Latin; and the words and letters are counted. The German specimen so treated is diminished to considerably less than half the number of words and a little less than half the number of letters. The French simmers down to one-third the number of Latin words and less than half the number of letters; and in the French of descriptive botany to less than one-half. The Italian extract of 51 words and 256 letters is expressed in Latin of Linnæan form by 21 words and 127 letters.

Style in botanical works is discussed in Chapter XVIII, which all young botanists should study, especially the portion which treats of the admirable style of Linnæus. In speaking of botanical style in the modern languages, the author notices the great advantage which the languages of Latin stock have inherited, and which the English-writing botanists have acquired, of ready and free use of Latin and latinized technical words by direct transference. Botanical French, English, and Italian, are contrasted with the German in this respect. Noting that the German of conversation inclines to be clear and sententious, while in botanical writings the words lengthen more and more and the sentences become badly involved, our author remarks that recently having read a couple of pages of Vegetable Anatomy, and feeling his brain somewhat fatigued with the frequency of such words as *Sclerenchymfäsergruppen*, *Gefässbundentwickelung* and *Entwickelungseigenthümlichkeit*, he asked himself if that was good German style. He then recollected that Goethe, one of the very greatest of German literary writers, was also a profound naturalist. He opened his *Metamorphose der Pflanzen*, read a page or so, and experienced a relief which he likens to that felt by a sea-tossed ocean voyager when the vessel suddenly glides into a quiet harbor.

Chapter XIX discusses the propositions to employ letters and figures, chosen arbitrarily or otherwise, to represent specific and generic characters,—repulsive contrivances, to which our author lends no countenance.

Chapter XX treats questions of orthography, abbreviations and signs, pagination, typography; the twenty-first chapter, of titles and indexes; both full of interesting details upon which we cannot touch, although we are longing to put in our oar.

Chapter XXII animadverts upon the tendency of certain modern cryptogamists to set all botanical rules at naught. The next gives advice about articles in journals, dissertations, and the like; the next treats of translations; another, of figures, and has many noteworthy remarks; Chapter XXVI, of auxiliary and bibliographical works; and Chapter XXVII, is a chronological table of the progress of phytography, beginning with a Chinese encyclopedia 1000 years before Christ, and ending with Sachs' Lehrbuch, 1868–1877. Botanical students will find it very interesting and instructive.

The remaining Chapter begins the second part of the volume, *Preuves des Descriptions ;* which is principally devoted to herbaria, their history, formation, and management ;—a most important chapter, the analysis of which would form an article by itself. Last in order and not least in importance, a full enumeration is given of botanical collectors and authors who have formed herbaria, with an indication of the place where their herbaria or collections are preserved. A. G.

3. *Occurrence at Newport, R. I., of two littoral species of European Shells not before recorded as American ;* by A. E. VERRILL.—In the latter part of July and in August, of this year, I found living among the decaying sea-weed, at high-water mark in the docks at Newport, R. I., numerous specimens, both full grown and young, of *Truncatella truncatula* and *Assiminea Grayana.* They were associated with *Alexia myosotis, Anurida maritima, Chernes oblongus*, a large species of *Ligia, Orchestia agilis*, and other littoral species. Whether these shells have been

accidentally introduced, at that point, by shipping, or are really indigenous, cannot at present be determined. They are now certainly well established inhabitants of our shores. They may have been overlooked hitherto.

4. *Rapid diffusion of Littorina littorea on the New England Coast;* by A. E. Verrill.—It is well-known to American conchologists that this common European species has become well-established on the New England coast within ten or twelve years, appearing first on the coast of Maine about 1868; Dr. Dawson, however, states that he collected it on the shores of Nova Scotia at a much earlier date. I wish, at present, merely to put on record some additional data, as to its recent progress along the coast. In 1873, it was collected, in abundance, at Saco, Maine, by the U. S. Fish Commission, and was found sparingly at Peake's I., Casco Bay. In 1872 it was very rare at Provincetown, Mass., but in 1875, it was common there. In 1875, it was collected by the writer at Barnstable, Mass., on the shores of Cape Cod Bay, in large quantities. In 1879, it had become exceedingly abundant at Provincetown. In 1875, our parties found two specimens only, on the southern shores of Cape Cod, at Wood's Holl, but in 1876 it was found to be common there, and is now very abundant. The first specimen found so far westward as New Haven was obtained by Professor S. I. Smith, during the past winter. Other solitary specimens have since been obtained here by Mr. E. A. Andrews, and by Mr. J. H. Emerton. It is, at present, exceedingly abundant at Newport, R. I.

5. *Artificial propagation of the Spanish Mackerel* (*Cybium maculatum*)*;* by A. E. Verrill.—That this highly valued fish habitually breeds at certain localities in Chesapeake Bay was recently ascertained by Mr. R. E. Earll, of the U. S. Fish Commission. In July, he visited the locality and made experiments upon its artificial propagation. He was very successful and easily hatched many thousands of the young fish. These, though among the most minute of larval fishes, proved to be hardy and easy to transport. The eggs hatched in less than 24 hours after fecundation. The U. S. Fish Commission will undoubtedly be able to utilize this discovery next year on a large scale, and there is every reason to believe that this excellent fish may be thus introduced into all the waters south of Cape Cod, in great abundance.

6. *Occurrence of Ciona ocellata* (*Ascidia ocellata* Agassiz) *at Newport, R. I.;* by A. E. Verrill.—This ascidian, which is one of the largest and most elegant found on our coast, occurs in abundance at Newport, both on the rocks and on the piles of wharves, at low-water, and on dead shells, to the depth of 20 fathoms. It seems to be very local in its distribution, for I have never seen it at any other locality on our coast. It was originally obtained by Agassiz, at New Bedford, Mass., according to Binney, in Gould's Invert. of Mass., where it is figured, but not described. It grows to the length of four or five inches, and about an inch in diameter. It is very translucent, allowing the internal organs to be well

seen through the pale greenish or yellowish-white test. It is usually attached by the base and lower part of one side. The apertures are surrounded by a circle of bright lemon-yellow, and the ocelli are bright red. There are also two bright red spots connected with the nervous ganglia. The *Ciona tenella* (Stimp.), which is common in the Bay of Fundy, has the circles around the apertures bright red.

7. *Note by* C. A. WHITE.—In the August number of this Journal, p. 158, Mr. R. E. Call calls attention to two slight errors in my article "On the Antiquity of certain Subordinate Types of Fresh-water and Land Mollusca;" referring to the geographical distribution there attributed to *Unio complanatus* Solander, and to my use of the name "*Unio gibbus* Barnes." The latter is so plainly a typographical error that, if inexcusable, it is in no danger of misleading any one. My statement in relation to the former question was based upon the identification as *Unio complanatus* Solander of certain shells (collected by myself in Iowa) by the late J. G. Anthony. I accepted that decision without serious question because other species of branchiferous mollusks are well known to inhabit both Atlantic and Gulf drainage waters. Perhaps Mr. Call is correct in his opinion, but he gives it with an emphatic assurance which experienced naturalists seldom express upon such subjects, and in view of such facts. No fact in natural history is really unimportant, but as my only object in that paper was to show the antiquity of the types referred to, the question of the actual geographical distribution of a particular species of one of those types is not essential in that connection, however important it may be in connection with the subject of the origination of those species.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *The American and British Associations* meet this year on the same day of August—the 25th, the former at Boston, the latter at Swansea. The President of the American Association is LEWIS H. MORGAN; the Vice-Presidents, ASAPH HALL, of Section A, and ALEXANDER AGASSIZ, of Section B. The President of the British Association is Dr. A. C. RAMSAY, Director-General of the Geological Survey, and the General Secretaries are Captain DOUGLAS GALTON and Dr. PHILIP L. SCLATER.

2. *Deep-Sea Sounding and Dredging: A description and discussion of the methods and appliances used on board the Coast and Geodetic Survey Steamer "Blake,"* by CHARLES D. SIGSBEE, Lieut. Commander U. S. Navy. 208 pp. 4to, with 41 plates. Washington, 1880. U. S. Coast and Geodetic Survey, Carlile P. Patterson, Superintendent.—This valuable volume describes in full detail, and with a profusion of excellent illustrations, the methods and appliances employed for deep-sea sounding and dredging on board the steamer "Blake."

The work of Lieut. Commander Sigsbee, on the "Blake" was carried on for four years beginning in the autumn of 1874. It has resulted not only in the accumulation of much important data from soundings—12,766 nautical miles of sounding-lines, with serial temperatures, were run by him in the Gulf—but also in the invention by him of many new forms of apparatus and the improvement of previous ones, calculated to facilitate the operations of sounding and dredging. Prof. Alexander Agassiz was connected with the expedition of the Blake in the winter of 1877–1878, from December to March, and also during its later cruising, having had special charge of the collections from the dredgings, and has already published part of his results. The Superintendent of the Coast Survey, Captain Carlile P. Patterson, says with reason, in the preface:

"Without specifying the great results obtained from this continuous research, I may be pardoned in referring with some gratification to the fact that in the small steamer 'Blake,' of only three hundred and fifty tons burthen, N. M., under the energetic and skillful commands of Lieutenant-Commander Sigsbee and Commander Bartlett, with a complement of forty-five including officers and crew, more rapid work was done than had been accomplished with the old methods and appliances by the 'Challenger,' a vessel of over 2,000 tons burthen, with a complement of twenty-nine naval and civil officers and a correspondingly large crew." He adds with reference to the present volume, "There being no special publications with detailed instructions on the systems and methods adopted for deep-sea sounding and dredging, although much attention is now paid by all maritime nations to the subject, it has been thought advisable to publish the methods used on board the 'Blake.' These methods, in even so small a vessel as the 'Blake,' have been prosecuted with celerity, ease, and precision, showing that deep-sea work has become nearly as ready of accomplishment as ordinary littoral soundings."

The plates are partly heliotypes; and all details are given so as to make the work a full exposition of the best methods of deep-sea dredging, and of keeping records of the observations and working up the results.

OBITUARY.

Louis François de Pourtalès, died at Beverly Farms, Mass., in the 57th year of his age, on the 17th of July, 1880. Spite of a magnificent constitution and a manly vigor of body and mind, which seemed to defy disease and to promise years of activity, he sank after a severe illness under an internal malady.

Educated as an engineer, he showed from boyhood a predilection for natural history. He was a favorite student of Professor Agassiz and when his friend and teacher came to America in 1847 he accompanied him and remained for some time with the little band of naturalists who, first at East Boston and subsequently at Cambridge, shared his labors. In 1848 Pourtalès entered the U. S. Coast Survey, where his ability and indefatigable industry were at once recognized, and he remained attached to that branch of our public service for many years. He there became deeply interested in everything relating to the study of the bed of the ocean. Thanks to the enlightened support of the then Superintendent of the Coast Survey, Professor Bache, and of his successors, Professor Pierce and Captain Patterson, he was enabled to devote his talents and industry to the comparatively new field of "Thalassography" and the biological investigations related to it. The large collections of specimens from the sea bottom accumulated by the different hydrographic expeditions of the U. S. Coast Survey were carefully examined by him and the results were published in advance of their appearance in the Coast Survey Reports in Peterman's Mittheilungen, accompanied by a chart of the sea bottom on the east coast of the United States. So interesting and valuable were the results obtained, not only as an aid to navigation, but in their wider bearing on the history of the Gulf Stream and on the distribution of animal life at great depths, that in 1866 he was sent out by Professor Pierce, then Superintendent of the Coast Survey, to continue these investigations on a larger scale. During 1866, 1867 and 1868 he was in charge of the extensive dredging explorations carried on by the U. S. Coast Survey steamer "Bibb," acting Master Platt, along the whole line of the Florida Reefs and across the Straits of Florida to Cuba, Salt Key and the Bahama Banks. The results of these expeditions, published in the bulletin of the Museum of Comparative Zoölogy, excited great interest among zoölogists and geologists. Mr. Pourtalès was indeed the pioneer of deep-sea dredging in America, and he lived long enough to see that these expeditions had paved the way not only for similar English, French and Scandinavian researches but had led in this country to the "Hassler" and finally to the "Blake" expeditions under the auspices of the Hon. Carlile Patterson, the present Superintendent of our Coast Survey. On the Hassler Expedition from Massachusetts Bay through the Straits of Magellan to California he had entire charge of the dredging operations. Owing to circumstances beyond his control the deep sea explorations of that expedition were not as successful as he anticipated.

At the death of his father Mr. Pourtalès was left in an independent position, which allowed him to devote himself more completely than ever to his zöological studies. He resigned his official connection with the Coast Survey and returned to Cambridge, where he became thenceforth identified with the progress of the Museum of Comparative Zoölogy. To Professor Agassiz his presence there was invaluable. In youth one of his favorite pupils, throughout life his friend and colleague, he now became the support of his failing strength. The materials of the different deep-sea dredging expeditions, above mentioned, had been chiefly deposited at the museum in Cambridge, and were thence distributed to specialists in this country and in Europe. A large part of the special reports upon them have already appeared. Mr. Pourtalès reserved to himself the corals, halcyonarians, holothurians and crinoids. A number of his papers on the deep-sea corals of Florida, of the Caribbean Sea, and of the Gulf of Mexico have appeared in the museum publications. He had begun to work at the magnificent collection of halcyonarians made by the "Blake" in the Caribbean Sea, and had already made good progress with his final report on the holothurians. The crinoid memoirs published by him relate to a few new species of Comatulæ, and to the interesting genera Rhizocrinus and Holopus.

The titles of his memoirs indicate the range of his learning and his untiring industry. His devotion to science was boundless. A model worker, so quiet that his enthusiasm was known only to those who watched his steadfast labor, he toiled on year after year without a thought of self, wholly engrossed in his search after truth. He never entered into a single scientific controversy nor even asserted or defended his claims to discoveries of his own which had escaped attention. But while modest to a fault and absolutely careless of his own position, he could rebuke in a peculiarly effective though always courteous manner, ignorant pretentions or an assumption of infallibility.

Appointed keeper of the Museum of Comparative Zoölogy after the death of Professor Agassiz, he devoted a large part of his time to the administration of the museum affairs. Always at his post, he passed from his original investigations to practical details, carrying out plans which he had himself helped to initiate for the growth of the institution. As he had been the devoted friend of Professor Agassiz he became to his son a wise and affectionate counselor without whose help in the last ten years the museum could not have taken the place it now occupies.

If he did not live to see the realization of his scientific hopes he lived at least long enough to feel that their fulfillment is only a matter of time. He has followed Wyman and Agassiz, and like them has left his fairest monument in the work he has accomplished, and the example he leaves to his successors. A. AG.

Cambridge, Mass., July 31, 1880.

Professor E. B. ANDREWS, of Lancaster, Ohio, one of the corps of geologists engaged since 1869 on the Geological Survey of Ohio, and the author of a very valuable volume among its final reports, as well as various geological memoirs, died on the 21st of August, in his sixtieth year. He was a graduate of Marietta College, Ohio, and its Professor of Geology from 1851 until he entered on his work in connection with the State Geological Survey. During the five years previous to 1851 he was pastor of churches in Housatonic, Mass., and New Britain, Conn. The State of Ohio owes much to him for his careful study of the coal deposits of the southeastern part of the State—the part under his special charge,—and for other labors connected with the development of its mineral and geological resources. Mr. Andrews was highly esteemed for his many excellencies, and will have his place in scientific history for his part in the progress of American geology.

General Albert J. Myer, the efficient head of the United States Signal Service, died in Buffalo, on the 24th of August, in his fifty-second year.

This number of the American Journal of Science not only is much enlarged in consequence of the demand of its long articles, but fails of several book notices which should have appeared in it. The following are among the volumes received.—

Report of the Superintendent of the U. S. Coast Survey, showing the progress of the work for the fiscal year ending with June, 1876. 416 pp. 4to, with 24 maps. Washington, 1879.

The Natural History of the Agricultural Ant of Texas: a monograph of the habits, architecture and structure of Pogonomyrmex barbatus, by Henry Christopher McCook. 312 pp. 8vo. Philadelphia, 1880. (J. B. Lippincott & Co.)

The Geological Record for 1877: An account of works on Geology, Mineralogy, and Paleontology published during the year, with supplements for 1874–76. Edited by William Whitaker, B.A., F.R.S., of the Geological Survey of England. 432 pp. 8vo. London, 1880.

Contributions to Paleontology, Nos. 2–8, by C. A. White, M.D. [Extracted from the 12th annual Report of the U. S. Geological Survey, 1878, F. V. Hayden, U. S. Geologist in charge.] Author's edition. 171 pp. 8vo, plates 11 to 42. Washington, 1880.

Annals of the Astronomical Observatory of Harvard College, vol. xii: Observations made with the Meridian Circle during the years 1874 and 1875, and prepared for publication under the direction of Joseph Winlock and Edward C. Pickering, successive Directors of the Observatory, by William A. Rogers, Assistant Professor of Astronomy in the Observatory. Printed from the Sturgis fund. 271 pp. 4to (with introduction i–xcii). Cambridge, 1880.

Catalogue of 618 Stars observed at the Astronomical Observatory of Harvard College, with the Meridian Circle during the years 1871–2, 1874, 1875. [Extracted from vol. xii of the Annals, see above.]

First Annual Report of the Department of Statistics and Geology of the State of Indiana, 1879. 514 pp. 4to. Indianapolis, 1880.

Elementary Treatise on Electric Batteries. From the French of Alfred Niaudet, translated by L. M. Fishback. 266 pp. 8vo. New York, 1880. (John Wiley & Sons.)

Science Primers: Introductory by Professor Huxley, F.R.S. 94 pp. 12mo. New York, 1880. (D. Appleton & Co.)

Water Analysis for Sanitary Purposes; with hints for the interpretation of results, by E. Frankland, Ph.D., etc. 144 pp. 8vo. Philadelphia, 1880. (Presley Blakiston.)

Interesting Chemical Exercises in Qualitative Analysis for ordinary schools, by Geo. W. Rains, M.D. 59 pp. 8vo. New York, 1880. (D. Appleton & Co.)

Proceedings of the National Microscopical Congress, held at Indianapolis, August 14–19, 1878; and of the American Society of Microscopists, held at Buffalo, N. Y., August 19–24, 1879. 77 pp. 8vo. Indianapolis, 1880.

The Microscopists Annual for 1878. Number 1.—containing useful tables, rules, formulæ, memoranda, list of Microscopical Societies, directory of prominent makers, etc. 48 pp. 12mo. New York, 1880. (Industrial Publication Company.)

Regenwaarnemingen in Nederlandsch-Indië. Eerste Jaargang 1879 door Dr. P. A. Bergsma, Directeur van het Observatorium te Batavia. 257 pp. 8vo. Batavia, 1880.

Mémoires sur les Terrains Crétacé et Tertiares préparés par feu André Dumont. Pour servir a la description de la Carte Géologique de la Belgique. Édités par Michel Mourlon. Tome iii, Terrains Tertiaires, seconde partie. 459 pp. 8vo. Brussells, 1878. Musée Royal d'Histoire Naturelle de Belgique.

PLATE IV.

J. H. Emerton, del.

...and New Haven Ct.

THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XXIX.—*On the Mineral Locality at Branchville, Connecticut:* Fourth Paper.* *Spodumene and the results of its Alteration;*† by GEORGE J. BRUSH and EDWARD S. DANA. (With Plate IV).

IN the present paper we give the results we have obtained in a study of the spodumene from Branchville, Conn., and of the various minerals derived from its alterations. It is, after the feldspars, mica and quartz, the most important of the original minerals of the locality, and occurs, though mostly in an altered condition, in very large quantities.

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* For previous papers upon this subject see this Journal, III, xvi, 33, 114, 1878; xvii, 359, 1879; xviii, 45, 1879.

† An extended and valuable memoir upon "Spodumene and its alterations from the granite veins of Hampshire Co., Mass.," has been recently published by Mr. A. A. Julien in the Annals of the New York Academy of Sciences, Vol. i, No. x (see this Journal, xix, 237, March, 1880). It is proper that we should state here that most of the results of this paper, including every analysis, had been completed previous to the appearance of that of Mr. Julien, and when we had no further knowledge of its contents than is suggested by the preliminary notice of cymatolite published by him in this Journal for May, 1879 (xvii, 398). The fact, however, that Mr. Julien was engaged upon this investigation and had been at work upon it for several years was known to us, and we felt it only right that we should defer the publication of our article until his had appeared. It will be seen that our results, though arrived at independently and based upon material from a different source, in many cases confirm those of Mr. Julien, and this, as we believe, adds much to the interest of the whole subject. Our conclusions, however, differ essentially in some respects. We have found that cymatolite is not a true species, but only a mechanical mixture of albite and muscovite. This fact, taken with the presence of the analogous complex substance, β spodumene, makes it now possible to give a reasonably clear and thorough explanation of all the changes involved in this most interesting case of pseudomorphism.

A. UNALTERED SPODUMENE.

The greater part of the unaltered spodumene occurs in confusedly crystalline masses, showing distinct cleavage, but seldom any approach to crystalline form. It is possible to obtain the mineral nearly pure, though somewhat intermingled with albite, in blocks weighing several hundred pounds. In this form the spodumene has a dull white color; it is in many cases somewhat discolored, and is only partially translucent; the cleavage surfaces are often coated with delicate dendrites of manganese oxide. The associated minerals, in addition to the albite and a little quartz and mica, are apatite, lithiophilite, columbite, garnet and uraninite, with various other uranium minerals formed from alteration.

In addition to this massive variety, the spodumene also occurs in an unaltered condition as nuclei of distinct pseudomorphous crystals. These crystals often occur of enormous size, imbedded for the most part in massive quartz, though sometimes extending into the albite. The nucleus of spodumene (see below and figures 1*a*, 5, 8, 14, Plate IV*) is in every case sharply separated from the altered mineral surrounding it, and its characters show that the crystals must originally have had rare beauty. One of the finest crystals that we have found thus far had, as imbedded in the quartz, a length of three feet, a width of eight inches and a thickness of two inches. The unaltered spodumene, of a fine amethystine color, made up about one-fourth of the whole, extending rather regularly through the middle of the crystal. Unfortunately, the spodumene was much rifted and fractured, so that its former transparency had, for the most part, disappeared. The exterior of the crystal consisted principally of β spodumene, with small quantities of cymatolite and albite. Another altered crystal was measured while imbedded in the quartz, of which a length of over *four feet* was exposed. It is not possible to extract these crystals entire, but many fragments have been obtained which have a width of over a foot across the prism and a thickness of two to four inches. In habit the crystals are much like those from Norwich, Massachusetts. They are generally broad or flat, through the development of the orthopinacoid, and comparatively thin; not unfrequently they are well terminated. Occasional stout crystals, having a square prismatic form, much like pyroxene, are also observed.

In the better specimens the spodumene is perfectly transparent, sometimes colorless, and again of a beautiful rose-pink or amethystine-purple color. It shows the prismatic cleavage with unusual perfection, and that of the clinopinacoid irregu-

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* Figures 1 to 14 inclusive are to be found on the accompanying Plate, the other figures (15–20) are in the text.

larly. The angle of the prismatic cleavage—viz., 87° 13′—was obtained with great exactness.

Chemical composition.—An analysis of the transparent pink spodumene was made by Mr. S. L. Penfield with the following results. Specific gravity =3·193.

	I.	II.	Mean.		Ratio.	
SiO_2	64·32	64·18	64·25		1·071	4
Al_2O_3	27·14	27·26	27·20	·262	·263	·98
Fe_2O_3	0·18	0·22	0·20	·001		
Li_2O	7·64	7·59	7·62	·254	·260	·97
Na_2O	0·39	0·39	0·39	·006		
K_2O	tr	tr	tr			
Ignition	0·24	0·24	0·24			
	99·91	99·88	99·90			

The ratio of $Li_2O : Al_2O_3 : SiO_2 = 1 : 1 : 4$; this corresponds to the oxygen ratio[*] of 1 : 3 : 8. The formula is then, neglecting the very small amount of soda,

$$Li_2Al_2Si_4O_{12}.$$

This result agrees exactly with that reached by Dœlter in his investigation of the composition of spodumene,[†] and with that of Julien.[‡] It is to be noted, however, that the percentage of lithia here obtained is higher and that of soda lower than in any analyses previously published. For example, Dœlter found in the Norwich mineral 7·04 Li_2O, 1·10 Na_2O and 0·12 K_2O; in that from Brazil 7·09 Li_2O and 0·98 Na_2O. Julien obtained in the Goshen spodumene 6·89 Li_2O, 0·99 Na_2O, 1·45 K_2O; and in that from Chesterfield 6·99 Li_2O, 0·50 Na_2O, and 1·33 K_2O. Dœlter concludes for the Norwich mineral that the amount of lithia obtained is rather too small than too large, and attributes the soda present to incipient alteration. The correctness of this view seems to be proved by the analyses here published of the Branchville mineral, which certainly left nothing to be desired in regard to purity or freedom from alteration. The great tendency of spodumene to change by the assumption of potash or soda and loss of lithia will be made evident by what follows.

B. ALTERATION OF SPODUMENE.

As the result of the alteration of the spodumene, we have found two substances which at first sight seem to be homogeneous, and each of which has a definite chemical composition, and which, notwithstanding, are only intimate mechanical mixtures of two species; one of these, called by us β spodumene, is made up of albite and a new lithia mineral to which

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[*] This ratio was obtained by Brush from analyses of the Massachusetts mineral in 1850. Am. Jour. Sci., II, x, 370.

[†] Tschermak, Min. u. Petr. Mitth., i, 517, 1878.

[‡] l. c., p. 325.

we have given the name *eucryptite;* and the other is cymatolite, an aggregate of albite and muscovite. We have also found the following independent minerals:—albite, microcline, muscovite, and killinite. The two complex substances and all of the last named minerals, except the mica, occur as distinct pseudomorphs, having the form of the spodumene. The mica, taken independently of its constant associate the albite, plays only a secondary part. In addition there are other pseudomorphs, of composite character, consisting, as Mr. Julien has well expressed it, "of vein granite."

We will first give the physical and chemical characters of the various minerals (including the two aggregates) taken separately, and then go on to describe more minutely the way in which they are associated together.

I. PRODUCTS OF THE ALTERATION.

1. *β Spodumene.*

The substance which we have, for convenience, called β spodumene, since we do not regard it as deserving an independent name, seems to mark the first step in the alteration of the spodumene.

Physical characters.—It is a compact, apparently homogeneous mineral, having a rather indistinct fibrous to columnar structure, this being always at right angles to the adjoining surface of the original mineral. Hardness 5·5 to 6; specific gravity 2·644–2·649. Color white to milk white, and again slightly greenish-white; translucent. Fusibility=2·25.

Chemical composition.—Analyses of three independent specimens have been made by Mr. S. L. Penfield. Number 1 was taken from a crystal, part of which consisted of the transparent pink spodumene, described above, and the outer portion was this mineral (similar to fig. 5). The line of demarcation was perfectly sharp, so that the purity of the material analyzed cannot be questioned. The results of the analysis are as follows:—

No. 1, G.=2·649.	I.	II.	Mean.		Ratio.	
SiO_2	61·35	61·42	61·38		1·023	4
Al_2O_3	26·26	25·74	26·00	·253	·255	·99
Fe_2O_3	0·24	0·24	0·24	·002		
Li_2O	3·63	3·59	3·61	·120	·254	·99
Na_2O	8·32	8·25	8·29	·134		
K_2O	tr	tr	tr			
Ignition	0·46	0·46	0·46			
	100·26	99·70	99·98			

The second portion analyzed was from a fragment of a large and entirely altered crystal; its dimensions were 9 by 8 by 2½ inches. It consisted mostly of cymatolite, and the β spodumene had all the appearance of passing insensibly into it; a single fragment, across the prism, could be obtained made up of both minerals, the fibrous structure of the one being continued in the other (similar to fig. 1*b*). The analysis yielded:—

No. 2, G.=2·644.	I.	II.	Mean.		Ratio.	
SiO_2	61·46	61·57	61·51		1·025	4
Al_2O_3	not determined	26·56	26·56		·258	1
Li_2O	3·55	3·44	3·50	·117	·249	0·97
Na_2O	8·15	8·13	8·14	·131		
K_2O	0·15	0·15	0·15	·001		
Ignition	0·29	0·29	0·29			
		100·14	100·15			

The third portion was part of a smaller and well developed crystal, having the external prismatic form complete. It consisted in the interior of spodumene, then the β spodumene making up the greater part of the whole, and finally a thin crust of cymatolite. The specimen analyzed was, as far as the eye could detect, perfectly pure and homogeneous. The color was greenish-white and it was decidedly translucent. The analysis afforded:—

No. 3, G.=2·649.	I.	II.	Mean.		Ratio.	
SiO_2	61·78	61·64	61·71		1·028	4
Al_2O_3	26·57	26·69	26·63		·259	1
Li_2O		3·83	3·83	·128	·260	1
Na_2O		8·16	8·16	·132		
K_2O		tr	tr			
Ignition		0·21	0·21			
		100·53	100·54			

If the mean analyses of the three groups be compared, it will be found that they agree very closely with one another; in fact the agreement is as close as could be expected for three successive analyses made upon the same material. But, as will be seen from what has already been said, the three samples were entirely *independent*, being taken from different parts of the ledge and differing in manner of association; the agreement between them thus becomes very striking. The ratio obtained for each

$$\overset{\text{I}}{R}_2O : R_2O_3 : SiO_2 = 1 : 1 : 4$$

is the same as that of spodumene, from which it differs only in this: that one-half of the lithium has been removed and its place (chemical equivalent) taken by sodium. The formula is then:—

$$(Li, Na)_2Al_2Si_4O_{12} = Li_2Al_2Si_4O_{12} + Na_2Al_2Si_4O_{12} \qquad (1)$$

$$\text{or} = Li_2Al_2Si_2O_8 + Na_2Al_2Si_6O_{16} \qquad (2)$$

It is shown below that the formula given in (2) is the correct one.

The facts stated thus far would seem to be sufficient to prove that the mineral was homogeneous and had a definite composition; there are, however, other facts which have an important bearing upon this point.

It was found by Mr. Penfield that, although the mineral gelatinizes with acid, it is not entirely decomposed. On the contrary, it is divided into two portions by the treatment with hydrochloric acid, viz:—a soluble portion (A), and an insoluble remainder (B), the latter including also the silica extracted from the soluble part. The results of three analyses gave

	A. Soluble in HCl.	B. Insoluble in HCl, with SiO_2 from A.
No. 1	(17·97)	82·03 = 100·
2	16·65	83·01 = 99·66
3	17·91	82·18 = 100·09

In the case of No. 2, complete analyses of both the soluble and insoluble portions were made; these were independent of the total analyses of the same sample already given. The method of analysis was, briefly, as follows:—A gram of the mineral was digested with HCl, evaporated to dryness, then moistened with HCl and a second time evaporated to dryness. After being again moistened with HCl the soluble portion, A above, was filtered off and the alumina and alkalies determined in it by the usual methods. The insoluble portion, which included the silica extracted from A, after being weighed, was boiled with Na_2CO_3 and (in the case of No. 3) with a little KOH. By this means the soluble silica of A was dissolved out and the insoluble remainder being weighed, the amount of the soluble silica was determined by the difference. Finally, the insoluble part was analyzed in full by the usual methods. The results of the analyses were as follows:

	No. 2.
B. Insoluble in HCl with silica of A	83·01
Insoluble remainder after treatment with soda	67·56
	15·45
A. Soluble in HCl (16·65), plus silica extracted by soda from B	32·10

The two parts, therefore, into which the original mineral is divided by hydrochloric acid, are:—

	No. 2.
A. Soluble portion	32·10
B. Insoluble portion	67·56
	99·66

The composition obtained for A was as follows:—

A. *Soluble portion.*

	No. 2.	Calculated to 100. No. 2.	Calculated from formula.
SiO_2	15·45	48·13	47·51
Al_2O_3	13·00	40·50	40·61
Li_2O	3·50	10·90	11·88
K_2O	0·15	0·47	----
	32·10	100·00	100·00

For the above analysis the ratio is, nearly:—

	SiO_2	:	Al_2O_3	:	Li_2O
No. 2	2	:	1	:	1

This corresponds to the formula, $Li_2Al_2Si_2O_8$, the percentage composition of which, given above, agrees well with the analysis.

The composition obtained for B was:—

B. *Insoluble portion.*

	No. 2.	Calculated to 100. No. 2.	Calculated from formula.
SiO_2	46·06	68·18	68·62
Al_2O_3	13·56	20·07	19·56
Na_2O	7·94	11·75	11·82
	67·56	100·00	100·00

The ratio calculated from the preceding analysis is:—

	SiO_2	:	Al_2O_3	:	Na_2O
No. 2	6·		1·07		1·00

This ratio is very closely that of *albite*, viz: 6 : 1 : 1, so that the formula for the insoluble portion is $Na_2Al_2Si_6O_{16}$.

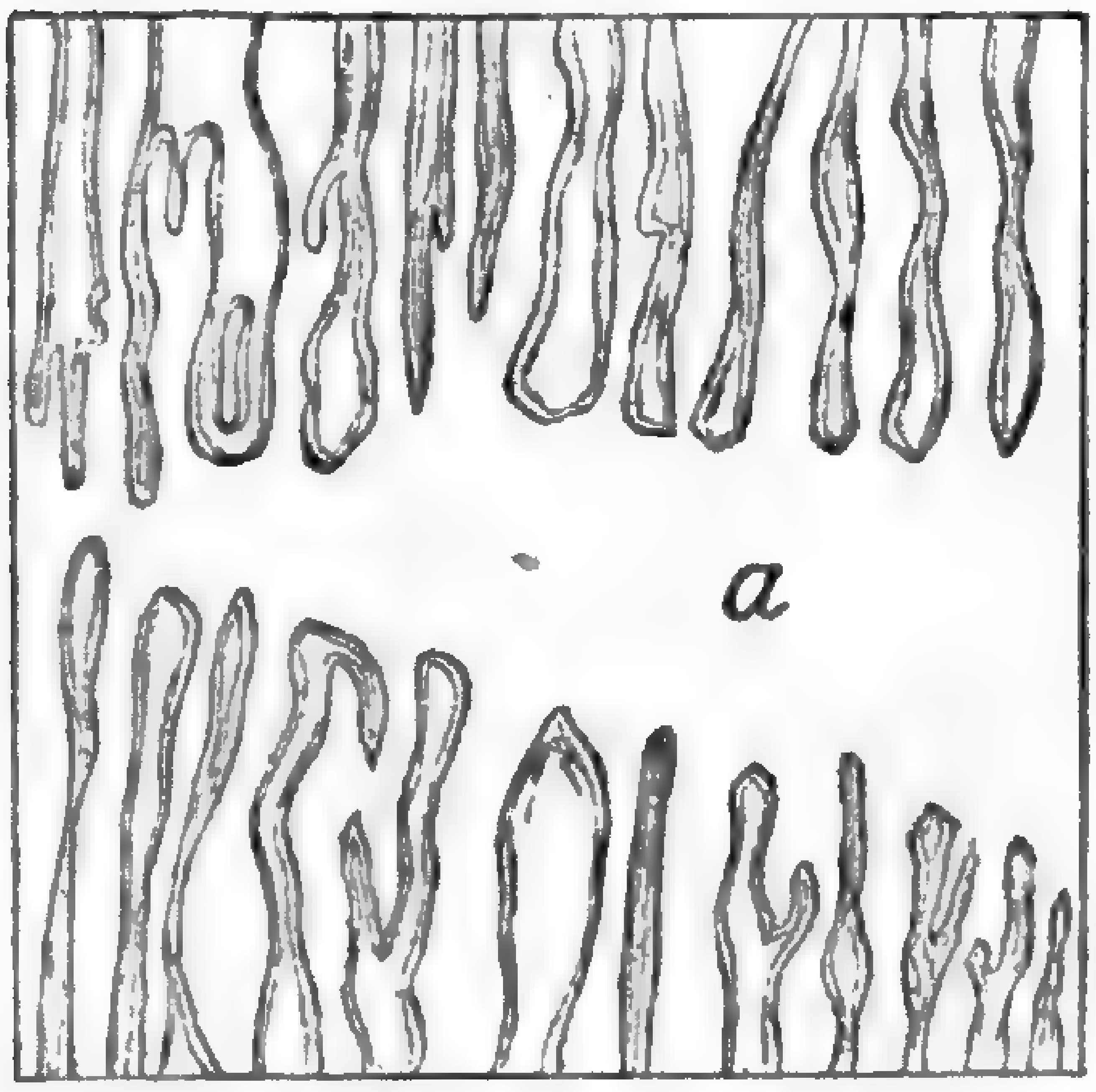
An analysis was also made of sample No. 3, but the separation was a little less complete than of No. 2; the first digestion in acid left behind a very little of the soluble mineral, as shown by the presence of lithia in B, and then in the subsequent treatment of the insoluble part (in which also KOH was employed) there seemed to have been a slight decomposition of the albite. The results, although for the reason given hardly worth putting on record, were satisfactory in this, that they confirmed those of No. 2.

The point thus far established may be stated as follows: A chemical examination proves that the substance, called provisionally β spodumene, is not a distinct species, but only a very uniform mixture of two minerals; one of these, called by us *eucryptite*, dissolves with gelatinization in hydrochloric acid, and has the composition, $Li_2Al_2Si_2O_8$; the other, not attacked by acid, is *albite*, $Na_2Al_2Si_6O_{16}$. The true expression of the chemical composition of the substance is, therefore, seen to be that (2) given above. That the mixture is truly mechanical, and not a molecular one broken up by the acid (if that were possible), is proved by this significant fact: the insoluble residue (B above), left after the digestion in sodium carbonate, was in one case examined under the microscope, and found to be *crystalline*, and to have the peculiar semi-fibrous structure belonging to the pseudomorphous albite, as described below.

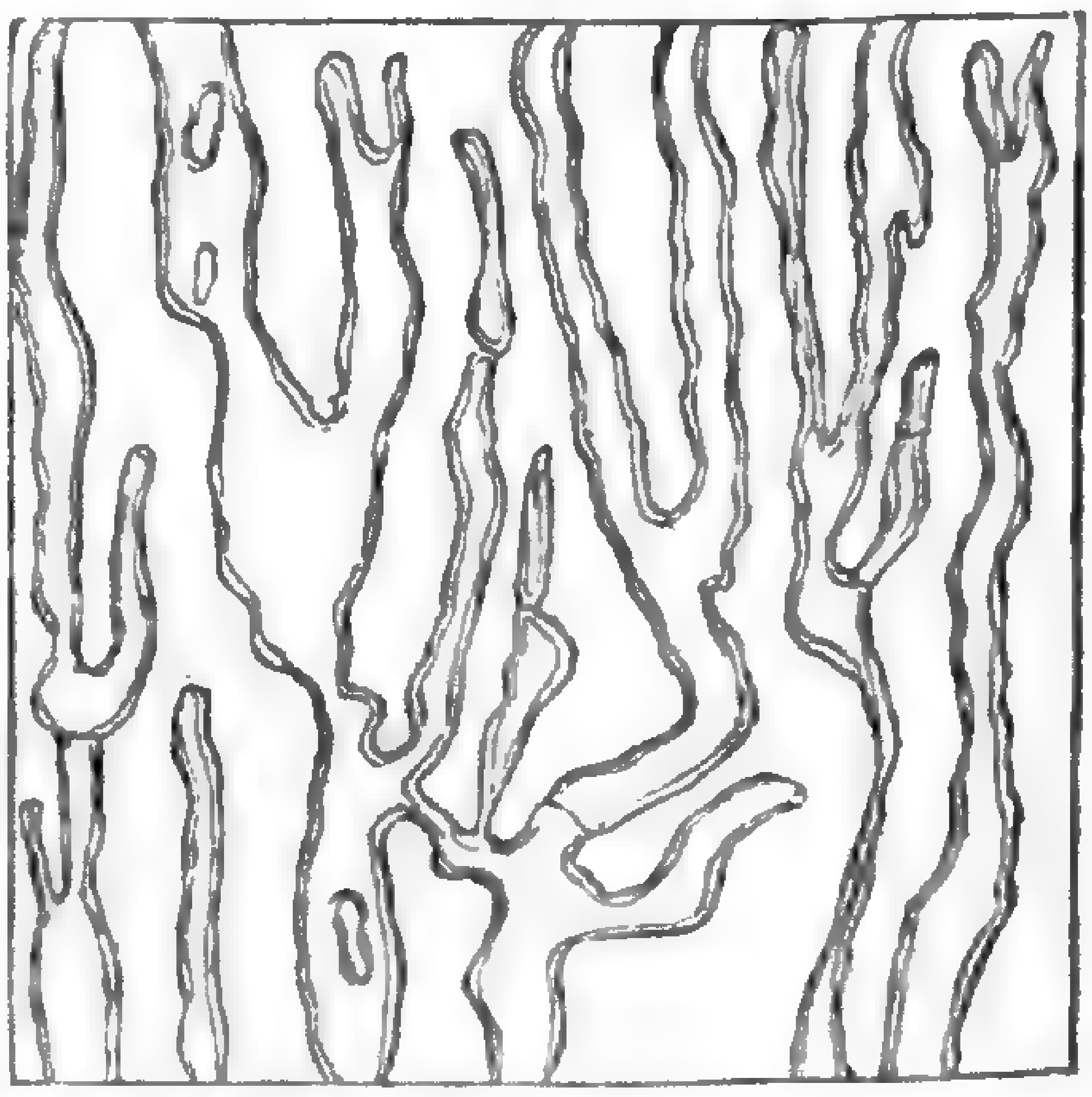
The microscopic examination of thin sections of β spodumene confirms the results reached from the chemical side as to the complex nature of the substance, and gives, in addition, a very satisfactory determination of the crystalline character of the new lithia mineral. A series of thin sections were prepared, some parallel to the fibrous structure, that is at right angles to the original mineral (spodumene), and others transverse to the fibers and consequently parallel to the original prism. The sections parallel to the fibers, when examined under the microscope, seemed at first sight to give no proof of want of homogeneity. The fibers, seemingly of rounded form, and though in general parallel yet quite wavy in outline, are packed so closely together that the question of the presence or absence of any substance between the fibers and enclosing them could not be answered; the whole gave the effect of aggregate polarization. The above statement is true for the greater portion of each of the slides—the result thus far was negative.

Occasional irregularities, however, in the usually parallel fibrous structure, which may not inaptly be compared in appearance to the grain of wood-fiber in the neighborhood of a knot, as seen in a smooth board, gave better results. The fibers in such cases are much curved and irregular in outline, and so separated from one another that they are seen to be merely enclosures in a surrounding matrix. In other cases, this enclosing material forms open spots, where the structure (in polarized light) is found to be that of ordinary albite, and into this the needle-like fibers of the other mineral project (this is illustrated in fig. 15, a = albite). Still again, on the edges of the sections where a degree of thinness impossible for the whole slide is sometimes attained, a similar satisfactory result is reached. The fibers in such cases are distinctly seen, independently of each other and of the enclosing albite. They are generally nearly straight and parallel, but not infrequently the shape is more or less irregular; branching forms recalling some kind of coralline

15.



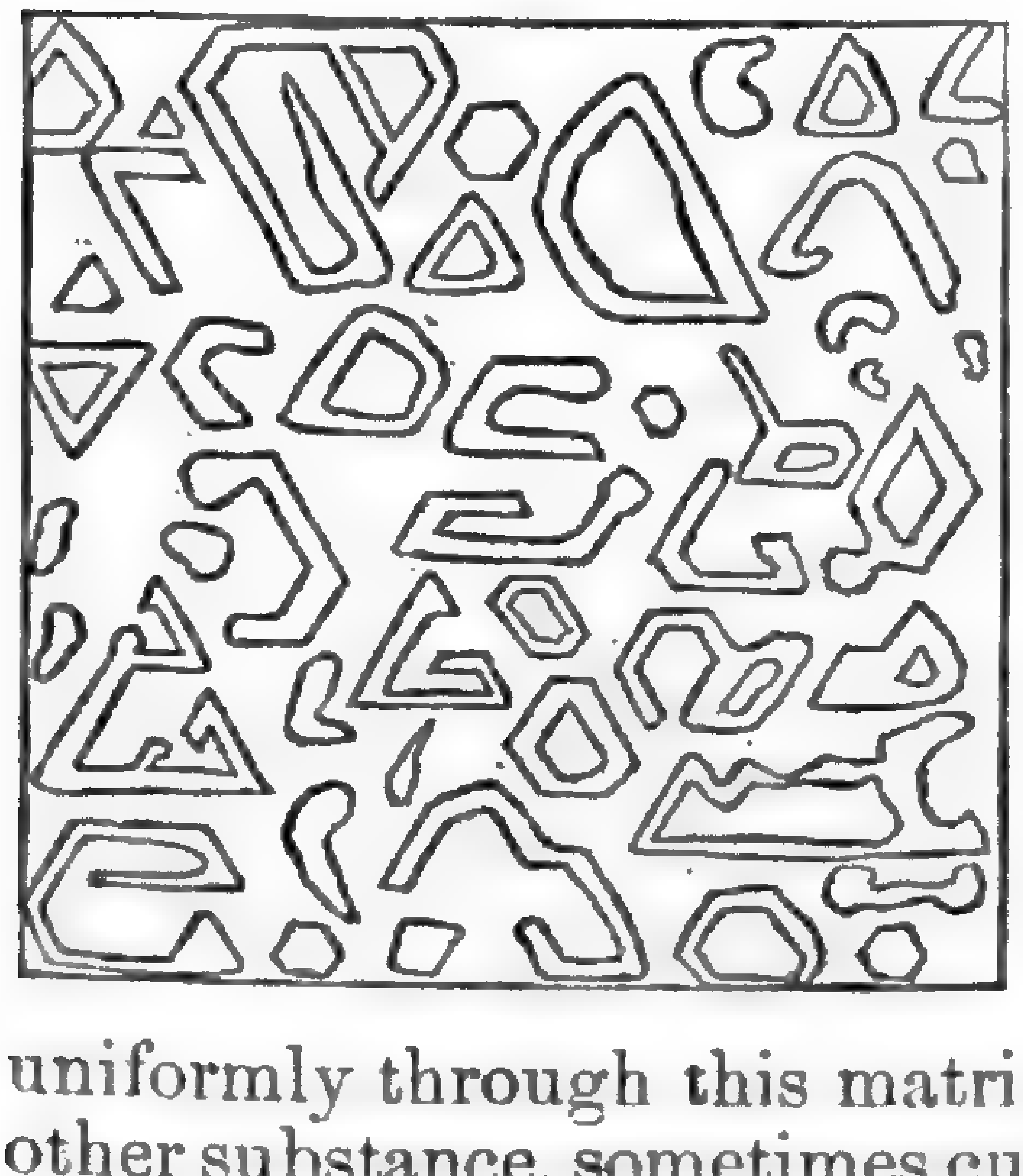
16.



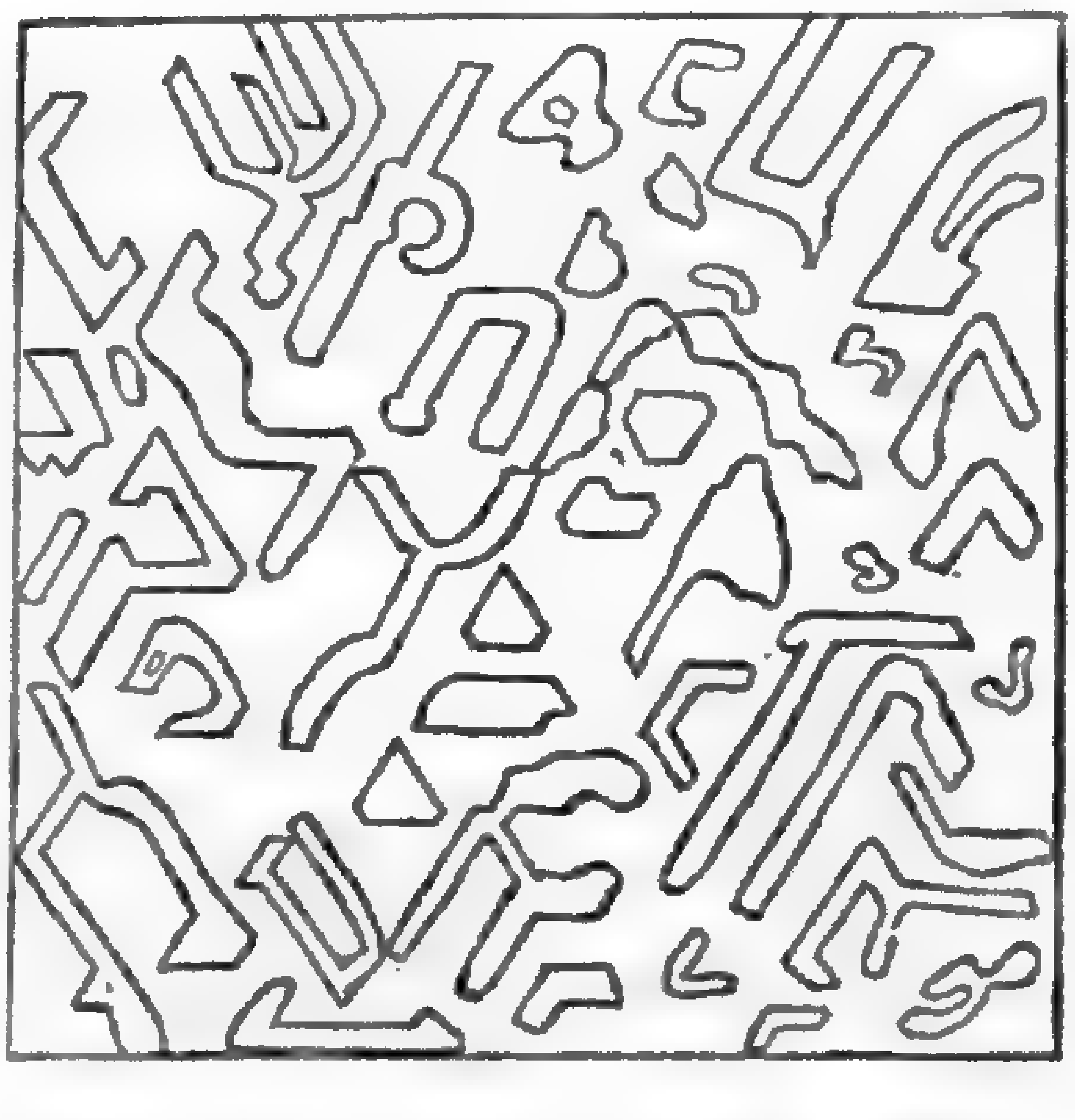
structure are common. The latter forms are shown in fig. 16; the fibers here are much more irregular and coarser than is generally true. (Compare also fig. 19.) The fibers are apparently rounded but the outlines are usually indistinct, and the form can be made out only by repeatedly changing the focus of the microscope. The explanation of all these irregularities in outline is given by the result obtained on examining the sections cut transverse to the fibers. Several additional facts were brought out in the study of the sections now described. It was found that, when examined between crossed Nicols, the extinction of the light took place *parallel* to the length of the fibers; moreover, the fibers have not infrequently a transverse fracture, probably indicating cleavage. The form of the terminations of the needles could not be certainly observed. In cases like those above described (fig. 15), the extremities seem to be given entire, but no absolute assertion can be made in regard to them. In many cases, probably the majority, they taper out gradually to a fine point, while in others they seem to be terminated by a low pyramid.

The examination of the other set of sections, cut across the fibers, was even more satisfactory and conclusive. The appearance in polarized light, as the plate is revolved on the stage of the microscope, is at once striking and beautiful. The section as a whole is divided into irregular patches (albite), changing from dark to light and the reverse with the revolution, giving the whole a strangely mottled look. Distributed closely and uniformly through this matrix are seen also minute areas of another substance, sometimes curved but generally bent at an angle of 60° or 120°; they are *unchanged* by the revolution between the crossed Nicols. The effect will be best appreciated from the accompanying sketches (figs. 17, 18). When a high power is employed (say 600 diam.) and the attention is confined to a small portion at once, it is seen that these narrow bands, which

17.



18.



in a cursory glance under a low power seem to be quite irregular in form, are, on the contrary, approximately in parallel position. The solid portions are triangular or hexagonal in outline, and the bands are bent at angles of 60° and 120°, sometimes so as to form complete rings;—they are all more or less rounded. In short, the structure is that of the most regular pegmatite or "graphic granite," and the explanation is the same. These regular forms, like those of the quartz in the feldspar in the other case, are due to the restricted crystallization in the albite of the new mineral in question. They mark the mineral as belonging to the hexagonal system, and the result of the optical examination both parallel and transverse to the fibers confirms this conclusion.

Taking the section as a whole, there are portions in which the directions of the new mineral are quite irregular, but for the greater part there is an obvious tendency toward regularity, sometimes leading to most perfect forms. As would be expected, the axial directions (60°) change at small distances, so that a given set of directions belongs only to a limited area; this is obviously determined by the enclosing albite.

We are now able to connect the results of the microscopic examination with those of the earlier chemical investigation. The enclosing material in which the fibers lie is the *albite;* this is proved indeed by what has been stated, and moreover by the fact that it, whenever distinctly separate, has the same structure as in undoubted cases of the same pseudomorphous material; it is also shown by the examination of the insoluble portion alluded to before, for in this the fibers have been removed and the matrix left unattacked. The enclosed mineral is that which with the albite makes up the β spodumene, having the composition $Li_2Al_2Si_2O_8$.

In view of the fact that this lithia-bearing mineral is thoroughly defined, as well crystallographically as chemically, and considering, moreover, the important part it plays in the history of the spodumene, we feel obliged to give it a distinctive name. We call it *eucryptite*, from *εὖ* well, and *κρυπτός* concealed.

EUCRYPTITE crystallizes in the hexagonal system, with probably basal cleavage. Its specific gravity, calculated from that of β spodumene, 2·647 and that of the pseudomorphous albite 2·637, is 2·667. It gelatinizes with hydrochloric acid and fuses easily. It is a unisilicate, and its chemical composition is expressed by the formula $Li_2Al_2Si_2O_8$=silica 47·51, alumina 40·61, lithia 11·88=100·00. Its mineralogical relations are not very certain; still, in form, and essentially in composition, it is analogous to nephelite. It also might be viewed as a lithia-anorthite, it having the same ratio as anorthite; though it is different crystallographically. On the other hand, the fact that it changes so readily into muscovite, and has the same ratio as the normal varieties of that species, might seem to place it near it; but it certainly has no micaceous structure. The true lithia mica (lepidolite) has a very different composition.

2. *Cymatolite.*

The name cymatolite was given in 1867 by Prof. Shepard to a mineral found at Goshen and Norwich, Mass., a result of the decomposition of spodumene. The analysis given by him left the composition of the supposed new mineral in question, and this doubt was not removed by a subsequent analysis by Mr. B. S. Burton. Mr. Julien gives in his paper several analyses of cymatolite which agree well together and which correspond to a simple chemical formula. In our earlier investigations we assumed it to be an established point that the species was a good one and had a definite composition. This assumption was confirmed by two closely agreeing analyses (given below) made upon the Branchville material. Further study, however, which was made necessary by the results reached in the case of β spodumene—for the cymatolite is directly derived from the β spodumene—has convinced us that the supposed species is only a remarkably uniform and intimate *mechanical mixture of muscovite and albite.* We shall, however, throughout this paper retain the name cymatolite as a convenient way of designating this interesting compound substance, and shall describe it first as if it were a true species.

The *physical* characters of the cymatolite of Branchville are as follows:—It has a distinct fibrous structure, sometimes straight but more generally wavy. It is also at times confusedly fibrous and again scaly. The specific gravity = 2·692–2·699. The color is generally white, but it is often slightly discolored and occasionally it has a faint pink hue.

As has been stated on p. 258, the crystals of spodumene, which have been altered to cymatolite, are numerous and often very large. The way in which the fibrous structure is developed is seen in fig. 2, which is a section across the prism. It is usually true, as seen here, that the direction of the fibers at the edge is at right angles to the bounding surface. In the interior the structure is more irregular and the fibers interlace in an intricate manner, giving sometimes a feather-like appearance. Usually all trace of the original prismatic structure and cleavage of the spodumene has disappeared. In rare cases, however, in the interior of a crystal this longitudinal structure is still apparent, although the direction of the fibers remains transverse. (Compare also other figures in the Plate, in which c = cymatolite.)

Two analyses of cymatolite have been made by Mr. Penfield. Number 1 was made from a portion of an entirely altered crystal; it was perfectly white and apparently free from any impurities. The results are as follows:—

No. 1, G.=2·692.	I.	II.	III.	Mean.		Ratio.	
SiO_2	59·38	----	----	59·38		·989	4
Al_2O_3	26·67	----	----	26·67		·259	1·05
CaO	0·62	----	----	0·62	·011	·283	1·13
Na_2O	----	7·66	7·70	7·68	·124		
K_2O	----	3·53	3·49	3·51	·037		
H_2O	2·01	----	----	2·01	·111		
				99·87			

The second analysis was made on the pure mineral associated on the same crystal, which afforded sample 2 of β spodumene. The results afforded are, as follows:—

No. 2, G.=2·699.	I.	II.	Mean.		Ratio.	
SiO_2	60·61	60·49	60·55		1·009	4
Al_2O_3	26·37	26·39	26·38		·256	1·016
MnO	0·08	0·06	0·07			
Na_2O	8·08	8·16	8·12	·131	·263	1·044
K_2O	3·33	3·35	3·34	·035		
Li_2O	0·17	0·17	0·17	·006		
H_2O	1·65	1·66	1·65	·091		
	100·29	100·28	100·28			

The agreement between these two analyses is as close as could be expected; the ratio obtained from No. 2 is nearly

$$\overset{\text{I}}{R}_2O : Al_2O_3 : SiO_2 = 1 : 1 : 4.$$

This is the same ratio as that obtained for spodumene and β spodumene. The formula is therefore

$$(Na, K, H)_2Al_2Si_4O_{12} = (K, H)_2Al_2Si_2O_8 + Na_2Al_2Si_6O_{16}$$

Since the cymatolite is certainly derived from the β spodumene, while the latter substance has been proved to be a mixture of albite and what—as was shown—has the composition of a lithia muscovite, the fact that the formula of cymatolite can be written as a compound of one molecule *muscovite* and one molecule *albite* is significant. Were no other facts at hand the conclusion that cymatolite also must be a mechanical mixture could hardly be questioned. The facts, however, are in themselves sufficient to prove this, independent of any other considerations. It may be mentioned that the chemical method of attacking the problem, employed in the case of the β spodumene, is not here applicable, since the muscovite is not decomposed by hydrochloric acid. A preliminary examination was made with sulphuric acid, which resulted in showing that the cymatolite was attacked by it, as was the mica of the locality, while the albite was barely so. This method was, however, not carried further, for the microscope gave all the solution that could be desired.

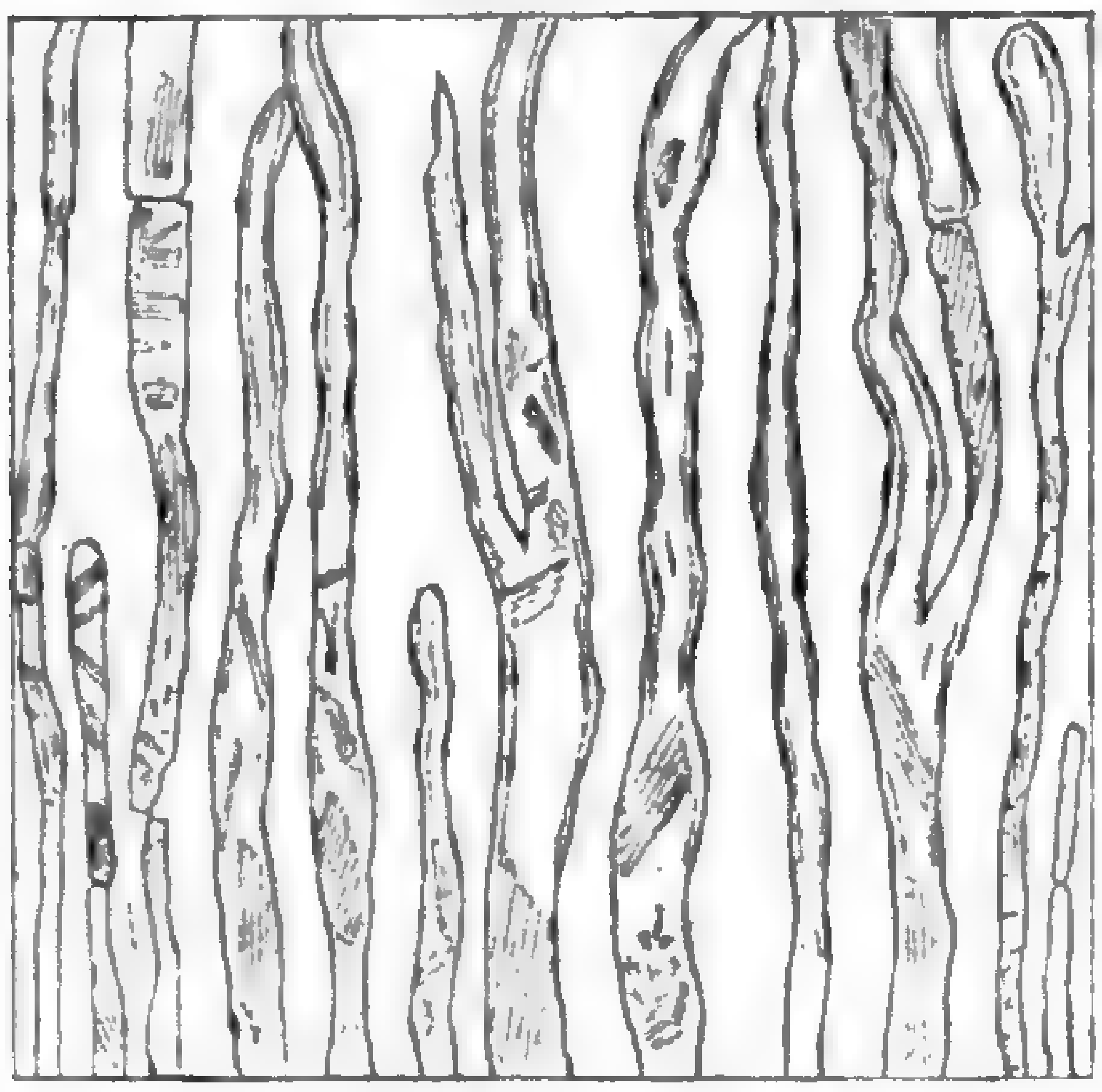
A considerable number of sections of cymatolite, both in its purest normal varieties, and in its transition forms from β spodumene on the one hand and to albite on the other, were examined. The result not only proved the fact of the mixture of muscovite and albite, but also gave the explanation for the remarkable uniformity of the analyses, for in most cases the mixture is in the highest degree intimate. A section of cymatolite like that represented in fig. 1*c* (Plate), when examined in polarized light, is found to consist of long, slender, somewhat curved fibers, giving very brilliant colors and showing the characteristic structure of mica, and between them grayish portions of albite. In some cases the fibers of mica are so close together that the albite is invisible, but in others they spread out divergent and then the background of the other mineral is clearly seen. Still again, the mica needles are few and run out in brilliant lines over a broad surface of albite.

The sections increase in beauty with the irregularity of the structure of the cymatolite. For example, two sections were made from the crystal represented in fig. 2 (Plate). One of these was, like the figure, transverse, and the other was vertical, and showed something of the prismatic structure of the original spodumene. All the details of the structure came out most clearly in the sections in polarized light. The feather-like structure was particularly distinct and beautiful: a deeply colored rib of mica, and from this diverging regularly on both sides the narrow fibers of the same mineral, the albite between them becoming more and more distinct as their distance apart increased. Other sections were examined of the scaly varieties of cymatolite, where the mica scales were parallel to the surface. In these the albite had the mottled appearance in polarized light, mentioned under β spodumene, and the mica was scattered very uniformly as brilliantly colored scales through it. Other sections transverse to the fibers, in the distinctly fibrous kinds, gave somewhat different effects. Many details could be added, but enough has been said to make the character of the observations apparent on which the statement as to the compound nature of cymatolite is based. The mica and albite are always distinct from one another. In some cases they both appear in larger masses having segregated together in the process of alteration. More is said about this later.

The only foreign mineral observed in the slides was one which occurs in hexagonal prisms, and can hardly be anything but *apatite*, as it agrees optically and crystallographically with that species. It is seen scattered through the cymatolite sometimes rather abundantly, occasionally also in the β spodumene, it is, however, not for a moment to be confounded with eucryptite. The presence of apatite would explain the lime found in analysis 1 of cymatolite.

Certain of the sections which show the transition from β spodumene to cymatolite are most interesting and instructive. While in much of the cymatolite there seems to have been a tendency to the partial separation of the mica and albite, there are other specimens in which the two are as intimately mixed as the eucryptite and albite in the β spodumene. In cases like those last named, the structure of the cymatolite is exactly that of the β spodumene, only that the rounded fibers of eucryptite have been replaced by the thin elongated scales of mica, proving that the one has been formed from the other. In still other cases we may pass on the same slide from normal cymatolite on the one side to normal β spodumene on the other. Between them is a zone where the two substances shade off into one another, in other words where the change of the eucryptite is only partial. This will be understood from fig. 19. As here seen, some of the fibers are apparently unchanged, while others are partly altered, the last containing many minute scales of mica, often packed closely together. These small scales are irregularly situated, often across the original fiber of eucryptite: the direction can always be observed both by the cleavage line and too by the direction of the extinction of the light between crossed Nicols. Where the process has been completed, however, the scale of mica is generally parallel to the line of the original eucryptite. The eucryptite fibers along this intermediate zone, even when mica scales are not visible, have generally lost their smoothness of outline, and sometimes have separated into lines of minute, irregular, transparent granules.

19.



The transition of β spodumene into cymatolite can also often be seen by the unaided eye, along the line of contact. In such cases the silvery lines of mica, though the scales are too minute to be distinguished, can be seen shooting up into the compact β spodumene.

3. *Albite.*

The albite, which occurs pseudomorphous after spodumene, appears in several rather distinct varieties. It is sometimes finely granular, showing no crystalline structure. Again it has a fibrous structure, similar to that of β spodumene and cymatolite, the fibers transverse to the prism. Still again it is found forming parts of altered crystals, in which it has the curved and wavy laminated structure which is characteristic of the mineral that makes up so large a part of the vein; it also appears as rosettes implanted on the surfaces of many crystals, evidently owing its origin in such cases to the alteration.

An analysis of the fibrous variety of the species afforded Mr. Penfield the following results:—

G. = 2·637.	I.	II.	Mean.	Ratio.		
SiO_2	67·61	67·59	67·60		1·127	6·
Al_2O_3	20·07	20·11	20·09		1·195	1·03
MgO	·16	·14	·15	·004		
Na_2O	11·71	11·66	11·69	·188	·193	1·02
K_2O	·11	·11	.11	·001		
Ignition	·14	·14	·14			
	99·80	99·75	99·78			

This analysis corresponds closely to the formula $Na_2Al_2Si_6O_{16}$, or that of albite.

The occurrence of albite pseudomorphs after spodumene is mentioned by Mr. Julien, but among the Massachusetts specimens they seem to play a comparatively unimportant part. Mr. Julien speaks of the albite as mixed with a little muscovite and quartz, and states that these pseudomorphs are "a mere variety" of the coarse agglomerates of quartz, feldspar and mica, which he calls pseudomorphs of *vein granite.*

At the Branchville locality the albite as an independent mineral occupies a more common and perhaps more interesting place among the products of the alteration of the original spodumene.

The fibrous albite, of which the above analysis was made, formed the whole of a perfectly distinct crystal. A section was made of it and examined microscopically. It was found to be essentially pure, with only traces of mica (note the potash in the analysis). The structure was rather indistinctly fibrous and it was most interesting to note that its appearance was very closely that of the albite with the mica in cymatolite, as too with eucryptite in β spodumene. A number of the groups of fibers were found to consist of two parts optically, and the angle between the extinction of the light for them was from 10°–11°. As this is the angle for albite twins examined parallel to the basal plane, the agreement can hardly be accidental, and is a point of some interest.

A number of other sections of what we have called albite were also examined. The result proves that pure albite is rather rare, and that most of the granular albite in the crystals contains a considerable quantity of mica, and hence verges toward cymatolite. This qualification is to be remembered in examining the plate. In many cases the albite is found to be in broad plates characteristically twinned, and with them are found scales of mica, large too as compared with those in normal cymatolite.

4. *Muscovite.*

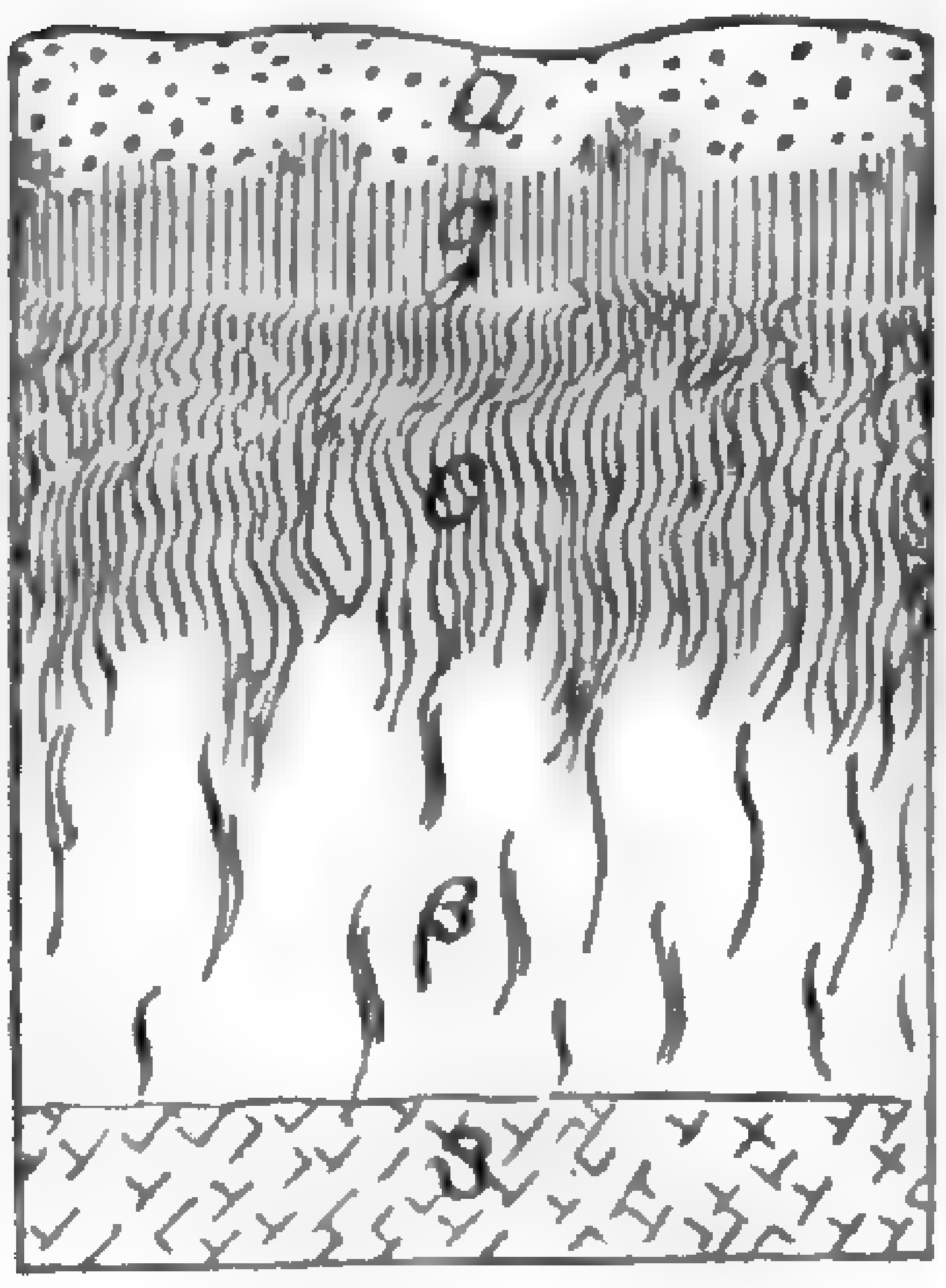
As a distinct mineral, independent of its usual associate the albite, the potash-mica, muscovite, plays an unimportant part among the spodumene pseudomorphs at Branchville. It occurs very commonly in thin scales coating fracture-surfaces in the interior of the altered crystals. It is also found in small segregated masses, or as scattered plates imbedded in the mass of the crystal itself. It occurs in this way more particularly in the complex pseudomorphs where the feldspars (albite and microcline) are also present in distinct masses. Its presence is indicated in figs. 6 and 8 (Plate, *g*=mica). This mica is commonly of a light greenish-yellow color and has a greasy luster; in some cases though more rarely it is pink in color, but is not a lithia-mica. It was not found possible to obtain enough pure material for an analysis.

The occurrence of the mica with the albite, forming the cymatolite, has already been described under that head. The analyses of the cymatolite show that the mica has the formula of normal muscovite, viz: $(K, H)_2Al_2Si_2O_8$. Taking the ratio of $K_2O : H_2O = 1 : 3$, corresponding approximately to analysis 2, the calculated composition of this muscovite is:—

SiO_2	46·23
Al_2O_3	39·52
K_2O	9·35
H_2O	5·20
	100·00

The complex nature of cymatolite having once been established, it is easy to find many specimens in which the mica and albite are so distinct that their independent existence can be proved by the unaided eye. The occurrence of albite containing small quantities of mica has been mentioned. Conversely, we find specimens in which the mica is more or less completely separated from the albite. Fig. 20 shows a part of a section across a crystal, with the nucleus of spodumene (*s*), then β spodumene (β), next cymatolite (*c*) graduating into pure and soft silvery mica (*g*), and finally a coating of albite (*a*). Such a case shows the extent to which the segregation of the constituents of the cymatolite can go on.

20.



In the Massachusetts specimens, the mica, as an independent mineral, is, according to Mr. Julien, much more abundant. We quote, on a following page, a remark of his on this point.

5. *Microcline.*

A second potash mineral, arising from the alteration of the spodumene, is a potash feldspar having the composition and optical character of microcline. This is a much rarer occurrence than that of the albite pseudomorphs. The microcline, where it occurs alone, which is seldom, has a fine granular structure, showing no cleavage whatever. The color is yellow, and under the microscope it is resolved into independent grains having the characteristic appearance of microcline in polarized light. In the best specimen observed, the crystalline planes, both prismatic and terminal, are perfectly distinct, but nothing was left of the original mineral. This pseudomorph consisted, for the most part, of the potash feldspar, but a small portion of one side was soda feldspar (or albite). The relation of these two minerals is shown in fig. 10, a case in which the albite is present in much larger quantities than in that described, it making up about half the crystal.

The composition of the yellow granular feldspar is shown by the following analysis by Mr. Penfield:—

G. = 2·548.	I.	II.	Mean.	Ratio.		
SiO_2	64·55		64·55		1·076	6·
Al_2O_3	19·70		19·70		·191	1·07
K_2O	15·66	15·59	15·62	·166	·176	·98
Na_2O	0·53	0·64	0·58	·010		
Ignition	0·12	0·12	0·12			
			100·57			

It will be seen that the above analysis corresponds very closely with the normal composition of microcline, $K_2Al_2Si_6O_{16}$.

Figures 3 and 4 show further the manner in which the potash feldspar is contained in the interior of the soda feldspar, both forming part of perfectly distinct pseudomorphous crystals of spodumene. In addition to this method of occurrence, the microcline is also observed in broad cleavage plates forming sometimes almost entire crystals of the original mineral. Here, too, it is commonly associated with albite, as shown in figs. 11 and 13. One most interesting and significant fact in connection with this is that the separate fragments of microcline scattered through a single crystal at different points, though sometimes several inches apart, are uniformly in *parallel position.* The angles of the cleavages of the microcline differ in different specimens, so that their position seems to have no definite relation to the axes of the spodumene crystals.

It is worth while to call attention here to the fact that the potash feldspar, microcline, occurs in very large quantities at this locality. Several hundreds of tons have already been taken out by the Messrs. Smith for use in making porcelain. The feldspar is obtained in cleavage masses as large as can be handled, and nearly pure; a single continuous cleavage surface *ten feet long* has been observed in the ledge.

6. *Killinite.*

Killinite is a hydrous silicate of aluminum and potassium ordinarily included among the pinite group of minerals. It was first described from Killiney Bay, Ireland, and a series of analyses is published in the Mineralogy of Greg and Lettsom. It was described as occurring in granite associated with spodumene, and has its cleavage. The same mineral is described by Mr. Julien as occurring at Chesterfield, Mass. Our results, which we give here, are for the most part identical with his.

The killinite from Branchville is sometimes compact and structureless, but more generally it has an indistinct fibrous structure parallel to the prism of the original mineral. Many specimens show distinctly the cleavages of the original spodumene. The color ranges through various shades of green, from light bluish-green to oil-green and dark grass-green.

Two analyses, on independent material, have been made for us; the first, number 1, is by Mr. S. L. Penfield, of the prismatic variety; and the other, number 2, is by Mr. F. P. Dewey, of the compact variety.

	No. 1.	No. 2.
SiO_2	48·93	53·47
Al_2O_3	34·72	32·36
Fe_2O_3	0·54	0·79
FeO	0·33	0·42
MnO	0·64	0·72
CaO	----	0·17
K_2O	9·64	7·68
Na_2O	0·35	0·44
Li_2O	----	0·04
H_2O	5·04	4·07
	100·19	100·16

The two analyses show a rather wide variation in composition between the material analyzed in the two cases. If, moreover, the analyses referred to above as published by Greg and Lettsom be compared together, and with that of Mr. Julien from Chesterfield Hollow and those here given, it will be seen that they vary between quite wide limits. It cannot be doubted, however, that essentially the same material was under examination in the several cases, and that the difference noted is probably due to a want of homogeneity.

Killinite gives water in the closed tube. B. B. glows and fuses at about 5 to a white enamel. Not decomposed by hydrochloric acid.

Several sections of killinite were examined in the microscope. The parallel fibrous structure is there clearly seen and in addition there appear to be scales inclined at equal angles in opposite directions on either side of each parallel line. They exert a considerable action on polarized light. Most of the specimens are of so fine a texture as not to allow of satisfactory resolution. One section, however, which was somewhat coarser, seems to offer an explanation. This one appeared to consist mostly of minute scales having all the appearance of *mica*. These scales were strikingly similar to those of unquestioned character formed from the alteration of eucryptite and illustrated by fig. 19. There seems to be but little doubt that this is the true resolution of the mineral. In addition to these scales, there are small portions which do not polarize light, which may be amorphous silica, and occasional other particles less easily defined.

The idea of a relation, between the minerals of the pinite group and those potash micas which yield water on analysis, is not a new one, but was long since advanced. It is recognized by Professor J. D. Dana, in the 5th edition of his System of Mineralogy (1868), p. 447.

If analysis 1 of killinite be compared with the composition of muscovite on p. 272, and also with the analyses of muscovite in Dana's Mineralogy, 5th edition, the correspondence will be at once recognized. The variation of analysis 2 of killinite would be explained by supposing the presence of several per cent of free silica; the correspondence would then be quite close. Moreover, the observations with the microscope have already independently led to the suggestion of the probable presence of amorphous silica. In view of the part played by mica in the alteration of the spodumene the suggestion here made certainly seems plausible, although the want of perfect homogeneity in the killinite makes it impossible to give it a definite formula.

7. *Pseudomorphs of Vein-granite.*

We employ the same term, as Mr. Julien, to describe certain pseudomorphous crystals of spodumene, which consist of a more or less coarse agglomeration of feldspar (albite and microcline), and mica. In such cases, which seem to be rarer at Branchville than at Chesterfield, the constituent minerals are well developed and have the same character as in the vein as a whole. The feldspar, for example, is not granular and without apparent cleavage, as is generally true of the special cases before described, but occurs in rather broad cleavage fragments. The surfaces of these crystals are very rough, often covered with rosettes of albite, and yet the general form of the original spodumene can always be distinctly seen. It is to be noted that quartz is almost entirely absent in these complex pseudomorphs, in which they differ essentially from the Chesterfield specimens.

II. RELATION IN METHOD OF OCCURRENCE BETWEEN THE VARIOUS MINERALS PRODUCED BY THE ALTERATION OF THE SPODUMENE.

The individual characters of the several minerals produced from the change of the spodumene have already been given, and something has been said as to their mutual relations; it seems best, however, to add a few more general remarks as to their method of occurrence.

Spodumene and β Spodumene.—The way in which these two minerals occur together will be better understood from fig. 5. As indicated in this case, the alteration product, β spodumene, forms a more or less thick crust about the original mineral, and also penetrates in bands which follow the directions of the cleavage surfaces, and which are sometimes mere lines and again have considerable thickness. It is worthy of note, that in all cases the line of separation between the two is perfectly distinct, and the spodumene so associated seldom shows at most more than a trace of alteration. The direction of the fibers is, as stated, transverse to the neighboring surface of spodumene in each case, though in some cases it is so compact as to show little structure.

In one very interesting case the crystal consisted in part of β spodumene and in part of the original mineral, but the latter though unchanged in other respects had already taken the transverse structure of the former, and the longitudinal prismatic structure was nearly obliterated. This must evidently be an early step in the process of change.

β Spodumene and Cymatolite.—Many crystals and fragments of crystals which do not show a trace of spodumene exhibit these two minerals in very distinct relations. The aspect of them is such as to leave no doubt that the first passes gradually into the other, the blades of cymatolite interlacing with the less distinct fibers of β spodumene wherever the two come in contact (see fig. 1*b*). The appearance, however, is always that of two distinct substances, even when the line of union is examined under the microscope. It is consequently necessary to conclude that while the alteration went on gradually there was chemically an abrupt change from the one substance to the other. As already remarked, the analysis 2 of β spodumene was made of a portion, which, though apparently pure, immediately adjoined the cymatolite, and the result is identical with the others, where the idea of a regular gradation could not be suggested. Many of the large crystals of cymatolite, when examined carefully, show a trace of the other mineral, and we are forced to believe that at least for this locality it always preceded it.

Spodumene, β Spodumene and Cymatolite.—It only remains to speak of the cases in which all three of the minerals named occur together in the same crystal. Many instances could be given, but it will be sufficient to describe a single striking case. In figs. 1*a*, 1*b*, 1*c*, there are represented three sections across the same crystal. This crystal had a length of 15 inches, a width of 4½, and was 1 inch in thickness; it was well terminated at one extremity. The sections, taken in order from the terminated end down, divide the crystal into three approximately equal parts. No. 1 (fig. 1*a*) shows the β spodumene (β) forming the mass of the crystal, with original spodumene (*s*) as a band on the lower surface, and the cymatolite (*c*) as a thin coating more or less continuous around the whole. No. 2. (fig. 1*b*) shows no spodumene, but the β spodumene forms the greater part, though the cymatolite has increased much beyond the first section. No. 3 (fig. 1*c*) shows only the cymatolite.

Figure 5, referred to above, shows all the three minerals, though the cymatolite is only sparingly present, and that on the edges. In figures 8 and 14 the spodumene forms a few points and small isolated portions having surfaces parallel to the cleavage. It is surrounded by β spodumene and cymatolite, the latter radiating out from the centers of spodumene. Crystals, in which only spodumene and cymatolite are present, are rare. In fig. 14 a single narrow band is shown which is still β spodumene, while all the rest is changed to cymatolite and albite.

Albite and Cymatolite.—The albite, as has already been remarked, is a common mineral among these pseudomorphs. In some cases it makes up almost the entire crystal, and again it is present only in small isolated portions. The commonest form is that which is very finely granular, although the fibrous form is not rare. It is to be remembered, however, that between the normal cymatolite (1 mol. albite + 1 mol. muscovite) and the pure albite on the one hand, and the pure muscovite on the other, there are many gradations.

Figure 3 is a vertical section of a portion of a crystal, the exterior of which is fibrous cymatolite (*c*), and the interior granular albite (*a*) with some bands of microcline (*m*). Fig. 7 is a section across a large crystal in which the two minerals are similarly disposed. Fig. 10 shows the albite and microcline, as also 11 and 13. Figs. 6, 8, 12, 14 show the way in which the granular albite is intermixed with the other species which have been mentioned. In still other cases, the albite is in broad curved plates, which would seem to have nothing of a pseudomorphous character except that the outlines of the spodumene crystals, of which they form a greater or less part, are still distinct.

Occurrence of Killinite and Cymatolite.—In many of the massive specimens, the spodumene is changed in part to killinite and in part to cymatolite, the two minerals being intimately associated with each other. This association is illustrated by fig. 9, in which *c* is the fibrous cymatolite and *k* the killinite. The latter makes up the mass of the specimen, and the cymatolite, with its usual transverse fibrous structure, is in thin bands following nearly the original cleavage lines.

It is the confusedly massive variety of the spodumene which has furnished nearly all of the killinite. In the distinct crystals it rarely appears, though here it is sometimes seen, as indicated by fig. 12, as a more or less irregular surface covering.

III. GENETIC RELATION BETWEEN THE ORIGINAL SPODUMENE AND THE VARIOUS PRODUCTS OF ITS ALTERATION.

The general character of the process of alteration, by which the spodumene was changed into the various products already described, was, in a word, as follows:—it consisted essentially in the substitution of sodium and potassium for the original alkali lithium. The interesting facts, that have been detailed, in regard to the compound nature of the substances called β spodumene and cymatolite, taken in connection with the occurrence of the two feldspars and the muscovite, make the whole process tolerably clear and simple. The fact that two molecules of spodumene would, with a change in alkalies, yield one molecule of muscovite and one of albite, was clearly brought out by Mr. Julien; and he uses it to explain the occurrence of the complex pseudomorphs consisting of distinct individuals of albite and muscovite. The study of the specimens from Branchville enables us to extend and complete this explanation.

The relations of the various minerals involved in the change are presented in the following table, showing what may be derived from the spodumene, assuming the change in alkalies to take place.

$$\begin{aligned}
\underset{\text{Spodumene.}}{2\,[Li_2Al_2Si_4O_{12}]} &= [\underset{\text{Eucryptite.}}{Li_2Al_2Si_2O_8} + \underset{\text{Albite.}}{Na_2Al_2Si_6O_{16}}],\ \beta\ \text{Spodumene.} && (1)\\
&= [\underset{\text{Muscovite.}}{(K,H)_2Al_2Si_2O_8} + \underset{\text{Albite.}}{Na_2Al_2Si_6O_{16}}],\ \text{Cymatolite.} && (2)\\
&= \underset{\text{Muscovite.}}{(K,H)_2Al_2Si_2O_8} + \left\{\begin{array}{l} Na_2Al_2Si_6O_{16},\ \text{Albite.}\\ \text{or } K_2Al_2Si_6O_{16},\ \text{Microcline.}\end{array}\right. && (3)
\end{aligned}$$

The first step in the process of alteration was the formation of the β spodumene, by the substitution of sodium for one-half the lithium and the breaking up of the original spodumene, so as to form equal parts molecularly of *albite* and the new mineral which we have called *eucryptite.* The true nature of this second mineral has already been detailed. It would seem to be a comparatively unstable compound, since it changes so readily to muscovite.

The second step in the alteration was the formation of cymatolite out of β spodumene; this change consisting in the substitution of potassium (and hydrogen) for the remaining equivalent of lithium in eucryptite, and the consequent formation of muscovite. The result is a compound, in equal molecular proportions, of *muscovite* and *albite.* It is certainly most striking that this compound substance, as derived from different localities, should be of so uniform chemical character. The explanation for this is to be found in the nature of the chemical process by which the alteration was brought about, the reaction going on uniformly through the mass, without, in the majority of cases, any distinct segregation of the two constituents formed. The change to β spodumene must have been produced by the action of a soda solution, and the subsequent change to cymatolite by that of a solution containing potash.

We have now to speak of the pseudomorphs in which the resulting minerals, mica and feldspar, appear in distinct form, and not as almost irresolvable aggregates. It was first remarked in regard to the cymatolite that in its usual varieties the mixture between the muscovite and albite was an extremely close and uniform one. This is ordinarily the case with respect to the normal material, as is exhibited in hundreds of specimens. There are others, however, of which this is not true, but where the silvery luster due to the mica is more or less absent, and the substance approximates in character to pure albite; and, on the contrary, there are others where the albite is nearly absent and the mica is nearly pure (see fig. 20). The conclusion to which these facts have led us is that there are many gradual transition cases between the normal cymatolite and the pure albite and muscovite, that is, cases, where there has been a decided separation and segregation of these two minerals. These cases, however, require no especial explanation, for that the conditions should be such as to lead occasionally to such segregations was to have been expected. It is rather remarkable that they are comparatively rare, and that normal cymatolite is the rule.

The scheme, presented above, obviously requires that the muscovite and albite should be formed in equal parts molecularly, and by weight in the ratio of 1 : 2 nearly. The question now arises, independently, as to the almost entire absence of mica not infrequently observed in connection with large masses of albite. It appears, to be sure, in separate form as a scaly covering of fracture-surfaces through the altered crystals, and occasionally in small segregated masses, but the amount so observed is much smaller than the equation requires.

We are obliged to conclude that either the muscovite, if formed at the same time with the albite, has entirely disappeared, or else that the method of formation of the albite was sometimes different from that previously explained. It can hardly be questioned that in the cases mentioned it must have been formed independently of its associate, the muscovite. Where the albite has a distinct fibrous structure it must have been formed from the β spodumene (compare also figs. 8 and 12). The albite was probably made from this by the action of a solution of sodium silicate changing the remaining lithium of the eucryptite to sodium and introducing two molecules of silica. It may also have been formed immediately from the spodumene, as expressed in the following equation:

$$\underset{\text{Spodumene.}}{Li_2Al_2Si_4O_{12}} + 2SiO_2 = \underset{\text{Albite.}}{Na_2Al_2Si_6O_{16}}. \qquad (4)$$

Besides the albite pseudomorphs, there are also those consisting of the potash-feldspar, microcline, which require explanation. In regard to them, as has already been stated, there are the cases where the granular microcline is enclosed in albite, again others where it forms substantially the whole crystal, and still others where it is scattered through in large cleavage masses. Reference to formula (3) above shows that the explanation given for the albite and muscovite will answer for the microcline and muscovite, the only difference being in the alkali exchanged for the lithium. Generally, however, the mica is absent and then we must write, as in the case of the albite, taking into account the change of alkali,

$$\underset{\text{Spodumene.}}{Li_2Al_2Si_4O_{12}} + 2SiO_2 = \underset{\text{Microcline.}}{K_2Al_2Si_6O_{16}} \qquad (5)$$

There is no reason to think that the microcline was not formed directly from the spodumene; no trace of any potash series to correspond to the β spodumene and cymatolite was observed.

But little additional explanation is needed beyond what has been given, in the case of the coarse complex pseudomorphs, consisting of mica and the two feldspars. The method of their formation is involved in what has been given, the only essential difference being that the conditions were such as to lead to the segregation and simultaneous crystallization of the resulting minerals in large masses instead of as intimate mixtures. In connection with these it is interesting to call attention again to the fact that the masses of microcline in a single crystal, though often isolated and apparently quite independent, are yet in most cases in parallel position. This is a significant fact in its bearing upon the conditions of formation.

These agglomeration pseudomorphs seem to be more abundant at the Massachusetts localities, as described by Mr. Julien, than with us. Moreover, they differ from those of Branchville in that they contain much more mica and also quartz, which latter mineral with us is practically absent. Mr. Julien, besides his general explanation of the relation of the soda feldspar and muscovite to the original spodumene (which as stated above we have adopted), calls attention to the fact that by an exchange of alkali and the loss of two molecules of silica, spodumene would yield muscovite—that is

$$\underset{\text{Spodumene.}}{Li_2Al_2Si_4O_{12}} = \underset{\text{Muscovite.}}{(K,H)_2Al_2Si_2O_8} + 2SiO_2 \qquad (6)$$

He remarks upon the free quartz present in the pseudomorphs as evidence that this process actually went on.

It is interesting to note in this connection the following statement made by Mr. Julien, he says: "Many pseudomorphs were found in the Chesterfield vein which consist in large part or entirely of a greenish-yellow muscovite with peculiar greasy luster. In fact all stages of intermixture of cymatolite were observed, from the almost pure pseudomorphs of the latter mineral in which muscovite occurred only in minute or even microscopic scales lying mostly parallel to the axis of the crystal—to others in which the mica was so abundant as to have imparted a yellow or greenish color to the mixture, and at last to micaceous pseudomorphs perfectly free from cymatolite retaining the form and superficial striation of the spodumene even to its terminations." He also speaks of the occurrence of large quantities of quartz in the pseudomorphs.

In the specimens we have studied the case is reversed, quartz is nearly entirely absent, mica occurs in separate form only sparingly, and in the formation of the two feldspars there has often been an assumption of silica from some outside source.

Thus far we have said nothing in regard to one important pseudomorphous mineral—the killinite. It seems impracticable to give this a certain place in such a scheme as that given above, for the good reason that its true composition is somewhat in doubt. It is certainly a more or less impure material, having the same want of homogeneity and definite composition that is so often observed among the minerals of the pinite group. The microscopic structure, and, too, the results of the analysis, seem to justify us in the suggestion that it may be essentially a hydrous potash mica, not very unlike that in the cymatolite. In this case its presence is not strange, for the distinction between it and the other would be more in its state of aggregation than in composition. The chemical process which led to the formation of the killinite is in any case clear, for the change consisted essentially in the introduction of potassium and hydrogen in place of lithium, with the loss of silica. It may consequently be expressed by equation (6), given above, and the silica thus set free may have played a part (see equation 4) in the formation of albite. It is interesting to note that the killinite was probably always formed immediately from the original spodumene, since it so commonly shows its cleavages.

General Summary.—The remarks in the preceding paragraphs may be summed up as follows:—The spodumene was subjected to the action of solutions containing respectively soda and potash. The first action of the soda solution, by the partial exchange of alkali, resulted in the formation, from the spodumene, of an apparently homogeneous but really complex substance, consisting of equal parts molecularly of albite and a new lithia silicate (eucryptite.) A further action of the soda solution (sodium silicate), by the complete change of alkali and the accompanying assumption of silica, led in some cases to the formation of albite. On the other hand, the action of the potash more frequently changed the lithia silicate, above named, into normal muscovite, so that another apparently homogeneous but really complex substance resulted, cymatolite, consisting of muscovite and albite in equal molecular proportions; again, the segregation of these two minerals produced, in place of normal cymatolite, a mixture of separate masses of albite and mica. Still further the action of the potash, by an exchange of alkali and simultaneous assumption of silica, led to the formation of potash-feldspar or microcline. In some cases the result was a coarse mixture of the mica and the two feldspars. Finally, the action of the potash solution, and the simultaneous loss of silica, led to the formation from the original spodumene of a mineral very closely related to mica, namely, killinite.

Two questions arise here, to neither of which we can give a very satisfactory answer. The first is as to the source of the soda and potash involved in the changes that have been described—to this nothing more can be said than that they were probably furnished by the previous decomposition of feldspars, though under just what conditions we are unable to say.

The other question is as to the final disposition of the lithia removed from the spodumene—this seems to have disappeared entirely, unless the fact that some of the biotite in the vein now carries lithia may account for some of it. In this connection it should be stated that the manganese triphylite—lithiophilite—is certainly an original mineral of the vein, and occurs rather abundantly with the massive spodumene. Its decomposition has also led to an increase of this supply of lithia. Furthermore, it is more than possible that the formation of the remarkable series of phosphates of manganese, described by us from this locality, was connected with the extensive changes in the spodumene. The fact that two of the phosphates are almost unique among that group of minerals in containing alkalies, (see analyses of dickinsonite and fillowite in our earlier papers) would almost prove this. The lithiophilite may be then the original phosphate of manganese from which the others have been derived. We shall return to this last subject at some future time.

A few additional remarks remain to be made. The cymatolite has been subjected to further change beyond that already described. The result is to lead to the formation of a soft soapy white mineral, filled with scales of mica, and obviously an impure kaolin. This is not at all a surprising result; for it is known that kaolin is formed from the soda-feldspar as well as the potash-feldspar, and the finely divided state in which the albite exists in the cymatolite would make it very liable to undergo the well understood change leading to kaolin.

Associated with the soft, partially kaolinized cymatolite, is an interesting pink clay-like mineral, closely related to *montmorillonite.* It also occurs coating the cleavage surfaces of the partially altered spodumene. It is most abundant, however, in independent deposits of considerable extent in the vein not far from the point where the spodumene occurs. It forms soft masses, easily dug out with a spade, and enough of it was found in one spot to fill an ordinary cart. It also penetrates the vein material, filling cavities in the unaltered albite and quartz. It is quite impure, often blackened in spots with manganese oxide, and contains crystals of apatite.

When first exposed it was moist and soft, easily crushed between the fingers, and in the purest parts entirely free from gritty material when placed in the mouth. Upon being exposed to the air for some weeks it lost much of its moisture and hardened considerably.

The color is a delicate rose-pink, growing somewhat lighter on being exposed to the air. It is easily fusible, B. B.

An analysis of the air-dried material was made by Mr. Horace L. Wells, with the following results:—

	I.	II.	Mean.	Ratio.	
SiO_2	51·21	51·19	51·20		·853
Al_2O_3	22·07	22·20	22·14		·118
FeO	*tr.*	--	*tr.*		
MnO	0·16	0·20	0·18	·002	·130
MgO	3·76	3·68	3·72	·091	
CaO	3·55	3·51	3·53	·030	
Li_2O	*tr.*	--	*tr.*		
Na_2O	0·18		0·18	·003	
K_2O	0·38		0·38	·004	
H_2O	17·11	17·04	17·08		·955
P_2O_5	1·40	1·43	1·42		
			99·83		

The phosphoric acid shows that a little apatite was present, and the corresponding amount of lime (1·86) should consequently be deducted. The analysis' agrees reasonably well with the analyses of montmorillonite from Montmorillon, France. It is also closely related to a similar clay described by Helmhacker, from Macskamezö, Transylvania.[*]

It has been stated that this mineral was, as first found, very moist and coherent. It seemed a matter of some interest to determine the way in which it lost its water, and consequently two grams of air-dried mineral were taken and placed in the desiccator over sulphuric acid. Repeated weighings showed that it continued to lose weight gradually for a period of six or seven weeks, the loss being then 9·80 p. c. The total loss after ignition was about 17 p. c.

The exact relation of this montmorillonite to the spodumene pseudomorphs cannot be given. The fact that it occurs so intimately with the spodumene, and too with the cymatolite, seems to imply that it owes its origin to the former. It belongs, however, to a later part of the process, for it is almost entirely free from alkalies. The suggestion that it may have been made from feldspar and thus have afforded the alkalies involved in the alteration of the spodumene would seem at first sight plausible. But in the first place the feldspar of the vein with which it occurs is entirely fresh and unaltered, and then, as far as our observations have yet gone, the quantity is much too small. It would rather seem to be a local result of the further alteration of the cymatolite. We do not feel able at present, however, to speak with decision about it.

In concluding our paper, we would express our acknowledgments to Mr. Penfield, and to Messrs. Wells and Dewey, to whom we are indebted for the analyses here published.

DESCRIPTION OF PLATE.

In the figures the letters employed have the following signification:—*a* = albite, though here it is to be remembered that (as remarked earlier) most of the albite contains scales of muscovite, and hence shades into cymatolite; *c* = cymatolite; *g* = muscovite; *k* = killinite; *m* = microcline; *s* = spodumene; β = β spodumene.

1*a*, 1*b*, 1*c*: Three sections across a single crystal, 15 inches wide and 4½ long, at intervals of about 5 inches. 1*a*, from near the terminated extremity, consists principally of β spodumene (β), with cymatolite (*c*) along the edges, and a little glassy spodumene (*s*) on the lower side. 1*b* shows only β spodumene and cymatolite, the latter occupying a larger portion than in 1*a*. 1*c*, from the lower extremity of the crystal shows cymatolite only.

2. Section across a crystal, 4½ inches wide, now entirely altered to cymatolite. The intricate wavy structure of this mineral is shown, as also the tendency of the fibers to be at right angles to the edges.

3. Partial section taken longitudinally; the central portion consists of finely granular albite (*a*), with lines of coarsely granular, and cleavable, microcline (*m*); the exterior is cymatolite (*c*).

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[*] Tschermak. Min. u. Petro. Mitth. 1879, p. 251.

4. Fragment of a crystal showing the granular albite (*a*) inclosing microcline (*m*).

5. Section across a large crystal; the exterior fractured and irregular. It consists mostly of clear pink spodumene (*s*) with bands of β spodumene (β) passing through it, following the directions of the cleavage; also some cymatolite (*c*) on the exterior.

6. Consists of granular albite (*a*), and cymatolite (*c*), also some plates of mica (*g*).

7. Section across a large crystal (natural size), the interior consisting of fibrous albite (*a*) and the exterior cymatolite (*c*).

8. Section showing some of the original spodumene (*s*) in detached points, with cymatolite (*c*) radiating from them, also some β spodumene, granular albite (*a*), and a few plates of mica (*g*).

9. A fragment consisting of killinite (*k*) with narrow bands of cymatolite (*c*) following approximately the original cleavage directions of the spodumene.

10. Section across a large crystal (7½ inches wide), consisting of albite (*a*) and granular microcline (*m*).

11, 13. Fragments showing granular albite (*a*) and imbedded in it broad cleavage plates of microcline; in each crystal these plates are all in parallel direction.

12. Fragment of a crystal, showing β spodumene (β) inclosed in albite (*a*), the exterior portion consisting of killinite.

14. Portion of a crystal with the spodumene (*s*) cymatolite (*c*) radiating from it, and granular albite (*a*); one band through the spodumene is still β spodumene.

ART. XXX.—*Floating Magnets;* by R. B. WARDER and W. P. SHIPLEY.

IN repeating Professor Mayer's beautiful experiments with floating magnets,* we have modified the field of magnetic force by sending an electric current through a coil surrounding the vessel of water to repel the floating magnets to the center, either with or without the fixed central magnet. With these modifications, we still have radial lines of force (counting the horizontal component only), the intensity of which varies with the distance from the center of the bowl, but according to two very different functions of this distance. Assuming the solenoidal distribution of magnetism as a sufficient approximation for our present purpose, it may be readily shown that

$$F_1 = k_1 \left(\frac{r}{(r^2+A^2)^{\frac{3}{2}}} - \frac{r}{(r^2+B^2)^{\frac{3}{2}}} + \frac{r}{(r^2+C^2)^{\frac{3}{2}}} - \frac{r}{(r^2+D^2)^{\frac{3}{2}}} \right) \quad (1)$$

in which F_1 = the attraction of each floating magnet towards the center;

k_1 = the force acting between a pole of the central magnet and a pole of a floating magnet, when they are at unit distance;

r = the horizontal distance of the floating magnet from the center of the field, and

A, B, C and D are vertical distances which remain constant in each experiment.

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* This Journal, xv, 276, 477, and xvi, 247; 1878.

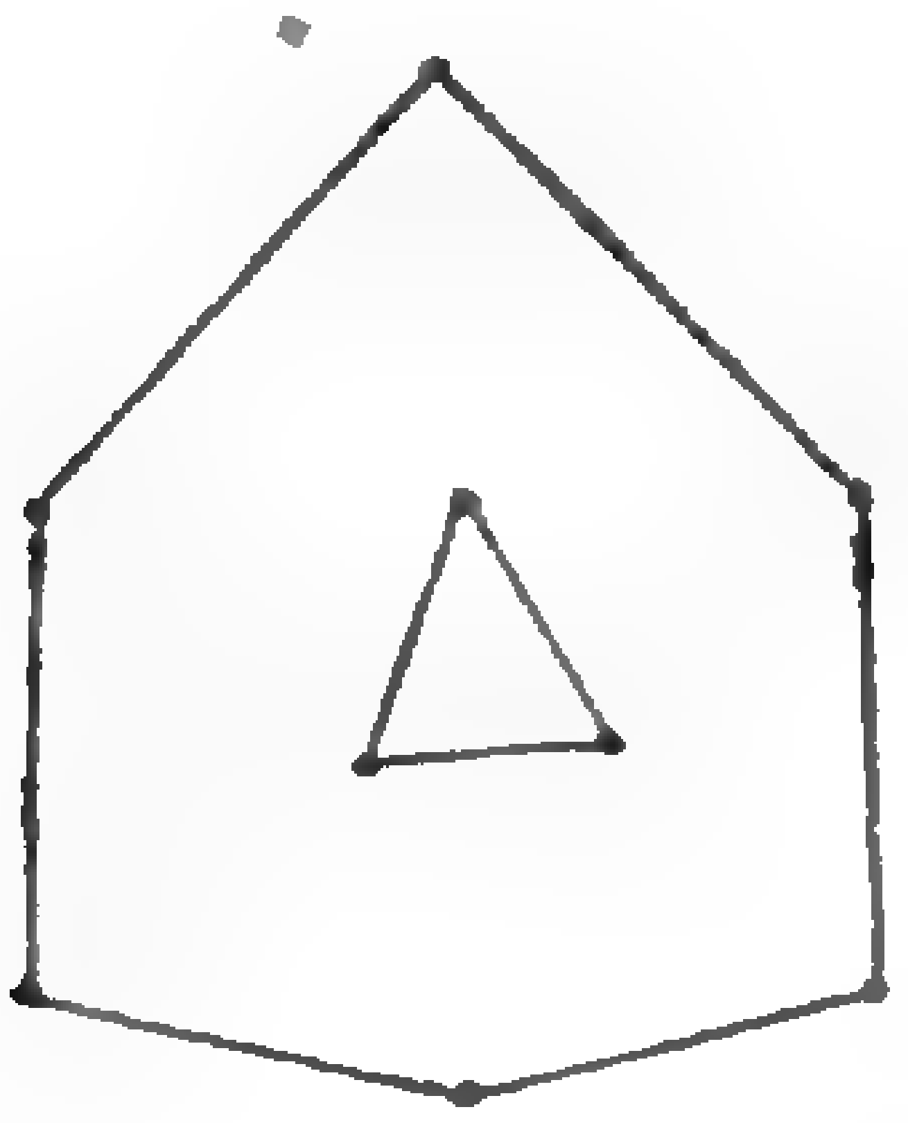
Under the new method of experiment, on the other hand, if the magnets may be regarded as indefinitely short, Professor I. Sharpless has shown us that

$$F_2 = k_2 \frac{r}{R^2 - r^2} \qquad (2)$$

in which F_2 is the repulsion towards the center,
k_2 is a constant depending upon the current strength and the number of turns in the coil, and
R = radius of the coil.

As may readily be supposed, a variety of configuration with a given number of magnets results from the use of forces which may be varied at will by combining these two unlike functions. This is clearly seen in the accompanying figures, which were all obtained by taking prints from nature in the usual way. The configurations 1 to 4 were obtained by the original method, with the central attracting magnet; Nos. 5 to 8 by the electric current. These figures represent two parallel series, having 9 and 10 floating magnets respectively. The configuration No. 9 was obtained by the combined repulsion of the central magnet and the current.

1.



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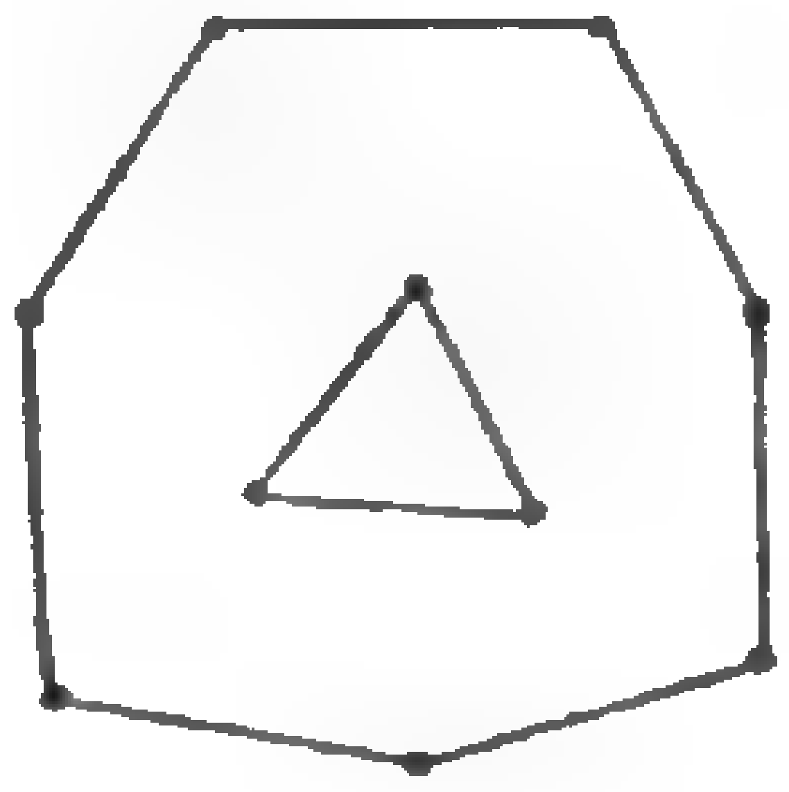

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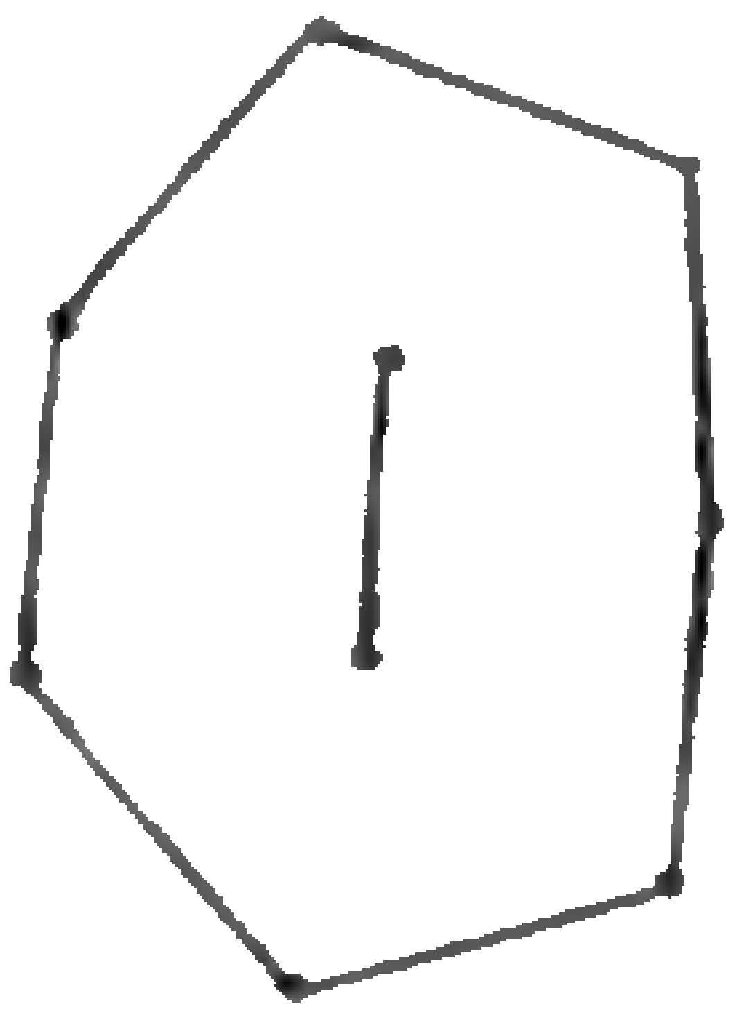

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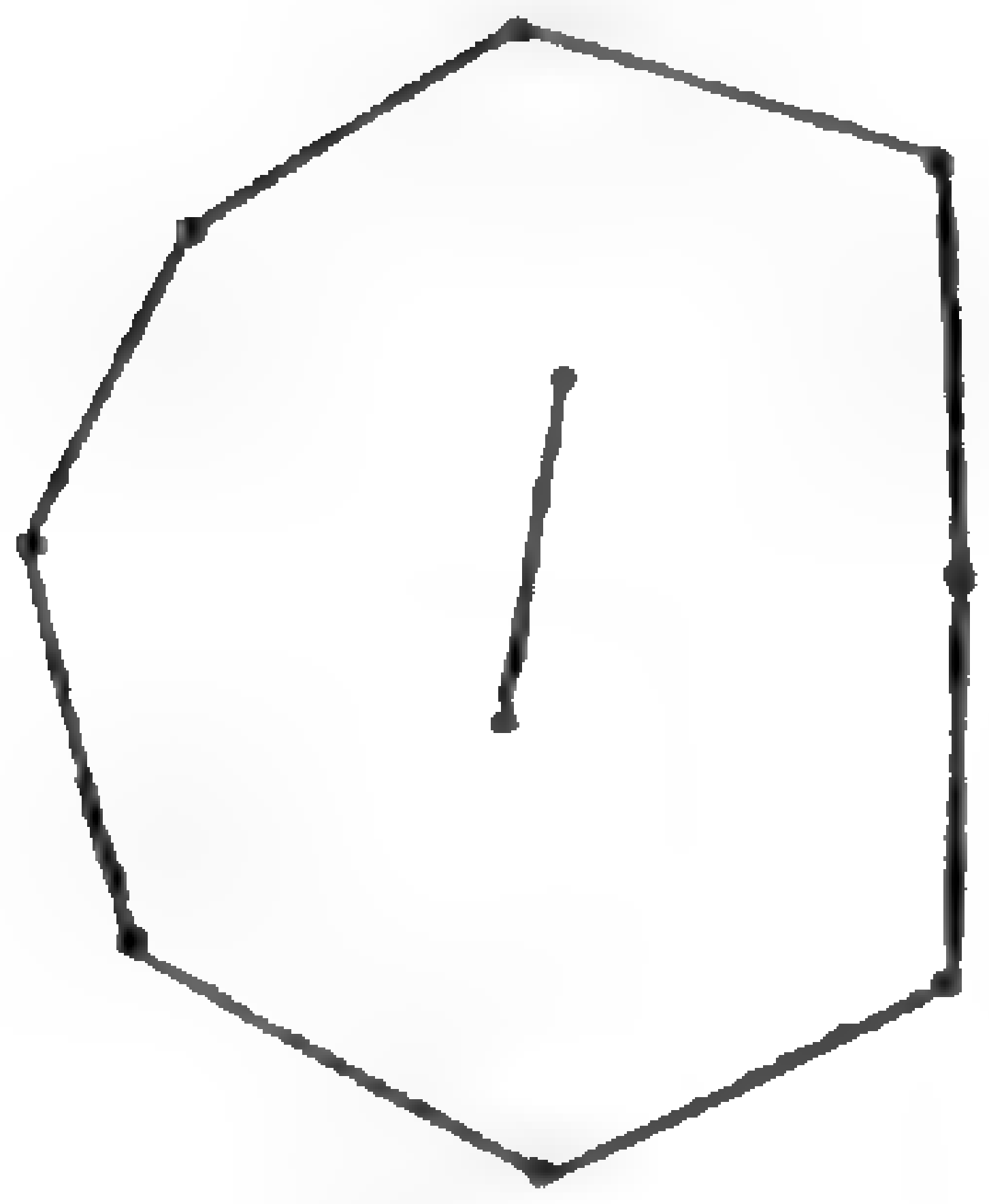

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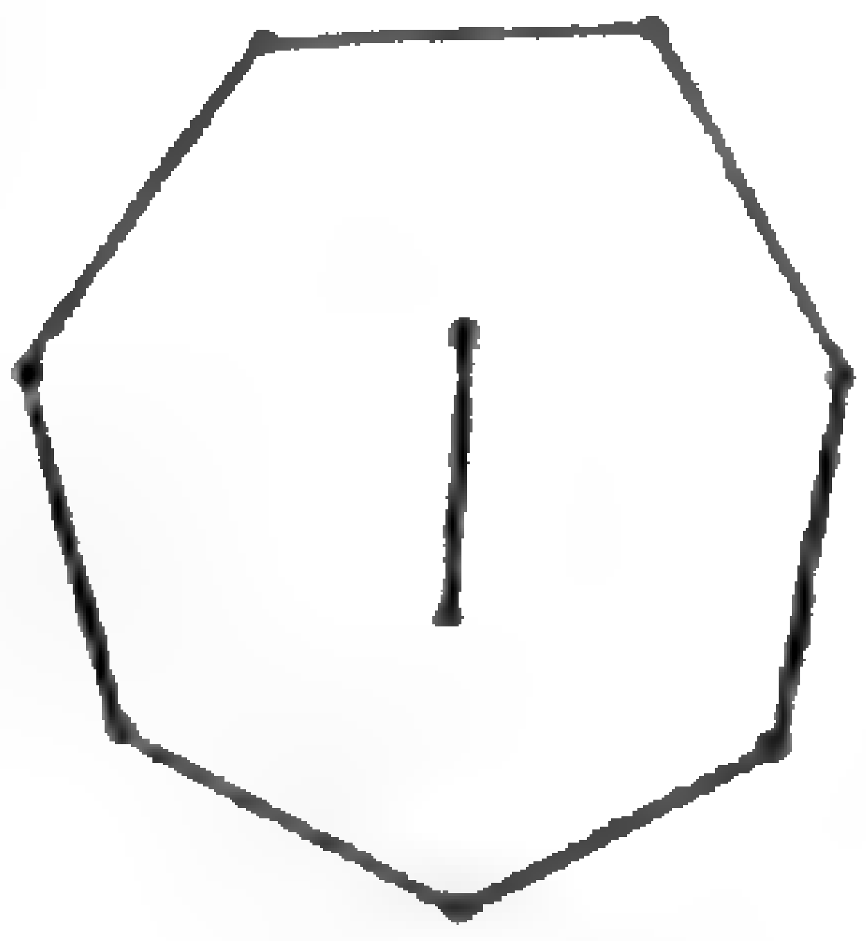
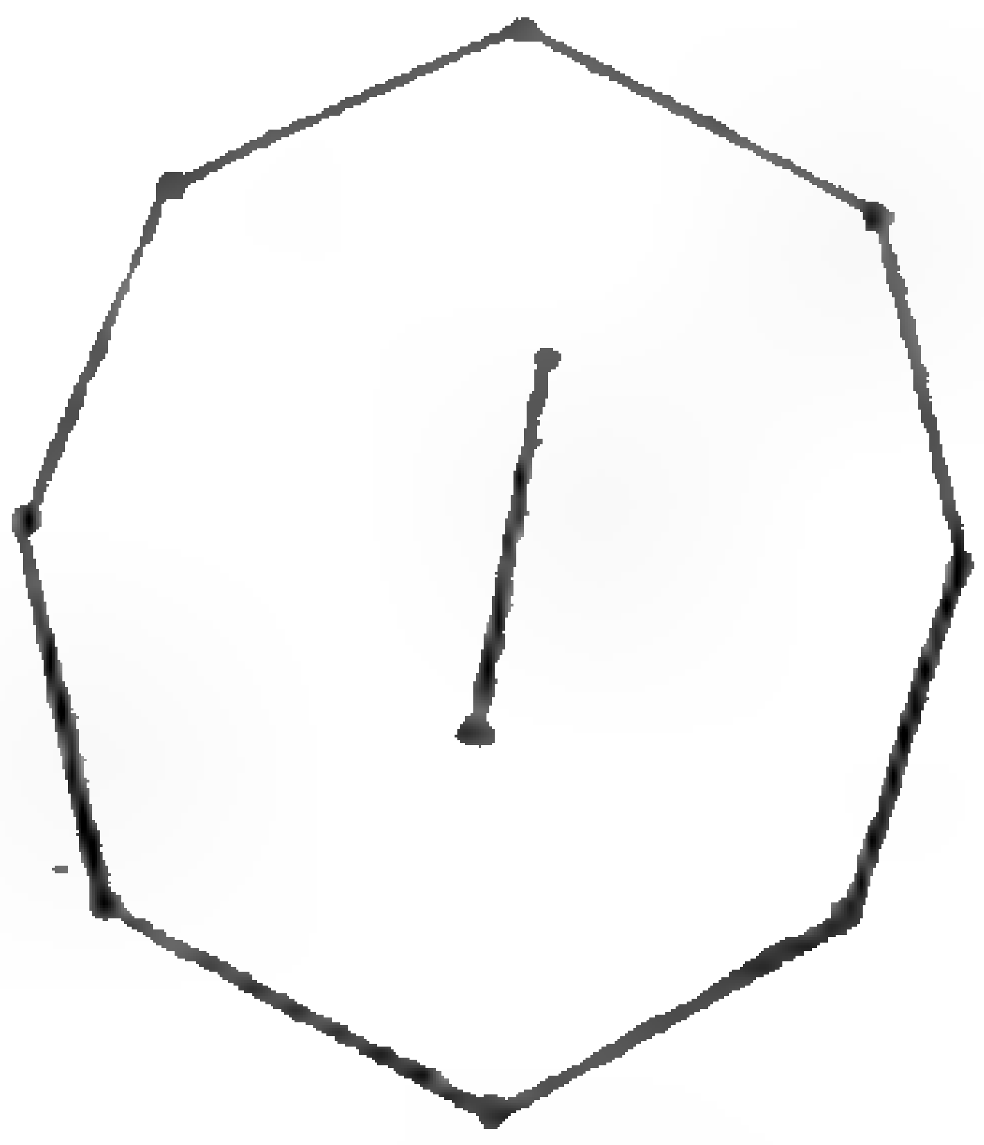
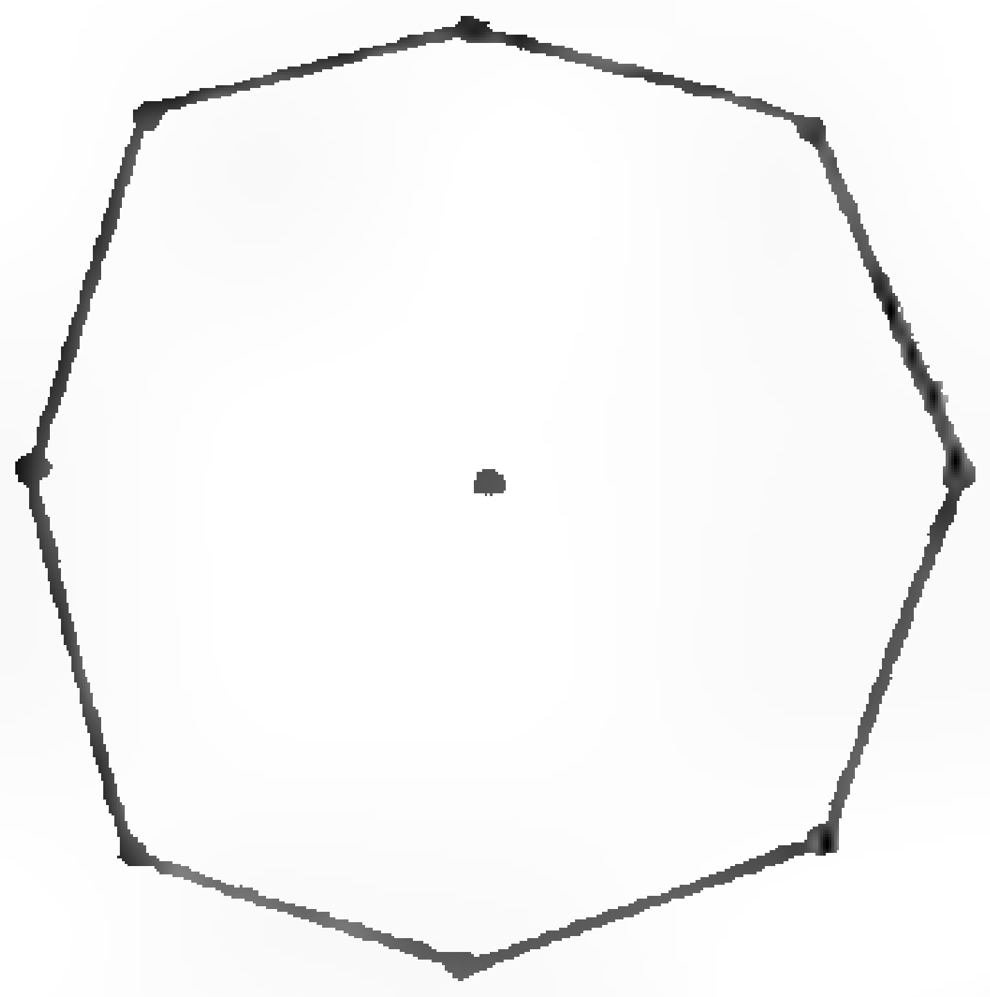


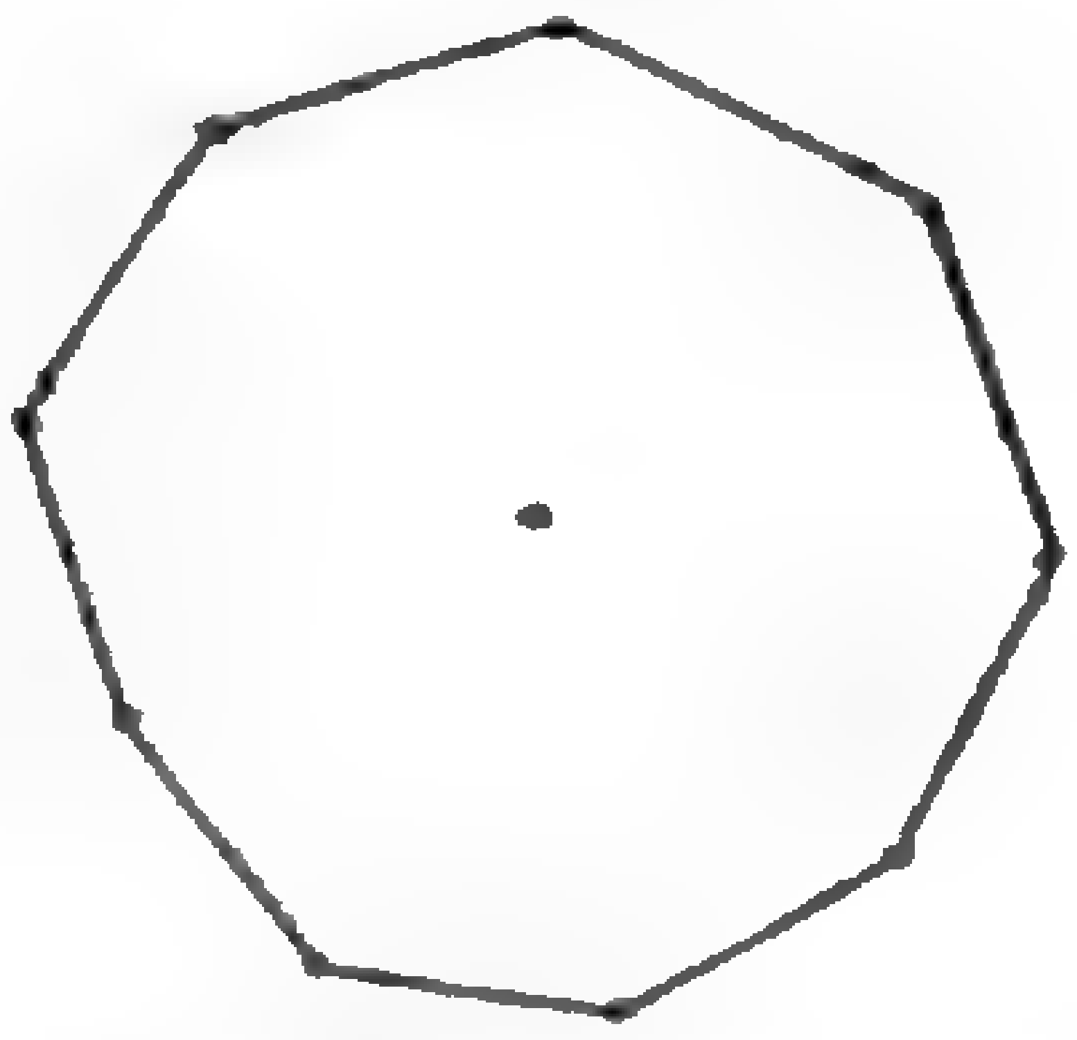
6.



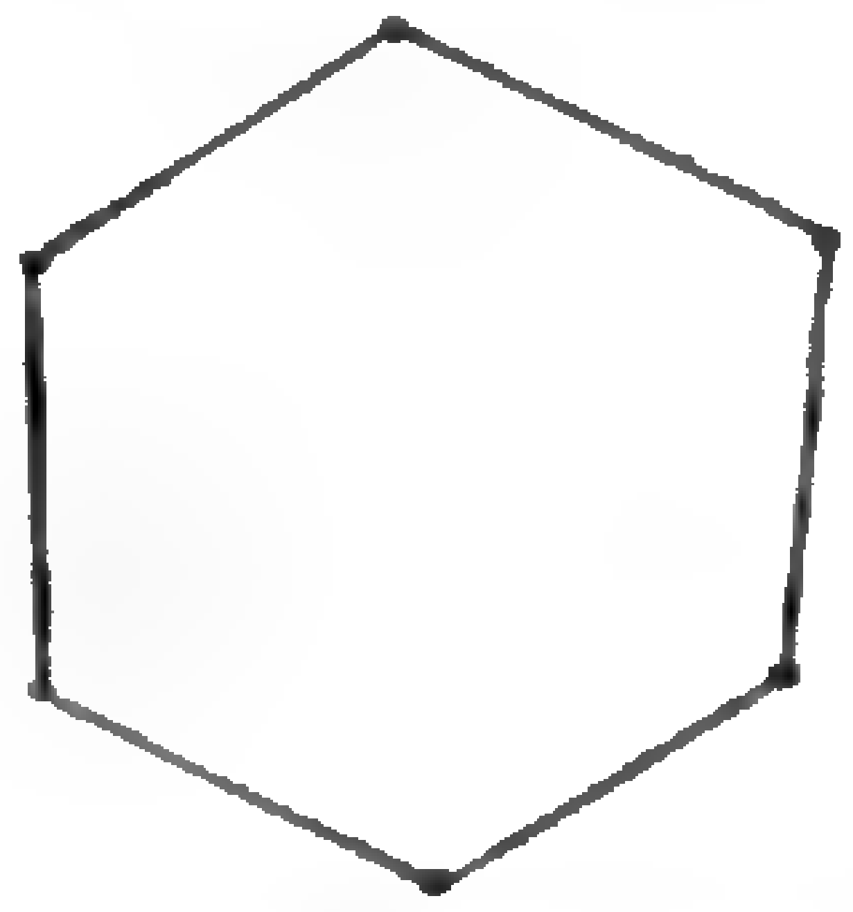
7.



8.



9.



An inspection of the first eight figures will show a marked qualitative contrast; for when the force varies according to the law expressed by equation (1) there is a decided tendency toward concentration of magnets near the center of the field, while under law (2) the tendency is toward a greater concentration in the periphery of the figure; under law (1), an angle of the polygon is sometimes very obtuse, under law (2) much greater apparent regularity is seen. In fig. 9, the magnet being reversed, the centralizing tendency becomes negative, and we obtain the figure discussed by Mayer and by Pierce in Nature, vol. xviii, pages 258, 381. In our experiments, the figures 1 and 2, 7 and 8, seemed to be more stable than 3 to 6; Nos. 1 and 2 were not stable without the central attracting magnet; and No. 7 could not be obtained without the repulsion of the electric circuit, unless the magnet was placed at some distance above the water. In this case, an electro-magnet was used, in order to obtain sufficient intensity. Under law (1) the mean distance of neighboring magnets is least in the central part of the figure, under law (2) at the periphery. It will also be seen that the alternation of acuter and obtuser angles in the periphery of figures 1 and 7 is just what is required to equalize, as far as possible, the actual distance of neighboring magnets.

To compare these facts with deductions from the formulas given above, let us consider the purely ideal case of single magnetic poles in one plane with an infinite electric current of infinite radius. The equations (1) and (2) given above may then be reduced by making A equal to zero, and B, C, D and R each equal to infinity, or

$$F_1 = \frac{k_1}{r^2} \qquad (1\,a)$$

$$F_2 = r \times \text{constant} \qquad (2\,a)$$

If we suppose the attracting magnetic pole to be above the plane of floating magnets, equation (1) would become

$$F_1 = k_1 \frac{r}{(r^2 + A^2)^{\frac{3}{2}}}$$

and when the ratio $\frac{A}{r}$ becomes very great, we have (as a close approximation)

$$F_1 = r \times \text{constant} \ (1\,b), \text{—as in eq. } (2\,a)$$

In both forms of experiment, the force very near the center increases directly as the distance; but it soon reaches a maximum under law (1), and then rapidly diminishes, so that three, or at least two, of the floating magnets are held near each other in the central part of the figure. As already stated, it is only when the zone of maximum force is widened, by raising the central magnet, that fig. 7 is stable without the repulsion of the electric current. In the new form of the experiment, on the other hand, while the force near the center of the field increases directly as the distance, towards the margin it increases still more rapidly, and in this case but one or at most but two of the magnets take their place near the center, as we should expect.

In our ignorance of the mechanical structure of a molecule, or the law of the variation of the force that controls the motions of its several parts, we offer no opinion as to which mode of experiment (both being confined to plane figures) affords the better illustration of the still unknown forms of atomic and molecular configuration. Equation (2), however, is far simpler than equation (1).

Both modes of experimenting are readily carried out, if the necessary precautions are taken; but the attempt fails when the needles are imperfectly magnetized. Our water was drawn from service pipes under considerable pressure, and we were obliged to renew it every ten or fifteen minutes; otherwise the magnets failed to move freely. Whether this would be the case with water freed from an excess of air, we have not determined. In our modification, we used one or two Bunsen cells, with five turns of No. 16 copper wire in a coil of 15 c. m. diameter. A single one-fluid cell is sufficient.

The work already accomplished is only qualitative; but we propose to continue the investigation (both by experiment and by analysis) with regard to the stability of certain figures, under the various modifications of the experiment.

Haverford College, Pa., June, 1880.

Art. XXXI.—*Notes from the Chesapeake Zoological Laboratory of the Johns Hopkins University.*

No. I.—*The Homology of the Cephalopod Siphon and Arms;* by W. K. Brooks.

While studying the development of the squid (*Loligo Pealii*), I fortunately procured embryos at stages which fill gaps in the account which has been given by Grenacher, and which seem to place the homology between the cephalopoda and the ordinary mollusca in a very clear light, and I give a diagram of an early stage of development of the squid, and another of a gasteropod, in a corresponding stage. Without discussing the literature of the subject I will pass at once to the description of the figures.

Figure 1 is a squid embryo with its head and yolk sac, Y, below, and the so-called posterior end above; the so-called ventral surface, which in the adult carries the siphon, at the left, and the so-called dorsal surface at the right.

Figure 2 is the embryo of a fresh-water pulmonate in a similar position: with the foot, F, below; the shell area, SA, above; the mouth, M, tentacles, T, and head on the right side, and the rectum, R, on the left. The figure therefore shows the right side of the pulmonate.

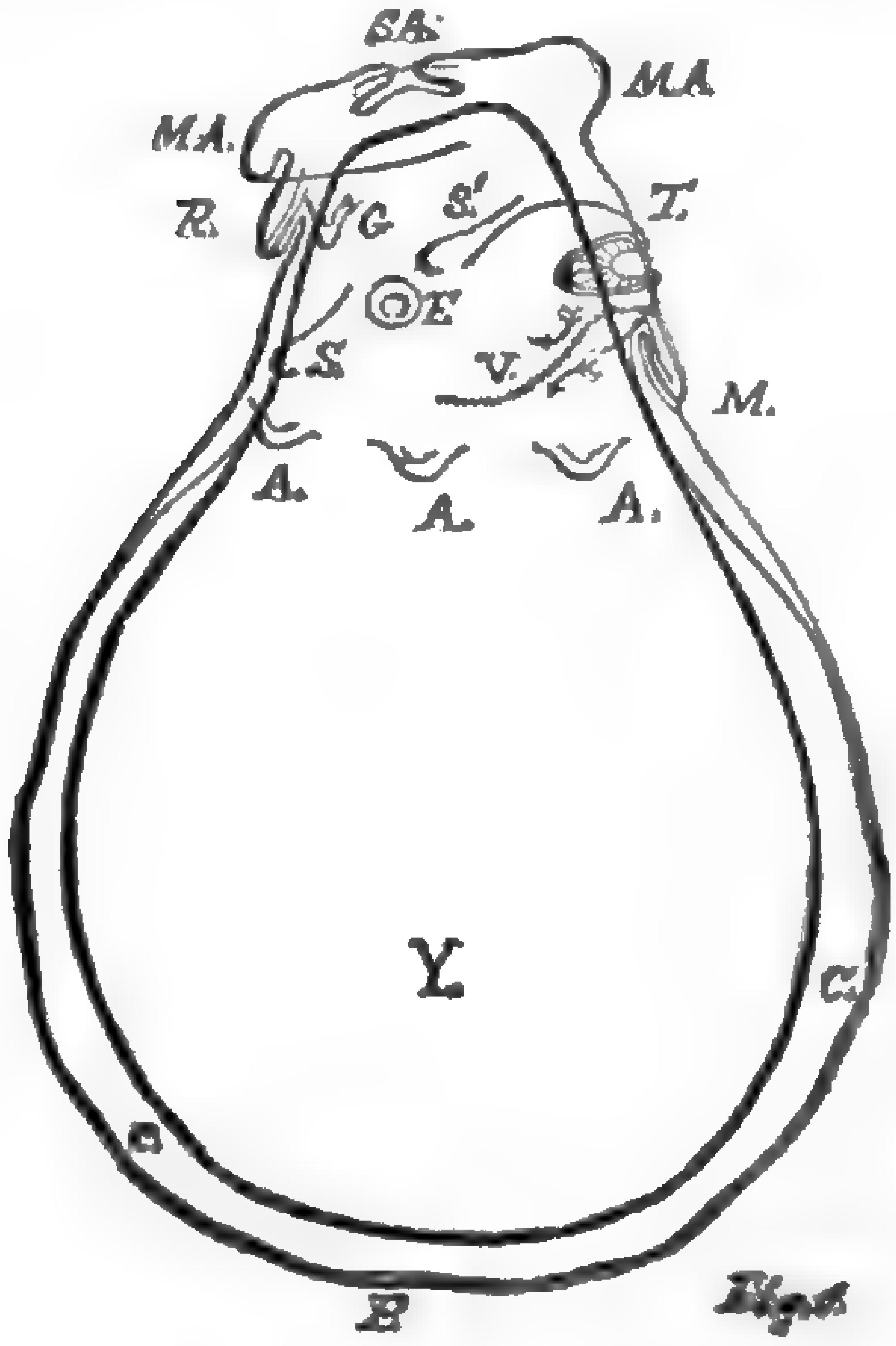


Fig. 1

Fig. 3

Fig. 2

SH is the bilaterally symmetrical shell, resting like a cap upon the dorsal surface of the body, and surrounded by a reflected ridge of integument, SA, the margin of the shell area.

In the squid, figure 1, there is also an external shell which is surrounded by a reflected ridge of integument, SA, as in the pulmonate.

Running around the shell and shell area, in both, is a second ridge of integument, the margin of the mantle, MA, which, in the cephalopod, already projects a little, forming the outer wall of the rudimentary mantle chamber.

On the median line of the posterior, or *ventral,* surface of the body, just below the mantle ridge, in both, is the rectum, R, with its opening the anus.

In the cephalopod the anus is raised from the surface of the body upon an anal papilla, but in other respects it is alike in the two forms.

On each side of the rectum of the cephalopod is a tentacular gill, G, underneath the projecting edge of the mantle. There are no corresponding structures in the pulmonate.

On the anterior surface of the body, the surface which is usually called dorsal in the cephalopod, and which is on the right in both figures, we have, first the thickened mantle ridge, MA, which forms the angle between the dorsal and the anterior surface; next we have the long pulsatile "neck" region of the pulmonate, H. In the cephalopod embryo this region is short, not pulsatile, and forms the back.

Below the "neck" of the pulmonate a tentacle, T, is developed on each side of the body, and the eyes subsequently make their appearance upon these tentacles.

On each side of the corresponding region of the body of the cephalopod embryo there is a projecting eye-stalk, T, upon the rounded tip of which the eye is formed by an involution of the integument.

Crossing the middle line of the body of the pulmonate just below the tentacles, is the rudimentary velum, V, which runs out onto the sides and then bends up towards the dorsal surface in such a way as to almost surround the tentacles. This line is marked in the pulmonate by a row of granular ciliated cells.

When the corresponding surface of the body of the cephalopod is examined, a well defined line or groove, V, figure 1, will be found to run from the median line out into the sides of the body, bending up posteriorly in such a way as to nearly surround the eye-stalk. The motion of particles floating in the water shows the presence of ciliary currents, as indicated by the arrows, and there does not seem to be any reason for doubting that this is a true rudimentary velum. In both forms the mouth, M, is situated just below the point where this line crosses the median line of the body.

We have then the following structures which are so similar in position, relations, mode of development, and function, as to leave no doubt of their homology; the mouth; the velum; the sensory tentacles; the mantle; the shell area; the shell; the rectum and the anus.

These features furnish enough points of orientation to assure us that the cephalopod must be placed as it is in our figure 1, in order to be in a position homologous with that of the gasteropod embryo, figure 2. The views which have been advocated by Huxley are therefore essentially correct.

In order to show the relation between figure 1 and an adult cephalopod, I give, in figure 3, an outline sketch, much less magnified, of an older embryo which has acquired most of the adult characteristics. As the position of this figure is like that of the other two the dorsal surface is that which is above, the ventral is below, the anterior surface on the right, the posterior on the left, and the figure shows the left side of the animal.

We are now in a position to discuss the disputed points in cephalopod structures; the homology of the siphon, and the arms; and the equivalent of the gasteropod foot.

The latter, figure 2, F, is a median unpaired structure on the ventral surface of the body between the mouth and the anus. In the pulmonate and in many other gasteropod embryos a large sinus space, C, separates the integument of the foot from the endoderm and its derivatives; the integument is rhythmically pulsatile, and the sinus space has the function of a circulatory organ.

The only unpaired structure on the median line of the ventral surface of the body of the cephalopod embryo is the large food yolk, figure 1, Y, and in this, if any where, we must find the homologue of the gasteropod foot.

In the cephalopod a sinus space, C, separates the food yolk from the layer of integument, F, which surrounds it, and this wall of integument is rhythmically contractile, like the foot of the pulmonate embryo, and I think we must conclude that the cephalopod foot, as a locomotor organ, has been suppressed by the great development of a food yolk at the point where it should be found.

The arms of the squid make their appearance as little elevations, A, A, A, arranged in pairs around the neck or constriction which separates the food yolk from the body proper.

As they are, at first, ventral to the mouth, and as a true velum is present, we cannot accept Grenachers' view that they represent this structure. As they are paired structures we cannot agree with Huxley in regarding them as the representative of the foot, although they are, perhaps, to be regarded as paired outgrowths from the foot-region.

The siphon originates as two pairs of folds, S and S′, of the integument of the lateral walls of the body, and if we follow Huxley in regarding these four folds as homologous with the epipodial folds of a gasteropod, we must regard the arms as structures which have been independently acquired.

If on the other hand we regard the arms as modified epipodial folds we must consider the four siphon folds to be independently acquired structures, and in the absence of any test nothing seems to be gained by the uncertain homology of either the arms or the siphon with any part of the body of a typical gasteropod.

Beaufort, N. C., July 5th, 1880.

No. II.—*Notes on the Early Stages of some Polychætous Annelides;* by E. B. Wilson.

In view of the morphological interest of the marine annelides as the most highly specialized forms among the "Vermes," and the scarcity of detailed accounts of their early stages of development, the following preliminary abstract of studies on the eggs of *Arenicola* and *Clymenella* seems of some interest. The eggs are small and very numerous, and are embedded in transparent gelatinous masses issuing from the mouths of the tubes or burrows inhabited by the worms. The egg-masses of *Arenicola* are of great size, being sometimes five or six feet in length and from two to four inches in diameter; such a mass must contain several hundred thousand eggs. Those of *Clymenella* are usually about the size and shape of a pigeon's egg; the eggs are much fewer and considerably larger than those of *Arenicola.*

The whole course of development is essentially alike in the two forms. No polar globules of constant relation to the yolk were observed. The first cleavage divides the egg into two unequal spherules. The second, passing at right angles to the first, divides the smaller spherule into two equal parts, and the larger into two unequal parts. The third cleavage separates from these four blastomeres four much smaller ones at one pole of the egg. The latter (micromeres) soon become so displaced as to alternate with the former (macromeres). The micromeres now divide more rapidly than the macromeres which they come ultimately to include by growing down over them. The ectoderm is formed by the derivatives of the micromeres, and in part, I believe, of the macromeres. The remaining portions of the macromeres form the entoderm. Two large spherules, which originally formed a part of the largest of the four primary blastomeres, are visible up to a late stage at the posterior extremity of the embryo. They are at first at the surface but ultimately are grown over by the ectoderm and disappear. It is possible that they are concerned in the formation of the mesoderm and are to be regarded as primary mesoblasts. The mouth arises on the ventral side nearly opposite that pole of the egg where the first four micromeres were formed. The anus arises at the posterior end of the embryo. The egg-membrane is directly converted into the cuticle of the larva. The egg exhibits, during segmentation, alternate periods of activity and quiescence.

The embryo acquires two dorsal eye-specks, præ-oral and præ-anal belts of cilia and a broad ventral band, and becomes a "Telotrochous" larva which passes directly into the adult. The setæ develop from before backwards, and those of the dorsal ramus appear before those of the ventral.

The segmentation is closely similar to that of some Oligochæta (*Euaxes*, *Tubifex*) and resembles also that of the leeches. The gastrula stage is not attained by a typical invagination but by a down-growth of the ectoderm over the entoderm.

Beaufort, N. C., July, 1880.

No. III.—*The Rhythmical Character of the Process of Segmentation;* by W. K. BROOKS.

A number of observers have called attention to the fact that in certain animals the segmenting eggs pass through alternating stages in which the segmentation products are first conspicuous and well defined, and then flattened and fused together.

In a paper on the development of the fresh water pulmonates I have attempted to show that the alternation is due to the fact that periods of segmenting activity alternate with periods of rest, and that the tendency which the elasticity of the egg exerts to render its form spherical when no other force is acting upon it causes the partial obliteration of the outlines of the spherules during each resting stage.

The essential factor is therefore the alternation of rest with activity, and the change of shape during the resting periods is a secondary phenomenon, brought about incidentally by the physical properties of the yolk.

In most eggs the yolk is not sufficiently elastic to allow any great change of form, but careful time-records show that the process of segmentation is rhythmical, and that short periods of active change alternate with longer periods during which there is no external change.

During the past year various members of the Biological Department of the University have observed this alternation in various Vertebrate and Invertebrate eggs. Dr. Clarke has noticed it in an amphibian, *Amblystoma*, where the segmentation is total. I have observed it in the egg of an unknown fish, where segmentation is restricted to a blastoderm. Mr. Wilson has observed it in three annelides, where segmentation is total and irregular; *Arenicola*, *Clymenella* and *Lumbricus*. It is very well marked in an arthropod, *Leucifer*, whose eggs undergo total regular segmentation.

Its occurrence in so many widely separated groups, with such different methods of segmentation renders it probable that it will be found in nearly all eggs upon sufficiently careful examination.

ART. XXXII.—*Paleontological and Embryological Development;* Address by ALEXANDER AGASSIZ, Vice-president of Section B, at the recent Boston meeting of the American Association for the Advancement of Science.

SINCE the publication of the "Poissons Fossiles" by Agassiz, and of the "Embryologie des Salmonidées" by Vogt, the similarity, traced by the former between certain stages in the growth of young fishes and the fossil representatives of extinct members of the group, has also been observed in nearly every class of the animal kingdom, and the fact has become a most convenient axiom in the study of paleontological and embryological development. This parallelism, which has been on the one side a strong argument in favor of design in the plan of creation, is now, with slight emendations, doing the duty on the other as a newly discovered article of faith in the new biology.

But while in a general way we accept the truth of the proposition that there is a remarkable parallelism between the embryonic development of a group and its paleontological history, yet no one has attempted to demonstrate this, or rather to show how far the parallelism extends. We have, up to the present time, been satisfied with tracing the general coincidence, or with striking individual cases.

The resemblance between the pupa stage of some Insects and of adult Crustacea, the earlier existence of the latter, and the subsequent appearance of the former in paleontological history, furnished one of the first and most natural illustrations of this parallelism; while theoretically the necessary development of the higher tracheate insects from their early branchiate aquatic ancestors seemed to form an additional link in the chain, and point to the Worms, the representatives of the larval condition of Insects, as a still earlier embryonic stage of the Articulates.

Indeed, there is not a single group of the animal kingdom in which embryology has not played a most important part in demonstrating affinities little suspected before. The development of our frogs, our salamanders, has given us the key to much that was unexplained in the history of Reptiles and Batrachians. The little that has been done in the embryology of Birds has revolutionized our ideas of a class which at the beginning of the century seemed to be the most naturally circumscribed of all. Embryology and paleontology combined have led to the recognition of a natural classification uniting Birds and Reptiles on the one side and Batrachians and Fishes on the other. It is to embryology that we owe the explanation of the affinities of the old Fishes in which Agassiz first recognized the similarity to the embryo of Fishes now living, and by its aid we may hope to understand the relationship of the oldest representatives of the class. It has given us the only explanation of the early appearance of the Cartilaginous Fishes, and of the probable formation of the earliest vertebrate limb from the lateral embryonic fold, still to be traced in the young of the Osseous Fishes of to-day.

Embryology has helped us to understand the changes aquatic animals must gradually undergo in order to become capable of living upon dry land. It has given us pictures of swimming-bladders existing as rudimentary lungs in Fishes with a branchial system ; in Batrachians it has shown us the persistence of a branchial system side by side with a veritable lung. We find among the earliest terrestrial Vertebrates types having manifest affinities with the Fishes on one side and Batrachians on the other, and we call these types Reptiles; but we should nevertheless do so with a reservation, looking to embryology for the true meaning of these half-fledged Reptiles, which lived at the period of transition between an aquatic and a terrestrial life, and must therefore always retain an unusual importance in the study of the development of animal life.

When we come to the embryology of the marine Invertebrates, the history of the development of the barnacles is too familiar to be dwelt upon, and I need only allude to the well-known transformations of the Echinoderms, of the Acalephs, Polyps, in fact of every single class of Invertebrates, and perhaps in none more than in the Brachiopods, to show how far-reaching has been the influence of embryology in guiding us to a correct reading of the relations between the fossils of successive formations. There is scarcely an embryological monograph now published dealing with any of the later stages of growth which does not speak of their resemblance to some type of the group long ago extinct. It has therefore been most natural to combine with the attempts constantly made to establish the genetic sequence between the genera of successive formations an effort to establish also a correspondence between their paleontological sequence and that of the embryonic stages of development of the same, thus extending the mere similarity first observed between certain stages to a far broader generalization.

It would carry me too far to sketch out, except in a most general way, even for a single class, the agreement known to exist in certain groups between their embryonic development and their paleontological history. It is hinted at in the succession of animal life of any period we may take up, and per haps cannot be better expressed than by comparing the fauna of any period as a whole with that of following epochs;—a zoölogical system of the Jura, for instance, compared with one made up for the Cretaceous; next, one for the Tertiary, compared with the fauna of the present day. In no case could we find any class of the animal kingdom bearing the same definitions or characterized in the same manner. But apply to this comparison the data obtained from the embryological development of our present fauna, and what a flood of light is thrown upon the meaning of the succession of these apparently disconnected animal kingdoms, belonging to different geological periods, especially in connection with the study of the few ancient types which have survived to the present day from the earliest times in the history of our earth!

Although there is hardly a class of the animal kingdom in which some most interesting parallelism could not be drawn, and while the material for an examination of this parallelism is partially available for the Fishes, Mollusks, Crustacea, Corals, and Crinoids, yet for the illustration and critical examination of this parallelism, I have been led to choose to-day a very limited group, that of Sea-urchins, both on account of the nature of the material and of my own familiarity with their development and with the living and extinct species of Echini. The number of living species is not very great—less than three hundred—and the number of fossil species thus far known is not, according to Zittel, more than about two thousand. It is therefore possible for a specialist to know of his own knowledge the greater part of the species of the group. It has been my good fortune to examine all but a few of the species now known to exist, and the collections to which I have had access contain representatives of the majority of the fossil species. Sea-urchins are found in the oldest fossiliferous rocks; they have continued to exist without interruption in all the strata up to the present time. While it is true that our knowledge of the Sea-urchins occurring before the Jurassic period is not very satisfactory, it is yet complete enough for the purposes of the present essay, as it will enable me, starting from the Jurassic period, to call your attention to the paleontological history of the group, and to compare the succession of its members with the embryological development of the types now living in our seas. Ample material for making this comparison is fortunately at hand; it is material of a peculiar kind, not easily obtained, and which thus far has not greatly attracted the attention of zoölogists.

Interesting and important as are the earliest stages of embryonic development in the different classes of the animal kingdom, as bearing upon the history of the first appearance of any organ and its subsequent modifications, they throw but little light on the subject before us. What we need for our comparisons are the various stages of growth through which the young Sea-urchins of different families pass from the time they have practically become Sea-urchins until they have attained the stage which we now dignify with the name of species. Few embryologists have carried their investigations into the more extended field of the changes the embryo undergoes when it begins to be recognized as belonging to a special class, and when the knowledge of the specialist is absolutely needed to trace the bearing of the changes undergone, and to understand their full meaning. Fortunately the growth of the young Echini has been traced in a sufficient number of families to enable me to draw the parallelism between these various stages of growth and the paleontological stages in a very different manner from what is possible in other groups of the animal kingdom, where we are overwhelmed with the number of species, as in the Insects or Mollusks, or where the paleontological or the embryological terms of comparison are wanting or very imperfect.

Beginning with the paleontological history of the regular Sea-urchins at the time of the Trias, when they constituted an unimportant group as compared with the Crinoids, we find the Echini of that time limited to representatives of two families. One of these, the genus Cidaris, has continued to exist, with slight modifications, up to the present time, and not less than one-tenth of all the known species of fossil Echini belong to this important genus, which in our tropical seas is still a prominent one. It is interesting here to note that in the Cidaridæ the modifications of the test are not striking, and the fossil genera appearing in the successive formations are distinguished by characters which often leave us in doubt as to the genus to which many species should be referred. In the genus Rhabdocidaris, which appears in the lower Jura, and which is mainly characterized by the extraordinary development of the radioles, we find the extreme of the variations of the spines in this family. From that time to the present day, the most striking differences have existed in the shape of the spines, not only of closely allied genera, but even in specimens of the same species; differences which in some of the species of to-day are as great as in older geological periods. The oldest Cidaridæ are remarkable for their narrow poriferous zones. It is only in the Jura that they widen somewhat; subsequently the pores become conjugated, and only later, during the Cretaceous period, do we find the first traces of any ornamentation of the test (Temnocidaris) so marked at the present day in the genus Goniocidaris. As far, then, as the Cidaridæ are concerned, the modifications which take place from their earliest appearance are restricted to slight changes in the poriferous zone and in the ornamentation of the test, accompanied with great variability in the shape of the primary radioles. We must except from this statement the genera Diplocidaris and Tetracidaris, to which I shall refer again. The representatives of the other Triassic family become extinct in the lower Tertiaries. The oldest genus, Hemicidaris, undoubtedly represents the earliest deviations from the true Cidaris type; modifications which affect not only the poriferous zone, but the test, the actinal and the abactinal systems, while from the extent of these minor changes we can trace out the gradual development of some of the characteristics in families of the regular Echini now living. The genus Hemicidaris may be considered as a Cidaris in which the poriferous zone is narrow and undulating, in which the granules of the ambulacral system have become minute tubercles in the upper portion of the zone and small primary tubercles in its actinal region, in which many of the interambulacral granules become small secondaries, in which the plates of the actinal system have become reduced in number, and the apical system has become a narrow ring, and finally in which the primary radioles no longer assume the fantastic shapes so common among the Cidaridæ.

We can trace in this genus the origin of the modifications of the poriferous zone, leading us, on the one side, through genera with merely undulating lines of pores to more or less distinct confluent arcs of pores, formed round the primary ambulacral tubercles, and, on the other, to the formation of open arcs of three or more pairs of pores. The first type culminates at the present day with the Arbaciadæ, the other with the Diadematidæ, Triplechinidæ, and Echinometradæ. This specialization very early takes place, for already in the lower Jura Stomechinus has assumed the principal characteristics of the Triplechinidæ of to-day.

Although in Hemicidaris the number of the coronal plates has increased as compared with the Cidaridæ, and while we find that in many genera, even of those of the present day, the number of the coronal plates is still comparatively small, yet, as a general rule, the more recent formations contain genera in which the increase in number of the interambulacral plates is accompanied by a corresponding decrease in the number of plates of the interambulacral area so characteristic thus far of the Cidaridæ and Hemicidaridæ, a change also affecting the size of the primary ambulacral tubercles. This increase in the number of the coronal plates is likewise accompanied by the development of irregular secondary and miliary tubercles, and the disappearance in this group of the granular tuberculation, so important a character in the Cidaridæ. With the increase in the number of the interambulacral coronal plates, the Pseudodiadematidæ still retain prominent primary tubercles, recalling the earlier Hemicideridæ and Cidaridæ, and, as in the Cidaridæ proper, the test is frequently ornamented by deep pits or by ridges formed by the junction of adjoining tubercles. The genital ring becomes narrower, and the tendency to the specialization of one of its plates, the madreporite, more and more marked.

With the appearance of Stomechinus, the Echinidæ proper already assume in the Jura the open arcs of pores, the large number of coronal interambulacral plates, the specialization of the secondary tubercles, and the large number of primary tubercles in each plate. With the appearance of Sphærechinus in the early Tertiary come in all the elements for the greater multiplication of the pairs of pores in the arcs of the poriferous zones, while the gigantic primary spines of some of the genera (Heterocentrotus), and the small number of primary tubercles are structural features which had completely disappeared in the group preceding the Echinometradæ, to which they appear most closely allied.

Going back again to the Hemicidaridæ, it requires but slight changes to pass from them to Acrosalenia and to the Saleniæ proper; the latter have continued to the present day, and have, like the Cidaridæ, retained almost unchanged the characters of the genera which preceded them, combined, however, with a few Cidaridian and Echinid features which date back to the Triassic period. We can thus trace the modifications which have taken place in the poriferous zone, the apical and actinal systems, the coronal plates, the ambulacral and interambulacral tubercles, as well as in the radioles, and in the most direct manner possible indicate the origin of the peculiar combination of structural features which we find at any geological horizon. On taking in succession the modifications undergone by the different parts of the test, we can trace each one singly, without the endless complication of combinations which any attempt to trace the whole of any special generic combination would imply.

Leaving out of the question for the moment the Palæchinidæ, we find no difficulty in tracing the history of the characters of the genera of the regular Echini which have existed from the time of the Trias and are now living, provided we take up each character independently. Nothing can be more direct than the gradual modification of the simple, barely undulating poriferous zone, made up of numerous ambulacral plates covered by granules, such as we find it among the Cidaridæ of the Trias, first into the slightly undulating poriferous zone of the Hemicidaridæ, next into the indistinct arcs of pores of the Pseudodiadematidæ, then into the arcs with a limited number of pores of the Triplechinidæ, and finally to the polyporous arcs of the Echinometradæ. What can be more direct than the gradual modification to be traced in the development of the primary ambulacral tubercles, such as are characteristic of the Echinidæ of the present day, from their first appearance at the oral extremity of the ambulacral system of the Hemicidaridæ, and the increase in the number of primary interambulacral tubercles, accompanied by the growth of secondaries and miliaries, which we can trace in Hemicidaris, Acrosalenia, and Stomechinus,—the increase in number of the primary and secondary tubercles being accompanied by a reduction in the size of the radioles and a greater uniformity in their size and shape?

But while these modifications take place, the original structural feature may be retained in an allied group. Thus the Cidaridæ retain unchanged from the earliest time to the present day the few primary tubercles, the secondary granules, the simple poriferous zone, the imbricating actinal system, and the few coronal plates, with the large apical system and many-shaped radioles; while in the Salenidæ the primary interambulacral tubercles, the secondary granules, the radioles, the genital ring, are recognized features of the Cidaridæ, associated, however, with an Echinid actinal and anal system, Hemicidarid primary ambulacral tubercles, and an Echinid poriferous zone. In the same way in the Diadematidæ, the large primary interambulacral tubercles are Cidaridian features, while the structure of the ambulacral tubercles is Hemicidaridian. The existence of two kinds of spines is another Cidaridian feature, while the apical and actinal systems have become modified in the same direction as that of the Echinidæ. The more recent the genus, the greater is the difficulty of tracing in a direct manner the origin of any one structural feature, owing to the difficulty of disassociating structural elements characteristic of genera which may be derived from totally different sources. This is particularly the case with genera having a great geological age. Many of them, especially among the Spatangoids, show affinities with genera following them in time, to be explained at present only on the supposition that, when a structural feature has once made its appearance, it may reappear subsequently, apparently as a new creation, while in reality it is only its peculiar combination with structural features with which it had not before been associated (a new genus), which conceals in that instance the fact of its previous existence. A careful analysis, not only of the genera of the order, but sometimes of other orders which have preceded this combination in time, may often reveal the elements from which have been produced apparently unintelligible modifications.

There is, however, not one of the simple structural features in the few types of the Triassic and Liassic Echini from which we can so easily trace the origin of the structural features of all the subsequent Echinid genera, which is not also itself continued to the present day in some generic type of the present epoch, fully as well characterized as it was at the beginning. In fact, the very existence to-day of these early structural features seems to be as positive a proof of the unbroken systematic affinity between the Echini of our seas and those of the Trias, as the uninterrupted existence of the genus Pygaster or Cidaris from the Trias down to the present epoch, or of the connection of many of the genera of the Chalk with those of our epoch (Salenia, Cyphosoma, Psammechinus, etc.).

Passing to the Clypeastridæ, we find there as among the Desmosticha that the earliest type, Pygaster, has existed from the Trias to the present time; and that, while we can readily reconstruct, on embryological grounds, the modifications the earliest Desmosticha-like Echini should undergo in order to assume the structural features of Pygaster, yet the early periods in which the precursors of the Echinoconidæ and Clypeastridæ are found have thus far not produced the genera in which these modifications actually take place. But, starting from Pygaster, we naturally pass to Holectypus, to Discoidea, to Conoclypus, on the one side, while on the other, from Holectypus to Echinocyamus, Sismondia, Fibularia, and Mortonia, we have the natural sequence of the characters of the existing Echinanthidæ, Laganidæ, and Scutellidæ, the greater number of which are characteristic of the present epoch. If we were to take in turn the changes undergone in the arrangement of the plates of the test, as we pass from Pygaster to Holectypus, to Echinocyamus, and the Echinanthidæ, we should have in the genera which follow each other in the paleontological record an unbroken series showing exactly what these modifications have been. In the same way, the modifications of the abactinal and anal systems, and those of the poriferous zone, can equally well be followed to Echinocyamus, and thence to the Clypeastridæ; while a similar sequence in the modifications of these structural features can be followed from Mortonia to the Scutellidæ of the present period.

Passing finally to the Petalosticha, we find no difficulty in tracing theoretically the modifications which our early Echinoconidæ of the Lias should primarily undergo previous to the appearance of Galeropygus. The similarity of the early Cassiduloid and Echinoneoid types points to the same systematic affinity, and perhaps even to a direct and not very distant relationship with the Palæchinidæ. For if we analyze the Echinothuriæ of the present day, we find in genera like Phormosoma many structural features, such as the shape of the test, the character of the spines, the structure of the apical system, that of the poriferous zone, indicative of possible modifications in the direction of Pygaster or of Galeropygus, which have as yet not been taken into account.

Adopting for the Petalosticha the same method of tracing the modifications of single structural features in their paleontological succession, we trace the comparatively little modified paleontological history of the Echinoneidæ of the present day from the Pyrina of the lower Jura. This, in its turn, has been preceded by Hyboclypus and Galeropygus, while the Echinolampadæ of the present day date back, with but trifling modifications, to the Echinobrissus of the Lias, itself preceded by Clypeus: and they have been subject only to slight generic changes since that time, Echinobrissus being still extant, while such closely allied genera as Catopygus and Cassidulus of the earlier Cretaceous are still represented at the present day: the modifications taking place in the actinal system, in the ambulacral zones of the Echinoconidæ and of the Echinolampadæ showing the closest possible systematic affinity in these families. Starting again from Hyboclypus, with its elongate apical system, we naturally pass to Collyrites and the strange Dysasteridæ forms which in their turns are closely allied to the Holasteridæ. From Holaster on the one side and from Toxaster on the other, we find an unbroken sequence of structural characters uniting the successive genera of Holasteridæ, such as Cardiaster, Offaster, Stenonia, Ananchytes, and Asterostoma, with Paleopneustes, Homolampas and the Pourtalesiæ of the present day, while from the genera of the Toxasteridæ we naturally pass to the cretaceous Hemiaster; in this genus and subsequent Micraster we find all the elements necessary for the modifications which appear in the Spatanginæ from the time of the Chalk to the present day. These modifications result in genera in which we trace the development of the fascioles, of the actinal, anal, and abactinal plastrons, of the beak, the formation of the petaloid ambulacra, first flush with the test, and little by little changed into marsupial pouches, the growth of the anterior groove and the manifold modifications of the ambulacral system in Spatangus, Agassizia, and Echinocardium, often recalling in some of its features structural characters of families which have preceded this in time.

Apparently in striking contrast with the Echini of the secondary period and those which have succeeded them stand the Paleozoic Echini; but when we have examined the embryology of Echini, we shall be better prepared to understand their structure and the affinities of the Palæchinidæ with the Echini of the present day and their immediate predecessors.

[To be continued.]

ART. XXXIII.—*New Planetary Nebulæ;* by EDWARD C. PICKERING.

MEASUREMENTS of the light of the planetary nebulæ have been made during the past year with the fifteen-inch telescope of the Harvard College Observatory. In connection with these observations the spectrum of each nebula has also been examined. A spectroscope of the usual form would be open to many objections for this work, especially as it must be frequently removed, and replaced by the photometer. Accordingly a direct-vision prism was placed between the eye-piece and objective of the telescope, thus forming a spectroscope without a slit. When a star was brought into any part of the field it was spread out into a colored line of light, the rays of each wave-length forming an image of the star in a different place. A nebula, on the other hand, being mainly monochromatic, would form a point or small disk of light, while a minute cluster would give a spectrum like that of a star. The difference in these appearances is so marked that the idea suggested itself that this device might serve to detect any minute planetary nebulæ, which could not otherwise be distinguished from stars. Accordingly a systematic search for such bodies was undertaken. A power of about 140 is employed with a field 12′ in diameter. The telescope is clamped in right ascension and moved through 5° in declination. This is repeated so frequently that the successive sweeps shall overlap, the region continually varying by the diurnal motion. Great numbers of stars pass through the field and are spread out into lines. The position of any object presenting a different appearance is at once determined by observing the declination and time, The position of bright stars are also observed to furnish corrections for the limits of the zone. Various precautions must be taken; for instance, if the spectra run north and south, the lines cannot be distinguished from points, when the telescope is moved, owing to the persistence of vision. The prism is therefore always turned so that the direction of the spectra shall be perpendicular to the line of motion. Even then the eye is constantly deceived and an object thought to be a nebula is seen to be a star when the telescope is stopped. The retina appears to be especially sensitive to rays of particular wave-lengths. The strain upon the eye and mind in examining so many objects, several a second, renders this work very fatiguing and I have found it best not to continue it for more than half an hour without an intermission. A count of the number of stars to be seen at a time in fields taken at random shows that the spectra of over ten thousand stars are often examined in this time.

The first sweep was made on July 13, and revealed in a few minutes a bright point of light wholly unlike the lines formed by the stars. This proved to be a new planetary nebula having the position for 1880 R. A. $18^h\ 25{\cdot}2^m$ and Dec. $-25°\ 13'$. Its disk is so small that it can scarcely be distinguished from a star and would not probably have been detected with an ordinary eye-piece even if brought into the field of view. Measures of its light show that it is about eight magnitudes fainter than λ *Sagittarii* or of about the eleventh magnitude on the scale of Pogson. The next evening another new nebula was found somewhat fainter than this, but with a larger disk. Its position for 1880 is R. A. $18^h\ 4{\cdot}3^m$ and Dec. $-28°\ 12'$. This region was selected since it contains four of the fifty previously known planetary nebulæ. Sweeps on several subsequent evenings in this vicinity and elsewhere revealed nothing new.

On August 28 an object entered the field having a very singular spectrum. Two bright bands were seen near the ends of a faint continuous spectrum. The position of this object for 1880 was found to be R. A. $18^h\ 1^m\ 17^s$, Dec. $-21°\ 16'$. It therefore is identical with the star Oeltzen No. 17681. Its position was observed once by Argelander and twice in the Washington zones. It must therefore have had nearly its present position and brightness over thirty years ago It appears to be slightly fainter than Oeltzen No. 17648 which precedes it about a minute and is 4′ north, so that even a small change in its light can be easily detected hereafter. A careful examination of the spectrum shows that the bright portions are longer than they are wide, and accordingly that they are bands and not lines. This view was confirmed by attaching a spectroscope of the usual form to the telescope. The less refrangible band extends from the wave-length 5800 to 5850, the other from 4670 to 4730. A third band was suspected at about 5400. All these measures are only approximate, and should be repeated at some observatory where spectroscopy is made a special study. A large telescope is needed, since at best the spectrum of so faint a star will not be easily measured. It will be noticed that the first of these bands is in the yellow not far from the D line, but of somewhat less wave-length. The other band is in the blue between the F and G lines. This spectrum is unlike that of any other source of light so far as is yet known. It is difficult to know in what class to place this body. From its spectrum of bright bands on a faint continuous back-ground, we might place it with the nebulæ, since most of the planetary nebulæ seem to have a faint, continuous spectrum not due to the presence of stars in their vicinity. The material of which this object is composed must, however, be different. On the other hand, it resembles a star in other respects, showing no disk and having a much greater intrinsic brightness than other nebulæ.

The fourth new object was discovered on September 2, and consists of a very minute nebula in R. A., $18^h\ 14{\cdot}3^m$ and Dec. $-26°\ 53'$. This is the smallest planetary nebula known and could not be distinguished from a thirteenth magnitude star in an ordinary telescope. The difference between it and a star is, however, very marked in the prism, and had it been a magnitude fainter its peculiar character would probably have been detected.

It is estimated that the spectra of about a hundred thousand stars have so far been examined, although only about one hundredth part of the heavens has as yet been explored. A more rapid survey of the whole heavens is also being made with a comet-seeker of about four-inches aperture, to show the presence or absence of peculiarities in the spectra of the brightest stars.

Cambridge, U. S., Sept. 7, 1880.

ART. XXXIV.—*On the Production and Reproduction of Sound by Light;* by ALEXANDER GRAHAM BELL, Ph.D.

[Read before the American Association for the Advancement of Science, in Boston, August 27, 1880.]

IN bringing before you some discoveries made by Mr. Sumner Tainter and myself, which have resulted in the construction of apparatus for the production and reproduction of sound by means of light, it is necessary to explain the state of knowledge which formed the starting point of our experiments.

I shall first describe that remarkable substance "selenium," and the manipulations devised by previous experimenters; but the final result of our researches has widened the class of substances sensitive to light vibrations, until we can propound the fact of such sensitiveness being a general property of all matter.

We have found this property in gold, silver, platinum, iron, steel, brass, copper, zinc, lead, antimony, german-silver, Jenkin's metal, Babbitt's metal, ivory, celluloid, gutta-percha, hard rubber, soft vulcanized rubber, paper, parchment, wood, mica, and silvered glass; and the only substances from which we have not obtained results, are carbon and thin microscope glass.*

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* Later experiments have shown that these are not exceptions.

We find that when a vibratory beam of light falls upon these substances *they emit sounds*, the pitch of which depends upon the frequency of the vibratory change in the light. We find farther, that when we control the form or character of the light, vibrations on selenium (and probably on the other substances), we control the quality of the sound, and obtain all varieties of articulate speech. We can thus, without a conducting wire as in electric telephony, speak from station to station wherever we can project a beam of light. We have not had the opportunity of testing the limit to which this photophonic effect may be extended, but we have spoken to and from points 213 meters apart; and there seems no reason to doubt that the results will be obtained at whatever distance a beam of light can be flashed from one observatory to another. The necessary privacy of our experiments, hitherto, has alone prevented any attempts at determining the extreme distance at which this new method of vocal communication will be available.

I shall now speak of selenium.

Selenium.—In the year 1817, Berzelius and Gottlieb Gahn made an examination of the method of preparing sulphuric acid in use at Gripsholm. During the course of this examination they observed in the acid a sediment of a partly reddish, partly clear brown color, which under the action of the blowpipe gave out a peculiar odor, like that attributed by Klaproth to tellurium.

As tellurium was a substance of extreme rarity, Berzelius attempted its production from this deposit, but he was unable after many experiments to obtain farther indications of its presence. He found plentiful signs of sulphur mixed with mercury, copper, tin, zinc, iron, arsenic and lead, but no trace of tellurium.

It was not in the nature of Berzelius to be disheartened by this result. In science every failure advances the boundary of knowledge as well as every success; and Berzelius felt that if the characteristic odor that had been observed did not proceed from tellurium, it might possibly indicate the presence of some substance then unknown to the chemist. Urged on by this hope he returned with renewed ardor to his work.

He collected a great quantity of the material and submitted the whole mass to various chemical processes. He succeeded in separating successively the sulphur, the mercury, the copper, the tin and the other known substances, whose presence had been indicated by his tests; and after all these had been eliminated, there still remained a residue, which proved upon examination to be what he had been in search of—*a new elementary substance.*

The chemical properties of this new element were found to resemble those of tellurium in such a remarkable degree that Berzelius gave to the substance the name of "selenium," from the Greek word *σελήνη*, the moon, ("tellurium," as is well known, being derived from *tellus*, the earth). Although tellurium and selenium are alike in many respects, they differ in their electrical properties; tellurium being a good conductor of electricity, and selenium, as Berzelius showed, a non-conductor.

Knox* discovered in 1837, that selenium became a conductor when fused; and Hittorff† in 1851, showed that it conducted at ordinary temperatures when in one of its allotropic forms.

When selenium is rapidly cooled from a fused condition it is a non-conductor. In this, its "vitreous" form, it is of a dark brown color, almost black by reflected light, having an exceedingly brilliant surface. In thin films it is transparent, and appears of a beautiful ruby red by transmitted light.

When selenium is cooled from a fused condition with *extreme slowness*, it presents an entirely different appearance, being of a dull lead color, and having throughout a granular or crystalline structure and looking like a metal. In this form it is opaque to light even in very thin films. This variety of selenium has long been known as "granular" or "crystalline" selenium; or as Regnault called it, "metallic" selenium. It was selenium of this kind that Hittorff found to be a conductor of electricity at ordinary temperature.

He also found that its resistance to the passage of an electrical current diminished continuously by heating up to the point of fusion; and that the resistance suddenly increased in passing from the solid to the liquid condition.‡

It was early discovered that exposure to sunlight § hastens the change of selenium from one allotropic form to another; and this observation is significant in the light of recent discoveries.

Although selenium has been known for the last sixty years, it has not yet been utilized to any extent in the arts, and it is still considered simply as a chemical curiosity. It is usually supplied in the form of cylindrical bars. These bars are sometimes found to be in the metallic condition, but more usually they are in the vitreous or non-conducting form.

It occurred to Willoughby Smith that, on account of the high resistance of crystalline selenium, it might be usefully employed at the shore-end of a submarine cable, in his system

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* Trans. Roy. Irish Acad. (1839), xix, 147; also Phil. Mag. III, xvi, 185.

† Pogg. Ann., lxxxiv, 214; also Phil. Mag., IV, iii, 546.

‡ See Draper and Moss in Proc. Roy. Irish Acad., Nov. 1873, II, vol. i, p. 529.

§ Gmelin's Handbook of Chemistry (1849,) ii, 235; see also Hittorff in the Phil. Mag. (1842,) IV, iii, 547.

of testing and signaling during the process of submersion. Upon experiment the selenium was found to have all the resistance required; some of the bars employed measuring as much as 1400 megohms—a resistance equivalent to that which would be offered by a telegraph wire long enough to reach from the earth to the sun! But the resistance was found to be extremely variable. Efforts were made to ascertain the cause of this variability, and it was discovered that *the resistance was less when the selenium was exposed to light than when it was in the dark!*

This observation was first made by Mr. May*—(Mr. Willoughby Smith's assistant, stationed at Valentia)—was soon verified by a careful series of experiments, the results of which were communicated by Mr. Willoughby Smith † to the Society of Telegraph Engineers, on the 17th of February, 1873. Platinum wires were inserted into each end of a bar of crystalline selenium, which was then hermetically sealed in a glass tube through the ends of which the platinum wires projected for the purpose of connection. One of these bars was placed in a box, the lid of which was closed so as to shade the selenium, and the resistance of the substance was measured.

Upon opening the lid of the box the resistance instantaneously diminished. When the light of an ordinary gas burner (which was placed at a distance of several feet from the bar,) was intercepted by shading the selenium with the hand, the resistance again increased; and upon passing the light through rock salt, and through glasses of various colors, the resistance was found to vary according to the amount of light transmitted. In order to be certain that temperature had nothing to do with the effect, the selenium was placed in a vessel of water so that the light had to pass through a considerable depth of water in order to reach the selenium. The effects, however, were the same as before. When a strong light from the ignition of a narrow band of magnesium was held about nine inches above the water, the resistance of the selenium immediately fell more than two-thirds, returning to the normal condition upon the removal of the light.

The announcement of these results naturally created an intense interest among scientific men, and letters of enquiry regarding the details of the experiment soon appeared in the columns of Nature, from Harry Napier Draper ‡ and Lieut. M. L. Sale,§ which were answered in the next number by Willoughby Smith. ‖

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* See lecture by Siemens in Proc. Roy. Inst. of Great Britain, vol. viii, p. 68.

† Jour. of Soc. of Teleg. Engin., ii, p. 31 (1873); Nature, vii, 303; Teleg. Journal, III, (1873), v, 301.

‡ Nature, vii, 340, March 6th, 1873.

§ Ibid.

‖ Nature, vii, 361, March 13th, 1873.

Sale and Draper were soon able to corroborate the statements that had been made by Willoughby Smith.

Sale* presented his researches to the Royal Society on the 8th of May, 1873, and in the following November, Draper† presented his results to the Royal Irish Academy in the shape of a joint paper by himself and Richard J. Moss.

Draper and Moss gave in their paper an admirable summary of the condition of our knowledge regarding selenium at that time. They confirmed Hittorff's observation that the temperature of minimum resistance of granular selenium was somewhere about 210° C., and that at 217° C. (the fusing point), the resistance suddenly increased. They carried the temperature to a still higher point than Hittorff had done, and found that the resistance again diminished, reaching a second minimum at 250° C.

During the course of their experiments they produced a variety of granular selenium not different in appearance from other specimens but having different electrical properties. In this form the resistance became greater instead of less when the temperature was raised.

They also used thin plates of selenium instead of the cylindrical bars formerly employed, and found great advantage from the increased sensitiveness of the former to light.

Sale found upon exposing selenium to the action of the solar spectrum that the maximum effect was produced just at or outside the extreme edge of the red end of the spectrum at a point nearly coincident with the maximum of the heat rays, thus rendering it uncertain whether the effect was due to light or to radiant heat.

In the winter of 1873–4 the Earl of Rosse‡ attempted to decide this question by comparing the selenium effects with the indications of the thermopile. He exposed selenium to the action of non-luminous radiations from hot bodies, but could produce no effect; whereas, a thermopile under similar conditions gave abundant indications of a current.

He also cut off the heat rays of low refrangibility from luminous bodies by the interposition of glass and alum between the selenium and the source of light without materially affecting the result; but when the thermopile was employed the greater portion of the heat-effect was cut off.

* Proc. Roy. Soc., xxi, 283; see also Pogg. Ann., cl, 333; Phil. Mag., IV, xlvii, 216; Nature, viii, 134.

† Proc. Roy. Irish Acad., II, Nov. 10th, 1873, 1, 529; see also a communication from Richard J. Moss to Nature, Aug. 12th, 1875, xii, 291; being an answer to a letter from J. E. H. Gordon upon the "Anomalous behavior of Selenium," published in that journal on the 8th of July, 1875; see vol. xii, p. 187.

‡ Phil. Mag., IV, March, 1874, xlvii, 161; see, also, this Journal, III, vii, 512.

Later, Prof. W. G. Adams,[*] of Kings College, took up the question, and his experiments seemed to prove conclusively that the action was due principally, if not entirely, to those rays of the spectrum which were luminous, and that the ultra-red or the ultra-violet rays had little or no effect.

This conclusion was supported by the marked effect produced by the light of the moon, and by the apparent insensitiveness of selenium to rays passed through a solution of iodine in bisulphide of carbon. He found that the maximum effect was produced by the greenish-yellow rays, and showed that *the intensity of the action depended upon the illuminating power of the light*, being *directly as the square root of that illuminating power.*

Professor Adams and Mr. R. E. Day[†] continued these researches, and among other interesting and suggestive results, discovered that light produces in selenium an electromotive force without the aid of a battery.

The most sensitive variety of selenium that has yet been produced was obtained in Germany by Dr. Werner Siemens, by continued heating for some hours at a temperature of 210° C., followed by extremely slow cooling.

Dr. C. W. Siemens,[‡] in a lecture delivered before the Royal Institution of Great Britain, on the 18th of February, 1876, stated that his brother's modification of selenium was so sensitive to light that its conductivity was *fifteen times as great in sunlight as it was in the dark.*

In Werner Siemens'[§] experiments special arrangements were made for reducing the resistance of the selenium.

For this purpose two fine platinum wires were coiled into a double flat spiral and were laid upon a plate of mica, so that they did not come into contact with one another. A drop of melted selenium was then placed upon the platinum wire arrangement and a second sheet of mica was pressed upon the selenium so as to cause it to spread out and fill the spaces between the wires. Each cell was about the size of a silver dime. The cells were then placed in a paraffine bath and annealed.

Siemens devised other arrangements of apparatus for reducing the resistance. In the form known as "Siemens' Grating," the

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[*] Proc. Roy. Soc., June 17th, 1875, xxiii, 535; see, also, Proc. Roy. Soc., Jan. 6th, 1876, xxiv. 163; Nature, Jan. 20th, 1876, xiii, 238; Nature, Mar. 23d, 1876, xiii, 419: Scient. Amer. Supplement, June 3d, 1876, i, 354.

[†] Proc. Roy. Soc., June 15th, 1876, xxv, 113.

[‡] Proc. Roy. Inst. Gt. Brit., Feb. 18th, 1876, viii, 68; see, also, Nature, xiii, 407; Scient. Amer. Supplement, Apr. 1st, 1876, i, 222; Scient. Amer. Supplement, June 10th, 1876, i, 375.

[§] Monatsbericht der Kön. preuss. Akad. der Wissenschaften zu Berlin for 1875, p. 280; Phil. Mag., Nov. 1875, IV, l, 416; Nature, Dec. 9th, 1875, xiii, 112; Monatsber. Berl. Akad., Feb. 17, 1876; Pogg. Ann., clix, 117; Monatsb. Berl. Akad., June 7, 1877; Pogg. Ann., 1877, ii, 521.

two wires, instead of being coiled together, were arranged in a zig-zag shape, forming a sort of platinum gridiron.

This was treated in the same way as the spiral arrangement. Another form of cell consisted of a sort of lattice-work or basket-work of platinum wires arranged upon a perforated mica plate, the wires interlacing with one another, and with the mica plate so as to make metallic contact only with alternate wires. He also found that iron and copper might be employed, instead of platinum.

Without dwelling further upon the researches of others I may say that all observations concerning the effect of light upon the conductivity of selenium have been made by means of the galvanometer, but it occurred to me that the telephone, from its extreme sensitiveness to electrical influences, might be substituted with advantage. Upon consideration of the subject, however, I saw that the experiments could not be conducted in the ordinary way, for the following reasons: The law of audibility of the telephone is precisely analogous to the law of electric induction. No effect is produced during the passage of a continuous and steady current. It is only at the moment of change from a stronger to a weaker state, or, *vice versa*, that any audible effect is produced; and the amount of effect is exactly proportional to the amount of *variation* in the current.

It was, therefore, evident that the telephone could only respond to the effect produced in selenium at the moment of change from light towards darkness, or, *vice versa*, and that it would be advisable to intermit the light with great rapidity so as to produce a succession of changes in the conductivity of the selenium, corresponding in frequency to musical vibrations within the limits of the sense of hearing. For I had often noticed that currents of electricity, so feeble as hardly to produce any audible effects from a telephone when the circuit was simply opened and closed, caused very perceptible musical sounds when the circuit was rapidly interrupted; and that the higher the pitch of the sound the more audible was the effect. I was much struck by the idea of in this way producing sound by the action of light.

I proposed to pass a bright light through one of the orifices in a perforated screen consisting of a circular disc or wheel with holes near the circumference. Upon rapidly rotating the disc an intermittent beam of light would fall upon the selenium and a musical tone should be produced from the telephone, the pitch of which would depend upon the rapidity of the rotation of the disc.

Upon further consideration it appeared to me that all the audible effects obtained from variations of electricity could also be produced by variations of light, acting upon selenium. I saw that the effect could not only be produced at the extreme distance at which selenium would normally respond to the action of a luminous body, but that this distance could be indefinitely increased by the use of a parallel beam of light, so that we might telephone from one place to another without the necessity of a conducting wire between the transmitter and receiver.

It was evidently necessary in order to reduce this idea to practice, to devise an apparatus to be operated by the voice of a speaker, by which variations could be produced in a parallel beam of light, corresponding to the variations in the air produced by the voice.

I proposed to pass light through a perforated plate containing an immense number of small orifices.

Two similarly perforated plates were to be employed. One was to be fixed and the other to be attached to the center of a diaphragm actuated by the voice; so that the vibration of the diaphragm would cause the movable plate to slide to and fro over the surface of the fixed plate, thus alternately enlarging and contracting the free orifices for the passage of light. In this way the voice of a speaker could control the amount of light passed through the perforated plates without completely obstructing its passage. This apparatus was to be placed in the path of a parallel beam of light, and the undulatory beam emerging from the apparatus could be received at some distant place upon a lens, or other apparatus by means of which it could be condensed upon a sensitive piece of selenium placed in a local circuit, with a telephone and galvanic battery.

The variations in the light produced by the voice of the speaker should cause corresponding variations in the electrical resistance of the selenium at the distant place, and the telephone in circuit with the selenium should reproduce audibly the tones and articulations of the speaker's voice.

I obtained some selenium for the purpose of trying the apparatus described; but found upon experiment that its resistance was almost infinitely greater than that of any telephone that had been constructed; and I was therefore unable at that time to obtain audible effects in the way desired. I believed, however, that this obstacle could be overcome by devising mechanical arrangements for reducing the resistance of the selenium, and by constructing special telephones for the purpose.

I felt so much confidence in this that in a lecture delivered before the Royal Institution of Great Britain, on the 17th of May, 1878, I announced the possibility of hearing a shadow by means of interrupting the action of light upon selenium. A few days afterwards my ideas upon this subject received a fresh impetus by the announcement made by Mr. Willoughby Smith,* before the Society of Telegraph Engineers, that he had heard the action of a ray of light falling upon a bar of crystalline selenium by listening to a telephone in circuit with it.

It is not unlikely that the publicity given to the speaking telephone during the last few years, may have suggested to many minds, in different parts of the world, somewhat similar ideas to my own; indeed, it has recently come to my knowledge that a writer (J. F. W.,† of Kew) on the 13th of June, 1878, asked the readers of "Nature" through the columns of that periodical, whether any experiments had been made with a telephone in circuit with a selenium galvanic element arranged as in Sabine's selenium battery;‡ and suggested that it was not unlikely that sounds would be produced in a telephone by the action of light of variable intensity upon a selenium element in circuit with it.

In September or October, 1878, Mr. A. C. Brown, of London, submitted to me, confidentially, the details of a most ingenious invention of his, of which we may yet hear more. This invention, although entirely different from my own, involved the use of selenium in circuit with a battery and telephone, and the production of articulate speech by the action of a variable light. I am also aware that Mr. W. D. Sargent, of Philadelphia, has had some ideas of a similar nature, the details of which I do not know. I understood from Mr. Sargent that he proposed submitting selenium to the influence of an oscillating beam of light which should be sent on and off the selenium by the action of the voice. If this is so the effect produced would be only of an intermittent character and a musical tone, not speech, would be heard from the telephone in circuit with the selenium.

Although the idea of producing and reproducing sound by the action of light, as described above, was an entirely original and independent conception of my own, I recognize the fact that the knowledge necessary for its conception has been disseminated throughout the civilized world, and that the idea may therefore have occurred, independently, to many other minds.

I have stated above the few facts that have come under my observation bearing upon the subject.

The fundamental idea, on which rests the possibility of producing speech by the action of light, is the conception of what may be termed an undulatory beam of light in contra-distinction to a merely intermittent one.

By an undulatory beam of light I mean a beam that shines

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* See Journ. of Teleg. Engin., May 23, 1878, vii, 284.

† Nature, xviii, 169.

‡ Nature, xvii, 512, Apr. 25, 1878.

continuously upon the receiver, but the intensity of which upon that receiver is subject to rapid changes corresponding to the changes in the vibratory movement of a particle of air during the transmission of a sound of definite quality through the atmosphere. The curve that would graphically represent the changes of light would be similar in *shape* to that representing the movements of the air. I do not know whether this conception had been clearly realized by J. F. W., of Kew, or by Mr. Sargent, of Philadelphia, but to Mr. A. C. Brown, of London is undoubtedly due the honor of having distinctly and independently formulated the conception and of having devised apparatus, though of a crude nature, for carrying it into execution.

It is greatly due to the genius and perseverance of my friend, Mr. Sumner Tainter, of Watertown, Mass., that the problem of producing and reproducing sound by the agency of light has at last been successfully solved. For many months past we have been devoting ourselves to the solution of this problem and I have great pleasure in presenting to you to-night the results of our labors.

Researches of Sumner Tainter and Alexander Graham Bell.

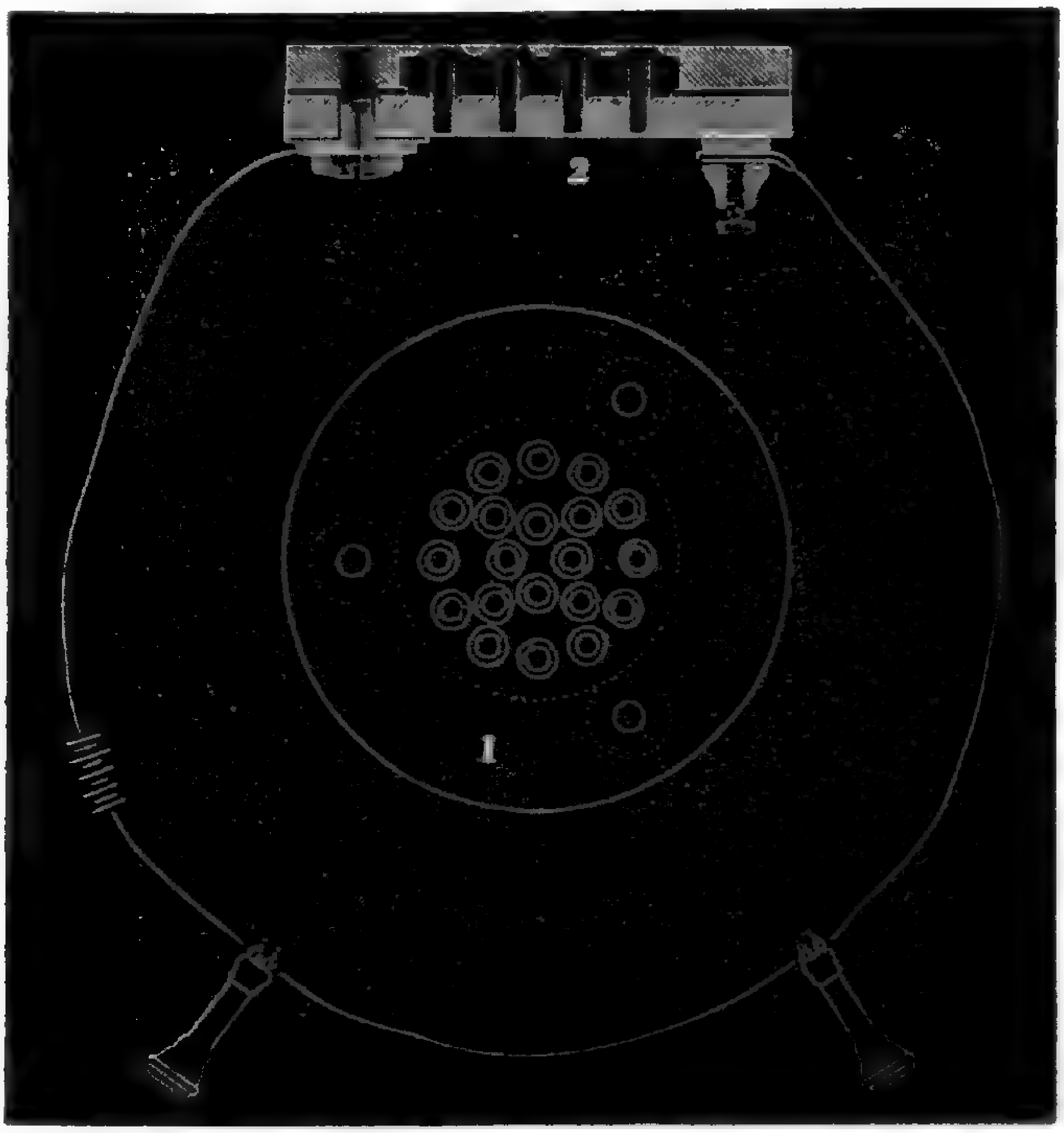
The first point to which we devoted our attention was the reduction of the resistance of crystalline selenium within manageable limits. The resistance of selenium cells, employed by former experimenters, was measured in millions of ohms, and we do not know of any record of a selenium cell measuring less than 250,000 ohms in the dark.

We have succeeded in producing sensitive selenium cells measuring only 300 ohms in the dark and 150 ohms in the light. All former experimenters seemed to have used platinum for the conducting part of their selenium cells, excepting Werner Siemens, who found that iron and copper might be employed. We have discovered that brass, although chemically acted upon by selenium, forms an excellent and convenient material; indeed, we are inclined to believe that the chemical action between the brass and selenium has contributed to the low resistance of our cells by forming an intimate bond of union between the selenium and brass.

We have observed that melted selenium behaves to other substances as water to a greasy surface, and we are inclined to think that when selenium is used in connection with metals not chemically acted upon by it, the points of contact between the selenium and the metal offer a considerable amount of resistance to the passage of a galvanic current, and thus serve to increase the apparent resistance of the selenium.

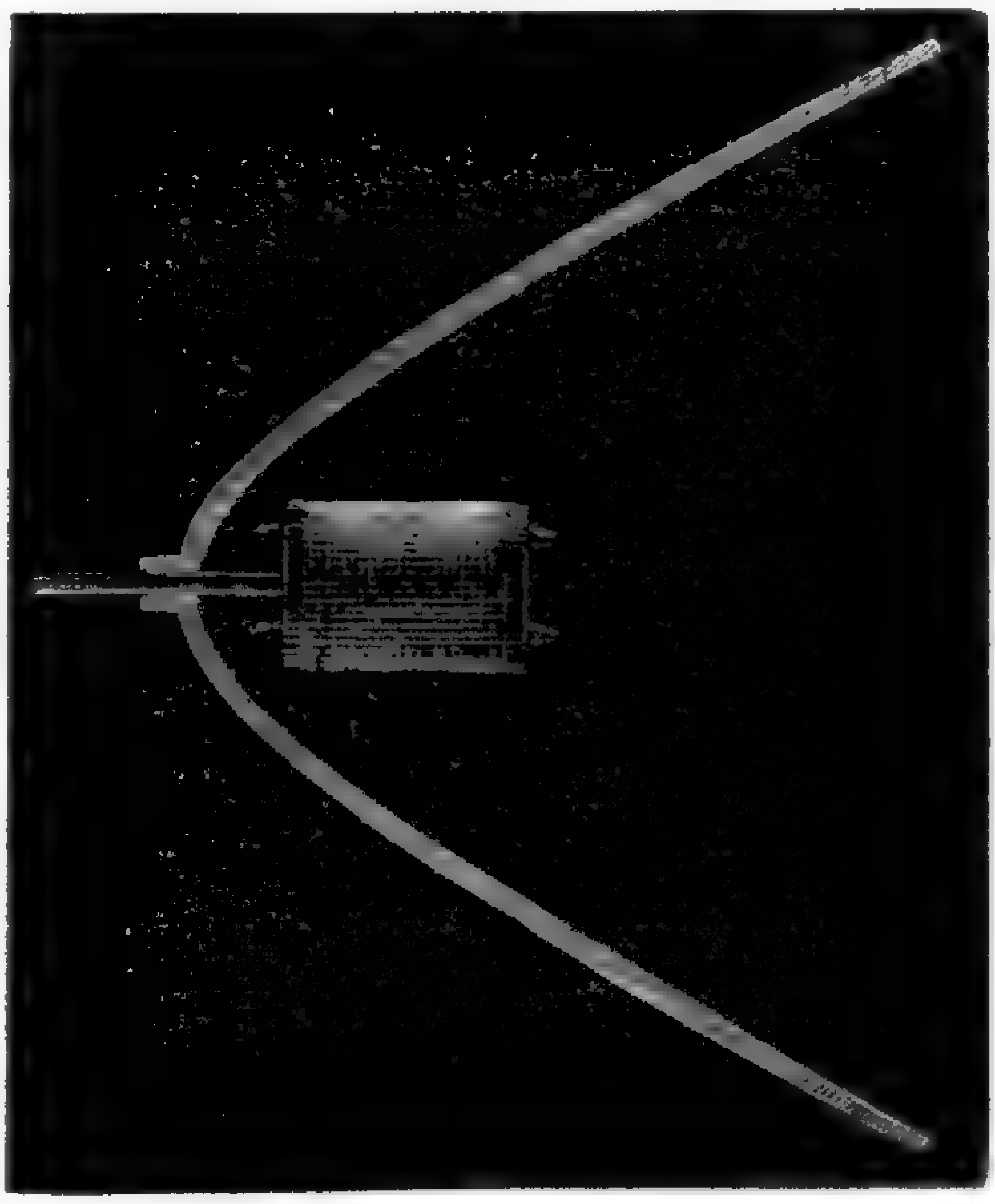
By using brass we have been enabled to construct a large number of cells of different forms. Time will only admit of my showing you two typical forms. One of these is shown in plan in fig. 1, and in section in fig. 2.

1, 2.



This cell consists of two brass plates insulated from one another by a sheet of mica. The upper plate has numerous perforations and brass pins attached to the lower plate, pass through these orifices so that their ends without touching the upper plate are flush with its surface.

3.



The annular spaces between the pins and the plate are filled with selenium. The whole arrangement forms part of a galvanic circuit, and it will be observed that the current can only pass from the plate to the pins through the selenium rings.

It will also be seen that owing to the conical shape of the perforations the points of closest approximation between the pins and the plate are on the upper surface. As the effect produced by light upon selenium is chiefly a surface action, this arrangement is found to be of great advantage.

The second typical cell is cylindrical in form, for the purpose of being used with a concave reflector instead of with a lens (see fig. 3.)

This cell is composed of a large number of metallic discs separated by discs of mica slightly smaller in diameter. The spaces between the brass discs over the mica are filled with selenium, and the alternate brass discs are metallically connected. The arrangement practically consists of a large number of annular selenium cells united in mutiple arc.

The mode of applying the selenium is as follows:

The cell is heated, and when hot enough a stick of selenium is rubbed over the surface.

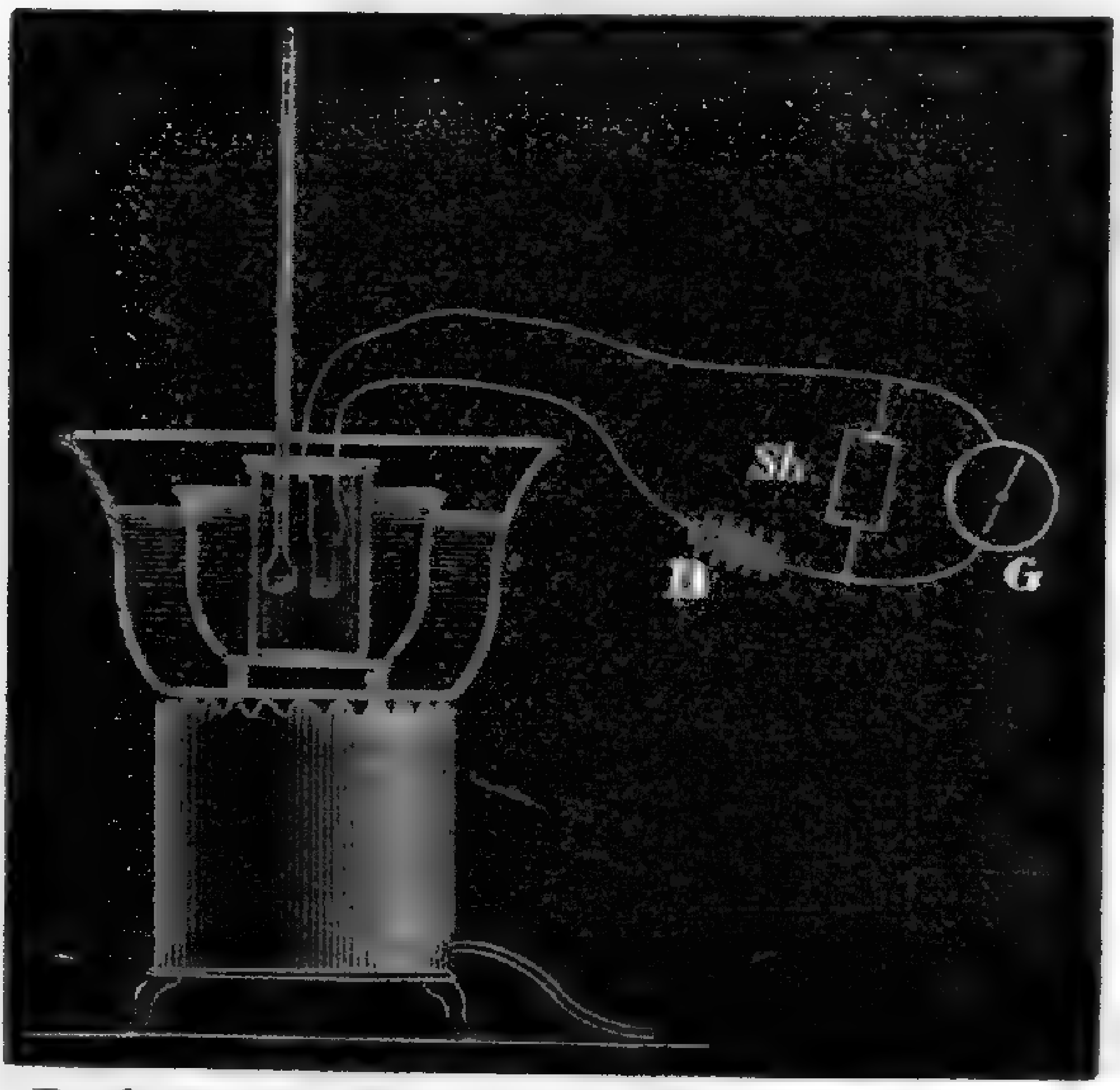
In order to acquire conductivity and sensitiveness the selenium must next undergo a process of annealing.

The method we first adopted was the following:

The selenium cell was placed with a thermometer in the interior of the cylindrical annealing chamber shown in fig. 4. This was inserted in a pot of linseed oil, and the latter stood upon glass supports within another similar pot containing linseed oil. The whole arrangement was then placed over a gas stove and heated to a temperature of about 214° C., which was found to be the temperature of maximum conductivity for the selenium used.

This temperature was retained for about twenty-four hours, and the pots, with their contents, were then packed in a box so arranged as to retard radiation of heat.

4.



B=battery; Sh=shunt; G=galvanometer.

The selenium took from forty to sixty hours to cool down to the temperature of the air.

A powerful battery current was passed through the selenium during the whole process of heating and cooling, in accordance with our theory that the current exerted a powerful influence in causing a set of the selenium molecules, and in retaining them in position until fixed by crystallization.

A shunted galvanometer was introduced into the circuit for the purpose of observing the changes of conductivity. We subsequently found this tedious process to be unnecessary, as during the course of our experiments we discovered a method of preparing sensitive selenium in a very few minutes.

We now simply heat the selenium over a gas stove and observe its appearance. When the selenium attains a certain temperature, the beautiful reflecting surface becomes dimmed. A cloudiness extends over it, somewhat like the film of moisture produced by breathing upon a mirror.

This appearance gradually increases and the whole surface is soon seen to be in the metallic, granular, or crystalline condition. The cell may then be taken off the stove and cooled in any suitable way. When the heating process is carried too far, the crystalline selenium is seen to melt.

Our best results have been obtained by heating the selenium until it crystallizes as stated above, and by continuing the heating until signs of melting appear, when the gas is immediately put out.

The portions that had melted instantly re-crystallize, and the selenium is found upon cooling to be a conductor, and to be sensitive to light. The whole operation occupies only a few minutes. This method has not only the advantage of being expeditious, but it proves that many of the accepted theories on this subject are fallacious.

Early experimenters considered that the selenium must be "cooled from a fused condition with extreme slowness." Later authors agree in believing that the retention of a high temperature—short of the fusing point—and slow cooling—are essential, and the belief is also prevalent that crystallization takes place only during the cooling process.

Our new method shows that fusion is unnecessary, that conductivity and sensitiveness can be produced without long heating and slow cooling; and that crystallization takes place during the heating process. We had found that on removing the source of heat, immediately on the appearance of the cloudiness above referred to, distinct and separate crystals can be observed under the microcsope, which appear like leaden snow flakes on a ground of ruby red.

Upon removing the heat when crystallization is further advanced, we perceive under the microscope masses of these crystals arranged like basaltic columns, standing detached from one another—and at a still higher temperature the distinct columns are no longer traceable, but the whole mass resembles metallic pudding-stone with here and there a separate snow flake, like a fossil on the surface. Selenium crystals formed during slow cooling after fusion, present an entirely different appearance, showing distinct facets.

I must now endeavor to explain the means by which a beam of light can be controlled by the voice of a speaker.

Photophonic Transmitters.

We have devised upwards of fifty forms of apparatus for varying a beam of light in the manner required, but only a few typical varieties need be described.

(1st.) The source of light may be controlled, or (2nd) a steady beam may be modified at any point in its path.

In illustration of the first method we have devised several forms of apparatus founded upon Kœnig's manometric capsule, operating to cause variations in the pressure of gas supplied to a burner, so that the light can be vibrated by the voice.

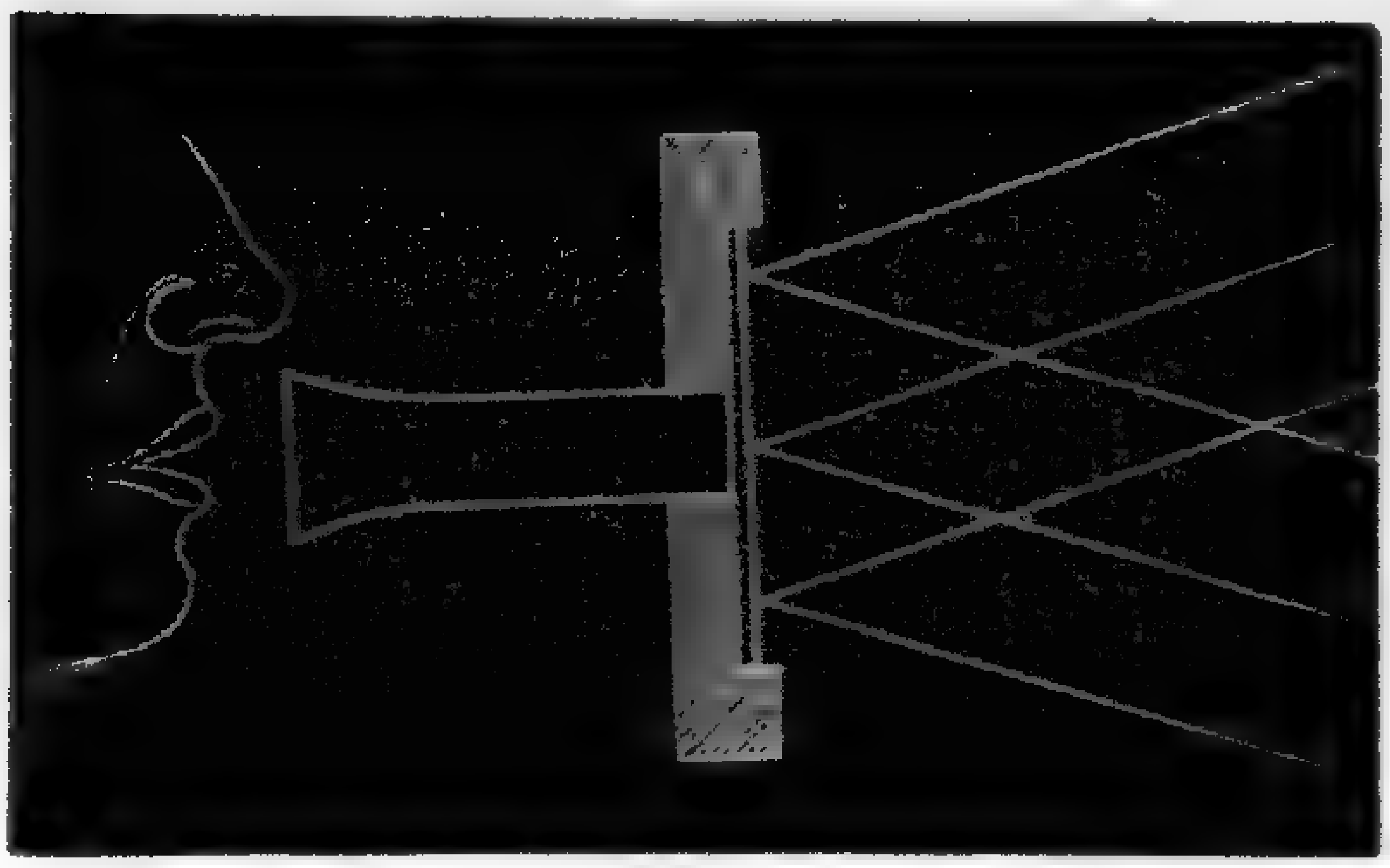
In illustration of the second method I have already shown one form of apparatus by which the light is obstructed in a greater or less degree, in its passage through perforated plates. But the beam may be controlled in many other ways. For instance, it may be polarized, and then affected by electrical or magnetical influences in the manner discovered by Faraday and Dr. Kerr.

Let a polarized beam of light be passed through a solution of bisulphide of carbon contained in a vessel inside a helix of insulated wire, through which is passed an undulatory current of electricity from a microphone or telephonic transmitter operated by the voice of a speaker.

The passage of the polarized beam should be normally partially obstructed by a Nicols prism, and the varying rotation of the plane of polarization would allow more or less of the light to pass through the prism, thus causing an undulatory beam of light capable of producing speech.

The beam of polarized light, instead of being passed through a liquid could be reflected from the polished pole of an electromagnet in circuit with a telephonic transmitter.

5.



Another method of affecting a beam of light is to pass it through a lens of variable focus* formed of two sheets of thin glass or mica containing between them a transparent liquid or gas. The vibrations of the voice are communicated to the gas or liquid, thus causing a vibratory change in the convexity of the glass surfaces and a corresponding change in the intensity of the light received upon the sensitive selenium. We have found that the simplest form of apparatus for producing the effect consists of *a plane mirror*

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* I observe that a lens of similar construction has been invented in France by Dr. Cusco, and is described in a recent paper in "La Nature." See, also, Scien. Amer., Aug. 28, 1880, xliii, 131. Mr. Tainter and I have used such a lens in our experiments for months past.

of flexible material, such as silvered *mica or microscope-glass, against the back of which the speaker's voice is directed*, as shown in the diagram (fig. 5).

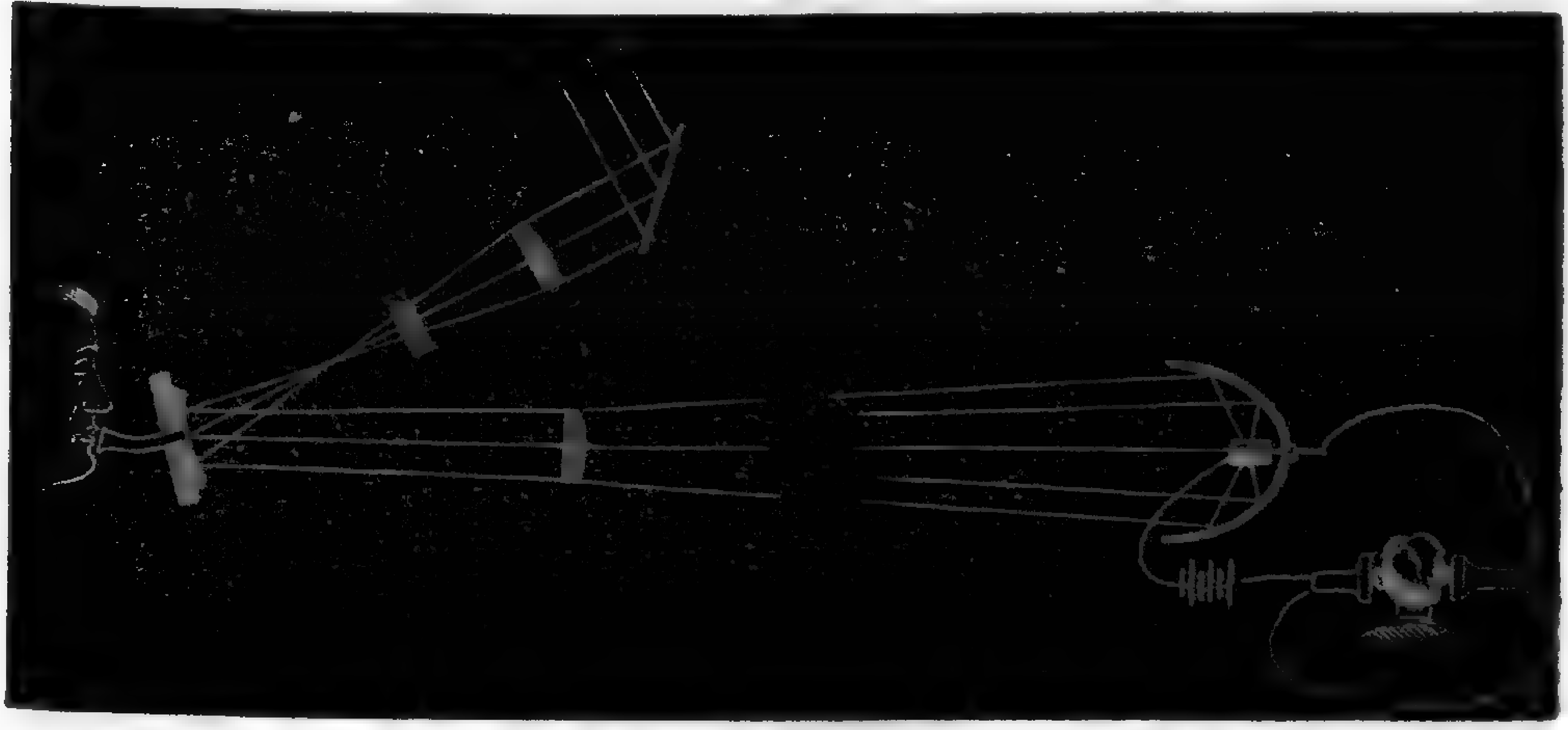
Light reflected from such a mirror is thrown into vibrations corresponding to those of the diaphragm itself. In its normal condition a parallel beam of light falling upon the diaphragm mirror would be reflected parallel. Under the action of the voice the mirror becomes alternately convex and concave, and thus alternately scatters and condenses the light.

When crystalline selenium is exposed to the undulatory beam reflected from such an apparatus, the telephone connected with the selenium audibly reproduces the articulation of the person speaking to the mirror.

In arranging the apparatus for the purpose of reproducing sound at a distance, any powerful source of light may be used, but we have experimented chiefly with sun-light.

For this purpose, a large beam is concentrated by means of a lens upon the diaphragm mirror and after reflection is again rendered parallel by means of another lens. The beam is received at a distant station upon a parabolic reflector, in the focus of which is placed a sensitive selenium cell, connected in a local circuit with a battery and telephone. We have found it advisable to protect the mirror by placing it out of the focal point, and by passing the beam through an alum cell, as shown in fig. 6.

6.



A large number of trials of this apparatus have been made with the transmitting and receiving instruments so far apart that sounds could not be heard directly through the air. In illustration I shall describe one of the most recent of these experiments.

Mr. Tainter operated the transmitting instrument, which was placed on the top of the Franklin School House in Washington, and the sensitive receiver was arranged in one of the windows of my laboratory, 1325 L Street, at a distance of 213 meters.

Upon placing the telephone to my ear, I heard distinctly from the illuminated receiver the words:—"Mr. Bell, if you hear what I say, come to the window and wave your hat."

In laboratory experiments the transmitting and receiving instruments are necessarily within ear-shot of one another, and we have therefore been accustomed to prolong the electric circuit connected with the selenium receiver, so as to place the telephones in another room.

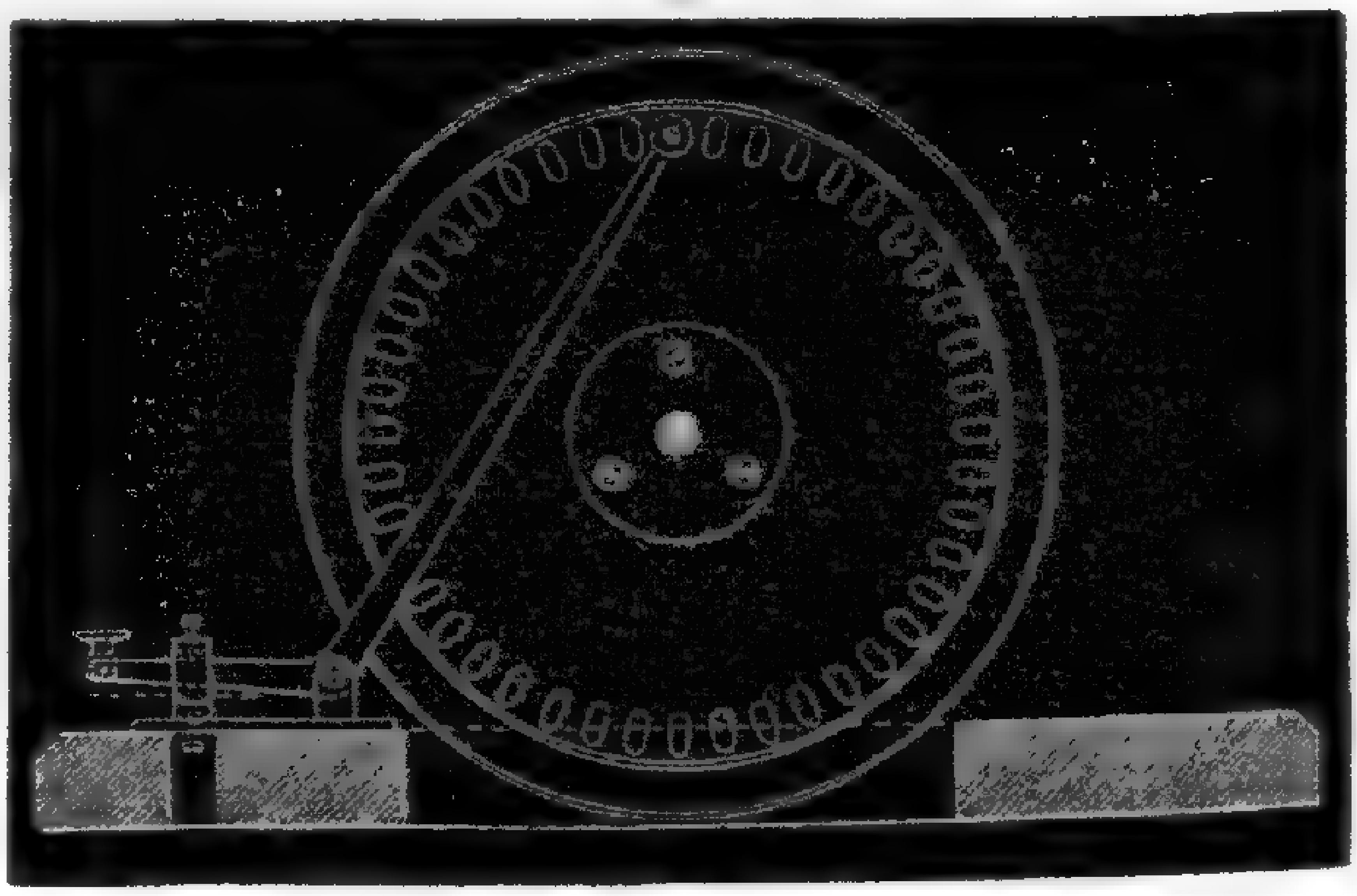
By such experiments we have found that articulate speech can be reproduced by the oxyhydrogen light, and even by the light of a kerosene lamp. The loudest effects obtained from light are produced by rapidly interrupting the beam.

A suitable apparatus for doing this is a perforated disc which can be rapidly rotated. The great advantage of this form of apparatus for experimental work is the noiselessness of its operation, admitting of the close approach of the receiver without interfering with the audibility of the effect heard from the latter—for it will be understood that musical tones are emitted from the receiver when no sound has been made at the transmitter. A silent motion thus produces a sound. In this way musical tones have been heard even from the light of a candle.

7.

When distant effects are sought the apparatus can be arranged as shown in fig. 7.

8.



By placing an opaque screen near the rotating disk the beam can be entirely cut off by a slight motion of the hand, and musical signals, like the dots and dashes of the Morse telegraph code, can thus be produced at the distant receiving station. Such a screen operated by a key like a Morse telegraph key is shown in fig. 8, and has been operated very successfully.

Experiments to ascertain the nature of the rays that affect selenium.

We have made experiments with the object of ascertaining the nature of the rays that affect selenium. For this purpose we have placed in the path of an intermittent beam various absorbing substances.

Prof. Cross has been kind enough to give his assistance in conducting these experiments.

When a solution of alum, or bisulphide of carbon, is employed, the loudness of the sound produced by the intermittent beam is very slightly diminished, but a solution of iodine in bisulphide of carbon cuts off most, but not all, of the audible effect. Even an apparently opaque sheet of hard rubber does not entirely do this.

This observation, which was first made in Washington, D. C., by Mr. Tainter and myself, is so curious and suggestive that I give in full the arrangement for studying the effect.

9.

When a sheet of hard rubber, A, was held as shown in the diagram (fig. 9) the rotation of the disc or wheel B interrupted what was then an invisible beam, which passed over a space of several meters before it reached the lens C, which finally concentrated it upon the selenium cell, D.

A faint but perfectly perceptible musical tone was heard from the telephone connected with the selenium that could be interrupted at will by placing the hand in the path of the invisible beam.

It would be premature without further experiments to speculate too much concerning the nature of these invisible rays; but it is difficult to believe that they can be heat rays, as the effect is produced through two sheets of hard rubber having between them a saturated solution of alum.

Although effects are produced, as above shown, by forms of radiant energy which are invisible, we have named the apparatus for the production and reproduction of sounds in this way "the Photophone," because an ordinary beam of light contains the rays which are operative.

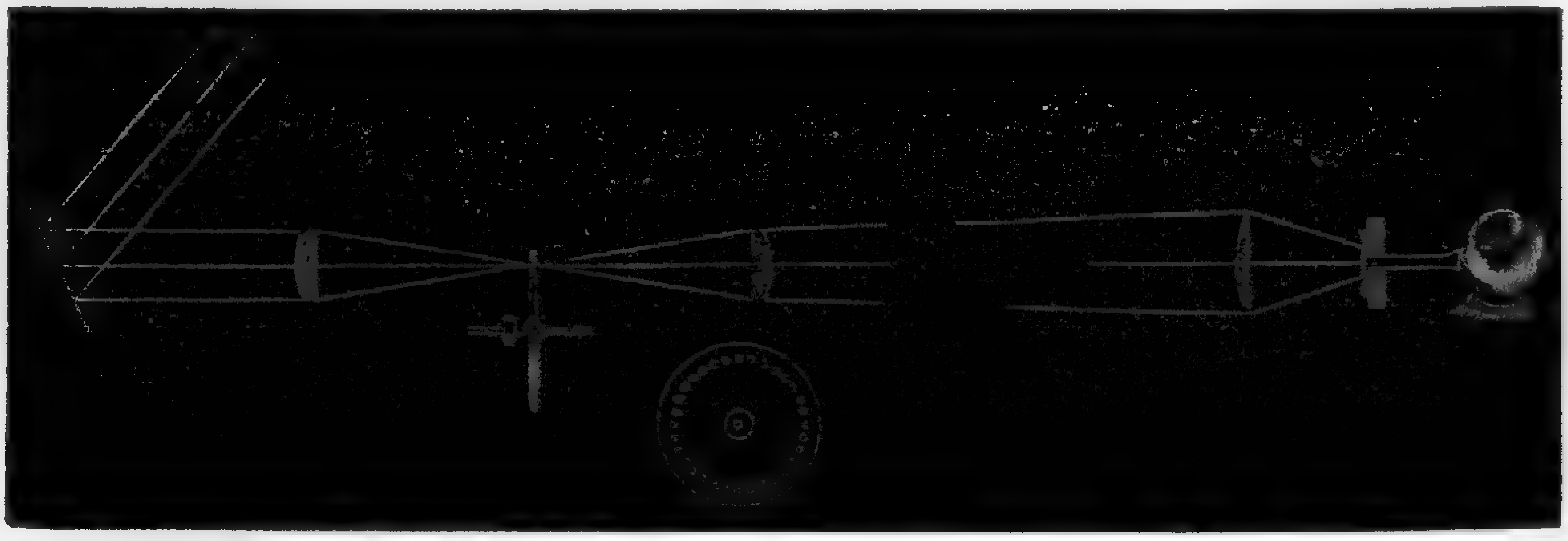
Non-Electric Photophonic Receivers.

It is a well known fact that the molecular disturbance, produced in a mass of iron by the magnetizing influence of an intermittent electrical current, can be observed as sound by placing the ear in close contact with the iron, and it occurred to us that the molecular disturbance produced in crystalline selenium by the action of an intermittent beam of light should be audible in a similar manner without the aid of a telephone or battery. Many experiments were made to verify this theory, but at first without definite results.

The anomalous behavior of the hard rubber screen alluded to above suggested the thought of listening to it also.

This experiment was tried with extraordinary success. I held the sheet in close contact with my ear while a beam of intermittent light was focussed upon it by means of a lens. A distinct musical note was immediately heard. We found the effect intensified by arranging the sheet of hard rubber as a diaphragm, and listening through a hearing tube, as shown in fig. 10.

10.



We then tried crystalline selenium in the form of a thin disc and obtained a similar but less intense effect.

The other substances, which I enumerated at the commencement of my address, were now successively tried in the form of thin discs, and sounds were obtained from all but carbon and thin glass.*

In our experiments, one interesting and suggestive feature was the different intensities of the sounds produced from different substances under similar conditions. We found hard rubber to produce a louder sound than any other substance we tried, excepting antimony and zinc; and paper and mica to produce the weakest sounds.

On the whole, we feel warranted in announcing as our conclusions that *sounds can be produced by the action of a variable light from substances of all kinds when in the form of thin dia-*

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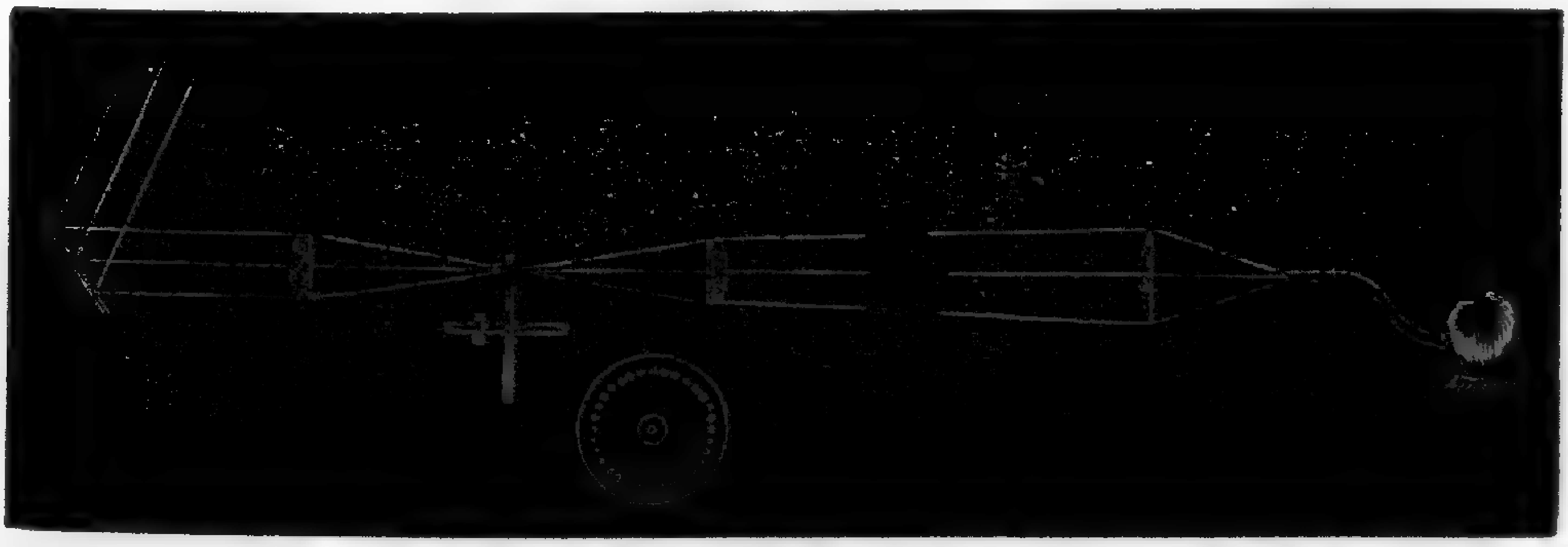
* We have since obtained perfectly distinct tones from carbon and thin glass.

phragms. The reason why thin diaphragms of the various materials are more effective than masses of the same substances, appears to be that the molecular disturbance produced by light is chiefly a surface action, and that the vibration has to be transmitted through the mass of the substance in order to affect the ear.

On this account we have endeavored to lead to the ear air that is directly in contact with the illuminated surface, by throwing the beam of light upon the interior of a tube; and very promising results have been obtained. Fig. 11 shows the arrangement we have tried. We have heard from interrupted sunlight very perceptible musical tones through tubes of ordinary vulcanized rubber, of brass, and of wood. These were all the materials at hand in tubular form, and we have had no opportunity since of extending the observations to other substances.*

11.



I am extremely glad that I have the opportunity of making the first publication of these researches before a scientific society, for it is from scientific men that my work of the last six years has received its earliest and kindest recognition. I gratefully remember the encouragement which I received from the late Professor Henry, at a time when the speaking telephone existed only in theory. Indeed, it is greatly due to the stimulus of his appreciation that the telephone became an accomplished fact.

I cannot state too highly also the advantage I derived in preliminary experiments on sound vibrations in this building from Professor Cross, and near here from my valued friend Dr. Clarence J. Blake. When the public were incredulous of the possibility of electrical speech, the American Academy of Arts and Sciences, the Philosophical Society of Washington, and the Essex Institute of Salem, recognized the reality of the results and honored me by their congratulations. The public interest, I think, was first awakened by the judgment of the

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* A musical tone can be heard by throwing the intermittent beam of light into the ear itself. This experiment was at first unsuccessful on account of the position in which the ear was held.

very eminent scientific men before whom the telephone was exhibited in Philadelphia, and by the address of Sir William Thomson before the British Association for the Advancement of Science. At a later period, when even practical telegraphers considered the telephone as a mere toy, several scientific gentlemen, Professor John Pierce, Professor Eli W. Blake, Dr. Channing, Mr. Clark and Mr. Jones, of Providence, R. I., devoted themselves to a series of experiments for the purpose of assisting me in making the telephone of practical utility; and they communicated to me, from time to time, the results of their experiment with a kindness and generosity I can never forget. It is not only pleasant to remember these things and to speak of them, but it is a duty to repeat them, as they give a practical refutation to the often repeated stories of the blindness of scientific men to unaccredited novelties, and of their jealousy of unknown inventors who dare to enter the charmed circle of science.

I trust that the scientific favor which was so readily accorded to the Telephone may be extended by you to this new claimant—" *The Photophone.*"

ART. XXXV.—*A New Meteoric Iron from North Carolina*; by W. E. HIDDEN.

ON the 19th of July, 1879, Mr. Gray W. Harris, while out prospecting for gold, on his land near Lick Creek, Davidson County, N. C., found an unusually heavy stone of the size of a large pear, which he at first mistook for a specimen of iron ore. On attempting to break it he found that the stone would not break but was covered with a uniformly thick skin or crust which scaled off under repeated blows of the hammer.

After carefully removing all he could of this crust, there remained a pear-shaped mass of what appeared to him to be a pure metal. The color of the metal, developed by hammering, was *white*, and this led him to conclude that it was silver. This "nugget of silver," as he called it, soon had a wide notoriety among all the mining camps in the region.

This story, substantially as above related, reached me at Concord, N. C., in the autumn of 1879; my informants were the Messrs. Richard Eames, Jr. and Sr. They had seen the "nugget" and believed it to be iron, perhaps native iron; they had noticed that the "nugget" had what Mr. Eames, Jr., aptly termed "night sweats." Little beads of a yellowish fluid*

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* These watery exudations I have myself noticed and found to consist of chloride of iron. W. E. H.

would gather upon its surface over night, which, if wiped away, would form again in the next twenty-four hours.

This last addition to the story of the "silver nugget" convinced me that the mass was really meteoric iron. After no little trouble and expense it was finally sent to Menlo Park, N. J., where it was at once recognized as *meteoric* iron. But for the active interest taken in this meteorite by the Messrs. Eames, it would have been in all probability lost to science; and I take this opportunity to express my indebtedness to them.

For the exact size and appearance of this meteorite see cut.*

Meteorite from Davidson County, North Carolina. (Exact size.)

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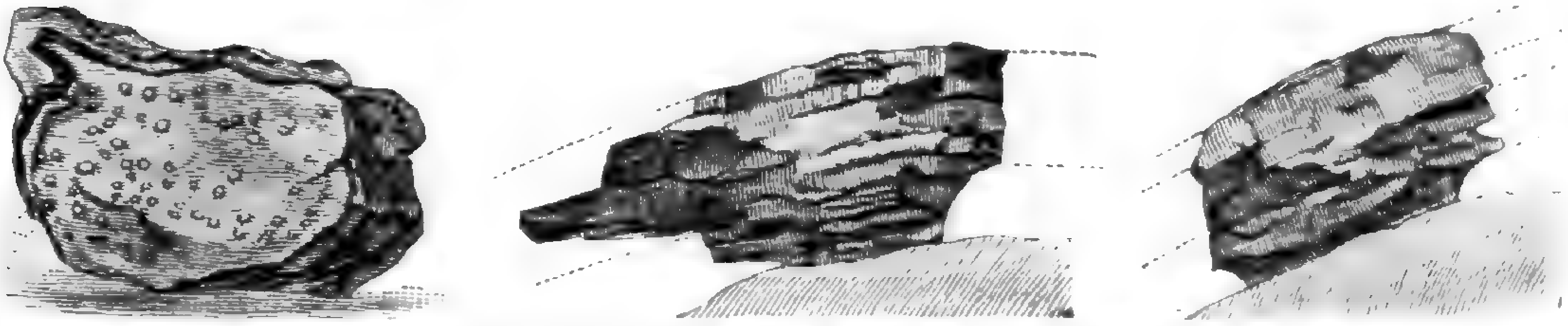
* I am indebted to the "Illustrated Scientific News," of New York, for the use of this fine engraving.
W. E. H.

It weighed when received here 1·24 kg., (= 2¾ lbs.). Its outward color is *dark* brown, not rusty, and some little of the original crust yet adheres to it. The crust of this meteorite is of unusual importance and quite unique, as illustrated in the accompanying figures. It averages 1^{cm} in thickness and resembles a hard, dark slate, shows a lamellar structure and readily breaks into flakes. Some cavities in this crust are lined with mammillary forms and it has many seams with a vitreous-like luster.



Crust on Davidson County, N. C., Meteorite. (Exact size.)

Last month I visited the spot where the meteorite was found and collected about six ounces of the crust. It lay there exactly as Mr. Harris had broken it off. I had no fears of mistake in identifying this crust as all the local gravel was composed of white quartz pebbles.

This iron has been analyzed by Dr. J. Lawrence Smith and J. B. Mackintosh, E.M. I here give the average of four closely agreeing analyses.

Iron, 93·00 per cent; nickel, 5·74 per cent; cobalt, 0·52 per cent; phosphorus, 0·36 per cent; traces of sulphur, chlorine and copper; carbon not determined. Total = 99·62 per cent. This iron does *not* show the customary Widmannstätten figures. I have etched all the exposed surfaces and obtained no well defined markings on a large scale, but I have found that the etched surfaces show crystalline faces which reflect the light at certain angles, giving a sort of sheen much like moonstone or labradorite. These reflecting surfaces are in parallel sets.

This is the second of the three *new* meteoric irons discovered in the Southern States, in the autumn of 1879, by the writer, who now holds in his possession the two already described in their original condition.

June 23, 1880.

ART. XXXVI.—*Results of Pendulum Experiments;* by C. S. PEIRCE, Assistant Coast and Geodetic Survey. [Published by authority of C. P. Patterson, Superintendent.]

THE following are the results obtained from observations made by me, for the U. S. Coast and Geodetic Survey, at four important stations, for the purpose of comparing the lengths of the seconds pendulum, together with reductions to the sea-level and to the equator. In making the last reduction I have assumed the ellipticity to be =1:293, which is the latest result from measurements of arcs.

	At station.	At sea-level.	At equator.
Hoboken	0·9932052^{m}	0·9932074^{m}	0·9910003^{m}
Paris	0·9939337	0·9939500	0·9910132
Berlin	0·9942399	0·9942482	0.9909865
Kew	0·9941776	0·9941790	0·9910083

The differences of the figures in the last column from 0·991^{m}, a value conveniently near their mean, when reduced to oscillations per diem are: Hoboken +0·01^{s}; Paris +0·58^{s}; Berlin −0·59^{s}; Kew +0·36^{s}. The following are the residuals of former observations according to Clarke (Geodesy, p. 349).

New York +0·20^{s}; Paris —3·29^{s}; Kew +2·89^{s}.

Colonel Clarke has used a value of the ellipticity =1:292·2 derived from pendulum experiments. This slight difference, however, is not important.

It should be explained that the result for Hoboken is derived from [T^{2} Inv.] "Regular Set," given on page 318, and also on page 416 of the Report of the Superintendent of the U. S. Coast and Geodetic Survey for 1876. This number is treated as explained on page 319, where in the second line from the bottom for [T^{2} Rev.] read [T^{2} Inv.] The altitude of the Hoboken station is stated on page 204. The numbers for the European stations are copied from page 320.

The length which I have taken as the meter has been derived from the German Eichungsamt, as fully explained in my report. This is about 19·2 microns shorter than the quantity which is considered to be a meter in our own office of weights and measures, and is admitted in Berlin to be doubtful. It is impossible to fix the true meter at present; but I have but little doubt the above values will ultimately have to be diminished by about twenty microns on account of the error in the standard used.

SCIENTIFIC INTELLIGENCE.

I. PHYSICS.

1. *Changes of volume produced by Electricity.*—**QUINCKE** sums up his results and those of other observers as follows: 1. Solid and fluid bodies change in volume when submitted like the glass of a Leyden jar to electrical force. 2. This change of volume does not arise from heating and is generally an expansion. In certain cases, however, it is a contraction, as for instance in the case of fat oils. 3. Quincke has not observed any change of volume in gases submitted to electrical influence. If a change takes place it must be smaller than $\frac{1}{3\,000\,000\,000}$ of the volume of air submitted to examination. 4. The change of volume is instantaneous in flint glass: but takes a longer time in Thüringian glass, which is a better conductor of electricity. Upon the discharge of the coatings of spherical or cylindrical formed condensers the glass resumes its original volume; this resumption is instantaneous in the case of flint glass, but slower with Thüringian glass. 5. The length of a cylindrical condenser alters at the same time that its volume changes. 6. The changes in volume and in length are greater the greater the difference of electrical potential and the less the thickness of the insulating substance of the condenser. 7. These changes are approximately proportional to the square of the ratio of the difference of potential and the thickness. These changes are different in different substances. 8. After the discharge of the coatings of the condenser a residual change of volume and length is observed. This effect is very small with flint glass, greater with Thüringian glass, and appears to depend upon the electric polarization of the mass of the glass. 9. The changes in volume and length do not arise from an electrical compression of the insulating substances. 10. In flint glass the electrical expansion is the same in all directions, and is independent of the kind and direction of the electricity. 11. Electrical changes of volume and length in glass increase with rising temperature in nearly the same proportion that the dielectric constant or the electric conductivity of glass increases. 12. Under the influence of electrical force the elasticity of flint glass, Thüringian glass, and caoutchouc diminishes, and that of mica and gutta percha increases. 13. The perforation of glass and other substances by electrical means results from unequal electrical dilatation at different points of the insulator. 14. By means of unequal electric expansion solid and fluid substances can be unsymmetrically dilated and be made doubly refracting, just as the unequal expansion of bodies by heat can effect the same result. 15. By means of electricity symmetrically dilated glass shows no electric double refraction. 16. The results of Dr. Kerr on positive and negative electrical double refraction depend on the manner in which the index of refraction in different substances changes with the density and the volume under electrical influ-

ence. 17. With a constant difference of potential between the coatings of a condenser, the electric strains in the successive layers of the substance between these coatings vary from time to time.—*Annalen der Physik und Chemie*, No. 8, 1880, p. 513.

J. T.

2. *A Phenomenon of Elasticity.*—If elastic gum is warmed, then expanded and wound in a spiral upon a glass tube or a wire and cooled for a short time in a cooling mixture, it shows no tendency to contract, but when it is submitted to hot water it returns quickly to its original length. This phenomenon can also be noticed without the use of the cooling mixture. If one holds heated gum a second in an expanded condition it shows no disposition to return to its original length; but if one immerses it in hot water it contracts to $\frac{1}{4}$ or $\frac{1}{5}$ and remains contracted to the third or fourth of its original length. Maxwell found similar phenomena in gutta percha, when this was submitted to expanding influences when in a cool condition. These are very marked phenomena of the secondary effects of elasticity.—*Proc. Edin. R. S.*, x, 1879, p. 52; *Beiblätter Annalen der Physik und Chemie*, No. 6, 1880, p. 422.

This property of rubber and gutta percha is significant in view of the recent experiments of Professor A. Graham Bell upon the effect of radiant energy upon thin discs of rubber. J. T.

II. GEOLOGY AND MINERALOGY.

1. *Moving snow-mass of Tuckerman Ravine, White Mountains, New Hampshire.*—Mr. W. H. PICKERING gives the following account of an excursion, July, 1879, to this glacier-like snow-mass, in the number of "Appalachia" for June, 1880.

The walk from the Crystal Cascade through the ravine was uneventful, and in about three hours I reached the snow patch. Much of the snow had melted, so that some of the stones placed upon it were gone, but of those that remained the middle ones had moved about thirteen feet in twenty days, or at the rate of eight inches per day. The side ones had not apparently moved so fast. The surface of the snow was convex, being considerably higher at the middle. Where not exposed to the sun, the snow was very hard, and differed from ice only in color. The roof of the ice cavern was now quite high, and it could be entered for some fifty feet or more, although wading through ice-water in the dark may be considered more unusual than agreeable. From the above, it would appear that we have here the same glacial action that occurs on a much larger scale in the Alps, the same transportation, and therefore grinding, and polishing of the rocks, the same phenomena of viscosity and regelation; only that we here miss the long tongues of blue ice, with their accompanying crevasses. Our snow-patch, therefore, corresponds to the *névé*, or upper portion of a glacier, the whole of the lower portion being wanting. It might, perhaps, be called an incipient glacier.

2. *Notes on the Geology of the Iron and Copper Districts of Lake Superior;* by M. E. WADSWORTH. Cambridge, July, 1880. 158 pp. 8vo, with six plates. Bulletin of the Museum of Comparative Zoology at Harvard College, Vol. VII (Geological Series, Vol. I).—The author devotes 76 pages of his memoir to the iron district, 56 to the copper district, and 24 pages to a bibliography of his subject. Under each head a large part of the space is devoted to an historical review, giving the opinions and statements of authors in chronological order and largely by citations from their works. He quotes freely from the valuable Report on the Lake Superior District by Foster and Whitney, and in the main supports the views which Prof. Whitney had there brought out.

He makes the iron ores and associated beds of jasper *intrusive.* The sandstones and conglomerates which accompany the trap in the copper region, and are more or less interstratified with it, owing to successive deposits and outflows as described by Whitney, are pronounced to be of the age of the Potsdam sandstone; but the conclusion is not based on the author's personal observations.

The kinds of copper deposits in the Portage Lake and Keweenaw Districts are stated to be as follows: 1st, The *amygdaloid,* in which the amygdaloidal rock contains bunchy and irregular deposits of copper which are in no sense veins or lodes. The Quincy and the Selden and Columbian Mines are examples; a variety of the Amygdaloid Mines, called in the region "ashbed" mines, are said to differ only in this that the amygdaloid is of a scoriaceous character. The Copper Falls and the Atlantic Mines are of this nature.

Besides these, there are, secondly, *Conglomerate* or true bed mines, like the Calumet and Hecla; and, thirdly, true *Fissure-vein* mines, like the Central, Phœnix and in part the Copper Falls.

In the Conglomerate mines, the beds of conglomerate have sometimes a cement of copper; and pebbles of trap appear occasionally to have been partly removed and to have had their places filled with copper. At the Calumet and Hecla mine, which is of this kind, the copper is found filling the joints of the overlying trap, and extending as a continuous sheet in fissures at right angles to one another.

At Copper Falls, "spikes of copper extend downward, out of the overhanging trap into the ashbed," or scoriaceous amygdaloid; and "these are generally large at the upper end and pointed at the lower." In the veins, the copper is found intimately mixed with the gangue, or in sheets or irregular masses; and the masses often enclose quartz, calcite and other kinds of vein materials, beside portions of the trap. "The farther from the sandstone and the nearer the heavy beds of trap, the larger have been the deposits of copper," as is exemplified at the Central, Cliff, and Calumet and Hecla mines.

The author holds that the copper and the associated minerals of the veins and amygdules were deposited in the veins or cavities where now found by waters, from an external source after the sandstones, conglomerates and traps had been formed. He does not agree with Bowerman and Pumpelly that the copper was derived from the sandstone and thence carried down by hot or cold waters, but inclines to hold that the copper was originally finely disseminated through the lava at the time of its outflow, and has since been locally concentrated, by percolating waters, in veins, amygdules and conglomerate beds. While rejecting the theory of Professor Dana with regard to the origin of the copper deposits, he agrees with him, it thus appears, in the view that the copper came up with the trap, but disagrees in that he makes the present distribution of the copper, and also the filling of amygdaloidal cavities and veins by minerals, the *result of a subsequent process acting from above downward.*

The writer has regarded it, as he has long since explained,* an insuperable objection to the theory of infiltration from above, that surface waters can get into amygdaloids by means of infiltration downward only a short distance—in some not an inch; and that, however deep, the result caused by the waters and the accompanying air is oxidation and the discoloration and destruction of the rock.† Notwithstanding all that is brought forward by Mr. Wadsworth, or, rather, in view of these and other facts respecting trap minerals, I believe that the most satisfactory theory of the origin of the ores and associated minerals is that which I have hitherto held, only slightly modified: that the copper came up with the igneous rock, and so also the moisture that made the steam cavities of the amygdaloid, though neither was derived, the one nor the other, from the deep-seated source of the eruption, but from sources encountered on the way up; that, while the rock was slowly cooling through the range of temperatures from that of fusion, over 2000° F., to 212° F. (when at last the vapors began to lose their chemical activity), and thence to 100° F. and below, the igneous material sooner or later received its vapor-made cavities in places where the pressure was little enough to permit it and the moisture was abundant enough to produce them, and the rocks also became jointed and fissured through the progressing contraction; that other fissures may have been opened by new subterranean movements while the cooling was going forward, that is, before the era of eruptions for the region had passed, and gave passage for ascending vapors and whatever they bore along; that the moisture which made the

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* This Journal, xlix, 49, 1845.

† The waters of hot springs might produce depositions in cavities or fissures that open upward; but it appears to be physically impossible that such waters, whatever they may hold in solution, should penetrate deeply through the mass of a cold trap or amygdaloid containing disseminated copper in grains, and take up and transport that copper into the amygdaloidal cavities, fissures, and joints. Surface waters sometimes descend for yards along the joints; but when so, the surfaces of the joints indicate it by their iron-rust discoloration. The gathering of copper from the adjoining sandstone into the trap cavities by such superficial waters seems to the writer to be not less impossible. J. D. D.

amygdaloidal cavities was the moisture which altered the pyroxene or other minerals of the rock to chlorite, and made the zeolites and quartz out of chiefly its feldspars, and that this kind of transformation of the igneous rock near all cavities or fissures into quartz and hydrous silicates kept going on as long as the rock was undergoing its refrigeration, different minerals resulting at different stages in the temperature; and that the copper which came up with the igneous rock was, in the course of the cooling, carried by the aid of the vapors into fissures and so formed veins, and into other cavities to help make amygdules at the same time that other minerals were making them, and so produced sometimes a cupriferous amygdaloid; and that simultaneously it was carried also to some extent into the adjoining sandstone. But all the conditions of the process are not yet explainable, and, therefore, while differing widely from the author on this and other points in his volume, I agree with him in this, that "until we know more about the occurrence of the copper, all theories regarding its origin should be held with a loose grasp, and dropped as the facts developed may require." J. D. D.

3. *Paleontological Notes;* by C. A. White.—Professor White has notes, in the Proceedings of the United States National Museum, on the occurrence of *Productus giganteus* from an argillaceous rock of Carboniferous age in the valley of McCloud River, Shasta Co., California, one of them 5½ inches in transverse diameter near the hinge; on a new Cretaceous Pinna, *P. Stevensoni*, from near Fort Wingate, Northern New Mexico, and on the occurrence of two species of *Stricklandinia*, *S. Salteri* Billings, *S. Davidsoni* Billings, in the town of Ringgold, Catoosa Co., Georgia, where they were collected by Lieut. A. W. Vogdes, U. S. A. With regard to the last he says that the other fossils of this collection were doubtless correctly referred by Lieut. Vogdes (in this Journal, Dec. 1879, xviii, 475, 477), to the Clinton Group of New York; and their discovery in Georgia, if the identification is correct, has special interest because the two species have hitherto been found only in strata of the island of Anticosti, and also because these (with the associated fossils) indicate the equivalency of the Georgia, Clinton, and Anticosti strata in America, and the Upper Llandovery of Great Britain. Professor White also states that the Discina-like Brachiopod from the Primordial strata at Antelope Spring, Southern Utah, which he has described under the name of *Acrotreta subsidua*, "referring it to that genus provisionally," belongs to Linnarsson's new genus *Acrothele;* and he adds that it is not unlikely that some American species referred to *Discina* will be found to belong to this genus.

Professor White has also 180 pages of descriptions of fossils, and 32 plates, in the Twelfth Annual Report of the U. S. Geological Survey for 1878, under Dr. F. V. Hayden, which were issued in an "author's edition" in July last. The species described are from the Tertiary, Laramie, Cretaceous, Jurassic, Triassic, and Carboniferous groups. The Report is a continuation of his Contributions to Invertebrate Paleontology in the Report for 1877.

4. *Stratigraphical Geology of Eastern Ohio*, by Prof. EDWARD ORTON. 34 pp. 8vo. Columbus, Ohio, 1880.—The Report of the Secretary of State of Ohio for 1879 contains a paper by Professor Orton which gives the results of recent work by him in Eastern Ohio, leading to modifications of some views as to the stratigraphy of the region, and also bringing out some of the connections between the geological series of Ohio, Pennsylvania and Kentucky. A map of Eastern Ohio shows the outlines of the formations—the Berea Grit, the Lowest Coal, the Ferriferous limestone, Nelsonville Coal and Pittsburgh Coal. He observes, in conclusion, that the results as to the latter point, match so well with the facts arrived at in Pennsylvania by Professor White and Mr. Chance and others engaged in the survey of the western part of that State, that a number of the questions are settled. The paper closes with a table of equivalents between the Ohio strata and those of Pennsylvania and remarks upon it. "The key to the equivalencies is the Ferriferous limestone, which divides the Lower Coal Measures of Western Pennsylvania and of Southern Ohio alike."

5. *On the occurrence of Chalk in the New Britain Group*; by ARCHIBALD LIVERSIDGE. — In October last the Rev. G. Brown, Wesleyan missionary, brought, among other specimens, from New Britain and New Ireland (New Britain Group, latitude 4 degrees south, and 150 degrees east longitude) certain grotesque figures of men and animals, which had been carved by the natives of the above islands out of a soft white somewhat pulverulent material, having much the appearance of plaster of paris or chalk. Some of these figures were deposited in the museum, and a fragment broken off from one of them was placed in my hands for identification.

On examination, the remains of numerous Foraminifera are at once detected, the forms of the larger ones being plainly visible even to the unaided eye; under the microscope the whole mass of the rock is seen to be almost entirely composed of the shells and fragments of shells of Foraminifera, the remains of Globigerina being most abundant.

I took an early opportunity, when writing, to enclose a portion to Mr. H. B. Brady, F.R.S., of Newcastle-on-Tyne. He says:

"Your chalk from the New Britain group is a Cretaceous chalk, and not a friable Tertiary limestone. All the Foraminifera, or nearly so, are south Atlantic recent deep-sea species, *Globigerina bulloides*, *Gl. inflata*, *Pulvinulina Menardii* (a thick variety which I do not think is yet named), *P. Micheliniana*, and probably *P. Karsteni*, *Pullenia spheroides*, *Nonionina depressula*, *Bulimina Buchiana*, fragments of *Dentalina*, *Uvigerina*, etc.; also a characteristic *Pulvinulina* with thick shell and honeycombed surface, not yet described, of which I have quantities in the "Challenger" material.

The Rev. G. Brown wrote to me further as follows:—

"The chalk of which the figures are formed is, I am informed, found only on the beach after an earthquake, being cast up there in large pieces by the tidal wave; and only, as far as we know at present, in one district on the east side of New Ireland."

An analysis shows that about 81 per cent of the specimen consists of calcium carbonate; thus it is undoubtedly a far less pure limestone than the ordinary white chalk. Its specific gravity is 2·199 at 59° F.—*Proc. of the Royal Society of New South Wales, July*, 1877.

6. *A new Theriodont Reptile.*—A new Theriodont from the Upper Permian sandstone near Orenburg in southeastern Russia has been described by W. H. Twelvetrees, in a paper read recently before the Geological Society of London. The beds rest on limestone which has the fossils of the Zechstein. Besides remains of Saurians and Labyrinthodonts, there are *Calamites, Lepidodendron, Conifers* and a *Unio.* The specimen is apparently the dentary part of the left mandibular ramus, with the crowns of a canine, an incisor, and ten of the molars. It is closely related to the genus *Rhopalodon;* but there are marked differences, and the author proposes to call it *Cliorhizodon Orenburgensis.*

7. *A new species of Iguanodon, I. Preswitchii.*—The remains of this new species of Iguanodon are from the Kimmeridge clay, three miles west of Oxford. The skeleton was probably almost entire, but as the clay had been mostly removed before attention was directed to it many bones are lost. The discovery is the subject of a paper before the Geological Society of London, April 14th, by Prof. J. Prestwich. Prof. Prestwich's paper was followed by another by J. W. Hulke, Esq., describing the bones in detail and giving the species the above name.—*Quart. J. Geol. Soc.*, No. 143.

8. *The Geological Record for* 1877. An account of Works on Geology, Mineralogy and Palæontology published during the year, with Supplements for 1874–1876. Edited by Wm. Whittaker, B.A., F.G.S., of the Geological Survey of England. 432 pp. 8vo. London, 1880. (Taylor & Francis.)—This volume of the Record, like its predecessors, will be found of great value to geologists. The author has had a dozen or more able coadjutors in the preparation of the volume. Its several subdivisions are Stratigraphical and Descriptive Geology arranged according to countries; Physical Geology; Applied and Economic Geology; Petrology; Mineralogy; Paleontology; and Maps and Sections. The volume would be still more welcome if it could be issued nearer to the year of which it is a Record. We find in the preface, however, that great delay in the publication was caused "by the loss of MS. in transmission—the missing part (European Geology) having been appropriated by some very wise person as an article of great value, and not recovered for months."

9. *Orographie de la partie des Hautes-alpes Calcaires comprise entre le Rhone et le Rawyl* (Groupes des Diablerets et du Wildhorn), par E. Renevier, Professeur a la Faculté des Sciences

de Lausanne. 98 pp. 12mo. Lausanne, 1880.—This little book is the itinerary for 1880–81 of the Swiss Alpine Club. Besides being a contribution to Swiss orography and geology it is even more prominently a guide book to various passes in the Alps; and for this purpose all the details are given as to the routes, excursions, objects of interest, distances, guides, hotels, club-huts and other matters of importance to the traveler. The region lies between the transverse valley of the Rhone, (from Martigny to Lake Geneva) and the passage of the Rawyl (from Lenk to St. Leonard). The highest summit is that of the Diablerets, 3246 meters.

10. *On a "Fossil Glacier" of Yakutal Bay, Alaska;* by W. H. DALL.—Extract from a letter dated Unalaska, July 30th, from W. H. Dall, Assistant Coast and Geodetic Survey, in charge of the party on the coast of Alaska.

The most striking discovery made so far this season is that of what may perhaps properly be called a "fossil glacier" of colossal dimensions, situated on the northwest side of Yakutal Bay. This consists of the remains of an immense glacier, of which it would seem the feeders have either greatly diminished in size or entirely disappeared; leaving a sheet of ice on the plain below the mountains, spread over an area of fifty to seventy-five square miles, with little if any motion, and which by its own melting has become covered with a thick layer of mud, sand, gravel and stones. This layer protects the ice from the sun, and except in a few places the ice is quite invisible. In some spots, however, the ice seems to have melted beneath and the covering has fallen in, leaving a forest of immense ice pinnacles, each with a protective cap of dirt, and presenting a most extraordinary and almost indescribable appearance. The waste in these exposed spots is probably made up for by the snows of winter, and as the ice does not appear to have any motion, there seems to be no reason why it should not, like a layer of rock, endure to the end of time. This phenomenon offers an explanation of some previously inexplicable appearances in Kotzebue Sound, which have been a puzzle to geologists for forty years, and which, if opportunity offers, we may visit. Its geological importance is undeniable.

11. *Optical examination of the red feldspar of the granite from Lyme, Conn.*, by M. DESCLOIZEAUX.—At the close of the Paris Exposition of 1878, a fragment of the beautiful coarse granite from the McCurdy quarry at Lyme, Conn., was given by the Connecticut Commissioner, Prof. W. P. Blake, to M. DesCloizeaux, for optical study. Some details of his preliminary examination of its feldspar are given in the following translation from a letter, to Prof. Blake, of April 14, 1879. They disclose a fact of much mineralogical interest, which explains, as Mr. Blake remarks, the chatoyant reflections that give special beauty to the granite.

"I have been able, lately, to examine your red feldspar from Lyme. It is a true microcline, but of an altogether peculiar structure, for the study of which the ordinary magnifying power is not sufficient, the constituent parts being exceedingly minute. The face of easy cleavage shows a series of very small spots of albite, interspersed with hemitropic plates of microcline, the angle of extinction of which, not easily determined with great exactness, is 13° to 15° measured from the edge between the two cleavage-faces. Across the second cleavage the structure is as it were fibrous, and, with a high power, the angle of extinction is found to be from 7° to 9° for the microcline, and from 18° to 20° for the albite. I have never before met with a feldspar with the elements so crowded together and so fine. I hope you will yet be able to find, or that the proprietor will supply you with, some fragments of this beautiful granite. An examination of such specimens would be of great interest on account of the enormous size of its feldspar individuals."

III. BOTANY.

1. *The Native Flowers and Ferns of the United States;* by **THOMAS MEEHAN**, illustrated by Chromo-lithographs. Series 2. Vols. I and II. Philadelphia: Chas. Robson & Co. 1880.—The last four parts of the issue of this series, now before us, if compared with the earlier show a great improvement in all respects. The drawings, and especially the chromo-lithography, the excellent typography, and the superfluously stout and high-calendered paper, combine to assure us that the editor has at length accomplished what he undertook, the production of attractive and characteristic illustrations of the U. S. Flora, accompanied by readable popular accounts of the plants, at a low price. The production of such a copious and discursive letter press to meet the demands of rapid serial publication is no light task, and it is not surprising if oversights now and then occur. Thus, under *Wyethia Arizonica*, which is remarkably well-figured, an account of Nuttall's crossing to the Pacific with Wyeth is given, in which it is said that this genus was not discovered on that route, but by Wyeth himself on the return trip. Now Nuttall's own publications and others show that Nuttall himself collected at least three species on his journey; and the date of the half-volume of the Academy's Journal, in which *Wyethia* was originally published, would show that this publication had taken place before Nuttall started upon that journey, and that the material was derived from an earlier expedition by Wyeth. If the readers of this work find it true that "Asters are not more difficult of study than other plants," (p. 159), their experience will be different from ours. *Heliopsis lævis* is not an "*Asteraceous* plant." As to the Compass-plant, it might be inferred that Longfellow's reference to "*this delicate plant*" preceded Gen. Alvord's account of it, "who seems to have been the first to direct scientific attention to the plant in 1848." Gen. Alvord's first account appeared in 1842, and was communicated to the poet. Under *Oxytropis Lamberti* (p. 191), why should it be said that Pursh seized on the labors of others and passed them off as his own? Pursh states

that he described from Bradbury's specimen (and this we believe is true), as well as from a living plant in Lambert's garden. In writing a flora of the country he could not have omitted it. That "Lambert, vice-President of the Linnean Society, was one of the most accomplished botanists of that time," was not the contemporary opinion. That he was, "indeed, the real editor of Pursh's work" is, we presume, a statement destitute of any foundation in fact. Good old Lambert used to say that he had great trouble in holding Pursh to his work, and had to shut him up for the purpose, during which Pursh "drank a whole barrel of beer." So that Pursh may properly, in his dedication, declare that the public has to thank his patron, Lambert, for the work, but surely not for editing it. A. G.

2. *Botany for High Schools and Colleges;* by Charles E. Bessey, M.Sc., Ph.D., Professor of Botany in the Iowa Agricultural College, etc. New York: Henry Holt & Co. 1880. pp. 611, 12mo.—It speaks well for the progress of science in the United States, when a professor in a college in so new a State as Iowa, situated mid-way between the Mississippi and the Missouri, can produce so creditable a book as this. The work concerns itself throughout with what the Germans call "Scientific Botany," —largely with vegetable anatomy and development, and with particular attention to the lower Cryptogamia. The plan in general is that of Sachs' *Lehrbuch,* the cuts of which are largely reproduced from electrotypes of the original blocks. The author says that his "book will thus, to a considerable extent, serve as an introduction to that work." It will indeed form a substitute for it; and the systematic part, so far as it goes, is an improvement upon the model. But that of itself would not be high praise, as this is the least valuable portion of the *Lehrbuch.* The figures from Sachs' blocks are good; but most of them were rather too large for his royal octavo page, and are out of proportion to the 12mo page in which they now appear. So, indeed, are some of the original ones. Some of the transfers from Maout and Decaisne have suffered in the process, although the paper and typography are excellent. Prof. Bessey's volume is a timely gift to American students of a good manual of vegetable anatomy and of the structure and classification of the lower cryptogamia, which was very much needed. Here at least is a commendable beginning. A. G.

3. *Manual of Swedish Pomology. Handbok i Svensk Pomologi* af Olof Eneroth. Stockholm. Vols. I, II. 8vo. 1864, 1866.—We notice this for its admirable figures, both the woodcuts and the chromolithographs; ignorance of the language excuses from reference to the text. We have managed to surmount this obstacle in respect to an accompanying pamphlet, entitled

Bidrag till Europas Pomona vid dess Nordgräns.—This is an account of the trial of various European and North American varieties of apples and other fruits, with the object of determining the northern limit at which they would come to perfection. This for twelve years of over 800 varieties yields results of general scientific as well as of local economical value. A. G.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Location of Lick Observatory on Mount Hamilton, California.*—In a report to the Trustees of the James Lick trust, Mr. S. W. Burnham gives the results of his observations made on Mt. Hamilton as to the location of the Lick Observatory. Mt. Hamilton is situated nearly east from San José, about twenty-six miles by the highway, but only thirteen in an air line. The approximate longitude of the Observatory peak is 121° 36′ 40″, and the latitude 37° 21′ 3″. The elevation of the point is 4,250 feet above the level of the sea, and 140 feet lower than the north peak which is about three-quarters of a mile distant. The view around is unobstructed, there being no higher ground within a radius of 100 miles. "The formation of Mt. Hamilton, as of all the near surrounding ridges, is of trap rock." Mr. Burnham's astronomical observations here reported had regard especially to the atmospheric conditions of the location with reference to its adaptation to observatory purposes. He states in his concluding remarks:

"So far as one may judge from the time during which these observations were made, there can be no doubt that Mt. Hamilton offers advantages superior to those found at any point where a permanent observatory has been established. The remarkable steadiness of the air, and the continued succession of nights of almost perfect definition, are conditions not to be hoped for in any place with which I am acquainted, and, judging from the published reports of the various observatories, are not to be met with elsewhere. The low altitude at which observations can be made is a matter of no small importance, particularly in connection with the portion of the southern sky not ordinarily accessible to observatories in the northern hemisphere. The ease with which difficult objects can be seen almost down to the horizon will be apparent from the southern declination of many of the new double stars. Close pairs can be observed at least down to 43° South Declination. The permanent steadiness of the air during the whole night will greatly increase the amount of telescopic work over what could ordinarily be done on good nights in most places. An examination of my observations at Chicago during the summer of the present year shows that the good seeing very rarely continued the whole night, even when it remained clear, and this has generally been the case heretofore. In many instances the conditions favorable for the observation of the most difficult objects would only last an hour or two, sometimes occurring in the first part of the night, and sometimes not commencing until after midnight. On Mt. Hamilton there is but little variation of any kind during the dry season. Each day was very much like every other day, and, as already shown, the same statement would apply equally well to the nights. Apparently there is but little to be feared from the ocean fogs, as they seldom reach this elevation. Nearly every night, commencing at or soon after sunset, this fog comes in from the Pacific at the Golden Gate on the north, and the Bay of Monterey on the south, and covers the whole valley, between the base of Mt. Hamilton and the coast range, with a dense mass of vapor, resembling, when seen from above, a great white sea, the tops of the lower hills standing up through it like islands. Ordinarily it is perhaps 2,000 feet lower than the summit of Mt. Hamilton. It does not appear to have any effect on the seeing so long as it is below the summit."

He adds the following from a communication to him from Prof. George Davidson, of the United States Coast Survey:

"In the dry season the best observing is at the close of the wet season, say from March 1 to June or July. After that time the smoke of the great valley and the heated air on the San Joaquin side of the coast range, and the chilled air and strong winds on the ocean side, combine to give unfavorable conditions of seeing. I should not expect to get the best seeing in August and September, unless as an exceptional case.

"I should say that on the higher peaks of the Coast Range (over 3,000 feet), or in the Sierra Nevada, or on San Bernardino, at 10,000 feet, the astronomer may be sure of 250 good nights every year, and that 150 of those nights will be such as are rarely ever experienced at the east. The stars, the planets, the moon, the sun, and the nebulæ, are absolutely new presentations to the observer, and are capable of the most searching and minute measurements. Moreover, at the great heights, the thermometer will seldom fall below zero; and having weathered two Sierra storms of wind and snow at 10,600 feet, in a remarkably exposed situation, I am sure that an observatory would be as perfectly safe there as at lower elevations.

"There is of course more moisture in the atmosphere in the wet season; but when the sky clears up and the northerly wind blows, it is a dry wind, and the outlines of every thing visible are wonderfully sharp, distinct and steady. In October I could readily pick out the principal characteristics of the trees on Mocho (near Mt. Hamilton) at 120 miles."

Mr. Burnham closes his report with a catalogue of 42 new double stars discovered by him at Mt. Hamilton.

The Trustees announce that the observatory will soon be in working order. The small equatorial, ordered of Alvan Clark & Sons, will be placed in position early in 1881.

2. *Fiftieth Meeting of the British Association, at Swansea, Aug. 25th.*—Prof. RAMSAY, on taking the Presidential chair, gave his inaugural address. His subject was "The recurrence of certain phenomena in geological time," and his chief object, as he states, was to show that all known formations are comparatively so recent in geological time that there is no reason to believe they were produced under physical circumstances differing, either in time or degree, from those with which we are now more

or less familiar,—which is the doctrine of uniformitarianism as taught by Lyell. In reference to this point he reviews facts with regard to metamorphism in various geological ages; volcanoes; the formation of mountains; formation of salt and salt lakes; the occurrence of fresh water deposits in various ages and glacial phenomena of different periods. Under the head of metamorphism he states that presumed Cambrian and also to some extent Lower Silurian rocks in Anglesey have been metamorphosed into chlorite schist, mica schist and gneiss; that as Prof. Hull had shown, the close of the Lower Silurian was the epoch of the greatest metamorphism in Ireland; that Silurian and Devonian rocks in Cornwall are converted into mica schist and gneiss; and refers to examples of metamorphism of Mesozoic and Eocene rocks in the Alps and Cretaceous in South America. Under Glacial phenomena, he refers to evidence, which he regards as good, of glacier action, in *roche moutonnée* surfaces over granite, preceding the Cambrian in northwest Scotland; and of glacier-transported bowlders in the Lower Silurian of Wigtonsshire and Ayrshire; in the Upper Silurian of the Lammermuir Hills; in Permian beds of England, Germany, South Africa and India; in Cretaceous beds of the Salt range in India, and in Miocene deposits in the north of Italy, near Turin. Facts are presented also under the other heads; the degree of uniformitarianism which Professor Ramsay advocates appears to require for its satisfactory demonstration a much wider range of them than he appeals to.

The opening address before the Geological section, by its President, H. C. Sorby, treats of the comparative structure of artificial slags and eruptive rocks; that of the Biological section, by Dr. Gunther, of museums, their use and improvement; that of Professor W. Grylls Adams, President of the Section of Mathematics and Physics, gives a review of recent deductions in molecular physics; and that of F. M. Balfour, Vice-President of the department of Anatomy and Physiology, traces the influence of the Darwinian theory on embryology.

The following paragraphs are from the address of Professor Adams, *on the molecular constitution of matter in the solid, liquid, and gaseous states.*

"We have become accustomed to regard matter as made up of molecules, and those molecules to be made up of atoms separated from one another by distances which are great in comparison with the size of the atom, which we may regard as the smallest piece of matter that we can have any conception of. Each atom may be supposed to be surrounded by an envelope of ether which accompanies it in all its movements. The density of the ether increases rapidly as an atom is approached, and it would seem that there must be some force of attraction between the atom and its ether envelope. All the atoms have motions of translations in all possible directions, and according to the theories of Maxwell and Boltzmann, and the experiments of Kundt, Warburg, and others on the specific heat of vapors, in *one-atom* molecules in the gaseous state there is no motion of rotation. According to the theory of Pictet, the liquid state, being the first condensation from the gaseous state, must consist of at least two gaseous atoms combined. These two atoms are bound to one another through their ether envelopes. Then the solid state results from the condensation of a liquid, and so a solid molecule must consist of at least two liquid molecules, i. e. at least four gaseous molecules, each surrounded by an atmosphere of ether. M. Pictet imagines these atoms to be centers of attraction; hence in the solid with four such centers the least displacement brings into action couples tending to prevent the molecule from twisting as soon as external forces act upon it. All the molecules constituting a solid will be rigidly set with regard to one another, for the least displacement sets in action a couple or an opposing force in the molecules on one another.

Let us now follow the sketch which M. Pictet has given of changes which we may consider it to undergo when we expend energy upon it. Suppose a solid body is at absolute zero of temperature, which may be regarded as the state in which the molecules of a body are in stable equilibrium and at rest, the application of heat gives a vibratory motion to the molecules of the solid, which increases with the temperature, the mean amplitude of vibration being a measure of the temperature. We may regard the sum of all the molecular forces as the specific heat of the body, and the product of the sum of all the molecular forces by the mean amplitude of the oscillations, i. e. the product of the specific heat and the temperature, will be the quantity of heat or the energy of motion of the body. As more and more heat is applied, the amplitude of vibration of the molecules increases until it is too great for the molecular forces, or forces of cohesion, and the melting point of the solid is reached. Besides their vibratory motion, the molecules are now capable of motions of translation from place to place among one another. To reduce the solid to the liquid state, i. e. to make the amplitude of vibration of the molecules sufficient to prevent them from coming within the sphere of the forces of cohesion, requires a quantity of heat which does not appear as temperature or molecular motion, and hence it is termed the latent heat of fusion. The temperature remains constant until the melting is complete, the heat being spent in bursting the bonds of the solid. Then a further application of heat increases the amplitude of vibration, or raises the temperature of the liquid at a rate depending on its specific heat until the succession of blows of the molecules overcomes the external pressure and the boiling-point is reached. An additional quantity of heat is applied which is spent in changing the body to a gas, i. e., to a state of higher potential, in which the motion of translation of the molecules is enormously increased. When this state is attained, the temperature of the gas again begins to increase, as heat is applied, until we arrive at a certain point, when dissociation begins, and the molecules of the separate substances of which the body is composed have so large an amplitude of vibration that the bond which unites them can no longer bring them again into their former positions. The potential of the substances is again raised by a quantity which is proportional to its chemical affinity. Again, we may increase the amplitude of vibration, i. e., the temperature of the molecules, and imagine the possibility of higher and higher degrees of dissociation."

Professor Balfour remarks as follows on the *development of organs of vision.*

"Another important fact shown by embryology is that the central nervous system, and percipient portion of the organs of special sense, are often formed from the same part of the primitive epidermis. Thus, in ourselves and in other vertebrate animals the sensitive part of the eye, known as the retina, is formed from two lateral lobes of the front part of the primitive brain. The crystalline lens and cornea of the eye are, however, subsequently formed from the skin.

The same is true for the peculiar compound eyes of crabs or Crustacea. The most important part of the central nervous system of these animals is the supraœsophageal ganglia, often known as the brain, and these are formed in the embryo from two thickened patches of the skin at the front end of the body. These thickened patches become gradually detached from the surface, remaining covered over by a layer of skin. They then constitute the supraœsophageal ganglia; but they form not only the ganglia, but also the rhabdons or retinal elements of the eye—the parts in fact which correspond to the rods and cones in our own retina. The layer of epidermis or skin which lies immediately above the supraœsophageal ganglia becomes gradually converted into the refractive media of the crustacean eye. A cuticle which lies on its surface forms the peculiar facets on the surface of the eye, which are known as the corneal lenses, while the cells of the epidermis give rise to lens-like bodies known as the crystalline cones.

It would be easy to quote further instances of the same kind, but I trust that the two which I have given will be sufficient to show the kind of relation which often exists between the organs of special sense, especially those of vision, and the central nervous system. It might have been anticipated *à priori* that organs of special sense would only appear in animals provided with a well-developed central nervous system. This, however, is not the case. Special cells with long delicate hairs, which are undoubtedly highly sensitive structures, are present in animals in which as yet nothing has been found which could be called a central nervous system; and there is every reason to think that the organs of special sense originated *pari passu* with the central nervous system. It is probable that in the simplest organisms the whole body is sensitive to light, but that with the appearance of pigment-cells in certain parts of the body, the sensitiveness to light became localized to the areas where the pigment-cells were present. Since, however, it was necessary that stimuli received by such organs should be communicated to other parts of the body, some of the epidermic cells in the neighborhood of the pigment-spots, which were at first only sensitive, in the same manner as other cells of the epidermis, became gradually differentiated into special nerve-cells. As to the details of this differentiation, embryology does not as yet throw any great light; but from the study of comparative anatomy there are grounds for thinking that it was somewhat as follows:—cells placed on the surface sent protoplasmic processes of a nervous nature inwards, which came into connection with nervous processes from similar cells placed in other parts of the body. The cells with such processes then became removed from the surface, forming a deep layer of the epidermis below the sensitive cells of the organ of vision. With these cells they remained connected by protoplasmic filaments, and thus they came to form a thickening of the epidermis underneath the organ of vision, the cells of which received their stimuli from those of the organ of vision, and transmitted the stimuli so received to other parts of the body. Such a thickening would obviously be the rudiment of a central nervous system, and it is easy to see by what steps it might become gradually larger and more important, and might gradually travel inwards, remaining connected with the sense-organ at the surface by protoplasmic filaments, which would then constitute nerves. The rudimentary eye would at first merely consist partly of cells sensitive to light, and partly of optical structures constituting the lens, which would throw an image of external objects upon it, and so convert the whole structure into a true organ of vision. It has thus come about that, in the development of the individual, the retina or sensitive part of the eye is first formed in connection with the central nervous system, while the lenses of the eye are independently evolved from the epidermis at a later period."

3. *American Association for the Advancement of Science, Boston Meeting, August* 25 *to September* 1, 1880.—The twenty-ninth meeting of this Association, held at Boston, was by far the most numerously attended session in its history; and judged by the number and quality of the papers presented, the important matters brought out in the public addresses, and the numbers of interested auditors in the several sections, we must conclude that it had a scientific value never before equalled. The arrangements of the Local Committee were so thorough that all the machinery of the meeting moved smoothly, and completely met the numerous wants of such an occasion.

The Institute of Technology, and the Boston Natural History buildings, afforded ample and convenient space for all the sections, and a large hall (Huntington Hall) for the public sessions.

The badge of gold-colored ribbon, worn by members, gave admission to all the public places in Boston, and ensured courteous treatment everywhere. Free luncheons of the most tasteful and ample character were served daily in the Gymnasium adjoining the Institute, and thus the members enjoyed an agreeable social reunion for the hour at noon, and were saved fatigue and loss of time.

The number of persons registered to the close of the meeting was very nearly one thousand—(979 to Tuesday evening, Aug. 31.) The number of papers entered was 280, and 595 new members were elected. The officers of the Association were in telephonic communication with all parts of Boston and the adjacent country; and members had, free of charge, the use of this facility as well as of the lines of the Western Union Telegraph Company for all scientific and domestic purposes, over the whole country. Among the many good deeds of the Local Committee, should be mentioned the distribution among the members of a map of Boston and its vicinity, and of a pamphlet containing "A brief account of the Scientific Institutions of Boston and vicinity, and a General Guide to the Museum of the Boston Society of Natural History," prepared by the custodian, Mr. Hyatt.

The meeting was under the Presidency of Mr. LEWIS H. MORGAN, of Rochester, N. Y., widely known for his Archæological investigations and memoirs.

The proper work of the Association commenced at 10 o'clock on Wednesday morning. Prof. Wm. B. Rogers, President of the Institute of Technology, welcomed the Association in a brief and graceful address; a welcome, renewed on behalf of the city of Boston by Mr. Frederick O. Prince the Mayor, and for the Commonwealth of Massachusetts by His Excellency Governor Long, to all of which President Morgan made a brief reply. After notices of members of the Association deceased during the year by the Secretary, the Association adjourned for the organization of the two Sections, A and B, and the Subsections of Chemistry, Microscopy and Anthropology. The Chairmen of the latter were, respectively, John M. Ordway of Boston, S. A. Lattimore of Boston, and J. W. Powell of Washington.

No papers were read on Wednesday. In the afternoon, at the meeting of the Physical Section, Mr. ASAPH HALL, Vice-President of the Section, gave his opening address, treating wisely of the best methods and chief objects of Astronomical research; and in the evening the Association, in General Session, listened to the address of the retiring President, Professor GEO. F. BARKER, "On some modern aspects of the Life-question," which held a large audience with interested attention for an hour.

The whole of Thursday, August 26, was given to Cambridge. At 11 o'clock, in Sander's Theatre of Harvard University, an excellent eulogy of the late Professor JOSEPH HENRY, was delivered by Alfred M. Mayer; and this was followed by the learned address of the Vice-President of Section B, ALEXANDER AGASSIZ, which will be found reproduced at length in these pages.

After these addresses the members, by invitation of the President and Fellows of Harvard College, dined, to the number of about 900, in Memorial Hall, one of the most extensive and beautiful dining halls in the world. The afternoon was given up to the Museums, Libraries and Laboratories, and the evening to a garden party and reception, by Professor and Mrs. Gray, at the Botanic Gardens, and a visit to the Observatory, where the members were received by Professor and Mrs. Pickering, and the evening to a reception at the residence of Mr. and Mrs. A. Graham Bell.

The evening of Friday was devoted to a General Session to hear the paper by Mr. Bell, on his new apparatus, the *Photophone*, a subject of great general as well as scientific interest.

On Saturday afternoon the Association enjoyed the sail down Boston harbor, as the guests of the City of Boston, about one thousand persons being present. It is quite impossible to follow the Association in detail through all it had to enjoy at the hands of the good people of Boston. There were excursions to Salem, with visits to the Museum there, and the liberal hospitality of Mr. Endicott Peabody; a Geological excursion to Marble Neck; visits to Lowell, and many other places.

On Monday, after the close of the meeting, came the excursion to the White Mountains, for which arrangements had been made by the Appalachian Club. Thanks to the liberality of the Eastern Railroad, free tickets were supplied for three hundred members.

The Association adjourned on Wednesday to meet at Cincinnati, under the Presidency of Professor GEORGE J. BRUSH, of the Sheffield Scientific School of Yale College.

The following is a list of the Papers accepted:

1. *Mathematics, Physics, Astronomy and Meteorology.*

H. S. PRITCHETT: Determination of the rotation-time of Jupiter, from observations of the red spot in 1879–80, together with the physical character and changes of the spot.

W. A. NORTON: The force of effective molecular action, and the mechanical laws and properties dependent upon it; Determination of the comparative dimensions of ultimate molecules, and deduction of the specific properties of substances.

B. J. JEFFRIES: Color-blindness.

W. FERRELL: Maxima and minima tide-predicting machine.

C. J. H. WOODBURY: Friction of lubricating oils.

T. HILL: Problems in Watson's coördinates.

T. CRAIG: Steady and vortex motion in viscous incompressible fluids.

W. H. BALLOU: Improvement of the Mississippi River.

C. A. YOUNG: Spectroscopic notes, being a notice of certain spectroscopic observations, principally solar, made in 1879–80.

J. TROWBRIDGE: Heat produced by magnetising and demagnetising iron and steel.

S. E. WARREN: Some observations on geometric beauty, as founded on angular rather than linear ratios.

W. A. ANTHONY: Lecture experiment for the direct determination of the velocity of sound.

W. A. ROGERS: Progress made at the Observatory of Harvard College in the determination of the absolute coördinates of 109 fundamental stars; A simple and expeditious method of investigating all the division errors of a meridian circle; The systematic errors of the Greenwich right ascensions of southern stars observed between 1816 and 1831; Preliminary determination of the equation between the British imperial standard yard and the meter of the archives; The probable error of a single observation at sea, deduced from the observations of W. H. Bacon, Cunard steamer "Scythia;" The errors of a few English, French and American stage micrometers.

W. BOYD: A new Morse-alphabet.

B. PEIRCE: Unity, inversion, and semi-inversion in linear associative algebra; Useful practical forms of linear associative algebra; Comets of minimum perihelion distance; Cooling and possible age of the sun; Cooling and possible age of the earth.

D. P. TODD: Speculative and practical search for a trans-neptunian planet.

EDW. W. MORLEY: Remarks on tables for the reduction to zero of the measured volumes of gases; The most convenient scale for a thermometer used in gas analysis.

E. C. PICKERING: New planetary nebulæ.

C. R. CROSS and W. T. MILLER: On the musical pitch at present in use in Boston and vicinity.

S. W. HOLMAN: The use of the mercurial thermometer at high temperatures.

L. WALDO: Methods in use at the Observatory of Yale College for the verification of thermometers, and the testing of time-pieces.

E. L. NICHOLS and A. W. WHEELER: The coefficient of expansion of gas solutions.

E. H. HALL: The new action of magnetism on a permanent electric current.

T. R. BAKER: An investigation of the vibrations of plates vibrated at the center.

J. D. WARNER: Theory of the tides.

H. C. LEWIS: Note on the Zodiacal light; The Aurora and Zodiacal light of May 2, 1877.

F. H. LOUD: Discussion of the barometric observations of Professor E. S. Snell, Amherst College.

C. S. HASTINGS: A comparison of the spectra of light from limb and center of sun.

A. S. CARHART: A simple device for projeting vibrations of a liquid film without a lens.

GEO. W. HOLLEY: Suggestions for improvement in the manufacture of glass, and of new methods for the construction of large telescopic lenses.

J. R. BLAKE: Observations on some recent hail storms in North Carolina.

S. WELLS: Apparatus used in photographing microscopical objects.

F. E. NIPHER: Results of a magnetic survey of Missouri.

H. MORTON and B. F. THOMAS: Observations on the electro-motive force of the Brush dynamo-electric machine.

H. MORTON: Observations on the displacement of absorption bands in solutions of Purpurine.

A. G. BELL and S. TAINTER: Upon the production of sound by light.

W. HAILES: A new freezing microtome.

W. A. ANTHONY: A lecture experiment, showing the movement of a horizontal current in the earth's magnetic field; A proposed improvement in the construction of the Gramme electric machine.

R. H. RICHARDS: A gauge for measuring the pressure of liquids and gases.

A. M. MAYER: On the spectral rays which act in forming the green color in the leaves of plants; The topophone: an instrument to determine the direction and position of a source of sound, with an account of the applications of this instrument to scientific investigation; The uses of the "chungkee-stone;" On monuments of physical constants; A simple means of measuring the angle of inclination of the mirrors used in Fresnel's experiments on the interference of light; The determination of the velocities of fowling-piece shot, with remarks on the applications of these experiments to the art of shooting on the wing; A new method of obtaining a permanent trace of the plane of oscillation of a Foucault pendulum.

E. FRISBY: Symmetrical Equations.

S. C. CHANDLER, Jr.: Two new instruments for the determination of time and latitude.

A. E. DOLBEAR: On the limits of visibility with the microscope; On some needed additions to physical terminology.

J. R. EASTMAN: The solar parallax for meridian observation of Mars in 1877.

O. STONE: On a continuation of Argelander's Durchmusterung; On the construction of a micrometer for double star observations; On the drawing of nebulæ; On uniform time.

C. J. Blake: A standard logograph.

R. H. Thurston: Experiments on strength of yellow pine timber.

C. A. Young: The thermoelectric electro-motive power of iron and platinum in vacuo.

E. B. Elliott: Electric lighting as applied to large areas.

A. W. Wright: On a form of vacuum tube for spectroscopic work; On the refractive index of metallic silver.

E. S. Holden: On some of the consequences of an hypothesis proposed by Professor Pickering, that the intrinsic brilliancy of the fixed stars is the same for each star.

E. P. Austin: A table of remainders of 2^n to various prime moduli.

F. H. Bailey: The astral lantern.

Geo. W. Coakle: Tidal theory of the forms of comets.

H. A. Rowland: Remarks on C. S. Peirce's paper on the ghosts in Rutherfurd's grating.

J. D. Warner: New method for finding the numerical roots of equations below the 4th degree; "Actio in distans" and its effects.

Wm. Harkness: On the color correction of achromatic telescope: On the spectroscopic measurement of the approach or recession of stellar objects.

N. D. C. Hodges; Maxwell's law of the distribution of velocities among gas molecules.

L. P. Kennicutt: Substitution of cones made from parchment paper for platinum cones in Bunsen's process of filtration.

2. *Chemistry.*

A. N. Leeds: Laws governing the decomposition of equivalent solutions of iodides under the influence of actinism, and their application to the actinometry of solar, electric and magnesium light; Action of sun-light in the production of chlorinated addition-products of Benzene and Naphthalene, with descriptions of two new chlorine derivatives of Naphthalene; Action of hyponitric anhydride upon organic substances, with descriptions of three new oxygenated derivatives of the aromatic group—Monoxybenzene, Tetroxynaphthalene and Naphthodiquinene.

C. F. Gissler: Evidences of the effect of chemico-physical influences in the evolution of branchipod crustaceans.

T. Gaffield: Action of sunlight on glass.

E. T. Cox: Oxide of antimony found in extensive lodes, in Sonora, Mexico.

N. B. Webster: On a solution of ferric gallate and ferric oxalate as a reagent for quantitative analysis of ammonia.

Edw. W. Morley: Remarks on Jolly's apparatus for determining the amount of oxygen in air; Some points in the construction of an apparatus for the accurate analysis of gases; Numerical results for the mean ratio of oxygen to the sum of oxygen and nitrogen in atmospheric air; Some conclusions as to the causes of the frequent fluctuations in the ratio of oxygen to nitrogen in the air at different times

F. W. Clarke and Helena Stallo: Constitution of the tartrates of antimony.

J. L. Kleinschmidt: Foreign substances in iron.

H. W. Wiley: Optical properties of commercial starch and glucose.

L. M. Norton: The valuation of indigo.

W. O. Atwater: The chemical composition and nutritive values of fish; The soil supply of nitrogen for plants; Some new forms of apparatus; The determination of phosphoric acid by the molybdic process; The determination of sulphuric acid; The determination of nitrogen by the hypobromite process; The quantitativs determination of fats.

E. G. Love: On the illuminating gas of New York City.

W. R. Nichols: Observations on the temperature and chemical character of the water of Mystic Lake, Mass., at different depths.

C. F. Mabery and Mrs. R. Lloyd: The substituted acrylic acids.

E. L. Nichols: Salt solutions and the absorption of gases.

H. B. Nason: Notice of incrustations formed in pipes used in gas wells.

C. E. Munroe: On the action of vegetable acids on tin; A modification of Berthier's method for the valuation of coal.

S. P. Sharples: Commercial testing of sugar, illustrated by samples of sugar and instruments used.

A. A. Breneman: New colors for salt-glazed pottery; Notes on water analysis.

H. W. Wiley: Influence of heating with dilute acids and shaking with bone coal on rotatory power of glucose.

W. Colegrove: Direct combination of hydrogen and nitrogen.

Ira Remsen: Formation of sulphoterephthlalic acid by direct oxidation.

G. F. Kunz: Density of a large diamond.

3. *Geology and Mineralogy.*

J. W. Dawson: The Pulmonates of the Paleozoic period.

N. H. Winchell: The Cupriferous series in Minnesota.

W. J. Beal: Distinguishing species of Populus and Juglans by the young naked branches.

W. A. Stearns: Iron mines of Ore Hill, Conn., and vicinity, and the making of pig iron.

Geo. H. Stone: Kames or Eskars of Maine.

A. A. Julien: The excavation of the upper basin and clove of the Kaaterskill, Catskill Mountains, N. Y.

G. F. Wright: Condition of the kames and moraines of New England, as bearing upon the date of the glacial epoch.

E. S. Morse: Japanese caves.

F. C. Hill: Fossil Dinocerata in the E. M. Museum at Princeton, N. J.

R. Owen: Law of land forming on our globe.

W. Boyd: The Island of Montreal, an island in the Ottawa.

L. W. Bailey: Progress of geological investigation in New Brunswick, 1870–1880.

W. H. Niles: Classification of mountains.

J. W. Pike: Preservation of fossil insects and plants at Mazon Creek.

G. W. Hawes: The granites in the White Mountain Notch, upon Mount Willard, and their contact phenomena.

A. S. Tiffany: Subsidence and erosion.

H. C. Lewis: The tertiary age of the iron ores of the lower silurian limestone valleys.

M. E. Wadsworth: The age of the copper-bearing rocks of Lake Superior.

B. Silliman: Coals of the Galisteo in New Mexico; Auriferous gravels of the Upper Rio Grande in New Mexico; Los Cerillos, New Mexico, an area of recent eruptive rocks with mineral veins; Note on the Turquois localities of Los Cerillos.

W. J. McGee: Notes on kames and aasar of N. E. Iowa; On maximum synchronous glaciation.

J. T. Humphreys: Mineral discoveries in Western North Carolina.

T. Sterry Hunt: The genesis of certain iron ores.

W. C. Kerr: Ancient topography in North Carolina; Recent geology as illustrated in the coast region of North Carolina; Some points in the structure of mica veins in North Carolina; A new mode of vein formation.

H. A. Cutting: Capability of the various building stones in general use, to stand heat and water, when hot.

E. S. Morse: A comparison between the shells of Kjökkenmöddings, and present forms of the same species.

W. O. Crosby and G. H. Barton: Extension of the Carboniferous formation in Massachusetts.

C. H. Hitchcock: Eruptive rocks of Mt. Ascutney; Occurrence of tin at Winslow, Me.

S. E. Warren: On an American example of a St. Giles' staircase at Marblehead.

G. F. Waters: Action of ice on modified drift in Portland, Me.

F. L. Capen: The value of the water-shed and water supply of the globe.

J. R. Proctor: On the gravel deposits of Kentucky; On several horizons of breccia in Kentucky.

T. Egleston: Origin of gold placer deposits and formation of nuggets.

4. *Zoology and Botany, exclusive of Entomology.*

H. **Allen**: Comparative anatomy as a part of the medical curriculum.

A. S. **Bickmore**: Improved Stereograph for delineating the outlines of crania.

C. C. **Merriman**: Microscopic studies in Central Florida.

Ellen H. **Walworth**: Field work by amateurs.

E. S. **Morse**: Notes on Japanese Pulmonifera; Observations on Japanese Brachiopoda.

S. V. **Clevenger**: Plan of the cerebro-spinal nervous system.

B. D. **Haldsted**: An investigation of the peach yellows.

P. R. **Hoy**: Menobranchus lateralis.

J. G. **Henderson**: A new craniograph.

L. F. **Ward**: Incomplete adaptation as illustrated by the history of sex in plants.

B. G. **Wilder**: Partial revision of the nomenclature of the brain; The foramina of Monro in man and the domestic cat; The *crista fornicis*, a part of the mammalian brain apparently not hitherto described.

T. **Meehan**: Evolution of parasitic plants.

T. **Taylor**: New method of quickening the germination of garden, field, and forest seeds, discovered by the author.

T. J. **Berrill**: Anthrax of fruit-trees, or the so-called fire-blight of the pear and twig-blight of the apple-tree.

C. V. **Riley**: Further notes on the pollination of Yucca, and on Pronuba and Prodoxus.

W. A. **Buckhout**: Contribution to the life-history of the Phitoptidæ.

G. **Macloskie**: The endo-cranium and maxillary suspensorium of the bee.

C. S. **Minot**: Anatomy of the tongue in snakes and other reptiles, and in birds—exhibition of sections; On the summation of muscular contractions; Notice of a complete bibliography on Plathelminths.

E. D. **Cope**: Origin and succession of Felidæ.

S. H. **Gage**: Permanent microscopic preparations of Amphibian blood corpuscles. Permanent microscopic preparations of Plasmodium.

C. V. **Riley**: Additional notes on the army worm (*Lucania unipuncta* Haw.)

C. **Scaler**: Minute anatomy of the human larynx.

S. P. **Sharples**: Some of the Infusoria found in Fresh ponds, Cambridge, Mass.

C. W. **Smiley**: The Spanish Mackerel and its artificial propagation.

C. J. **Blake**: Occurrence of exostoses in the external auditory canal in prehistoric man.

E. B. **Wilson**: The metamorphosis of Actinotrocha.

W. K. **Brooks**: Notes on the Medusæ of Beaufort, N. C.; The rhythmical character of segmentation.

C. V. **Riley**: Recent practical results of the cotton worm inquiry by the U. S. Entomological Commission.

E. **Cutter**: Contribution to the histological nature of the membrane in croup; Abundance of microscopic forms of life in the central and lateral surfaces of lakes and ponds.

R R. **Hoy**: Occurrence of *Aletia argillacea* in Wisconsin.

4A. *Entomology.*

C. F. **Gissler**: Sub-elytral air passages in Coleopetra.

A. J. **Cooke**: Two new methods of fighting injurious insects.

W. W. **Wheildon**: Brief remarks on the mechanical ingenuity of the house-spider, and the habits of the house fly.

C. H. **Fernald**: Method of preparing and mounting wings of microlepidoptera.

B. F. **Mann**: The contributions of the Cambridge Entomological Club to the progress of entomology.

W. H. **Seaman**: A method of mounting in glycerine and certain differentiations of structure produced by it on insects.

C. V. **Riley**: The life-habits of certain bee-flies (Bombyliidæ); Remarks on tree-crickets; Remarks on the curious stages of Blephorocera.

H. A. **Hagen**: On biological collections of insects: On some very rare insect deformities.

D. S. Martin: Insects from copal.

A. S. Packard, Jr.: Migrations of Rocky Mountain locusts.

E. L. Mark: Some points in the anatomy of the Coccidæ.

H. F. Bassett: Structure and development of certain hymenopterous galls.

J. L. LeConte: An essay on lightning beetles: List of Coleoptera hatched from a few hickory twigs.

H. C. McCook: The honey-ants of the Garden of the Gods, Colorado.

G. D. Putnam: Notes on N. A. Galeodes.

A. R. Grote: Generic characters of the Noctuidæ.

C. H. Fernald: On the classification of the Tortricidæ; On Phocopteris angulifascina.

H. A. Hagen: On the Hessian fly; On the anatomy of Prodoxus decipens.

E. Burgess: On the structure of the mouth organs in the Lepidoptera.

S. H. Scudder: Annual address of the President of the Entomological Club of A. A. A. S.

5. *Anthropology.*

H. B. Carrington: The Dacotah tribes.

A. S. Bickmore: Ethnology of Africa, illustrated by a large manuscript map.

A. Kocsis: The Voguls.

W. C. Holdbrook: Prehistoric altars of Whiteside County, Illinois.

C. F. Williams: Parturition in a kneeling posture, as practiced by the women of the moundbuilder and stone-grave race.

E. S. Morse: Persistance of Korean ornamentation in Japanese pottery; Prehistoric and early types of Japanese pottery.

E. A. Smith: Folk lore of the Iroquois.

J. M. Currier: Antiquities in the town of New Haven, Vermont.

D. W. Ross: Theory of primitive democracy in the Alps.

G. Mallery: Scheme of the tenth census for obtaining statistics of untaxed Indians.

C. C. Abbott: Exhibition of stone implements from the river drift of New Jersey; Indications of a pre-Indian occupancy of the Atlantic coast of North America, subsequent to that of palæolithic man.

J. G. Henderson: Textile fabrics of the ancient inhabitants of the Mississippi valley—Pt. I, Material—preparation of material and spinning; Part II, The loom and the fruit of the loom; Pt. III, Moundbuilder, stone-grave and cave fabrics; ancient mounds in vicinity of Naples, Illinois; Sign language and pantomimic dances among the North American Indians.

F. W. Putnam: Conventionalism in ornamentation of ancient American pottery; On the occurrence in New England of carvings by the Indians of the Northwest coast of America.

R. J. Farquharson: The probable existence in America of the pre-historic practice of trepanning, in the cutting of rondelles or amulets from the skull; Contemporaneous existence of mastodon and man in America.

Geo. H. Perkins: Relation of the archæology of Vermont to that of the adjacent states.

Wm. McAdams: The pipes of the mound-builders and pottery-makers; Ancient agricultural implements of stone; A stone implement, from the base of the drift in Illinois; Sea-shells in the mounds; The mounds of Illinois.

W. J. Knolton: Engraved tablet from a mound in Ohio.

W. M. Beauchamb: Antiquities of Onondaga County, New York.

J. F. Everhart: Ethnology.

D. A. Lyle: The Indian question.

S. S. Haldeman: Remarks on aboriginal pottery; On stone axes.

H. C. Hovey: Alabaster quarries, flint mines and other antiquities recently found in Mammoth, Wyandot and Luray Caverns.

Miss **Erminnie A. Smith**: On the Iroquois languages.

J. W. Powell: On the rank of Indian languages: The classification of kindred by the N. A. Indians.

S. D. Peet: The topographical survey of the works at Aztalan, Wis.; The military system of the emblematic mound-builders.

H. C. Lewis: The antiquity of man in Eastern America geologically considered.

6. *Miscellaneous.*

P. H. **Dudley**: Transportation expenses and their reduction.

Geo. M. **Sternberg**: Microscopical investigations of the Havana Yellow Fever Commission.

G. B. **Goode**: The first decade of the U. S. Fish Commission. Its plan of work and accomplished results, scientific and economical.

C. **Roosevelt**: Investigations for rapid and safe locomotion.

O. J. **Blake**: Phonophobia and the influence of noise on the health of dwellers in cities.

B. S. **Hedrick**: On patent laws as means for the advancement of science.

L. F. **Ward**: Feeling and function as factors in human development.

E. B. **Elliott**: The credit of the United States Government.

Wm. **McMurtrie**: On the deficiency of meteorological work in data of value to agriculture and means for supplying them.

F. L. **Capen**: Explanation of diagram for 24 hours London and Boston time, showing the method of obtaining formulas for weather prediction.

R. H. **Dudley**: Railroad time service.

A. J. **Cook**: Contributions of apiculture to science.

4. *Report of the Superintendent of the United States Coast Survey*, showing the progress of the work for the fiscal year ending with June, 1876. 418 pp. 4to, with 24 maps. Washington, 1879.—Among the various memoirs inserted as appendices to this Report, there are the following: A new system of binary arithmetic, by B. Peirce; Methods of registering tidal observations with illustrations, by R. S. Avery; Report on the physical survey of New York harbor, 1876; Note on the theory of economy in research, by Assistant C. S. Peirce; Measurement of gravity at initial stations in America and Europe; Comparison of the methods of determining heights by leveling, vertical angles, and barometer, by G. Davidson and C. A. Schott; Observations on atmospheric refraction, and hypsometric formulæ based on thermodynamic principles, by C. A. Schott; and a chart of the magnetic declination in the United States, by C. A. Schott. There is also a list of publications relating to the deep sea investigations carried on in the vicinity of the coast of the United States under the auspices of the Coast Survey, which commences with observations by Count Pourtalés in the year 1850.

5. *On Spodumene and the results of its alteration from Branchville, Ct.;* by G. J. Brush and E. S. Dana: note to the article on p. 257.—The sections represented in figs. 15 and 16 (p. 264), figs. 17 and 18 (p. 265), and 19 (p. 270), are magnified 300 diameters.

OBITUARY.

Charles Thomas Jackson, early eminent as a chemist, mineralogist, geological explorer and teacher, and long identified with the science of Boston, died on the 29th of August last, at Summerville, Mass. Dr. Jackson was born in Plymouth, Mass., June 21, 1805. While yet a student of medicine in Harvard University, Jackson prepared, in connection with the late Francis Alger, of Boston, a new geological and mineralogical map of Nova Scotia, which was published in the Memoirs of the American Academy at Boston. He subsequently studied science in Paris, under the most eminent masters, and retained the warm personal friendship of Elie de Beaumont, throughout life. Returning to America in 1832 he soon abandoned medical practice and devoted his energies and talents, with great enthusiasm, to the prosecution of science. He opened the first chemical laboratory in the United States for the instruction of students in mineral analysis, and there some of our leading chemists had their earliest laboratory experience. He became the director of the earliest geological explorations in Lake Superior, and of the geological surveys of Rhode Island and Maine. His controversy with Morse, for the prior invention of the electro-magnetic telegraph, is well remembered, and the more acrimonious one on the subject of etherial anesthesia will probably never be settled to the satisfaction of the friends of either Jackson or Morton. The French Academy, after an investigation, decreed a prize of 2,500 francs to each of the contestants. In the catalogue of the Royal Society there are sixty-nine titles under Dr. Jackson's name, prior to 1863, and his name is found often as a contributor to the early volumes of this Journal. The older chemists will remember his powerful blast-lamp for alkaline fusions, which did good service before the introduction of street gas became general in laboratories. He was an active member, and long the president, of the Boston Society of Natural History. B. S.

Professor SAMUEL SHERMAN HALDEMAN died on Friday, the 17th of September, at his home in Chickies, Pennsylvania, aged sixty-eight years. He was born near Columbia, Pa., in 1812, and graduated at Dickinson College in 1830. In 1836 he was connected with the Geological Survey of New Jersey, and the following year with that of Pennsylvania. He was Professor of Natural History in the University of Pennsylvania from 1851 to 1855, and in 1855 took the same chair in Delaware College, and also that of Professor of Geology and Chemistry in the Agricultural College of Pennsylvania. He afterward became Professor of Philology in the University of Pennsylvania. For many years he worked with great zeal and success in entomology and conchology, and published various memoirs, describing new species and illustrating the broader subject of geographical distribution. Among these are his work on the "Freshwater Mollusca of the United States," his "Zoological Contributions," and a paper on the Coleoptera Longicornia of the United States. Later he devoted himself especially to philological studies, phonetics and orthography. His "Analytic Orthography" obtained for him in England, the Trevelyan prize in 1858. He paid much attention to the Indian languages of North America and their pronunciation. The diversity of his tastes and learning is further shown in his "Tours of a Chess Knight" (1864), a volume of ninety pages illustrated with 114 figures, and containing a bibliography including sixty references.

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AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

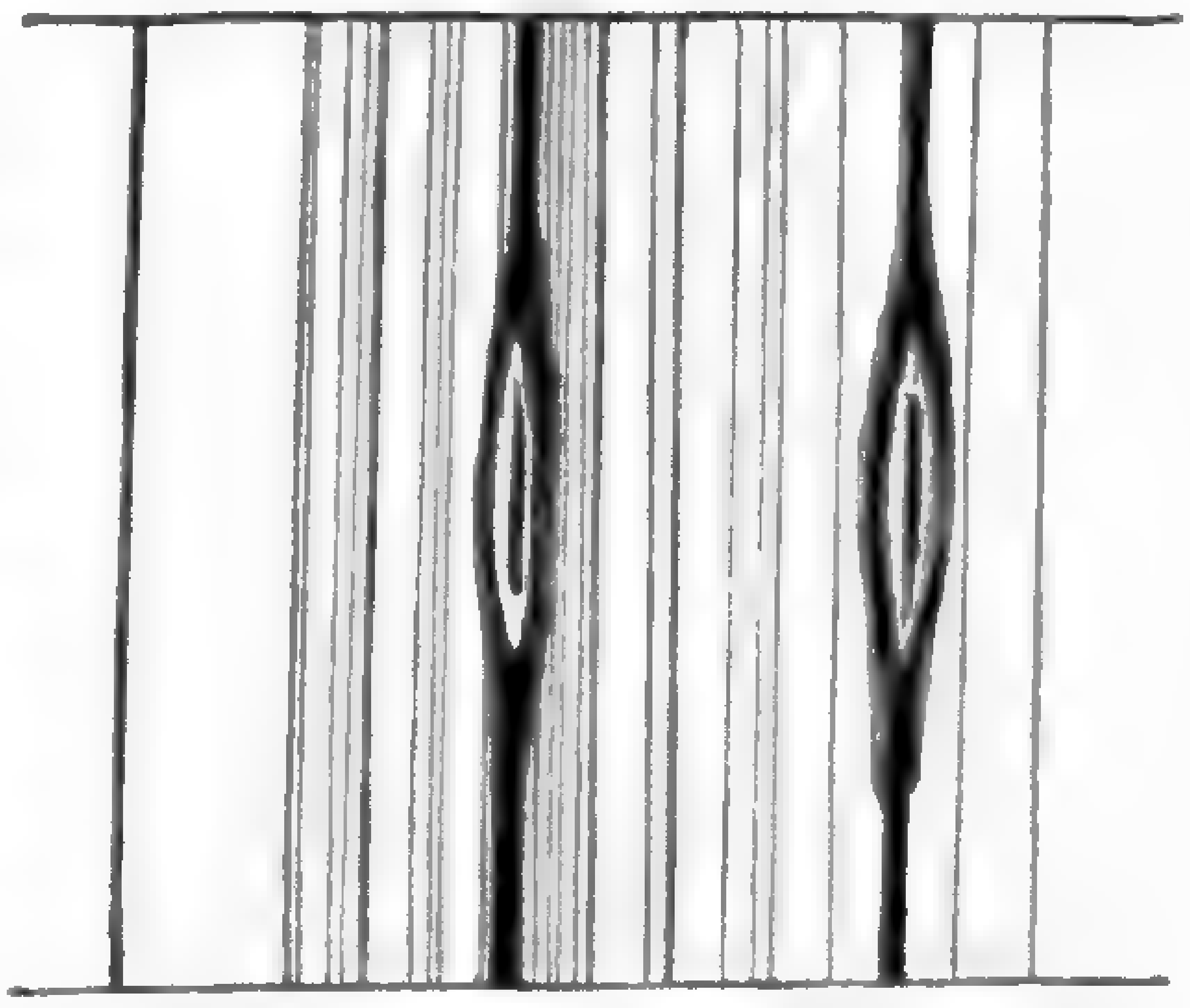
ART. XXXVII.—*Spectroscopic Notes*, 1879–80; by Professor C. A. YOUNG, Princeton, N. J.

I. *Double reversal of lines in Chromosphere Spectrum.*

THE magnesium lines of the *b* group, and the two D-lines of sodium have been seen several times (first on June 5, 1880) *doubly-reversed* in the spectrum at the base of a prominence.

A bright line first appears in the center of the widened dark lines; then this bright line grows wider and hazy at the edge, and a thin dark line appears in its center, as shown in the figure. The phenomenon lasts usually from ten minutes to an hour. It is evidently the exact correlative of the double reversal of the bright sodium lines, observable in the flame of a Bunsen burner or alcohol lamp under certain circumstances when the quantity and temperature of the sodium vapor in the flame are greatly increased.

1.



Double reversal of D-lines.

II. *The* H-*lines in the Chromosphere and Sun-spot Spectra.*

In 1872, I found the H- and K-lines to be reversed in the spectra of prominences and sun-spots, as observed at Sherman, 8,000 feet above the sea. Until recently I have not been able to verify the observation, except for a moment during the eclipse of 1878. During the past summer, however, I have succeeded in seeing them again, and with suitable precautions as to shade-glass, adjustment of slit to true focal plane for these special rays, and exclusion of extraneous light, I have no further difficulty with the observation. The spectroscope employed has collimator and view-telescope each of 1¼ inches aperture, and about thirteen inches focal length, and a speculum-metal Rutherfurd grating with 17,300 lines to the inch. A shade of cobalt blue glass greatly aids the observation. The solar image is 1¼ inches in diameter.

In the spectrum of the chromosphere, H and K are both *always* reversed. I have never failed to see them both when circumstances were such that *h*, the nearest of the hydrogen lines, could be seen.

Furthermore, H, in the chromosphere spectrum, is *always double:* that is, a fine bright line always accompanies the principal line, about one division of Ångstrom's scale below. The principal line seems to be exactly central in the wide dark shade, the other is well within the nebulosity. K on the other hand shows no signs of duplicity.

In the spectrum of a sun spot H and K are also, both of them, generally, though not always, reversed; and the reversal is not confined to the spot, but covers often an area many times larger in its neighborhood.

In the spot spectrum, however, H has never yet been seen double. The companion line of H is therefore probably due to some other substance than that which produces H and K; a substance prominent in the chromosphere, but not specially so in the neighborhood of spots. In view of the recent observations of Vogel, Draper and Huggins, it is natural to think that hydrogen is probably the element concerned. If so, it may be expected that H will be found doubled in the spectrum of a spot which reverses the hydrogen line *h*. I have not yet been able to test it in this way, as *h* is rarely seen reversed, though C and F occur pretty frequently. (See, further, a note by the author in the miscellany beyond.)

III. *Examination of lines in the Solar Spectrum which are given in the Maps as common to two or more substances.*

For this purpose a spectroscope of high dispersion has been constructed by combining the grating mentioned above, which has about four square inches of ruled surface, with a collimator and observing telescope each of three inches aperture and about 42 inches focal length, using magnifying powers ranging from 50 to 200. The apparatus is arranged upon a wooden frame work, and when in use is strapped to the tube of the

12-feet equatorial of our observatory, so that it is kept by the driving clock directed to the sun. An image of the sun is formed on the slit by an achromatic object glass of three inches aperture, in order to increase the light and to avoid the widening of the lines due to the sun's rotation. A large prism of about 20° angle was sometimes placed in front of this object glass (between it and the sun) to separate the colors before reaching the slit; and in examining the darker portions of the spectrum a concave cylindrical lens was sometimes used next the eye, like a shade glass, to reduce the apparent width of the spectrum and thus increase its brightness.

The grating is an admirable one, on the whole the best I have ever seen. But I have been greatly surprised at its excessive sensitiveness to distortion by pressure or inequalities of temperature. Although the plate is fully $\frac{3}{8}$ of an inch thick, and only 3½ inches square, an abnormal pressure of less than a single ounce at one corner will materially modify its behavior, and a quarter of a pound destroys the definition entirely. In fact the plate is not naturally exactly flat, and to get its best performance it is necessary to crowd a little wedge gently under one corner. When it is in good humor and condition, however, the performance is admirable; one could wish for nothing better, unless for a little more light in the violet portions of the spectrum.

With this instrument I have examined the 70 lines given on Ångstrom's map as common to two or more substances. (At the time of the meeting of the American Association for the Advancement of Science, at Boston, I had finished the examination of only 47). Of the 70 lines, 56 are distinctly double, or triple; 7 appear to be single; and as to the remaining 7, I am uncertain; in most cases, because I was unable to identify the lines satisfactorily on account of their falling upon spaces thickly covered with groups of fine lines, none of which are specially prominent.

As a general rule the double lines are pretty close, the distance being less than that of the components of the 1474 line. Generally also the components are unequal in width or darkness or both, though in perhaps a quarter of the cases they are alike in appearance. The doubtful lines are the following, designated by their wave length on Ångstrom's map: 5489·2, 5425·0, 5396·1, 5265·8, 4271·5, 4253·9 and 4226·8. I strongly suspect 5396·1 and 5265·8 (which present no difficulty in identification), of being double, but could never fairly split either of them, and therefore leave them among the doubtfuls.

Those which show no signs of doubling, so far as could be seen, were: 6121·2, 6064·5, 5019·4, 4585·3, 4578·3, 4249·8, and 4237·5.

In respect to the lines 5019·4, 4585·3 and 4237·5 it is quite possible there may be some mistake as to the coincidence, since in his *tables* Thalen gives neither of them as due to iron. An accidental strengthening of the dotted line, which, on the map, leads up from the symbol of the element concerned, through the iron spectrum, would account for the matter, by making the line appear on the map as belonging to iron also.

As the facts stand, therefore, it is obvious that arguments which have been based upon the coincidence of lines in the spectra of different elements lose much of their force; it appears likely that the coincidences are in all cases only near approximations. At the same time this is certainly not yet demonstrated. The complete investigation of the matter requires that the bright line spectra of the metals in question should be confronted with each other and with the solar spectrum under enormous dispersive power, in order that we may be able to determine which of the components of each double line belongs to one, and which to the other element. If, in this research it should be found that *both* of the components of a double line were represented in the spectra of two different metals, and the suspicion of impurity were excluded, we should then indeed have a most powerful argument in favor of some identity of material or architecture in the molecules of the two substances involved.

IV. *Distortion of Solar Prominences by a diffraction spectroscope.*

Generally, in such an instrument, the forms seen through the opened slit are either disproportionately extended or compressed along the line of dispersion. The reason is this: if the slit be illuminated by monochromatic light, the images of the slit, formed on each side of the simple reflected image in the focus of the view-telescope (which is supposed to have the same focal length as the collimator), will have the same width as the slit itself only in one special case, not usually realized with a reflecting grating.

If the angle, between the normal to the grating and the view-telescope, is *less* than that between the normal and the collimator, the slit-image will be *narrower* than the slit, and a prominence seen through it will be *compressed* in the plane of dispersion. If the relation of the angles be reversed, then of course the distortion will also be reversed, and we shall have extension instead of compression.

The mathematical theory is very simple. Suppose the collimator and telescope to be fixed at a constant angle, as in the now usual arrangement.

Let angle between telescope and collimator = a.

Angle between telescope and normal to grating = τ.

Then angle between collimator and normal = $\varkappa = a - \tau$.

Also, let space between adjacent lines of grating = s,

And the order of spectrum observed = n.

Then, by principles of spectrum formation, we have

$$\lambda = \frac{s}{n} \left\{ \sin \tau - \sin \varkappa \right\},$$

λ being the wave length of the ray which is in the center of the field of view:

whence $$\sin \tau = \frac{n\lambda}{s} + \sin \varkappa.$$

Differentiating, we have at once

$$d\tau = \frac{\cos \varkappa}{\cos \tau} d\varkappa, \text{ or } \frac{\cos .(a-\tau)}{\cos \tau} d\varkappa;$$

which reduces to, $d\tau = (\cos a + \sin a \tan \tau) d\varkappa$. Distortion can only disappear in cases when this coefficient of $d\varkappa$ reduces to unity. Special cases—

1. If $\tau = \varkappa$ there is no distortion—but also no dispersion: it is the case of simple reflection.

2. If $\varkappa = 0$, the grating being kept normal to the collimator, then $d\tau = \sec a \, d\varkappa$.

3. If $\tau = 0$, the grating being kept normal to the telescope (which in this case must be movable), then $d\tau = \cos a \, d\varkappa$.

4. If $a = 90°$, $d\tau = \tan \tau \, d\varkappa$.

5. If $a = 0$, $d\tau = d\varkappa$, and there is no distortion.

This is possible only by using the same tube and object-glass both for collimator and view-telescope, the grating being slightly inclined at right angles to the plane of dispersion. The principal difficulty in this form of instrument lies in the diffuse light reflected by the surfaces of the object-glass. It is hoped that this may be nearly obviated by a special construction of the lens which will throw the reflected light outside of the eyepiece. An instrument on this plan is being made for Professor Brackett by the Clarks, for use in the physical laboratory at Princeton, and is now nearly completed.

Princeton, Sept. 27, 1880.

Note to the preceding Article, by Professor C. A. YOUNG.—An observation made since my paper was written, leads me to modify this opinion, that the companion of H is due to hydrogen, and satisfies me that in all probability both H and K must themselves be hydrogen-lines. At 11 A. M. on October 7, a bright horn appeared on the S. E. limb of the sun. When first seen it was about 3′ or 4′ in elevation, but it rapidly stretched up and before noon reached a measured altitude of over 13′ (350,000 miles +) above the sun's limb. It faded away and disappeared about 12.30. It was brightest about 11.30 with an altitude of about 8′, and at this time both H and K were distinctly, and for them, brilliantly reversed in it clear to the summit. H was not double in it to any notable elevation, though the companion of H was visible at the base of the prominence. The H- and K-lines also showed evidence of violent cyclonic action, just as C did. *h* was only faintly visible in the prominence; F and the line near Y were of course strong. But no other lines, either of sodium, magnesium, or anything else, could be traced more than a very few seconds of arc above the sun's limb. I am not able to say how long the H-lines continued visible, or to what elevation they extended afterwards, as I returned to the C-line to watch the termination of the eruption. If I remember rightly, this eruption reached a higher elevation than any before observed. There was (and is to-day) nothing on the sun's limb visible with the telescope which would account for it.

Princeton, Oct. 8.

ART. XXXVIII. — *On the thermo-electric power of Iron and Platinum in vacuo*; by Professor C. A. YOUNG, of Princeton, N. J.

EXNER, a few months ago, published a paper asserting that the thermo-electric power of antimony and bismuth is destroyed by removing them from all contact with oxygen, and immersing them in an atmosphere of pure nitrogen. From this he argues that the thermo-electric force in general is due to the contact of the gases which bathe the metals. The following experiment was tried to test the theory:

By the kindness of Mr. Edison and Mr. Upton a vacuum tube was prepared in Mr. Edison's laboratory, containing an iron wire, about two inches long, firmly joined to two platinum terminals which passed through the walls of the tube; the tube was exhausted until the spark from a two-inch induction coil would not pass ⅛ of an inch in the gauge-tube, indicating a residual atmosphere of about one-millionth. The wire was heated to incandescence during the exhaustion, in order to drive off any possible occluded gases. The platinum wires outside the tube were joined to iron wires, the joinings being covered by glass tubes slipped over them, and a sensitive reflecting galvanometer was included in the circuit. By laying the tube and connected joinings in the sunshine, and alternately shading one or several of the joinings it was found that the electro-motive power of the joinings within the tube was precisely the same as that of those without, and the development of current just as rapid. There was no trace of any modification due to the exhaustion.

ART. XXXIX.—*Geological Relations of the Limestone Belts of Westchester County, New York;* by JAMES D. DANA. (With a Map, Plate V.)

[Continued from page 220.]

2. DISTRIBUTION OF THE BELTS OR AREAS OF LIMESTONE.

The limestone areas of the county have the distribution shown on the accompanying map (Plate V),[14] the colored portions representing them. The intermediate surface is occupied by the crystalline schists—mostly mica schist and gneiss—as already explained. I have not attempted, in my study of the rocks, to ascertain the outlines of the areas of these schists, because my purpose was accomplished when their conformability and their conformable relations to the limestone beds were ascertained, and the time I could command, without aid in the work, was insufficient for a complete survey of the county. Moreover, the distinction of mica schist, micaceous gneiss, thick-bedded feldspathic gneiss, hornblende schist, is, in many parts, of no stratigraphical value, these unlike rocks, as has been stated (p. 29), often occurring in alternations and graduating into one another in the direction of the bedding as well as transverse to it, rendering a correct mapping of their distribution next to impossible. There are, however, areas of the hard feldspathic gneiss in which micaceous bands seldom occur, that might, after careful study, be more or less perfectly laid down. The limestone areas often contain, as stated on p. 29, more or less mica schist or gneiss, which is not indicated on the map, partly owing to the small scale of the map, but largely to the fact that the two are often so interstratified that their separation is hardly possible, especially under the difficulties from the covering of alluvium or drift. In several cases the schist is an overlying or underlying stratum, included in the flexure; and further study may prove this to be true in some not so explained in the descriptions beyond. A geologist, on commencing his study of the limits of these limestone areas, would be likely to give less weight than I have done to the evidence from the form and flat bottom of the valleys, while with longer study he would be pretty sure to be satisfied with the conclusions arrived at.

The T-shaped symbols on the map indicate the strike and dip of the beds, both of the limestone and schist; the top

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[14] This map, apart from its geological facts, is Colton's pocket map of Westchester County reduced one-half, with also the roads and most of the names of places omitted. A slight change has been made in the coast west of Cruger's, and the Putnam County portion has been put on from Putnam County maps. By photographing it double of its present size, the position of the areas and T-symbols with reference to all roads may be ascertained on comparison with Colton's map.

of the T shows the direction of the strike, and the stem that of the dip (or pitch) of the beds for the locality situated at their junction. Moreover, the length of the stem as compared with that of half the top of the T is made to give an approximate idea of the amount of dip, according to the following scheme: ratio for 80°, 1 : 4; for 70°, 1 : 3; for 60°, 1 : 2; for 50°, 1 : 1⅓; for 45°, 1 : 1; for 35°, 1¼ : 1; for 25°, 1½ : 1; for 15°, 2 : 1.

In the following descriptions of the belts I speak: *first*, of the SOUTHERN section of the county, from New York Island to White Plains; *secondly*, of the MIDDLE section, from White Plains to Croton Lake; and *thirdly*, of the NORTHERN section, north of the latitude of Croton Lake. The areas are numbered on the map, and these numbers are used in connection with the descriptions.

The following pages contain only the general facts respecting the several belts—their position and features; the average strike and dip; the characteristics of the limestone, and the kinds of adjoining rocks and their relations as to position. The details with regard to the various directions of strike and dip at all the points marked by symbols on the map and for other points not thus indicated, which make part of this paper as prepared, are reserved, with other details, for an Appendix.

a. *Southern Section of the County.*

Three areas or belts commence in New York Island and extend two to four miles into Westchester County. The adjoining rocks are mica schist and micaceous gneiss and in some parts thick-bedded gneiss.

Area 1.—The eastern of these three belts, which may be called the Tremont, extends from Fordham southward to Harlem River, and from thence into New York Island. It reaches Harlem River by *two* lines, a *western* at Mott Haven and an *eastern* at the mouth of Morris Mill brook, west of Brook avenue. The main strike is N. 18–25° E.[15]

The *western* of these southern terminations, or that of Mott Haven, shows itself just east of the railroad, south of the Mott Haven railroad station, in two limestone hills which will soon disappear from grading. The rock on the west or opposite side of the railroad at this point is somewhat contorted mica schist; and layers of the same kind of schist are involved among the beds of the northern of the hills. Near the Mott Haven depot, the limestone passes to the west side of the railroad, and from thence it continues northward on both sides. The *eastern* line has large outcrops of purer limestone near

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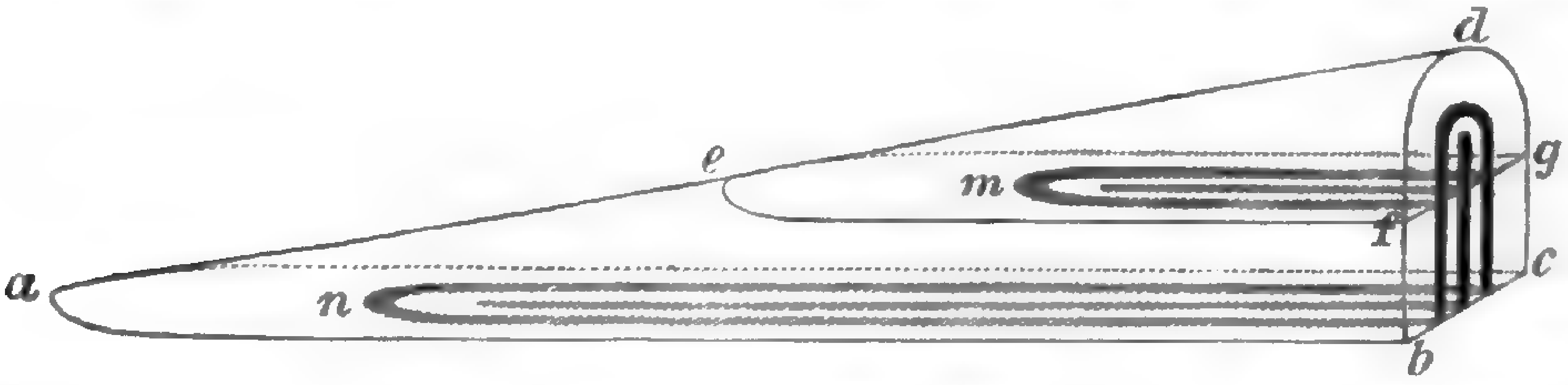
[15] The angle here (and so elsewhere in this paper) is corrected for magnetic variation. In stating the *dip*, only the point of the compass is mentioned in a general way, the exact direction being at right angles to the strike.

142d street, and at many points to the north. The eastern and western lines become united in one wide belt in Morrisania which continues northward through Tremont to Fordham. Toward Harlem River the interval between these two lines is low and flat, without outcrops of rock at the present time except some micaceous gneiss to the eastward. On 142d street, east of the brook, there is a locality of hydrous anthophyllite and impure serpentine which will soon be graded away. The dip of the beds of limestone in Tremont, and at points south of the place, indicate that the belt of limestone from Fordham southward is a denuded anticlinal fold; and assuming that the limestone of the belt divides southward, as the facts appear to show, the axis of the fold has a small *northward* pitch. This division of the limestone to the south into two bands, an eastern and western, separated by intervening schist, would come from the wearing down of such a fold to a horizontal surface.

That this statement may be understood by readers not familiar with the subject, the accompanying diagram, giving a general idea of the condition supposed, is here introduced: it is intended to represent an anticlinal fold with an inclined axis but vertical axial plane, in which layers of gneiss are enveloped by a stratum of limestone. In the horizontal section, *e f g*, the limestone of the two sides is in one connected mass from *e* to *m*, but in two bands separated by intervening gneiss from *m* to *f g*. The same also is shown in the section *a b c*.



Professor Gale states[16] that the gneiss along 4th avenue from 118th to 120th street is in places half limestone: and Professor D. S. Martin has observed[17] the same on 124th street; and these localities are in a line with the Mott Haven and Tremont belt, and indicate its southward extension into New York Island, as recognized by Mr. R. P. Stevens.[18]

This Tremont belt is widened on its west side in Morrisania, over Fleetwood Park, in consequence of a second anticlinal (see map), but one *having the axis inclined southward*, or in the opposite direction from that of the main belt. That the axis has this inclination is shown by the strike and dip of the mica schist which divides the northern end of this western extension, and its widening northward. At a section of the schist on the north side of the park the dip is in opposite directions;

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[16] Mather's N. Y. Report, p. 593.

[17] Proc. Lyc. Nat. Hist. New York, 1871, i, 222.

[18] Annals, ibid., viii, 116.

and farther north on the Morrisania side, the anticlinal is a more gentle one. The limestone here extends over half a mile west of the railroad, the western limit being nearly half way up the slope that makes the high western side of the park.

Area 2.—The *second* belt, or that of "the Clove," follows Cromwell's Creek, north of Central (or McComb's Dam) Bridge and the brook emptying into it. The most southern outcrop occurs about a mile north of the bridge above the crossing of the brook by Central avenue. Some of the layers at this place contain much chlorite in bright green scales. It outcrops again near the "Club House." North of this the presence of limestone is indicated only by the form and definiteness of the valley and by the outcropping schist on its sides. The limestone varies much in strike, owing to contortions, but the adjoining schist gives for the strike about N. 25° E.

This belt probably continues southward into New York Island, as R. P. Stevens has observed,[19] who says that in grading east of 6th avenue in 132d street, limestone was cut through.

Area 3.—This limestone belt is a prominent feature of the north end of New York Island. From the island it extends three miles northward into Westchester County, along Tibbit's Brook. At Kingsbridge a deep cut is made through it for the Hudson River railroad. North of this place it is not in sight along Van Cortland's Lake, but outcrops at points in the valley of Tibbit's Brook above this to if not beyond the stone-arched bridge, nearly three miles from Kingsbridge. Crumbling masses of the limestone lie on the eastern approach to this bridge which, as I am informed by the superintendent in its construction, Mr. John Wetherill, were quarried in that vicinity, his letter saying he "opened several quarries for stone for the bridge," and found "all the rock of the valley to be limestone of a poor kind." The mica schist on the east side of the valley along the Croton Aqueduct, south of the bridge referred to, has the strike N. 20° E., and that at Kingsbridge N. 37°–40° E., the dip in both 70°–75° to the eastward.

The limestone area from Kingsbridge southward was imperfectly mapped by Dr. L. D. Gale.[20] South of the Harlem, it widens on its *eastern* side for the first mile and just north of the east-and-west inlet called Sherman's Creek, extends from a point west of the "Kingsbridge road" or Inwood street to the Harlem River. Thence its *western* side has a narrow continuation southward along the Kingsbridge road in a well-defined valley wall-sided on the west, while its broad middle portion is fronted, south of Sherman Creek, by hills of micaceous gneiss; and it is probable, judging from its strike, that

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[19] Annals Lyc. Nat. Hist. New York, viii, 116.

[20] In Mather's N. Y. Geol. Rep., Plate I.

the eastern side has its narrow continuation down Harlem River, as is suggested on the map, although no outcrops appear to prove it. If this be the correct view, the area as a whole resembles in form the Tremont or No. 1, and, like that, owes the forked character to its being the remains of a denuded fold. The most southerly outcrop of the limestone on the Kingsbridge road is, as found by Dr. Gale, near 204th street, or about 500 yards south of Inwood street, where the width of the valley is nearly 300 yards. The valley fades out and is closed by the gneiss at 182d street; the limestone may exist beneath as far as 190th street, if not beyond.

The supposed Harlem River or *eastern* fork of the belt has an argument in its favor in the existence of a well-defined flat-bottomed valley, formerly more or less marshy and still so about its mouth, along 8th avenue in the direct line of the river. This valley, long since styled by Dr. Gale "the valley of 8th avenue," lies between 7th and 9th avenues, and has a wall of nearly vertical gneiss 40 to 80 feet high on part of its western side. The depression is well defined to 115th street, and is distinct to 110th.[21]

Over the more southern part of New York Island, in the line of the western fork of the belt, there are some localities where serpentine or "hydrous anthophyllite" occur in the gneiss; and, although no connection with this area can be traced, it is of interest to note them at this place. Dr. Gale states that from 59th street on 10th avenue to 63d street at the river, there existed a vertical bed of hydrous anthophyllite having gneiss on the east side and granite on the other.[22] Mr. I. Cozzens, in a volume on New York published in 1843, mentions the occurrence of black serpentine between 10th avenue and the river and between 54th and 62d street, in a bed twelve feet wide containing also limestone and talc. At 157th street, 100 feet west of 10th avenue, a mixture of limestone and serpentine has been observed.

North of Area No. 1, which stops at Fordham, the line of outcropping limestone is shifted a little eastward to the course of the valley of the Bronx, in which occur, at intervals, the areas numbered 4, 10 and 11; and from No. 3, there is a shift westward, to the course of the valley of Saw Mill River, along which there are, at Yonkers, two small parallel areas 7 and 8, and farther to the north, numbers 14 and 15. The line of No. 2 may perhaps be represented in No. 9, which follows the course of Grassy Sprain Brook. To the east are two areas, nearly in the same line of strike, numbered 5 and 6, which are the serpentine areas of New Rochelle and Rye.

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[21] Whether the fold in this limestone is a synclinal or anticlinal, facts do not positively decide. This point will be further considered in the appendix.

[22] Mather's N. Y. Geol. Report, p. 582.

As stated, these limestone areas follow the courses of the rivers mentioned; but the historical fact in each case is this, that the river follows the course of the limestone, the softness of the latter rock causing it to yield easily to eroding or denuding agents.

Area 4.—In this area, ledges of limestone show themselves just above the point of junction of the Harlem and New Haven railroads, and were cut through in grading for the tracks. The valley of the Bronx has here a flat marshy bottom and this continues, with the same bordering schist northward to West Mt. Vernon and southward to and below Williams Bridge, indicating the probable presence there of the limestone, as indicated on the map. I was informed at Williams Bridge of the former existence of an outcrop of limestone visible at low water, on the river just below the bridge, but failed to find any now. The strike of the mica schist adjoining the belt on the west is N. 20°–29° E., and dip 65°–75° E.; and west of the river at Williams Bridge N. 20° E., dip 65°–75° W.

Areas 5 *and* 6.—These areas of serpentine with some calcareous material, at New Rochelle and Rye, have been partly described on page 30. The map makes manifest, by its T-symbols, the conformability of the mica schist and micaceous gneiss between the West Mt. Vernon limestone and the area of New Rochelle; and also shows that the New Rochelle and Rye areas are nearly on the same line of strike. There is no essential difference in the schist adjoining them. The dip of the rocks around the latter afford evidence that it is situated along the axis of a local anticlinal. From Stamford westward to the Harlem the dip is in general westward; but at Portchester on the way toward Rye the dip changes to eastward, and then becomes westward again west of the area. The symbols indicate the wrenching the beds underwent in the making of the fold, and show that the fold was steepest and narrowest to the southwest, and had its axis inclined to the south-southwestward.

The positions of these areas with reference to the schists, and the conformity of the schists as to kind from Rye to New Rochelle and from the latter to Mt. Vernon, are facts favorable to the view that they correspond in origin to the limestone areas of the more western parts of Westchester County.

Over the elevated country between this region and the vicinity of the Harlem railroad, the rock changes to a hard gneiss, thick-bedded and granitoid; and, moreover, outcrops are few, the surface being one of wide fields under cultivation; and this continues northeastward into Western Connecticut. It appears that upon these high plains the earthy material or drift left by the glacier has remained almost undisturbed, instead of being cut through to the rocks as on the slopes that lead to the Sound on one side and to the valley of the Harlem railroad on the other. Along this railroad, limestone again appears, and before reaching it there is a return to micaceous gneiss and mica schist.

Areas 7 *and* 8.—Of these areas at Yonkers, number 7, or the western, follows the course of a north and south bend in Saw Mill River, and has a width of at least 100 feet. It lies beneath the city of Yonkers, and I am indebted for the facts respecting it to Mr. W. W. Wilson, Engineer of the Yonkers Water Works. Indications of a more eastern belt (No. 8) occur along the Saw Mill River valley, just north of the city, in the existence of loose masses of limestone on the east side of the river. But I found no outcrops in my observations along that southern portion of the valley, and its width and length are therefore undetermined. It is possible that the two areas may be one cut into two by a fracture and a horizontal or oblique faulting. The rocks are not open to view for a decision of this point.

Area 9.—This small area, on Grassy Sprain Brook, has a width to the south of 500 yards. The strike is N. 10°–20° E.

Areas 10, 11 *and* 12.—East of the last, on the River Bronx, a limestone belt begins near Bronxville, which, in Tuckahoe and Scarsdale, is the site of many marble quarries. The strike is N. 22°–27° E. This limestone belt tapers out to the south, while to the north, and for the most of its course, it is divided into two parts separated by a band of mica schist and gneiss. It is probable that the whole corresponds to a decapitated anticlinal having its inclined axis dipping at a small angle to the south. To the north of the Scarsdale depot the eastern line is not traceable, and the western line appears to thin out.

Limestone re-appears on the Bronx 100 to 200 rods to the north of the last, just east of the railroad—that of area 11—and thence continues to Hartsville, where the strike is N. 17°–24° E. A narrow strip of low land follows the east side of the Bronx nearly to White Plains, and it is possible that the belt is continued beneath it. About a mile and a half north of White Plains a small area of limestone shows itself, No. 12, the most of the exposure of which is due to the removal of the stratified drift.

Area 13.—Again, along the Hudson, north of Yonkers, occurs the Hastings belt. It was formerly visible at Dobb's Ferry; and it was cut into, as I learn from Mr. Benjamin S. Church, when excavations were going on there for the Croton aqueduct. This river-border belt may have much greater length than is given it on the map, and greater width also; for the high terrace deposits (stratified drift) of the valley conceal all shore rocks. The adjoining schists are gneiss with nearly vertical dip.

b. *Middle Section of the County.*

Areas 14 *and* 15.—In Saw Mill River valley—the same that has its limestone belts near Yonkers—a large limestone area commences, about two and a half miles north of Ashford. It widens much at East Tarrytown and continues northward to a near junction with the Pleasantville area, No. 15. The mean strike for its northern two-thirds is about N. 30° E.

The Pleasantville area also is broad and sinuous in course. It terminates just north of the Chappaqua depot. The strike near Unionville is N. 24° E., and at Pleasantville (where there are large and valuable quarries) mostly N. 30°–40° E. A small independent limestone area (No. 15*a*) occurs just east of the Pleasantville area.

Areas 16 *and* 17.—The long known Sing Sing belt commences south of the depot on the Hudson and extends north-northeast nearly to the north boundary of the town of Ossining; and it also branches eastward up a small valley toward the Camp Woods, a furcation which seems to indicate the existence of an anticlinal fold with the axis dipping southward, which was made thus to furcate by denudation as in the case of the Tremont area, No. 1, the opposite direction of pitch in the axis making the difference in the direction of the furcation.

No. 17 is a small area of contorted limestone giving nothing reliable as to strike or dip.

Areas 18 *and* 19.—A small Croton limestone area, No. 18, exists half a mile east of the village, without distinguishable planes of bedding. Mica schist bounds it on the north; but it may extend in the opposite direction to the bay, where drift and alluvium conceal the rocks.

South of Croton River a narrow area, No. 19, extends from near a bridge northeast of the last, called Quaker Bridge, to the furcation of the river at Huntersville, about two miles, following mostly the west side of the road. Its southern portion has a westward bend, with which the strike of the limestone corresponds.

Areas 20, 21 *and* 22.—No. 20 is a very small area at Merritt's Corners among contorted rocks, giving uncertain strike and dip. No. 21, to the northeast, on the east border of Croton Lake, may be the margin of a long belt following the course of that part of the lake, though such an inference is not suggested by the observed strike. No. 22 is another small area of contorted limestone near Bedford station on the Harlem railroad.

Area 23.—No. 23 lies to the east of the Pleasantville belt on the borders of New York and Connecticut, and follows the course of Byram River to its source in Byram Lake. It was first laid down on Percival's geological map of Connecticut and the limits assigned to it by him are here retained. I found the limestone outcropping along the eastern half of the broad valley. The mean strike to the south is N. 10° E.; and the same east of Armonk. The limestone exists in the lake and was quarried near the northeast when the water was quite low; but I found there no place for observing the strike excepting in the schists about the lake, where the rocks are greatly contorted (see the T-symbols on the map), as if situated about the end of a fold.

Areas 24 *and* 25.—These areas, to the northeast of Byram Lake (first mapped by Percival), are both bow-shaped, but in opposite directions. No. 24 follows a valley along the headwaters of Mianus River, and No. 25, that of Stone Hill River. The limestone outcrops to the east of the village of Bedford show that the bend corresponds with a change in the strike of the beds. In the Stone Hill River belt the strike of the bedding, in its southwestern part, is N. 55° E., but in its eastern, N. 23° E., showing that the bow-shaped form of the valley and outcrop was determined by the direction of the bedding.

c. *Northern Section of the County.*

Some of the areas in the northern part of the Middle section of the county have been shown to tend toward east-and-west in trend and in the strike of the beds. In the Northern section the larger part of the areas have approximately this abnormal course, the normal northeast trend existing only in a large eastern and in some of the northwestern areas.

Area 26.—This is the large eastern area of northeast, or rather north-northeast, trend, just alluded to. It extends into Connecticut and was hence studied by Percival; and our delineation of it is taken from his map. It has a range of mica schist and gneiss situated more or less regularly along its center, which is partly hornblendic, and in view of this fact, it is probable that the area is that of a denuded fold.

Areas 27 *and* 28, *and the small areas in the Verplanck Peninsula.*—These areas have been described on pages 205, 215. I add here that while the rocks on the *north* side of the Cruger's limestone (number 27) are mica schist, and micaceous gneiss with soda-granite, quartz-dioryte and various chrysolitic kinds, those on the *south* side are the ordinary gneisses of Westchester County, containing chiefly orthoclase with some triclinic feldspar, and vary in color from flesh-colored and grayish-white where the feldspar predominates, to black or grayish-black where mica (biotite) is abundant. Of the small limestone areas of the Verplanck Peninsula, No. 2 (see map on page 195) has black dioryte on its northeast side, but on the opposite, and plainly conformable with it, common gneissoid mica schist, and in the schist there are thin beds of limestone.

The Verplanck belt, No. 28, has the normal northeast trend, the strike averaging N. 35° E. (dip 60°–70° E.). But toward the Point there is much variation from this, the strike a third of a mile from the Point changing from N. 44° E. to N. 63° W., and near the river, south of the more northern brickyard, from N. 50° E. to N. 74° E., the dip 40°–70° E.

Areas 29, 30 *and* 30 *A*.—Number 29, another of the northern belts having a northeast course, extends up Sprout Brook Valley or Canopus Hollow, into the Archæan area of Putnam County. Its length is nearly five miles. It adjoins quartzyte conformably at the mouth of the brook (p. 214) with the strike N. 47°–54° E., and dip 60°–70° E.; near the crossing from Peekskill to Annsville, a hydromica slate lies between it and the quartzyte; and just below Annsville, near the river, it lies against Archæan hornblendic gneiss. The most northern outcrop I have found is situated to the west of the south end of Oscawana Lake. The limestone has been already described as for the most part but slightly crystalline, especially in its more southern portion. Two-thirds of a mile north of the Putnam County line, under a bridge over the stream, quartzyte in beds lies against the limestone; and above this at some of the outcrops the limestone is interstratified with mica schist.

The Canopus Hollow belt appears to be continued southwestward, across Hudson River, in the limestone of Tompkins Cove at the foot of the Archæan Highlands. This limestone forms a prominent bluff facing the water and has long been worked for lime. It is in its eastern part a whitish, compact, fine-grained, crystalline limestone, but to the westward a gray, uncrystalline rock. The area extends south-southeast nearly to Stony Point village, about two miles, and disappears because beyond this it is overlaid by the Triassic Red sandstone. The average strike is N. 20° E., and the dip 35° to 60° E. Just southwest of Stony Point it is covered by a grayish to reddish limestone conglomerate made up of pebbles and rounded stones which are worn fragments of the limestone bed; and this conglomerate is referred by Professor G. H. Cook to the Triassic.

Although the average strike of the beds of the limestone is as above stated, there are great variations at the Cove, they becoming even east-and-west in some parts. At the Cove the limestone has on its *western* side, a blackish, fragile, partly graphitic slate or hydromica schist (called talcose slate by Mather), resembling that of Canopus Hollow north of Peekskill, which, half a mile south, changes to a quartzose rock, partly feldspathic, resembling the granitoid quartzyte of Peekskill.

On its *eastern* side, toward the base of Stony Point, it is followed conformably by mica schist and micaceous gneiss, (good contacts being visible), having the strike (like the beds of limestone adjoining) N. 14°–20° E., and dip 60° E. This thin-schistose micaceous rock is followed eastward on the coast by a massive granitoid rock which is intermediate lithologically between soda-granite and ordinary granite, the feldspar being half orthoclase. Then succeed the noryte and chrysolitic rocks of the areas marked *z′* and *z* on the map on page 195, then the soda-granite of *y*, and lastly, near the extremity of the Point, the mica schist or micaceous gneiss of *x*. The succession along the *north* side of the Point from west to east thus is: (1) schist, (2) semi-soda-granite, (3) chrysolitic rocks, (4) soda-granite, (5) schist. Going between these points by the *south* a wholly different state of things is found; *schist continues all the way; and the strike varies from N. 20° E. where it adjoins the limestone, through northwest and west-and-east, to N. 62° –70° E.*, which is the strike on the south side of the Point, south of the eastern soda-granite, as already stated (page 213). This change of strike in the schist indicates a broad flexure, with the sides diverging to the northeastward. Inside of this flexure there are first the soda-granite, and then at or near the middle the chrysolitic rocks. But, as I have found, the soda-granite is interrupted south of the chrysolitic area, schist having its place, as if by a change of soda-granite to schist. The schist is mostly even in its bedding except about the bend, where it is much contorted. As near Cruger's, transitions exist of the schist into the soda-granite with the rock very garnetiferous at the junction—a good example of which may be seen northeast of the house on the south side of the point.

Notwithstanding doubts on some points, there is no question that the schist has the flexure pointed out, and is one continuous stratum; and that the limestone is an adjoining stratum, and must have participated in the flexure. Further, since the dip of the schist on both the south and west sides is toward the axis of the flexure, *the limestone stratum is probably an underlying one*, which would make the schist and soda-granite superior to it in stratigraphical position. Now *since the Cruger's limestone adjoins a schist that is similar to that of Stony Point in kind, and position, and in all of its relations to the soda-granite, the Cruger's limestone must be of the same stratum with the Tompkins' Cove limestone; and, if so, it is one, also, with the limestone of Canopus Hollow.*

The area Number 30 is like 29 in extending along a prominent valley—Peekskill Hollow—northeastward *far into the Archæan.* The most northern locality of limestone which I have found is a mile and a half above Tompkins' Corners (west of the mouth of Roaring Brook) about seven miles northeast of Oregon—a village on the borders of the two counties. It is a fine-grained white to blue limestone and occurs with a well characterized quartzyte in conformable beds, unconformable to the Archæan. It shows itself also about Adams Corners, two to three miles above Oregon, and near Oregon, at the spot marked by the T-symbols. Below this, there are no outcrops of rock, and its limits southwestward are consequently undetermined. This valley—Peekskill Hollow—is so narrow for much of the way above Adams Corners that it is probable that the limestone is not continuous, but that the present spots are what is left after long denudation. There can be no reasonable doubt that the large, open valley was once the course of a broad band of the limestone for the whole of the seven miles in Putnam County.

The facts observed with respect to area 30 A and the associated mica schist and quartzyte are mentioned on page 214. Mather speaks of an outcrop of limestone, with "hornblende rock adjoining it on the east," at the Lower Dock of Peekskill. This spot is now graded over and the observation cannot be confirmed; but it lies in the line of this area where it would reach the river. If it is correct, the rock which adjoins the limestone in this part is noryte, and no mica schist intervenes between this rock and the limestone, as it does 150 yards north.

To the eastward, in Peekskill village, there is limestone in the mica schist on the Crom Pond road, according to Mather; and north of the Academy grounds there appears to be an outcrop in the road; and this lies on the south margin of the valley in which this area occurs. The limit of the area eastward is not determinable; it may possibly connect with that of Peekskill Hollow, though this seems to be hardly probable.

Areas 31, 32, 33, 34 *and* 35.—Number 31, in the southern part of Somers, east of Hallock's Mills, trends nearly east and west; it is made up of two parts, a western and eastern, the strike in the former N. 53° E., and that in the latter east-and-west.

Number 32, in North Somers, east of Somers Center, is another nearly east-and-west area, the strike averaging N. 71° E. Numbers 33, 34 are small areas, too limited in extent of outcrop to determine their characters, beyond that of an approximately east-and-west trend. No. 35, or that of Lake Waccabuc, has, according to Percival, the extent given it on the map. I have seen outcrops only between the lake and the pond west of it.

Areas 36, 37 *and* 38.—The large North Salem belt, No. 36, first laid down by Percival, is six miles long, and has an east-and-west course. It has in some parts a band of gneiss along the middle, indicating that it is a denuded fold. Number 37 follows the course of Beaver Pond, and has a precipitous face of rocks on the north. Number 38 is like the preceding in course, and in its being an extension of a Connecticut area—that of Mill-Plain valley, which reaches to Danbury. Its most western outcrops are in the road between Brewster and Danbury, less than a mile and a half from the former place. These two east-and-west belts on Percival's map I at first viewed with distrust, since the fact expressed on the map was not fortified by any statements as to the strikes which he had obtained. But I found on examining the regions that the adjoining schist (gneiss and mica schist), as well as limestone sustained his map. The maker of Mather's map had the same wrong preconceptions, and put it into his delineation of the areas. The T-symbols on the accompanying chart make manifest the fact as to this position of the rocks.

3. GENERAL CONCLUSIONS.

Taking into consideration the facts that have been presented from Westchester County, those brought out with regard to the Green Mountain region of Vermont, Massachusetts, Connecticut, and Dutchess County in Eastern New York, and the observations on record from the region of the Highlands in New York and New Jersey, we have, I believe, sufficient grounds for the following statements.

The limestones and adjoining schists of Westchester County—

(1) *are one in series and system of disturbance.*

(2) *are probably part of the Green Mountain system.*

(3) *are younger than the Highland Archæan.*

(4) *are probably of the age of the Lower Silurian*—the Primordial or Cambrian being included under this designation.

(5) There are reasons for concluding also that they were made before the channel of the Hudson was cut through the Highlands; and the question will come up, finally, What bearing this may have had, if any, on the origin of the rocks of the "Cortland series."

1. *The Limestone and adjoining Schists one in series.*

From the facts presented on the map and in the preceding pages, and better from the special details as to the position of the beds and kinds of rocks given beyond in the Appendix, the important conclusion is derived that, throughout the county, the limestone of the several areas is conformable in its bedding to the schists which in each case adjoin it. There are contortions in the limestone, and in many places also in the schists; but this is so because such uplifting necessarily involved a warping of the beds, and was often attended also by torsion. The limestone areas are commonly the positions of upward or downward folds or flexures, with usually the axis in each case inclined in the direction of the fold and the axial plane also inclined to one side or the other; and in the making of them, contortions should have been often produced. The small serpentine area at Rye, No. 6, is a striking illustration; and the north end of area 23 is another. The varying strikes between areas 24 and 25 show the effects of torsion and the interference of the near extremities of two curving folds.

2. *Relation to the Green Mountain System.*

With reference to the relation of the rocks of the county to the Green Mountain system there are the following facts:

(1.) Westchester County is topographically a southern part of the Green Mountain elevation. The axis passes along the interlocking borders of Connecticut and New York, and extends on through New York Island.

(2.) The grade of metamorphism follows the same rule as to the north—that is, it is of greatest intensity to the eastward and to the southward. It is in accordance with this that the least degrees of metamorphism are found in the limestone and associated schists of the vicinity of Peekskill, in the northwest corner, while along the central and eastern portions of the county, and in the western, also, south of Croton, the crystallization is commonly very coarse. The limestone of the Verplanck, Cruger's and Croton areas (Nos. 28, 27, 18), are of intermediate texture.

(3.) The limestones have the same kinds of associated rocks, that is, of mica schists and gneisses, as in the eastern and more metamorphic portion of the region in Connecticut—a fact deserving mention though not of great weight.

(4.) The limestones have a like paucity in disseminated minerals and similar occurring species with those of Connecticut; mica (muscovite) and tremolite being the common kinds, white pyroxene of occasional appearance, and graphite sometimes present.

(5.) The ordinary normal trend of the rocks, N. 20° E. to N. 30° E., is very nearly the average trend of the beds of limestone and associated rocks in the Green Mountain system.

Through the Southern and Middle sections of Westchester County this trend or strike is almost uniform, except where great contortions occur; and on the east, this strike is continued northward into Connecticut. In the Northern section, on the contrary, the exceptions, excluding its eastern and northwestern portions, are almost universal; and the question is a serious one whether another system is not here represented. But, in opposition to this inference, we observe that the limestones and associated rocks are the same in character in both parts; moreover, there are in some portions of the Middle section large bends, and in the region of limestone areas 19, 24 and 25, a bend from nearly east-and-west to nearly north and south. Area 25 cannot be separated by its associated rocks from the adjoining area 26, which is normal in trend or in the strike of its rocks. Again, while area 29, to the northwest, is normal in its course, area 30 A, which is essentially conformable as the intervening rocks show, is nearly east and west. Through these areas or belts of intermediate curves the system of the Middle and Southern sections of the county graduates into that of the Northern. My study of the position of the beds has not resulted in the discovery of any want of conformity between the rocks of different areas except such as can be traced to contortion. The east-and-west and northeast trends appear therefore to have been results of one and the same system of disturbance.

This argument with reference to the relation of the rocks to those of the Green Mountain system cannot be regarded as wholly satisfactory without a fuller presentation of the facts from the adjoining portions of Connecticut, and this will be given in another number of this Journal.

3. *The limestone and associated rocks are younger than the Archæan of the Highlands.*

The proof with regard to this relation to the Archæan rocks of the Highland area must be looked for along those limestone belts that most closely adjoin it. The lithological evidence as to diversity of age is weak; for while the gneisses of Westchester Co. are usually much more schistose and micaceous than the Archæan, and while, also, the Archæan gneisses are generally hornblendic, there are gradations between the two in both respects which make the application of a lithological test very perplexing. The condition and position of the limestone areas which border the Archæan in the vicinity of Peekskill afford us a safe conclusion, and this is strengthened by other facts from the western portion of this area on the west side of Hudson River.

The region affords three classes of decisive facts.

(1.) The rock adjoining the Archæan in the southern part of Canopus Hollow near Annsville is a bluish slightly crystalline limestone, so slightly that it might for all this contain fossils. This nearly uncrystalline condition characterizes the limestone for a mile up the valley though not in so extreme a degree; and beyond this it has nowhere the coarseness of the limestones to the south.

(2.) The limestone area is bordered on its west side, opposite

Annsville, by a fine-grained hydromica schist which looks as much like argillyte as the Dutchess County slates at Poughkeepsie that contain Hudson River fossils; and this argillyte-like rock occurs at other points up Canopus Hollow, forming hills on its eastern side, and outcropping occasionally on the west side. Its feeble degree of crystallization corresponds with that of the limestone. Both rocks in this respect are like the rocks of Dutchess County, and unlike anything found in the Highland Archæan.

(3.) The limestone at the locality near Annsville lies unconformably against hornblendic Archæan gneiss, its beds much contorted; and another similar case of unconformability exists on the east border, half a mile northeast. In general, both in this valley and Peekskill Hollow, actual contacts are not in sight owing to the earth or alluvium of the valley; and the upturning of the limestone and its associated schist has usually placed them in near conformity to the strike of the Archæan rocks. Still, the unconformability is in some places distinct. Moreover the mica schist involved with the limestone in the more northeastern outcrops is very unlike the hard hornblendic gneiss of the adjoining Archæan.

The limestone of Peekskill Hollow is very finely crystalline, even at its most northeastern outcrop, and at Oregon it is associated with the same argillyte-like hydromica slate that occurs along Canopus Hollow.

West of the Hudson River at Tompkins Cove, where a high bluff of the limestone stands on the river directly facing Verplanck Point, much of it is even less crystalline than near Annsville, and the more western portion of it differs little from the ordinary blue limestone of uncrystalline regions. I had slices made for microscopic study, but detected nothing organic. The slate which lies between it and the Archæan gneiss of the adjoining Highlands—talcose slate of Mather—is only a glossy argillyte in aspect though representing (as Mather observes) the hydromica schist of Canopus Hollow east of the Hudson. No direct junction of the Archæan is here visible. A semi-crystalline condition also characterizes, for the most part, the limestone of the Verplanck belt,[23] and that of Cruger's area. We find thus that the nearer to the Highland Archæan the less is the degree of crystallization, which would not be the case if the rocks were of the age of the Highland Archæan.

Inasmuch then as the Westchester rocks are newer than the Highland Archæan, the limestone belts of Canopus Hollow and Peekskill Hollow occupy Archæan valleys—valleys that

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[23] The limestone of the *small* areas of the Verplanck peninsula, situated in the hornblendic and augite rocks, is often graphitic and more coarsely crystalline than that of the Point.

antedate the era of the limestone; and these broad and strongly marked valleys were arms of the sea in that era, stretching a third to a half of the way across the Putnam County Highland region. In these extensive bays the limestone and the associated stratified deposits, now slate or schist and quartzyte, were formed. Since, also, the limestone now in these valleys is what is left after long ages of denudation, it has but a small part of the breadth and thickness which belonged originally to the formation.

From the fact of the preëxistence of the Archæan Highlands, we appear to have also a reason for the contortions of the rocks in the northern half of Westchester County, and for the nearly east-and-west courses in the bedding. For in the upturning or flexing of the strata, which took place, and which put the beds in nearly vertical positions over the whole county, the Archæan stood as a stable barrier on the north; against it the rocks were forced by the lateral pressure that produced the great results. The *mass* of the Archæan has here an easterly trend, much more easterly than that of the New Jersey Archæan, although the strike of the Archæan beds is generally northeast.[24] The direction of the pressure and the resistance to movement in such a barrier, are the chief of the conditions that would have determined the direction of the folds, fractures and faults in the disturbed strata.

[To be continued.]

ART. XL.—*Paleontological and Embryological Development.* Address by ALEXANDER AGASSIZ, Vice-president of Section B, at the recent Boston Meeting of the American Association for the Advancement of Science.

[Continued from page 302.]

Taking up now the embryological development of the several families which will form the basis of our comparisons, beginning with the Cidaridæ, we find that in the earliest stages they very soon assume the characters of the adult, the changes being limited to the development of the abactinal system, the increase in number of the coronal plates, and the modifications of the proportionally gigantic primary radioles.

In the Diadematidæ the changes undergone by the young are limited to the gradual transformation of the embryonic spines into those which characterize the family, to the changes

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[24] In New Jersey, also, the trend of the mass of the Archæan has more easting according to Prof. G. H. Cook, as brought out in his New Jersey Geological Report (1868), than the strike of its beds, the former being about northeast and the latter north-northeast.

of the vertical row of pores in the ambulacral area into the arcs of three or four pairs of pores, and to the specialization of the actinal and abactinal systems.

In the Arbaciadæ the young stages are remarkable for the prominent sculpture of the test, for the flattened spines, for their simple poriferous zone, for their actinal system, and for their genital ring. The anal plates appear before the genital ring.

In the Echinometradæ the young thus far observed are characterized by the small number of their primary tubercles, the large size of the spines, the simple vertical row of pores, the closing of the anal ring by a single plate, and the turban-shaped outline of the test. Little by little, the test loses with increasing age this Cidaris-like character; it reminds us, from the increase in the number of its plates, more of Hemicidaris; then, with their still greater increase, of the Pseudodiadematidæ; and, finally, of the Echinometradæ proper. The spines, following *pari passu*, the changes of the test, lose little by little their fantastic embryonic, or rather Cidaris-like appearance, and become more solid and shorter, till they finally assume the delicately fluted structure characteristic of the Echinometradæ. The vertical poriferous zone is first changed into a series of connected vertical arcs, which become disjointed, and form, with increasing age, the independent arcs of pores, composed of three or more pairs of pores, of the Echinometradæ.

In the Echinidæ proper we find in the young stages the same unbroken vertical line of pores, which gradually becomes changed to the characteristic generic types. We find, as in the Echinometradæ, an anal system closed with a single plate, and an abactinal system separating in somewhat more advanced stages from the coronal plates of the test. This is as yet made up of a comparatively small number of plates, carrying but few large primary tubercles, with fantastically shaped spines entirely out of proportion to the test, but which, little by little, with the increase of the number of coronal plates, the addition of primary tubercles, and their proportional decrease in size, assume more and more the structure of the genus to which the young belongs. The original anal plate is gradually lost sight of from the increase in number of the plates covering the anal system, and it is only among the Temnopleuridæ that this anal plate remains more or less prominent in the adult. In the Salenidæ, of which we know as yet nothing of the development, this embryonic plate remains permanently a prominent structural feature of the apical system.*

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* The young of the following genera have served as a basis for the preceding analysis of the embryonic stages of the Desmosticha: Cidaris, Dorocidaris, Goniocidaris, Arbacia, Podocidaris, Strongylocentrotus, Echinometra, Echinus, Toxopneustes, Hipponoë, Temnopleurus, Temnechinus, and Trigonocidaris.

Among the Clypeastroids the changes of form they undergo during growth are most instructive. We have in the young Fibularinæ an ovoid test, a small number of coronal plates surmounted by few and large primary tubercles, supporting proportionally equally large primary radioles, simple rectilinear poriferous zones, no petaloid ambulacra,—in fact, scarcely one of the features we are accustomed to associate with the Clypeastroids is as yet prominently developed. But rapidly, with increasing size, the number of primary tubercles increases, the spines lose their disproportionate size, the pores of the abactinal region become crowded and elongate, and a rudimentary petal is formed. The test becomes more flattened, the coronal plates increase in number, and it would be impossible to recognize in the young Echinocyamus, for instance, the adult of the Cidaris-like or Echinometra-like stages of the Sea-urchin, had we not traced them step by step. Most interesting, also, is it to follow the migrations of the anal system, which, to a certain extent, may be said to retain the embryonic features of the early stages of all Echinoderm embryos, in being placed in more or less close proximity to the actinostome. What has taken place in the growth of the young Echinocyamus is practically repeated for all the families of Clypeastroids; a young Echinarachnius, or Mellita, or Encope, or a Clypeaster proper, resembles at first more an Echinometra than a Clypeastroid; they all have simple poriferous zones and spines and tubercles out of all proportion to the size of the test.*

When we come to the development of the Spatangoids, we find their younger stages also differing greatly from the adult. Among the Nucleolidæ, for instance, the young stages have as yet no petals, but only simple rectilinear poriferous zones. They are elliptical with a high test, with a single large primary tubercle for each plate, and a simple elliptical actinostome, without any trace of the typical bourrelets and phyllodes so characteristic of this family. Very early, however, this condition of things is changed, the test soon becomes more flattened, the petals begin to form as they do in the Clypeastroids, and we can soon trace the rudiments of the peculiar bourrelets characteristic of the family, accompanied by a rapid increase in the number of tubercles and in that of the coronal plates.

Among the Spatangidæ some are remarkable in their adult condition for their labiate actinostome, for the great development of the petals, for the presence of fascioles surrounding certain definite areas, for the small size of the tubercles, the general uniformity in the spines of the test, and the specialization of their anterior and posterior regions. On examining the

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* Among the Clypeastroids I have examined the young of Echinocyamus, Fibularia, Mellita, Laganum, Echinarachnius, Encope, Clypeaster, and Echinanthus.

young stages of this group of Spatangoids, not one of these structural features is as yet developed. The actinostome is simple, the poriferous zone has the same simple structure from the actinostome to the apex, the primary tubercles are large, few in number, surrounded by spines which would more readily pass as the spines of Cidaridæ than of Spatangoids. The fascioles are either very indistinctly indicated, or else the special lines have not as yet made their appearance; the ambulacral suckers of the anterior zones are as large and prominent as those of the young stages of any of the regular Echini. It is only little by little, with advancing age, that we begin to see signs of the specialization of the anterior and posterior parts of the test, that we find the characteristic anal or lateral fascioles making their appearance, only with increasing size that the spines lose their Cidaris-like appearance, that the petals begin to be formed, and that the simple actinostome develops a prominent posterior lip. In the genus Hemiaster, the young stages are specially interesting, as long before the appearance of the petals, while the poriferous zone is still simple, the total separation of the bivium and of the trivium of the ambulacral system, so characteristic of the earliest Spatangoids (the Dysasteridæ), is very apparent.*

From this rapid sketch of the changes of growth in the principal families of the recent Echini we can now indicate the transformation of a more general character through which the groups as a whole pass.

In the first place, while still in the Pluteus all the young Echini are remarkable for the small number of coronal plates, and for the absence of any separation between the actinal and abactinal systems and the test proper. They all further agree in the large size of the primary spines of the test, whether it be the young of a Cidaris, an Arbacia, an Echinus, a Clypeaster, or a Spatangoid. They all in their youngest stages have simple vertical ambulacral zones; beyond this, we find as changes characteristic of some of the Desmosticha, the specialization of the actinal system from the coronal plates, the formation of an anal system, the rapid increase in the number of the coronal plates, with a corresponding increase in the number of the spines and a proportional reduction of their size, the formation of an abactinal ring, and the change of the simple vertical poriferous zone into one composed of independent arcs.

In the Spatangoids and Clypeastroids we find common to both groups the shifting of the anal system to its definite place, the modifications of the abactinal part of the simple ambulacral

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* For this sketch of the embryology of the Petalosticha I have examined the young of Echinolampas, Echinoneus, Echinocardium, Brissopsis, Agassizia, Spatangus, Brissus, and Hemiaster.

system in order to become petaloid, and the gradual change of the elliptical ovoid test of the young to the characteristic generic test, accompanied by the rapid increase in the number of the primary tubercles and spines. Finally limited to the Spatangoids are the changes they undergo in the transformation of the simple actinostome to a labiate one, the specialization of the anterior and posterior parts of the test, and the definite formation of the fascioles.

Comparing this embryonic development with the paleontological one, we find a remarkable similarity in both, and in a general way there seems to be a parallelism in the appearance of the fossil genera and the successive stages of the development of the Echini as we have traced it.

We find that the earlier regular Echini all have more or less a Cidaris-like look,—that is, they are Echini with few coronal plates, large primary tubercles, with radioles of a corresponding size; that it is only somewhat later that the Diademopsidæ make their appearance, which, in their turn, correspond within certain limits to the modifications we have traced in the growth of the young Diadematidæ and Arbaciadæ. The separation of the actinal system from the coronal plates has been effected. The poriferous zone has either become undulating, or forms somewhat indefinite open arcs; we find in all the genera of this group a larger number of coronal plates, more numerous primaries, the granules of the Cidaridæ replaced by secondaries and miliaries, and traces of a Hemicidaris-like stage in the size of the actinal ambulacral tubercles.

Comparing in the same way the paleontological development of the Echinidæ proper, we find that, on the whole, they agree well with the changes of growth we can still follow to-day in their representatives, and that, as we approach nearer the present epoch, the fossil genera more and more assume the structural features which we find developed last among the Echinidæ of the present day. Very much in the same manner as a young Echinus develops, they lose, little by little, first their Cidaridian affinities, which become more and more indefinite, next their Diadematidian affinities, if I may so call the young stages to which they are most closely allied, and, finally, with the increase in the number of the coronal plates, the great numerical development of the primary tubercles and spines, and that of the secondaries and miliaries which we can trace in the fossil Echini of the Tertiaries, we pass insensibly into the generic types characteristic of the present day.

Although we know nothing of the embryology of the Salenidæ, yet, like the Cidaridæ, they have in a great measure remained a persistent type, the modifications of the group being all in the same direction as those noticed in the other Desmosticha; a greater number of coronal plates, the development of secondaries and miliaries combined with a specialization of the actinal system not found in the Cidaridæ.

An examination of the succession of the Echinoconidæ shows but little modification from the earliest types; the changes, however, are similar to those undergone by the Clypeastroids and Petalosticha, though they do not extend to modifications of the poriferous zone, but are mainly changes in the actinostome and in the tuberculation. In fact, the group of Echinoconidæ seems to hold somewhat the same relation to the Clypeastroids which the Salenidæ hold to the Cidaridæ, and the earliest genus of the group (Pygaster) has remained, like Cidaris, a persistent type to the present day.

The earliest Clypeastroids are all forms which resemble the Fibularina and the genera following Echinocyamus and Fibularia; they are mainly characterized by the same changes which an Echinarachnius or a Mellita, for instance, undergoes as it passes from its Echinocyamus stage to the Laganum or Encope stage. The comparison is somewhat more complicated when we come to the Spatangoids. The comparison of the succession of genera in the different families, as traced in the Desmosticha and Clypeastroids, is made difficult from the persistency of the types preceding the Echinoneidæ and the Ananchytidæ, which have remained without important modifications from the time of the lower Cretaceous; previous to that time the modifications of the Cassidulidæ are found to agree with the changes which have been observed in the growth of Echinolampas. The early genera, like Pygurus, have many of the characteristics of the test of the young Echinolampas. The development of prominent bourrelets and of the floscelle and petals goes on side by side with that of genera in which the modification of the actinostome, of the test, and of the petals is far less rapid, one group retaining the Echinoneus features, the other culminating in the Echinolampas of the present day, and having likewise a persistent type, Echinobrissus, which has remained with its main structural features unchanged from the Jura to the present day. That is, we find genera of the Cassidulidæ which recall the early Echinoneus stage of Echinolampas, next the Caratomus stage, after which the floscelle, bourrelets, and petals of the group become more prominent features of the succeeding genera. Accompanying the persistent type Echinobrissus, genera appear in which either the bourrelets or petals have undergone modifications more extensive than those of the same parts in the genera of the Echinoneus or Caratomus type.

The earliest Spatangoids belong to the Dysasteridæ, apparently an aberrant group, but which, from the history of the young Hemiaster, we now know to be a strictly embryonic type, which, while it thus has affinities with the true Spatangoids, still retains features of the Cassidulidæ in the mode of development of the actinostome and of the petals, as well as of the anal system. The genera following this group, Holaster and Toxaster, can be well compared, the one to the young stages of Spatangus proper before the appearance of the petals, when the ambulacra are flush with the test, and when its test is more or less ovoid, the other to a somewhat more advanced stage, when the petals have made their appearance as semipetals. In both cases the actinostome has the simple structure characteristic of all the young Spatangoids. The changes we notice in the genera which follow them lead in the one case through very slight modifications of the abactinal system, of the anterior and posterior extremities of the test, to the Ananchytid-like Spatangoids of the present day, the Pourtalesiæ, the genus Holaster itself persisting till well into the middle of the Tertiary period; while on the other side we readily recognize in the Spatanginæ which follow Toxaster (a persistent type which has continued as Palæostoma to the present day) the genera which correspond to the young stages of such Spatangoids as Spatangus and Brissopsis of the present day, genera which, on the one hand, lead from Hemiaster (itself still represented in the present epoch), through stages such as Cyclaster, Peripneustes, Brissus, and Schizaster, and, on the other, through Micraster and the like, to the Spatangoids, in which the development of the anal plastron and fasciole performs an important part, while in the former group the development of the peripetalous fasciole and of the lateral fasciole can be followed. None of the genera of Petalosticha belonging to the other groups develop any fasciole in the sense of circumscribing a limited area of the test.

The comparison of the genera of Echini which have appeared since the Lias with the young stages of growth of the principal families of Echini, shows a most striking coincidence amounting almost to identity between the successive fossil genera and the various stages of growth. This identity can, however, not be traced exactly in the way in which it has usually been understood, while there undoubtedly exists in the genera which have appeared one after the other a gradual increase in certain families in the number of forms, and a constant approach in each succeeding formation, in the structure of the genera, to those of the present day. It is only in the accordance between some special points of structure of these genera and the young stages of the Echini of the present day that we can trace an agreement which, as we go further back in time, becomes more and more limited. We are either compelled to seek for the origin of many structural features in types of which we have no record, or else we must attempt to find them existing potentially in groups where we had as yet not succeeded in tracing them. The parallelism we have traced does not extend to the structure as a whole. What we find is the appearance among the fossil genera of certain structural features giving to the particular stages we are comparing their characteristic aspect. Thus, in the succession of the fossil genera, when a structural feature has once made its appearance, it may either remain as a persistent structure, or it may become gradually modified in the succeeding genera of the same family, or it may appear in another family, associated with other more marked structural features which completely overshadow it. Take, for instance, among the Desmosticha the modifications of the poriferous zone of the actinal and abactinal systems of the coronal plates, of the ambulacral and interambulacral systems, the changes in the relative proportion of the primary tubercles, and the development of the secondaries. These are all structural features which are modified independently one of the other; we may find simultaneous development of these features in parallel lines, but a very different degree of development of any special feature in separate families.

This is as plainly shown in the embryological as in the paleontological development. In the Cidaridæ there is the minimum of specialization in these structural features. In the Diademopsidæ there is a greater range in the diversity of the structure of the poriferous zone and of the coronal plates, as well as of the actinal system. There is a still greater range among the Echinidæ, while among the Salenidæ the modifications, as compared to those of the Echinidæ and Diademopsidæ, are somewhat limited again, being restricted as far as relates to the poriferous zone and coronal plates, but specialized as far as the actinal system is concerned, and specially important with reference to the structure of the apical system. The special lines in which these modifications take place produce, of course, all possible combinations, yet they give us the key to the sudden appearance, as it were, of structural features of which the relationship must be sought in very distantly related groups. It is to this specialty in the paleontological development that we must trace, for instance, the Cidarid affinities of the Saleniæ, their papillæ, the existence of few large primary interambulacral tubercles, the structure of their apical system, and their large genital plates; while it is to their affinities with the Hemicidaridæ that we must refer the presence of the few larger primary ambulacral tubercles at the base of the ambulacral area, and by their Diademopsid and Echinidian affinities that we explain the indented imbricated actinal system with the presence of a few genuine miliaries. But all the structural features which characterize the earliest types of the Desmosticha can in reality be traced, only in a somewhat rudimentary form, even in the Cidaridæ. The slight undulation of the closely packed, nearly vertical poriferous zone is the forerunner of the poriferous zone first separated into vertical arcs and then into independent arcs. The limitation in the number of the rows of granules in the ambulacral zone, and their increase in size, is the first trace of the appearance of the somewhat larger primary ambulacral tubercles of the Hemicidaridæ and Saleniæ. The existence of the smooth cylindrical spines of the abactinal region of the test naturally leads to similar spines covering the whole test in the other families of the Desmosticha. The difference existing in the plates covering the actinal system from those of the coronal plates leads to the great distinction between the structure of the actinal system and of the coronal plates in some of the Echinidæ.

Passing to the Clypeastridæ and Petalosticha, we trace a parallelism of the same kind, and readily follow in the successive genera of fossil Clypeastroids, but often in widely separated genera, the precise modifications which the poriferous zone has undergone as it first becomes known to us in Echinocyamus and Fibularia, and as we find it in the most complicated petaloid stage of the Clypeastroids of the present day. We readily trace the changes the test undergoes from its comparatively ovoid and swollen shape to assume first that of the less gibbous forms, next that of the Laganidæ, and finally of the flat Scutellidæ; while we trace in the Echinanthidæ the persistent structural features of some of the earliest Clypeastroids, together with an excessive modification of the poriferous zone. Likewise for the Echinoconidæ we trace mainly the slight modifications of the poriferous zone and of the coronal plates, and finally, when we come to the Spatangidæ we find no difficulty in tracing from the most Desmostichoid of the Spatangoid genera, the modifications of a test in which the ambulacral and interambulacral areas are made up of plates of nearly uniform size, in which the anterior and posterior extremities are barely specialized, to the most typical of the Ananchytidæ, in which the anterior and posterior extremities have developed the most opposite and extraordinary structural features. In a similar way we can trace among the fossil genera of different families the gradual development of the actinal plastron from its very earliest appearance as a modification of the posterior interambulacral area of the actinal side, or the growth of the posterior beak into an anal snout, the successive changes of the anal groove, the formation of the actinal labium, or the development of the bourrelets and phyllodes from a simple circular actinostome, the gradual deepening of the slight anterior groove of some early Spatangoid to form the deeply sunken actinal groove. Equally well we can trace the modifications of the ambulacral system as it passes from the simple poriferous zones of the earlier Spatangoids to genera in which the petaliferous portion makes its appearance, and finally becomes the specialized structure of our recent Spatangoid genera, such as Schizaster, Moira, and the like. Finally, we can trace to a certain extent the development of the fascioles on one side from genera like Hemiaster, in which the peripetalous fasciole is prominent, to genera like Brissopsis, Brissus, and the like, of the present day; on the other, perhaps, or in both combined, the formation of a lateral and anal fasciole from genera like Micraster in Spatangus and Agassizia. Thus we must, on the same theory of the independent modifications of special structural features, trace the many and complicated affinities which so constantly strike us in making comparative studies, and which render it impossible for us to express the manifold affinities we notice, without taking up separately each special structure. Any attempt to take up a combination of characters, or a system of combinations, is sure to lead us to indefinite problems far beyond our power to grasp.

In the oldest fossil Clypeastroids and Petalosticha, as well as in the Desmosticha, we also find the potential expression of the greater number of the modifications subsequently carried out in genera of later date. The semipetaloid structure of some of the earlier genera of Spatangoids, the slight modifications of some of the plates of the actinal side near the actinostome, are the precursors, the one of the highly complicated petaloid ambulacra of the recent Spatangoids, the other of the actinal plastron, leading as it does also to the important differences subsequently developed in the anterior and posterior extremities of the test, as well as to the modifications which lead to the existence of a highly labiate actinostome. The appearance of a few miliaries near the actinostome constitutes the first rudimentary bourrelets.

Going back now to the Palæchinidæ, the earliest representatives of the Echini in palæozoic times, without any attempt to trace the descent of any special type from them, we may perhaps find some clew to the probable modifications of their principal structural features preparatory to their gradual disappearance. In the structure of the coronal plates, the specialization of the actinal and abactinal systems, the conditions of the ambulacral system, we must compare them to stages in the embryonic development of our recent Echini with which we find no analogues in the fossil Echini of the Lias and the subsequent formations. In order to make our parallelism, we must go back to a stage in the embryonic history of the young Echini in which the distinction to be made between the ambulacral and interambulacral systems is very indefinite, in which the apical system is, it is true, specialized, but in which the actinal system remains practically a part of the coronal system. But here the comparison ceases, and, although we can trace in the paleontological development of such types as Archæocidaris or Bothriocidaris modifications which would lead us without great difficulty, on the one side to the Cidaridæ, and on the other to the Echinothuriæ and Diadematidæ of the present day, we cannot fail to see most definite indications in some of the structural features of the Palæchinidæ of characteristics which we have been accustomed to associate with higher groups. The minute tuberculation, for instance, of the Clypeastroids and Spatangoids, already existing in the Melonitidæ, the genital ring, and anal system, are quite as much Echinid as Cidarid. The polyporous genera of the group represent to a certain extent the polypori of the regular Echini, and the lapping of the actinal plates of the Cidaridæ and of the coronal plates in some of the Diadematidæ, as well as the existence of such genera as Tetracidaris, of four interambulacral plates in Astropyga, and of a large number of ambulacral plates in some of the recent Echinometradæ, all these are Palæchinid characters which we can explain on the theory of the independent development of the structural features of which they are modifications. We should, however, remember, that the existence of a large number of coronal plates, especially interambulacral plates, in the Palæchinidæ, is a mere vegetative character, which they hold in common with all the Crinoids,—a character which is reduced to a minimum among the Holothurians, and still persists in full force among the Pentacrini of the present day, as well as the Astrophytidæ and Echinidæ.

It would lead me too far to institute the same comparison between the embryonic stages of the different orders of Echinoderms and their earliest fossil representatives. We may, however, in a very general way, state that we know the earliest embryonic stages of the orders of Echinoderms of to-day, which, with the exception of the Blastoidea and Cystideans, are identical with the fossil orders, and that as far as we know they all begin at a stage where it would be impossible to distinguish a Sea-urchin from a Star-fish, or an Ophiuran, or a Crinoid, or an Holothurian,—a stage in which the test, calyx, abactinal and ambulacral systems are reduced to a minimum. From this identical origin there is developed at the present day, in a comparatively short period of time, either a Star-fish, a Sea-urchin, or a Crinoid; and if we have been able successfully to compare, in the development of typical structures, the embryonic stages of the young Echini with their development in the fossil genera, we may fairly assume that the same process is applicable when instituting the comparison within the different limits of the orders, but with the same restrictions. That is, if we wish to form some idea of the probable course of transformations which the earliest Echinoderms have undergone to lead us to those of the present day, we are justified in seeking for our earliest representatives of the orders such Echinoderms as resemble the early stages of our embryos, and in following, for them as for the Echini, the modifications of typical structures. These we shall have every reason to expect to find repeated in the fossils of later periods, and, going back a step further, we may perhaps get an indefinite glimpse of that first Echinodermal stage which should combine the structural features common to all the earliest stages of our Echinoderm embryos.

And yet, among the fossil Echinoderms of the oldest periods, we have not as yet discovered this earliest type from which we could derive either the Star-fishes, Ophiurans, Sea-urchins, or Holothurians. With the exception of the latter, which we can leave out of the question at present, we find all the orders of Echinoderms appearing at the same time. But while this is the case, one of the groups attained in these earliest days a prominence which it gradually loses with the corresponding development of the Star-fishes, Ophiurans, and Sea-urchins, it has steadily declined in importance; it is a type of Crinoids, the Cystideans which culminated during Paleozoic times, and completely disappeared long before the present day. If we compare the early types of Cystideans to the typical embryonic Echinodermal type of the present day, we find they have a general resemblance, and that the Cystideans and Blastoids represent among the fossil Echinoderms the nearest approach we have yet discovered to this imaginary prototype of Echinoderms.

This may not seem a very satisfactory result to have attained. It certainly has been shown to be an impossibility to trace in the paleontological succession of the Echini anything like a sequence of genera. No direct filiation can be shown to exist, and yet the very existence of persistent types, not only among Echinoderms, but in every group of marine animals, genera which have continued to exist without interruption from the earliest epochs at which they occur to the present day, would prove conclusively that at any rate some groups among the marine animals of the present day are the direct descendants of those of the earliest geological periods. When we come to types which have not continued as long, but yet which have continued through two or three great periods, we must likewise accord to their latest representatives a direct descent from the older. The very fact that the ocean basins date back to the earliest geological periods, and have afforded to the marine animals the conditions most favorable to an unbroken continuity under slightly varying circumstances, probably accounts for the great range in time during which many genera of Echini have existed. If we examine the interlacing in the succession of the genera characteristic of later geological epochs, we find it an impossibility to deny their continuity from the time of the Lias to the present day. The Cidaris of the Lias and the Rhabdocidaris of the Jura are the ancestors of the Cidaris of to-day. The Saleniæ of the lower Chalk are those of the Saleniæ of to-day. Acrosalenia extends from the Lias to the lower Cretaceous, with a number of recent genera, which begin at the Eocene. The Pygaster of to-day dates back to the Lias; Echinocyamus and Fibularia commence with the Chalk. Pyrina extends from the lower Jura through the Eocene. The Echinobrissus of to-day dates back to the Jura. Holaster lived from the lower Chalk to the Miocene, and the Hemiaster of to-day cannot be distinguished from the Hemiaster of the lower Cretaceous.

Such descent we can trace, and trace as confidently as we trace a part of the population of North America of to-day as the descendants of some portion of the population of the beginning of this century. But we can go no further with confidence, and bold indeed would he be who would attempt even in a single State to trace the genealogy of the inhabitants from those of ten years before. We had better acknowledge our inability to go beyond a certain point; anything beyond the general parallelism I have attempted to trace, which in no way invalidates the other proposition, we must recognize as hopeless.

But in spite of the limits which have been assigned to this general parallelism, it still remains an all-essential factor in elucidating the history of paleontological development, and its importance has but recently been fully appreciated. For, while the fossil remains may give us a strong presumptive evidence of the gradual passage of one type to another, we can only imagine this modification to take place by a process similar to that which brings about the modifications due to different stages of growth,—the former taking place in what may practically be considered as infinite time when compared to the short life history which has given us as it were a *résumé* of the paleontological development. We may well pause to reflect that in the two modes of development we find the same periods of rapid modifications occurring at certain stages of growth or of historic development, repeating in a different direction the same phases. Does it then pass the limits of analogy to assume that the changes we see taking place under our own eyes in a comparatively short space of time,—changes which extend from stages representing perhaps the original type of the group to their most complicated structures,—may, perhaps, in the larger field of paleontological development, not have required the infinite time we are in the habit of asking for them?

Paleontologists have not been slow in following out this suggestive track, and those who have been anatomists and embryologists besides have not only entered into most interesting speculations regarding the origin of certain groups, but they have carried on the process still futher, and have given us genealogical trees where we may, in the twigs and branches and main limbs and trunk, trace the complete filiation of a group as we know it to-day, and as it must theoretically have existed at various times to its very beginning. While we cannot but admire the boldness and ingenuity of these speculations upon genetic connection so recklessly launched during the last fifteen years, we find that with but few exceptions there is little to recommend in reconstructions which shoot so wide of the facts as far as they are known, and seem so readily to ignore them. The moment we leave out of sight the actual succession of the fossils and the ascertainable facts of postembryonic development, to reconstruct our genealogy, we are building in the air. Ordinarily, the twigs of any genealogical tree have only a semblance of truth: they lead us to branchlets having but a slight trace of probability, to branches where the imagination plays an important part, to main limbs where it is finally allowed full play, in order to solve with the trunk, to the satisfaction of the writer at least, the riddle of the origin of the group. It seems hardly credible that a school which boasts for its very creed a belief in nothing which is not warranted by common sense should descend to such trifling.

The time for genealogical trees is passed; its futility can, perhaps, best be shown by a simple calculation, which will point out at a glance what these scientific arboriculturists are attempting. Let us take, for instance, the ten most characteristic features of Echini. The number of possible combinations which can be produced from them is so great that it would take no less than twenty years, at the rate of one new combination a minute for ten hours a day, to pass them in review. Remembering now that each one of these points of structure is itself undergoing constant modifications, we may get some idea of the nature of the problem we are attempting to solve, when seeking to trace the genealogy as understood by the makers of genealogical trees. On the other hand, in spite of the millions of possible combinations which these ten characters may assume when affecting not simply a single combination, but all the combinations which might arise from their extending over several hundred species, we yet find that the combinations which actually exist—those which leave their traces as fossils—fall immensely short of the possible number. We have, as I have stated, not more than twenty-three hundred species actually representing for the Echini the results of these endless combinations. Is it astonishing, therefore, that we should fail to discover the sequence of the genera, even if the genera, as is so often the case, represents, as it were, fixed embryonic stages of some Sea-urchin of the present day? In fact, does not the very history of the fossils themselves show that we cannot expect this? Each fossil species, during its development, must have passed through stages analogous to those gone through by the Echini of the present day. Each one of these stages at every moment represents one of the possible combinations, and those which are actually preserved correspond only to the particular period and the special combination which any Sea-urchin has reached. These stages are the true missing links, which we can no more expect to find preserved than we can expect to find a record of the actual embryonic development of the species of the present day without direct observation at the time. The actual number of species in any one group must always fall far short of the possible number, and for this reason it is out of the question for us to attempt the solution of the problem of derivation, or to hope for any solution beyond one within the most indefinite limits of correctness. If, when we take one of the most limited of the groups of the animal kingdom, we find ourselves engaged in a hopeless task, what must be the prospect should we attack the problem of other classes or groups of the animal kingdom, where the species run into the thousands, while they number only tens in the case we have attempted to follow out? Shall we say "ignorabimus" or "impavidi progrediamus" and valiantly chase a phantom we can never hope to seize?

ART. XLI.—*Notice of the remarkable Marine Fauna occupying the outer banks off the southern coast of New England;* by A. E. VERRILL. (Brief Contributions to Zoology from the Museum of Yale College: No. XLVII.)

DURING the present season the headquarters of the U. S. Fish Commission, Professor S. F. Baird, Commissioner, were at Newport, R. I. The investigation of the marine invertebrate fauna of the region was very effectually carried out by the large party employed under the general direction of the writer. Large collections were made in the shallower waters of the coast, both at the surface and along the shores, as well as by dredging and trawling. The new steamer "Fish Hawk," of 480 tons, built last year specially for the Fish Commission, and fitted up with suitable appliances for its scientific work, was employed in the trawling and dredging. It was commanded by Lieut. Z. L. Tanner, U. S. N., who was also in command of the "Speedwell" last season. The writer had, as associates and assistants, for the invertebrata, Mr. Richard Rathbun, Mr. Sanderson Smith, Mr. J. H. Emerton (as artist), Mr. B. F. Koons, Mr. E. A. Andrews, Mr. Charles Bent, Mr. N. P. Scudder. Capt. H. C. Chester, as usual, had charge of the apparatus. Wire rope was very satisfactorily used for the dredging and trawling. In September and October, three very successful trips were made to the outer banks, or the region where the wide area of shallow water more rapidly falls off into the deep water of the Atlantic basin.

The first of these trips was made Sept. 3d to 5th, south of Martha's Vineyard, about 75 to 80 miles (stations 865 to 872) where the depth was from 65 to 192 fathoms. The bottom was mostly fine compact sand, with some mud, and with a large percentage of Foraminifera. The second trip was made Sept. 12th to 14th, nearly south from Newport, 90 to 105 miles, where the depth was from 85 to 325 fathoms (stations 873 to 881). The third trip, Oct. 1st to 3d, was to the same region, but somewhat farther west and south, and in deeper water, (stations 891 to 895). At all these stations, except 867, a large beam-trawl was used; at 867 a heavy "rake-dredge," of a new form, was used with good success.

The temperature determinations, owing to the violent motions of the steamer, are unreliable at stations 865 to 872. At stations 873–878 the bottom temperature was usually 51° to 53° F.; at 879–881, it was 42° to 43° F.; at 893, 894, it was 40° F.

All these stations are located in the region designated on the charts as "Block Island Soundings," and nearly all proved to be exceedingly rich in animal life, the vast abundance of individuals of many of the species taken being almost as surprising as the great number and variety of the species themselves. Crustacea, Mollusca, Annelids and Echinoderms were the most numerous. The very large quantity of specimens obtained on these three trips has, as yet, been only partially examined, but enough has already been done to prove this region to be altogether the richest and most remarkable dredging ground ever discovered on our coast.

Dredging stations on the outer bank, in 1880.

No.	Locality.				Depth, Fathoms.	Nature of bottom.
	Lat.		Long.			
865	40° 05′	N.	70° 23′	W.	65	Fine compact sand with some mud.
866	40 05 18″	N.	70 22 18″	W.	65	“ “ “
867	40 05 42	N.	70 22 06	W.	64	“ “ “
868	40 01 42	N.	70 22 30	W.	162	“ “ “
869	40 02 18	N.	70 23 06	W.	192	Mud and fine sand, soft.
870	40 02 36	N.	70 22 58	W.	155	Fine sand with some mud.
871	40 02 54	N.	70 23 40	W.	115	“ “
872	40 05 39	N.	70 23 52	W.	86	Shells and sponges.
873	40 02	N.	70 57	W.	100	Fine sand and mud.
874	40	N.	70 57	W.	85	“ “
875	39 57	N.	70 57 30	W.	126	“ “
876	39 57	N.	70 56	W.	120	“ “
877	39 56	N.	70 54 18	W.	126	“ “
878	39 55	N.	70 54 15	W.	142½	“ “
879	39 49 30	N.	70 54	W.	225	“ “
880	39 48 30	N.	70 54	W.	252	Mud and fine sand.
881	Somewhat farther south.				325	Mud. Trawl partially fouled.
891	39 46	N.	71 10	W.	±500	Mud and fine sand.
892	39 46	N.	71 05	W.	487	Mud, fine sand, small stones.
893	39 52 20	N.	70 58	W.	372	“ “ “
894	39 53	N.	70 58 30	W.	365	“ “ “
895	39 56 30	N.	70 59 45	W.	238	“ “ “

Mollusca.—Of Mollusca, about 175 species were taken. Of these, 120 species were not before known to occur on the southern coast of New England; about 65 species are additions to the American fauna; of these about 30 species are, apparently, undescribed. The known species now added to our fauna have mostly been described by G. O. Sars, Jeffreys, and others, from the deep waters of the European coast and the Mediterranean.

List of Mollusca new to the New England coast.

[Those with *n* prefixed were previously known from off Nova Scotia or farther north. Various undetermined species are not included.]

Heteroteuthis tenera V., nov.
Calliteuthis reversa V., gen. and sp. nov.
Alloposus mollis V., sp. and gen. nov.
Argonauta Argo Linné.
Taranis Morchii Sars.
n. Bela tenuicostata Sars.
Pleurotoma Agassizii V. & S., nov.
Pleurotoma Carpenteri V. & S., nov.
Marginella roscida Rav.?
n. Neptunea propinqua (Alder).
Tritonofusus latericeus (Möll.) Morch.
Lamellaria pellucida V., nov.
n. Lovenella Whiteavesii Verrill, nov.
Cingula turgida (Jeff.)
n. Cingula Jan-Mayeni (Friele) V.
Lepetella tubicola V. & S., gen. and sp. nov.
Scalaria Dalliana V. & S., nov.
Scalaria (fragile).
Scalaria Pourtalesii V. & S., nov.
Solarium, sp. (sharply carinated).
Aclis Walleri J.
Calliostoma Bairdii V. & S., nov.

Margarita regalis V. & S., nov.
Margarita lamellosa V. & S., nov.
Turbonilla Rathbuni V. & S., nov.
Turbonilla formosa V. & S., nov.
Eulima intermedia Cantr.
Eulima distorta Desh.
n.Philine Finmarchica Sars.
Philine amabilis V., nov.
Amphisphyra globosa Lovén.
Diaphana gemma V., nov.
Diaphana nitidula (Lovén).
Pleurobranchæa tarda V., nov.
Doris complanata V., nov.
Carinaria Atlantica Ad. & R.
Clio pyramidata Linné.
Balantium.
Cymbulia calceola V., nov.
Spirialis retroversus (Flem.)
Cavolina longirostris (Les.)
Cavolina uncinata (Rang.)
Siphonentalis Lofotensis Sars.
Cadulus Pandionis V. & S., nov.
Cadulus Jeffreysii (Monteros.)
Cadulus propinquus G. O. Sars.
Poromya rotundata Jeff.
Neæra rostrata (Speng.) Lovén.
Neæra costellata ?
Neæra jugosa S. Wood.
Pecchiolia abyssicola Sars.
n.Kennerlia glacialis (Leach) Carp.
Cardium, sp. nov. (cancellated.)
Loripes lens V. & S., nov.
Cryptodon ferruginosus (Forbes).
n. Yoldia frigida Torell.
Leda unca Gould.
Limopsis cristata Jeff. ?
Limopsis minuta (Phil.)
Modiola polita V. & S., nov.
Avicula hirundo ? var. *nitida* V.
n.Pecten vitreus (Gmel.) Wood.
n.Pecten Hoskynsi Forbes, var. *pustulosus* V.
Pecten fenestratus Forbes ?
Limæa subovata (Jeffreys) Monteros.

List of Mollusca new to the southern coast of New England, but previously known to me from the northern coast.

Rossia sublevis Verrill.
Octopus Bairdii Verrill.
Admete Couthouyi Jay(=*A. viridula* Gld.)
Bela exarata (Möll.) Ad.
Bela impressa Morch (S. 814).
Bela violacea (Migh.) Ad. (S. 812).
Neptunea decemcostata (Say) Ad.
Neptunea Stimpsoni (Morch), (= *Fusus Islandicus* Gld.)
Anachis costulata (Cant.) (=*Columbella Haliæeti* Jeff.)
Lunatia Grönlandica (Möll.) Ad.
Lunatia nana (Möll.) (S. 812, 814).
Torellia vestita Jeff.
Aporrhais occidentalis Beck.
Calliostoma occidentale (Migh.) Dall.
Puncturella noachina (L.) Lowe.
Turbonilla nivea (St.) Ad.
Odostomia modesta Stimp.
Ringicula nitida V.
Scaphander puncto-striata (Migh.) Ad.
Amphisphyra pellucida (Brown) Lovén.
Cylichna occulta (Migh.) Ad.
Siphonodentalium vitreum Sars.
Dentalium occidentale Stimp. (=*D. abyssorum* Sars.)
Teredo megotara Hanl.
Saxicava Norvegica (Speng.) Woodw.
Cyrtodaria siliqua (Speng.) Woodw.
Neæra obesa Lovén (=*N. pellucida* St.)
Neæra arctica Lovén.
Neæra glacialis G. O. Sars.
Poromya granulata (Nyst.) F. and Han.
Thracia myopsis Möll.
Cardium Islandicum Linné.
Astarte crenata Gray (=*A. lens* St.)
Nucula delphinodonta Mighels.
Yoldia thraciformis (Storer) Stimp.
Yoldia expansa Jeff. (?)
Arca glacialis Gray.
Arca pectunculoides Sc., (? var. of last).
Crenella decussata (Mont.) Macg.
Dacrydium vitreum (Möll.) Sars.
Pecten Islandicus Müller.
Terebratulina septentrionalis (Couth.)

*Descriptions of new species included in the preceding lists.**

Heteroteuthis tenera Verrill, sp. nov.

Body small, rather short, scarcely twice as long as broad, obtuse. Fins thin, rounded, relatively very large, length about two-thirds that of the body, longer than broad, the anterior edge extending forward beyond the mantle. Arms

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* In an article in the Proceedings of the National Museum, detailed descriptions of the new species will be given. Therefore only the more diagnostic characters are given here.

slender; in the male the left dorsal arm is hectocotylized, being broader than its mate, with four rows of minute suckers, while on the right one, and in the female on both, there are two regular rows of larger suckers. Lateral and ventral arms have the middle suckers (eight to ten) much larger than the distal and proximal ones; in the male this disparity becomes very marked, the larger suckers being eight or ten times as large as the proximal ones. These suckers are deep, laterally attached, with small opening and smooth rim. Tentacular arms long, slender, with broader club; suckers numerous, unequal, in about eight rows, those in the upper rows much larger than the others, with denticulated rims. Color translucent white with large purple chromatophores, which are also found on the inner surfaces of the arms and between the suckers. Length of body 25 to 40^{mm}. More or less abundant at all the stations, from 865 to 880, inclusive. About 200 specimens were taken.

Calliteuthis Verrill, gen. nov.

Form much as in *Histioteuthis*, but without any web between the arms. Body short, tapering to a free tip; fins small, united behind. Siphon united to head by two dorsal bands; an internal valve. Mantle connected to sides of siphon by lateral elongated cartilages and grooves. Arms long, free; suckers in two rows, largest on middle of lateral and dorsal arms. Eyes large, with oval openings. Buccal membrane simple, sac-like.

Calliteuthis reversa Verrill, sp. nov.

Arms long, tapering, the lateral pairs equal; the dorsal and ventral about equal, somewhat shorter than laterals; tentacular arms slender, compressed, (the ends absent). Fins small, thin, transversely rhomboidal, white. Color reddish brown; the ventral surface of body, head and arms covered with large, rounded verrucæ; their center or anterior half pale, the border or posterior half dark purplish brown; upper surface of body with much fewer and smaller scattered verrucæ; a circle of same around the eyes; inner surface of arms and buccal membranes chocolate-brown. Total length, 133^{mm}; to base of arms, 67; of mantle, 51; of fin, 17; breadth of fins, 24; of body, 20; diameter of eye-ball, 16^{mm}. Station 894.

Alloposus Verrill, gen. nov.

Allied to *Philonexis* and *Tremoctopus*. Body thick and soft, smooth; arms all (in the male only seven) united by a web extending nearly to the ends, the length of the arms decreasing from the dorsal to ventral ones; suckers sessile, simple, in two rows; mantle united firmly to the head by a ventral and two lateral *commissures*, the former placed in the median line, at the base of the siphon, and by a broad dorsal band; free end of the siphon short, well forward. In the male the right arm of the third pair is hectocotylized, and developed in a sac, in front of the right eye; as found in the sac, it is curled up, and has two rows of suckers; the groove along its edge is fringed; near the end, the groove connects with a rounded, obliquely placed, lateral, concave lobe, with interior plications; the terminal portion of the arm is a lanceolate thickened process, with ridges on the inner surface. The permanent attachment of the mantle and neck, by means of commissures, is a very distinctive character.

Alloposus mollis **Verrill, sp. nov.**

Body stout, ovate, very soft and flabby. Head large, as broad as the body; eyes large, their openings small. Arms rather stout, not very long, webbed nearly to the ends, the dorsal 60^{mm} longer than the ventral arms; suckers large, simple, in two alternating rows. Color deep purplish brown, with a more or less distinctly spotted appearance. Length, total, 160; of body, to base of arms, 90; of mantle beneath, 50; of dorsal arms, 70; breadth of body, 70^{mm}. The sexes scarcely differ in size. Stations 880, in 225 fathoms, (2 ♂, 1 ♀), 892, 893, 895.

Cymbulia calceola **Verrill, sp. nov.**

Test thick, transparent, broad-ovate, rounded at both ends, covered, above and below, with low rounded verrucæ; aperture large, with simple unarmed edges. Animal pale pink, with brown nucleus; fins very large, connate, broadly rounded. Length of test, $·40^{mm}$; breadth, ·20. Stations 865 to 872, (near surface), common.

Pleurotoma Agassizii **Verrill and Smith,* sp. nov.**

Shell large and handsomely sculptured; whorls eight, convex, shouldered, with about sixteen thick, rounded, oblique ribs, separated by concave interspaces; the ribs do not extend above the shoulder, leaving a rather broad, flattened band, which is covered by raised revolving lines, more or less decussated by prominent lines of growth and slight riblets, running down from the suture; the revolving lines become stronger and more elevated below the shoulder, and cross the ribs as well as their intervals; toward the canal the ribs fade out and the revolving lines become still more prominent. Outer lip with a wide and rather deep rounded notch below the suture; below this it curves strongly forward, and recedes again at the canal, which is rather short, narrowed, and a little excurved. Columella smooth, curved, and obliquely

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* Mr. Sanderson Smith has been associated with me, during the present and two preceding seasons, in working up the testaceous mollusca. The species here briefly described under our joint names will be described, in detail, in a special article in the Proceedings of the National Museum.

narrowed at the canal. Aperture subovate, sinuous, rather large. Shell white, except the columella, which is stained with orange-brown. Length, 31; breadth, 14; length of aperture, 16; breadth, 6^{mm}. Stations 865–880; 891, 892; 894; 895.

The animal has neither operculum nor eyes, and does not properly belong to *Pleurotoma* (restricted). It is, perhaps, most nearly related to *Pleurotomella* V. The uncini differ from all those figured by G. O. Sars, resembling most those of *Thesbia.* The basal appendage is large and oblique.

Pleurotoma Carpenteri Verrill and Smith, sp. nov.

Shell rather small, solid, slender; surface glossy. Whorls eight, somewhat convex, crossed by about twelve strong, elevated, flexuous, smooth, rounded longitudinal ribs, which extend entirely across the upper whorls, and on the body whorls from the suture to the middle, below which the surface is smooth; the interstices between the ribs are deeply concave, wider than the ribs, and perfectly smooth, except the faint lines of growth. Outer lip with a broad shallow notch, below the suture. Aperture rather small, ovate; canal short, narrow, straight; columella nearly straight. Color, pale brownish. Length, 7; breadth, $2{\cdot}75^{mm}$. Stations 870–873.

Scalaria Pourtalesii Verrill and Smith, sp. nov.

Shell pure white, rather stout, with seven well-rounded whorls, crossed by about sixteen high, thin, lamellar, somewhat oblique ribs, which rise into acute angles or points just below the suture. Whorls scarcely united, except by the ribs, which often alternate on successive whorls. Interstices covered with fine revolving lines, not visible without a lens. Aperture round, with a broad, somewhat reflexed lip; umbilicus small, concealed behind the inner lip; no basal keel. Length, 17·5; breadth, 10; of aperture, 4^{mm}. Stations 873, 874.

Scalaria Dalliana Verrill and Smith, sp. nov.

Shell smaller and much slenderer than the last, thin, delicate, bluish white. Whorls eleven, evenly rounded, with deeply indented sutures. Ribs about twenty, on the lower whorls, moderately high, thin, oblique, often with a small sharp denticle, just below the suture; they often alternate; interstices wider than the ribs, smooth, without distinct revolving lines. Aperture round with a reflexed lip, nearly even all around; umbilicus none. Length, 10·5; breadth, $3{\cdot}5^{mm}$. Stations 869, 870, 871, 873, etc., not uncommon.

Lamellaria pellucida Verrill, sp. nov.

Animal yellowish brown mottled with darker, broad elliptical, swollen, without tubercles on the back. Shell ovate, with oblique spire, delicate, transparent, smooth; aperture broad ovate, not showing the interior of the spire, except from an endwise view. Middle tooth of the odontophore with the basal portion oblong and truncated posteriorly, (not bilobed as in other species). Length, 12 to 16^{mm}, when living. Stations 870, 871, 872, several specimens, ♂ and ♀

Lepetella Verrill, gen. nov.

Shell small, smooth, oval or oblong, limpet-shaped, conical, with a simple sub-central apex, not spiral. Animal much as in *Lepeta*, but with distinct eyes. Odontophore tænioglossate, with seven regular rows of teeth.

Lepetella tubicola Verrill and Smith, sp. nov.

Shell thin, white, smooth, conical, with the apex acute and nearly central; aperture broad elliptical, oblong, or subcircular, usually more or less warped, owing to its habitat; edge thin and simple. Sculpture none, lines of growth slight, outer surface dull white; inner surface smooth, with the pallial markings faint. Length of largest specimens 3·75; breadth, 3; height, 2^{mm}. On inside of old tubes of *Hyalinœcia;* twenty-seven were taken from one tube. Stations, 869, 192 fath., and 894.

Lovenella Whiteavesii Verrill, sp. nov.

Shell slender, white, acute, allied to *L. metula.* Whorls nine or ten, flattened, with a prominent nodulous carina below the middle, a smaller one just below the suture, and another on the last whorl, in line with edge of lip, below this smooth; the whorls are crossed by numerous elevated, rounded, curved ribs. Columella much incurved above; canal excurved; outer lip with three angles. Length $4·5^{mm}$; breadth $1·5^{mm}$; one is considerably larger. Stations 891, 894; also Gulf St. Lawrence (Whiteaves).

Calliostoma Bairdii Verrill and Smith, sp. nov.

Shell large, strong, regularly conical, with a flattened base, no umbilicus, yellowish white or light yellow, with more or less numerous narrow, spiral bands of pale brown or dark brown, and with large squarish spots of bright rosey red on the spire. Whorls nine or ten, flattened, or concave, below the suture, which is not impressed. The last whorl has eight to ten conspicuous, raised, nodulous revolving ribs, of which three or four are much smaller and alternate with the larger ones; the strongest rib is just below the suture; interstices concave, brownish, glossy, obliquely striated by the lines of growth, and sometimes with subordinate, revolving, raised lines. The four principal ribs are continued on the upper whorls, but the intermediate ones gradually disappear on the middle whorls. The nodules on the ribs are prominent, rounded and smooth, whitish, and extend to near the apex. Nuclear whorl smooth; next with three carinæ. Base with about twelve spiral, nodulous ribs with some intermediate, smaller ones; umbilical region slightly excavated, spirally. Columella strongly concave, terminating in an indistinct tooth. Animal yellowish with long tentacles, and with four long cirri on each side; eyes well developed. Dentition somewhat different from the typical species of the genus; there is no large lateral tooth, between the inner and outer series; outermost ones broad flat, curved. Operculum thin, circular, with many narrow whorls. Length, 32; breadth, 30; breadth of aperture, 15^{mm}. Taken alive at nearly all the stations, from 865 to 880, inclusive. A very handsome and showy species, having a tropical aspect.

Margarita regalis Verrill and Smith, sp. nov.

Shell rather large for the genus, thin and delicate, whitish, brilliantly iridescent or pearly, externally and internally, broad conical, turreted, wider than high, with a convex base, and deep umbilicus. Whorls seven, much flattened, with the suture scarcely impressed; the upper whorls are coronated by two, and the body whorl by three, revolving, strongly nodulous ribs, along which the conical, often acute nodules are very regularly arranged. The first of these rows of nodules is just below the suture; the second is separated from the first by a wide, flat, or slightly concave interspace; the third is not far from the second, and surrounds the periphery, usually corresponding with the line of the suture; the second and third are usually the most elevated; on the base there are five or six strong, rounded, revolving ribs, part of them usually somewhat nodulous, separated by deep, concave interspaces, rather wider than the ribs; one or two additional ones often appear in the umbilical opening, which is funnel-shaped and moderately large, but often partially obstructed by the reflexed edge of the inner lip. The interspaces between all the ribs are covered with close, slightly raised lines of growth, and usually with traces of a thin epidermis. Aperture somewhat quadrangular, large, lip thin. Animal with long tentacles and large black eyes; four large lateral cirri on each side, with a group of four or five small intermediate ones; snout with a broad, bilobed crescent-shaped expansion in front. Odontophore without a large lateral tooth between the inner and outer series, otherwise much like typical *Margaritæ*. Length, 14; breadth, 15^{mm}; often larger. Stations 865, 870, 871, 873, 880, 891–895, common.

Margarita lamellosa Verrill and Smith, sp. nov.

Shell small, fragile, conical, canaliculate, with a wide umbilicus. Whorls five, angulated and carinated below the middle, swollen just below the suture, which lies in a deep channel; they are crossed, above the peripheral carina, by numerous elevated, thin, oblique ribs, which rise into lamellæ near the suture, where they join the carina forming small nodules; between the ribs are fine parallel lines of growth and sometimes a few fine revolving lines. Below the periphery, in line with the posterior edge of the lip, there is a smaller, plain, angular rib, and around the umbilicus there is a strong nodulose rib. Between these ribs, the base is covered with fine revolving lines. Within the umbilicus are radiating raised lines which cross two or three small revolving ribs. Aperture rounded, with angles corresponding to the ribs. Length, 3; breadth, 3^{mm}. Station 871, scarce.

Turbonilla Rathbuni Verrill and Smith, sp. nov.

Shell white, large for the genus, elevated, with twelve rather convex whorls, and impressed sutures. The whorls are slightly flattened and crossed by numerous slightly flexuous, elevated, smooth, even ribs, of which there are about thirty on the lower whorls; intervals about as wide as the ribs, concave, crossed by impressed revolving lines, of which there are eight or ten on the spire. Aperture somewhat oblong, with the lip a little prolonged and slightly effuse anteriorly. Columella nearly straight, smooth. Umbilicus none. Length, 13; breadth, 4^{mm}. Station 869, 192 fathoms, common; 894, 895.

Turbonilla formosa V. and S., sp. nov.

Shell white, lustrous, large, in form and size resembling the preceding; whorls twelve, somewhat flattened; aperture ovate, effuse in front; sculpture, strong rounded ribs, but without any revolving lines. Stations 891, 892.

Pleurobranchæa tarda V., sp. nov.

Body ovate, stout, swollen, strongly convex, yellowish brown, reticulated with dark brown. Gill plumose, at middle of right side, purple. Tentacles short, inrolled, obtuse. Proboscis large, purple. Odontophore large and broad, with 150 to 170 rows of teeth, no median tooth; teeth all similar, but gradually changing toward margins; inner ones narrow, lanceolate, curved, acute, with a stout denticle on the inner edge, near the end; outer teeth have the side denticle rudimentary. Length 30 to 40^{mm}. Common at stations 814, 865–880; 28 to 250 fathoms; over 200 specimens taken. One, 60^{mm} long, from station 895.

Philine amabilis V., sp. nov.

Shell very thin, diaphanous, delicate, and shining with bright iridescence; very large for the genus, and very open, showing the interior of the spire, broad oblong, with rounded ends; outer lip evenly rounded posteriorly and scarcely projecting beyond the spire; apex occupied by a shallow pit. Sculpture, conspicuous wavy lines of growth, and microscopic wavy spiral striæ, over the whole surface. Length of shell, 15; breadth, 10^{mm}. Odontophore with a large hook-shaped inner lateral tooth, on each side, and a slender spiniform outer one. Gizzard large, with three calcareous plates. Station 876, several living specimens.

Diaphana (*Utriculus**) *gemma* V., sp. nov.

Shell white, rather solid, resembling, in size and form, *Cylichna occulta* (Migh.), but distinguished by having a small, distinct umbilicus, and also a narrow deep pit at the apex of the spire. Sculpture, a few distinct spiral lines at each end; middle region of shell smooth. Length, 4·2; breadth, $2·5^{mm}$. Stations 871, 873.

Doris complanata V., sp. nov.

Body large, broad elliptical, depressed, pale brown to dusky brown, more or less mottled, back nearly smooth, with few minute verrucæ. Dorsal tentacles stout, clavate, with many crowded lamellæ, sheaths plain. Gills ten, large, bipinnate, brown, retractile into a large cavity. Oral tentacles free, ovate, tapered. Odontophore with 70 to 80 rows of lateral teeth, the outermost smallest: 22 to 24 inner lateral ones, on each side, sharp, hook-shaped, with two side lobes; those exterior to these, have obtuse, incurved, denticulate ends. Length, 50; breadth, 25^{mm}. Station 872, eight specimens.

Cadulus Pandionis V. and S., sp. nov.

Shell very large for the genus, white, transparent, very smooth and polished, shining, strongly curved, largest in front of the middle, with the aperture oblique; sculpture none. The shell is somewhat transversely elliptical in section, slightly gibbous and most swollen at about the anterior third, on the convex side; from this point gradually tapering to the slender posterior end, and to the mouth, which is slightly broader than high, and recedes considerably on the convex side of the shell, with a thin smooth margin. Posterior opening small, with a semicircular notch above and below. Length, 10; breadth, 2·25; breadth of aperture, 1·75; of anal aperture, $·40^{mm}$. Stations 869–871, 873, 874, 876 (abundant), 877, 891.

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* I here use *Diaphana* for the restricted genus *Utriculus*, as adopted by G. O. Sars. It is peculiar in lacking the odontophore. *Utriculus* is preöccupied by Schumacher (1817). Our "*Utriculus Gouldii*" is, in its gizzard and dentition, a true *Cylichna* and should be called *Cylichna Gouldii*. The *Diaphana pertenuis* (Migh.) is very distinct from it.

Loripes lens **Verrill and Smith, sp. nov.**

Shell white, well-rounded, nearly equilateral, slightly convex, thin; lunule small, cordate, deeply excavated; sculpture slightly raised, concentric lines of growth, distinct at the ends, but nearly obsolete on the median portion of the shell. Posteriorly the outline is more obtusely rounded, so as to form a rounded angle with the dorsal and ventral edges; dorsal edge incurved in front of the beaks; a faint undulation runs from the beak to the posterior angle. Teeth none. Length, 14; height, 12·5^{mm}. Stations 865 to 872; 873 to 879, common. Also dredged off Cape Cod, 1879, in many places (40 to 120 fathoms).

Modiola polita **Verrill and Smith, sp. nov.**

Shell thin, translucent, without sculpture; epidermis pale yellow, smooth and polished. Umbos prominent; hinge-line straight; posterior end broadly rounded, compressed; anterior end prolonged decidedly beyond the beak, narrow, rounded. Greatest length, 40; breadth, 21^{mm}. Station 895, two specimens.

Pecten fenestratus Forbes (?).

The small species that I refer doubtfully to this species is beautifully marbled with brown, red and white. The ears are prominent. The lower valve is covered with thin concentric riblets, while the upper valve is cancellated with fine radiating and concentric raised lines. Station 872.

ECHINODERMS.

The star-fishes and ophiurans were exceedingly abundant and beautiful at all the stations, and many species not known previously on our coast were taken, several of which appear to be undescribed, while others were known only from northern Europe, or from the deep waters off Florida. Many of the species have only recently been obtained from the northern fishing banks off Nova Scotia, and are recorded in this Journal. One new species of *Archaster* (*A. Americanus*) was particularly abundant, several thousands of specimens having been taken; but the two largest and most beautiful species of this genus were *Archaster Agassizii* (new) and *A. Floræ*. Of *Odontaster hispidus*, over 100 were taken. One of the most conspicuous star-fishes was the remarkable *Pteraster multipes* Sars,* one specimen of which was over six inches in diameter, and very thick and heavy. Its color, in life, is rich purple above, with the lower side orange, streaked with brown, and

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* This species differs so widely from typical *Pteraster* as to merit generic separation. I propose for it the name *Diplopteraster*, characterized especially by having suckers in four rows, and by having the horizontal radiating interbrachial spines of the lower surface imbedded in, and concealed by, a thick skin, when adult, (exposed in the young).

with large dark purple suckers. A large and handsome orange-colored species of *Luidia* (apparently *L. elegans*) often ten to fifteen inches broad, was very common, but nearly all the specimens dismembered themselves before they came to the surface. Large specimens of two Floridian sea-urchins (*Echinus gracilis* and *E. Norvegicus*) were taken.

Partial List of Echinodermata.

E. = European; F. = off Florida; *n.* = northern coasts of New England or Nova Scotia; * = new species. Numbers refer to list of stations; ab. = abundant.

n. *Thyone scabra* Verrill. (876, 877.)
Caudina. (876.)
n. *Schizaster fragilis* D. & Kor. (865, 871, 873, 874, 876, ab., 877, ab.)
F. *Echinus gracilis* A. Ag. (872, two large specimens.)
F. *Echinus Norvegicus* D. & K.
F. *Temnechinus maculatus* A. Ag.
Asterias vulgaris Stimp. (869, one sp.)
* *Asterias Tanneri* V., nov. (869, 870, 871, 872, 877.)
n. *Stephanasterias albula* (Stimp.) Verrill. (865, 866, ab., 871, 872.)
Cribrella sanguinolenta Lütk. (871, 872.)
E. *Diplopteraster multipes* (Sars) Verrill. (869, one very large, 880, two, 895, one.)
n. *Porania grandis* Verrill. (869, several, 872.)
n. *Porania spinulosa* Verrill. (869, 879, three, 894, 895.)
n. *Porania borealis* Verrill (= *Asterina borealis* V.) (869, several, 879, few.)
* *Odontaster hispidus* V., gen. nov. (865, 869, ab., 871, 872, ab., 873, 878, 894, 895.)
n. *Archaster Floræ* Verrill. (869, several, large, 879, 881, 895.)
* *Archaster Americanus* V. (865–8, very ab., 871, ab., 873, 877, ab., 879.)
* *Archaster Agassizii* V. (879, 880, sev., 881, sev., 891–894.)
n. *Archaster Parellii* D. & K. (879, 892–894.)
F. *Luidia elegans* Perrier. (865–872, many large, 873, 876, 877.)
n. *Ctenodiscus crispatus* D. & Kor. (879, one.)
Ophiopholis aculeata Gray. (865, 869, 872, 879, 895.)
n. *Ophioglypha Sarsii* Lyman. (865–869, ab., 870, ab., 871, 877, ab., 879, 895.)
n. *Ophioglypha affinis* Lyman. (869, 875, 877, 878.)
* *Ophioglypha.* (879, 880, 895.)
n. *Ophiacantha millespina* Verrill. (869, ab., 871.)
n. *Ophioscolex glacialis* M. & Tr. (869, 871.)
n. *Amphiura Otteri* (?) Ljung.
Amphiura. (865, 879.)
Amphiura. (880, two.)
F. *Ophiocnida olivacea* Lym. (869, 871, ab., 872, 873–877, ab.)
n. *Antedon Sarsii* (D. & K.) (870, 871, 873–876, 878–880.)

Asterias Tanneri **Verrill, sp. nov.**

A large, handsome, five-armed, dark red species, with a small disk and long narrow arms. Radii about as 1 : 7. Skeleton-plates rather strong. Lateral and dorsal spines one to a plate, elongated, round, tapering, forming five simple rows, in adults; in young, only three distinct rows. Ventral spines, long, obtuse, two to a plate, forming a double row, remote from the lateral, with large groups of papillæ between. Adambulacral spines long, slender, two to a plate, divergent, forming two regular rows. Minor pedicellariæ form close wreaths around bases of lateral and dorsal spines, and clusters on outer side of external ventrals; major ones, large, long-ovate, pointed, scattered between the dorsal spines and clustered around their bases. Radius of disk, 11; of arms, 75^{mm}; larger specimens, 250^{mm} in diameter, were secured, but most of them had dismembered themselves, before reaching the surface.

Odontaster Verrill, gen. nov.

Form and appearance like *Archaster;* two rows of marginal plates; dorsal surface with paxillæ; ventral plates polygonal, spinulose. Each jaw bears a large, strong, sharp, erect or everted tooth, outside of the marginal spinules.

Odontaster hispidus V., sp. nov.

Rays five, rarely six, broad, tapering, sub-acute; body broad, densely spinulose beneath, flattened dorsally; larger paxillæ, each with a group of fifteen to twenty slender, equal, divergent spinules; those near the marginal plates much smaller. Upper marginal plates squarish, densely covered with small, sharp spinules; lower ones with larger and longer spinules; ventral plates, each with a crowded group of six or eight larger, stout, acute spinules, varying in stoutness; adambulacral plates, each with two, three, or more, blunt spinules, on the inner edge, in a row, and others, of similar form, outside of them. Central tooth of jaws with sharp, smooth tip, straight or recurved, longer and much larger than adjacent spines. Color pale salmon, or yellowish, when living. Radius of disk, 15; of arms, 42^{mm}.

Archaster Americanus Verrill, sp. nov.

Arms five, rarely six, long, regularly tapered, moderately broad, rather flat. Radius of disk to that of arms, commonly, 1 : 5. Color in life, pale yellow, orange-yellow, or salmon. Dorsal area covered with slender paxillæ, not crowded, each bearing a stellate group of eight to ten very slender, long spinules, with a central one of the same size. Upper marginal plates rather large, elongated vertically, densely covered with small spinules, which radiate around the margin; sometimes a few plates, in the angles between the arms, bear, each, a single spine, at the upper end. Lower plates large, broad, reaching nearly to the ambulacral groove, covered with slender, sharp spinules, the middle row longest; two or three of the outermost of these are much longer and larger than the rest, and more or less flattened. Ventral plates very few, spinulose. Adambulacral plates, each with an inner group of three or four slender spines, in a row, and an irregular outer group of three or four larger ones; jaw-spines numerous, blunt. Largest specimens have the larger radius 74; lesser 12^{mm}.

Archaster Agassizii **Verrill, sp. nov.**

A large and elegantly formed species, with rather large pentagonal disk and wide, rapidly tapered arms. Color, in life, bright orange-red.

Dorsal surface closely covered with large, even paxillæ, which are crowned with very numerous, short, blunt, granule-like spinules, six or eight larger ones forming a central group, with twenty to thirty smaller and more acute ones fringing the border; next the marginal plates the paxillæ are smaller and crowded; a group of larger and more conspicuous ones surrounds and partially covers the large madreporic plate. Upper and lower marginal plates equal in number and nearly so in size, their sutures coincident; proximal plates higher than long; those toward the ends of the arms nearly square; all are densely covered with small rounded granules; in many specimens the lower marginal plates bear, each, a single short, stout, blunt spine, on the outer side, but these are often partially wanting, and sometimes entirely absent. Ventral plates form triangular areas, extending out a short distance on the arms; they are angular, covered with short, rounded spinules, and form a close pavement. Adambulacral plates bear, each, about seven or eight slender, nearly equal spines, in one row, with a group of outer, small, short spinules. Greater radius 57; lesser 21^{mm}.

Luidia elegans? **Perrier. Arch. Zool. Expér., p. 256, 1876.**

The species taken by us grows to more than 350^{mm} in diameter. Color deep orange above, lighter below. Paxillæ crowded, smallest in middle of arms; large laterally; each bears a large group of slender spinules, and usually one to three larger, blunt pedicellariæ. Marginal plates with a vertical row of three long, tapering, acute spines, the upper ones largest; adambulacral plates also with a row of three sharp spines, which are smaller and recurved; the middle one largest. A row of large, ovate, bilabiate pedicellariæ between the lateral and adambulacral plates. The specimen described by Perrier was very young, if of this species.

ART. XLII.—*Revision of the Land Snails of the Paleozoic era, with Descriptions of New Species;* by J. W. DAWSON.

THE Gasteropods as a class occur as early as the Upper Cambrian, but all the earlier known types are marine. That portion of the group distinguished by the possession of air sacs instead of gills (Pulmonifera) has not hitherto been found in any formation older than the Carboniferous, and only four Carboniferous species have been described. In the present paper

I propose to state some additional facts respecting the species already known, to discuss their affinities, and to describe two additional species, making six in all from the Paleozoic rocks, including one from the Erian or Devonian. For reasons to be mentioned in the sequel, I do not admit the genus *Palæorbis* founded, by some German naturalists, on fossils which I believe to be tubes of Annelids.

It may be useful to premise that of the two leading subdivisions of the group of Pulmonifera, the Operculate and Inoperculate, the first has been traced no farther back than the Eocene. The second, or Inoperculate division, includes some genera that are aquatic and some that are terrestrial. Of the aquatic genera no representatives are known in formations older than the Wealden and Purbeck, and these only in Europe. The terrestrial group or the family of the *Helicidæ*, which, singularly enough, is that which diverges farthest from the ordinary gill-bearing Gasteropods, is the one which has been traced farthest back, and includes the Paleozoic species. It is further remarkable that a very great gap exists in the geological history of this family. No species are known between the Carboniferous and the early Tertiary, though in the intervening formations there are many fresh-water and estuarine deposits in which such remains might be expected to occur. There is perhaps no reason to doubt the continuance of the Helicidæ through this long portion of geological time, though it is probable that during the interval the family did not increase much in the number of its species, more especially as it seems certain that it has its culmination in the modern period, when it is represented by very many and large species, which are dispersed over nearly all parts of our continents.

The mode of occurrence of the Paleozoic Pulmonifera in the few localities where they have been found is characteristic. The earliest known species, *Pupa vetusta*, was found by Sir Charles Lyell and the writer, in the material filling the once hollow stem of a Sigillaria at the South Joggins in Nova Scotia, and many additional specimens have subsequently been obtained from similar repositories in the same locality, where they are associated with bones of Batrachians and remains of Millipedes. Other specimens, and also the species *Zonites priscus*, have been found in a thin, shaly layer, containing debris of plants and crusts of Cyprids, and which was probably deposited at the outlet of a small stream flowing through the coal-formation forest. The two species found in Illinois occur, according to Bradley, in an underclay or fossil soil which may have been the bed of a pond or estuary, and subsequently became a forest sub-soil. The Erian species occurs in shales charged with remains of land plants, and which must consequently have received abundant drainage from neighboring land. It is only in such deposits that remains of true land-snails can be expected to occur; though, had fresh-water or brackish water Pulmonates abounded in the Carboniferous age, their remains should have occurred in those bituminous and calcareo-bituminous shales which contain such vast quantities of debris of Cyprids, Lamellibranchs and fishes of the period, mixed with fossil plants.

With reference to their affinities, the Paleozoic land snails present no very remarkable peculiarity except their close resemblance to some modern forms. Of the known species, four belong to the genus *Pupa* in its wider sense, and are very near to sub-generic types still represented on the American continent and its islands. One is a small helicoid shell not separable from the modern genus *Zonites*, and the remaining one, though it has been placed in a new genus, is very near to some small American snails of the present day (*Stenotrema*, etc.) All the species are of small size, though not smaller than some modern shells of the same types.

I shall now proceed to give the characters and descriptions of the several species, adding to the account of those previously known, such new facts as have occurred in my more recent explorations and examinations. I should state here that many of the new facts detailed have been obtained in the course of excavations for the extraction of erect trees holding land animals, undertaken with the aid of a grant from the Government fund for aiding original researches, at the disposal of the Royal Society of London, and carried on within the past three years.

1. *Pupa vetusta* Dawson. (Figs. 1 to 4, and 14, *a*, *b*.)

[Sir C. Lyell and Dr. Dawson on Remains of Reptiles and a Land shell from the South Joggins in Nova Scotia. Journal of Geological Society of London, vol. ix, 1832 (figured but not named). Dawson's Acadian Geology, 1855, p. 160. Dawson's Air-breathers of the Coal Period, 1863. Acadian Geology, 2d and 3d editions, p. 384, 1868 and 1879.]

Description.—Shell cylindrical, somewhat abruptly conical at the apex, in some specimens tending to diminish in diameter in the later turns or whorls of the shell. Whorls nine in adult shells, slighly convex, in width equal to half the diameter of the shell. Suture impressed. Aperture evenly rounded, not continuous above, rather longer than broad, destitute of teeth; peristome slightly reflected and smooth. Surface shining, marked with longitudinal smooth ridges, separated by spaces a little wider than the ridges; spaces about $\frac{1}{500}$th inch in width. Shell calcareous, thin, prismatic in structure. Young specimens abruptly conical and helicoid in form. Nucleus round, smooth, the first turn below the nucleus marked with rows of little pits which gradually pass into the continuous striæ. The last whorl of the adult presents irregular lines of growth, instead of the regular microscopic ribs of the middle turns. Mature ovum membranous, or so slightly calcareous that it can be compressed without breaking: the embryo shell sometimes visible within. Length of adult shell rather less than 1 centimeter, breadth in middle 4 millimeters.

Variety tenuistriata.—Along with the ordinary form there are others of similar size and general structure, but with the apex less obtuse and a somewhat greater tendency to diminish in diameter in the later whorls. They have also the microscopic ridges in the shell about half as far apart as those of the ordinary form. This form I was at first disposed to regard as specifically distinct, but there seems to be a gradual transition from one to the other, and the two forms seem to accompany each other throughout the entire range of the species.

State of preservation.—The shells are usually entire, but often somewhat flattened, and cracked or distorted in the process. Many fragments of shells, however, occur with the entire specimens, and some of these have a whitened or bleached appearance like that of modern land shells after having been exposed to the weather. In one layer I found impressions of several flattened shells, the substance of the shell having been altogether removed. Ordinarily the shell remains in such a state as to show its structure, and the more perfect specimens found in the erect trees have a grayish brown color, like that of some modern Pupæ.

The habitat of this species was in forests of the Coal-formation period, composed of *Sigillaria*, *Calamites*, *Lepidophloios* and *Ferns*. The only known locality is the South Joggins, Nova Scotia. At this place the shells have been obtained in considerable numbers, though perfect specimens which can be disengaged from the matrix, are comparatively few. They have been found in erect *Sigillariæ* and also in a bed of shale. The lowest and highest beds in which they occur are separated by 2,000 feet of vertical thickness of strata including no less than thirty-five beds of coal and many underclays supporting erect trees, so that the species must have inhabited this locality for a very long time and must have survived many physical vicissitudes.

The first specimen, which was also the first known Paleozoic land shell, was found by Sir Charles Lyell and the writer in 1851, in breaking up the contents of an erect tree holding reptilian bones. The specimens obtained from this tree having been taken by Sir Charles to Cambridge and submitted to the late Prof. Jeffries Wyman, the shell in question was recognized by him and the late Dr. Gould, of Boston, as a land shell. It

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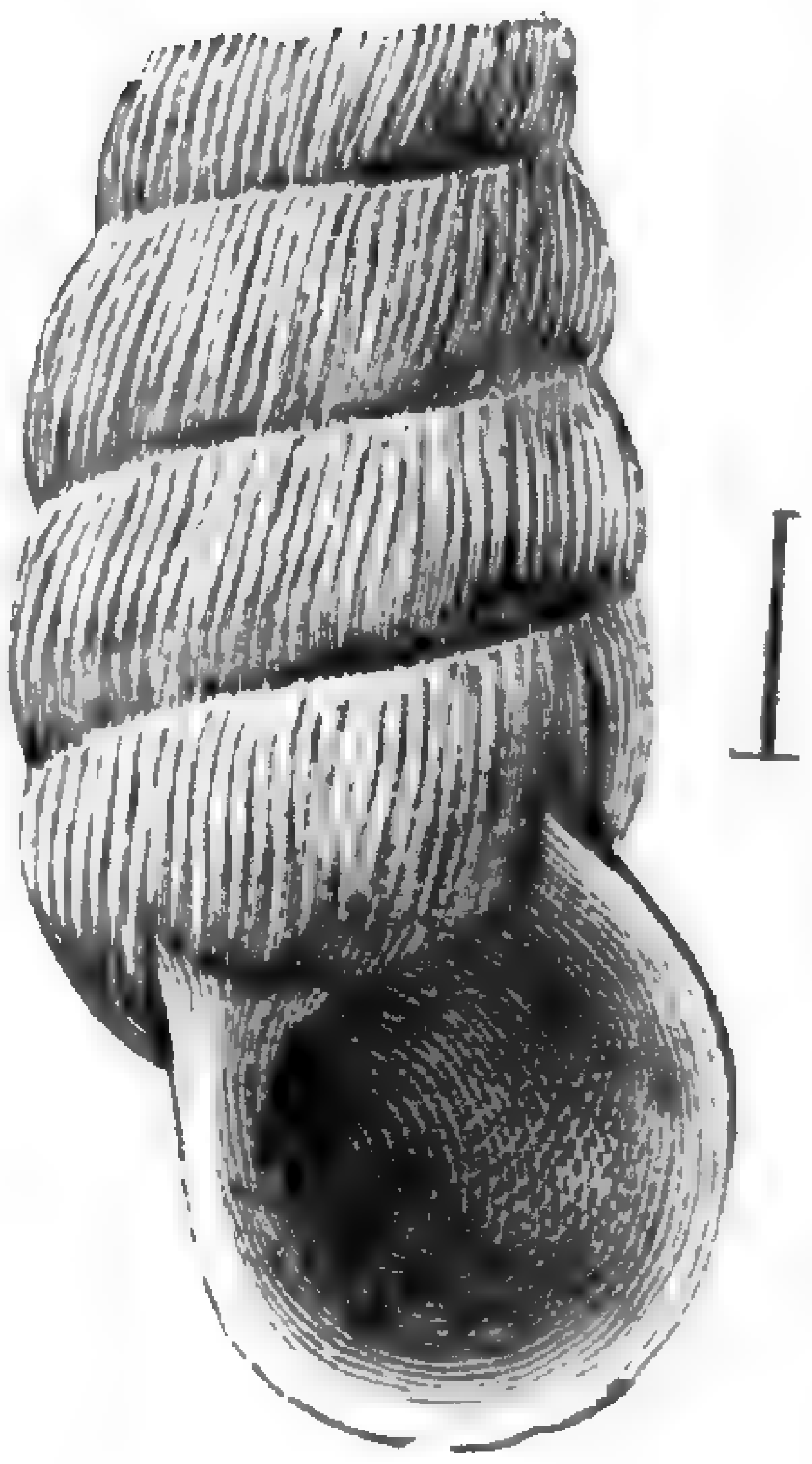

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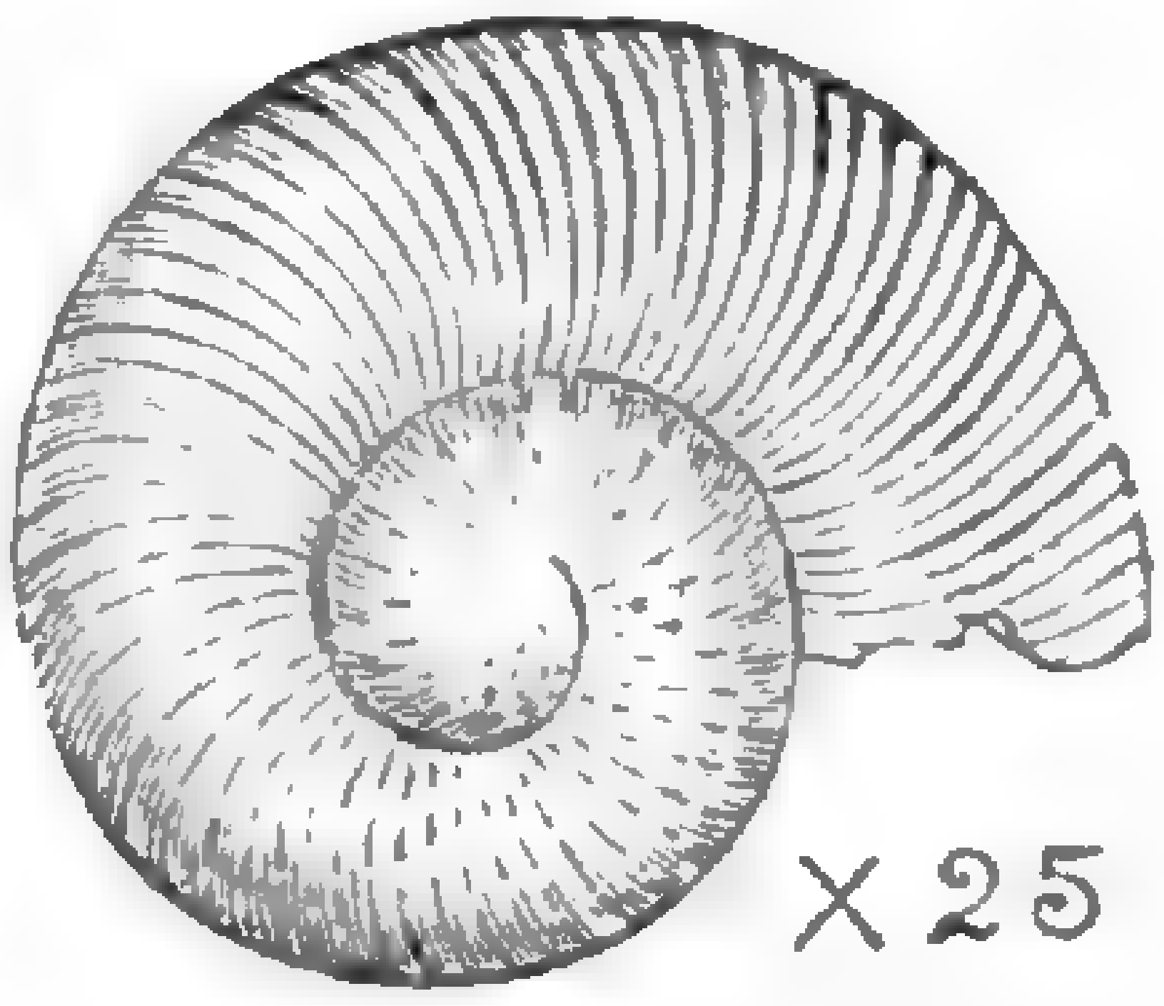

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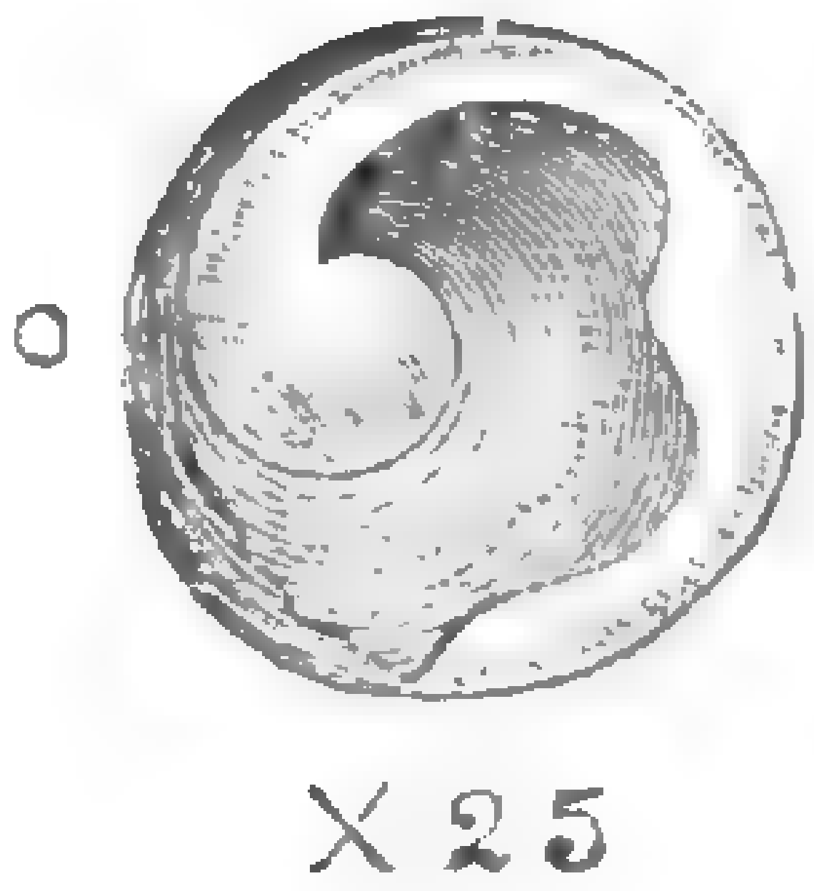

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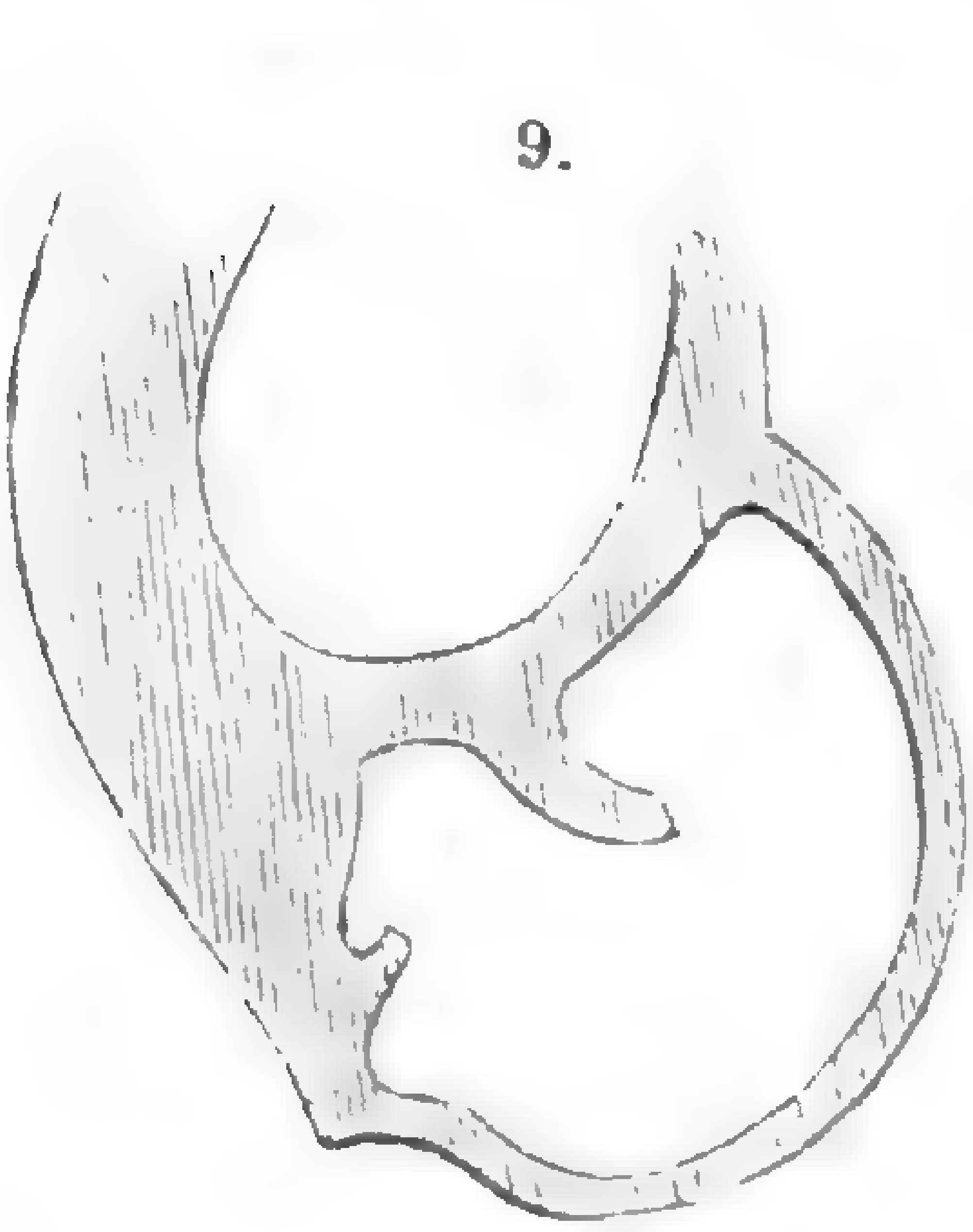

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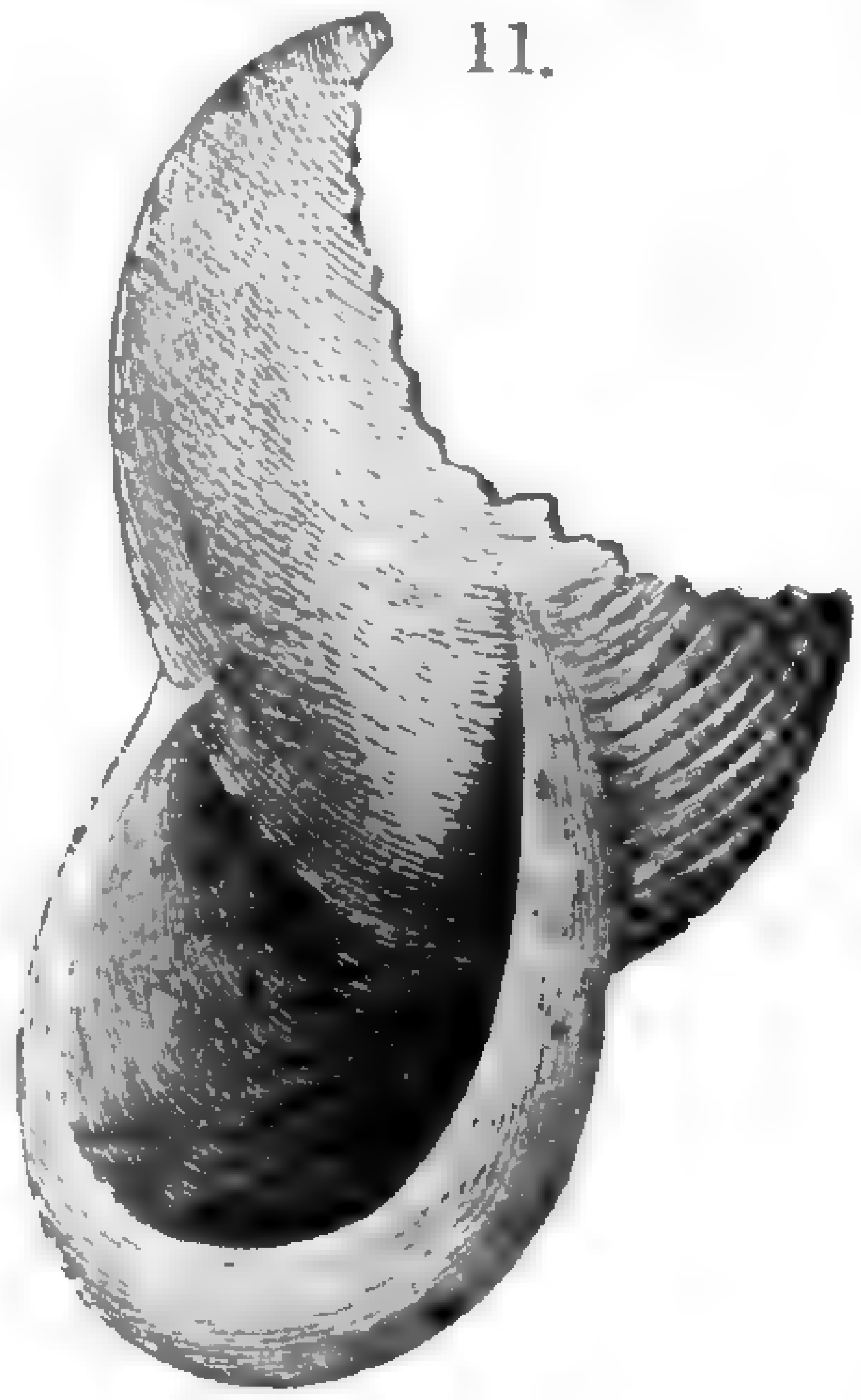

Fig. 1, *Pupa vetusta*, magnified 8 times lineally; 2, same, showing the aperture, ×8; 3, same, nuclear whorl, ×25; 4, same, mature egg and embryo shell, ×25. 5, 6, *Pupa Bigsbii*, ×8. 7. *Pupa Vermilionensis*, ×8; 8, same, showing aperture ×8, the small tooth on the columella somewhat exaggerated; 9, same, section of aperture, showing tooth ×16. 10, *Zonites priscus*, ×8; 11, same, crushed specimen, showing aperture ×20.

was subsequently examined by M. Deshayes and Mr. Gwyn Jeffries, who concurred in this determination; and its microscopic structure was described by the late Prof. Quekett, of London, as similar to that of modern land shells. The single specimen obtained on this occasion was somewhat crushed and did not show the aperture. Hence the hesitation as to its nature, and the delay in naming it, though it was figured and described in the paper above cited in 1852. Better specimens showing the aperture were afterward obtained by the writer, and it was named and described by him in his "Air-breathers of the Coal Period," in 1863. Prof. Owen, in his 'Palæontology,' subsequently proposed the generic name *Dendropupa.* This I have hesitated to accept, as expressing a generic distinction not warranted by the facts; but should the shell be considered to require a generic or sub-generic distinction, Owen's name should be adopted for it. There seems, however, nothing to prevent it from being placed in one of the modern sub-genera of simple-lipped Pupæ. With regard to the form of its aperture, I may explain that some currency has been given to an incorrect representation of it, through an unfortunate accident. In the case of delicate shells like this, imbedded in a hard matrix, it is of course difficult to work out the aperture perfectly; and in my published figure in the "Air-breathers," I had to restore somewhat the broken specimens in my possession. This restoration, specimens subsequently found have shown to be very exact. Nevertheless it was criticised by some English conchologists, and when Sir Charles Lyell was about to publish his Student's Manual, he asked me to give him one of my best specimens to be figured. This I sent with micro-photographs of others. It seems, however, that the artist or engraver mistook the form of the aperture and gave it an entirely unnatural appearance in the Student's Manual. That now given is taken from a photograph of the most perfect and least compressd specimen in my possession.

As already stated, this shell seems closely allied to some modern Pupæ. Perhaps the modern species which approaches most nearly to it in form, markings and size, is *Macrocheilus Gossei* from the West Indies, specimens of which were sent to me some years ago by Mr. Bland, of New York, with the remark that they must be very near to my Carboniferous species. Such edentulous species as *Pupa* (*Leucochila*) *fallax* of Eastern America very closely resemble it; and it was regarded by the late Dr. Carpenter as probably a near ally of those species which are placed by some European conchologists in the genus *Pupilla*.

The lowest bed in which *Pupa vetusta* occurs belongs to group VIII of Division 4 of my section of the South Joggins, and is between Coal 37 and Coal 38 of Logan's section, being about 42 feet below Coal 37. The next horizon, and that in which the shell was first discovered, is 1217 feet of vertical thickness higher, in group XV of Division 4 of my section. The shells occur here in erect *Sigillariæ*, standing on Coal 15 of Logan's section. The third horizon is in group XXVI of Division 4, about 800 feet higher than the last. Here also the shells occurred in an erect *Sigillaria.*

In the lowest of these three horizons, the shells are found, as already stated, in a thin bed of concretionary clay of dark gray color, though associated with reddish beds. It contains *Zonites priscus* as well, though this is very rare, and there are a few valves of *Cythere* and shells of *Naiadites* as well as carbonaceous fragments, fronds of ferns, *Trigonocarpa*, etc. The *Pupæ* are mostly adult, but many very young shells also occur, as well as fragments of broken shells. The bed is evidently a layer of mud deposited in a pond or creek, or at the mouth of a small stream. In modern swamps, multitudes of fresh-water shells occur in such places, and it is remarkable that in this case the only gasteropods are land shells, and these very plentiful, though only in one bed about an inch in thickness. This would seem to imply an absence of fresh-water Pulmonifera. In the erect *Sigillariæ* of group XV, the shells occur either in a sandy matrix, more or less darkened with vegetable matter, or in a carbonaceous mass composed mainly of vegetable debris. Except when crushed or flattened, the shells in these repositories are usually filled with brownish calcite. From this I infer that most of them were alive when imbedded, or at least that they contained the bodies of the animals; and it is not improbable that they sheltered themselves in the hollow trees, as is the habit of many similar animals in modern forests. Their residence in these trees as well as the characters of their embryology are illustrated by the occurrence of their mature ova. They may also have formed part of the food of the reptilian animals whose remains occur with them. In illustration of this I have elsewhere stated that I have found as many as eleven unbroken shells of *Physa heterostropha* in the stomach of a modern *Menobranchus.* I think it certain, however, that both the shells and the reptiles occurring in these trees must have been strictly terrestrial in their habits, as they could not have found admission to the erect trees unless the ground had been sufficiently dry to allow several feet of the imbedded hollow trunks to be free from water. In the highest of the three horizons the shells occurred in an erect tree, but without any other fossils, and they had apparently been washed in along with a grayish mud.*

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* The discovery of the shells in this tree was made by Albert I. Hill, C.E.

2. *Pupa Bigsbii* s. n. (Figs. 5 and 6.)

Description.—Shell half the size of *Pupa vetusta*, or between three and four millimeters in length and one and five-tenths millimeters in breadth. Form, long conical. Body whorl about one-third of the entire length, giving the shell a somewhat bulimoid form. Whorls five in the largest specimens found, tumid, suture much impressed. Surface smooth. Aperture apparently oval in form, but not perfectly known, as the body whorl is crushed in all the specimens.

A few specimens, none of them quite perfect, were found in the erect trees of group XV at the Joggins, along with *Pupa vetusta.* They differ from that species in smaller size, different form and absence of sculpture. The specimens do not show whether the aperture was toothed or simple, but it was probably the latter, as the lip is evidently very thin and delicate. From its form it is probable that it belongs to a different subgenus from *P. vetusta.* It is very much more rare than that species in the erect trees, and has not been found elsewhere.

I dedicate it to my venerable and dear friend Dr. Bigsby, F.R.S., of London, a pioneer in American geology, and still an indefatigable worker in the science.

3. *Pupa Vermilionensis* Bradley. (Figs. 8 and 9, and 14*c*.)

[Bradley in Report of Geological Survey of Illinois, vol. iv, p. 254. Id. in Am. Journ. Sci., III, vol. iv, p. 87.]

*Description.**—Shell spindle-shaped, tapering to an obtuse apex, covered with microscopic ridges (25 to 30 in a millimeter) parallel to the lines of growth. Aperture oblique, oval. Outer lip thin, slightly reflexed. Columella lip reflexed, thickened; furnished with a single central curved tooth, projecting nearly half way across the aperture. Junction of columella and outer lip somewhat angular and dentiform. In old individuals the columella tooth is often continuous through an entire turn or farther. It is not seen on shells having less than three turns. The last turn forms nearly half the length of the shell. Whorls rounded. Suture impressed. Surface glossy. Color black or gray. Length three and six-tenths millimeters. Width two millimeters. Some individuals are smooth or destitute of the fine microscopic ridges, but whether this is a natural peculiarity or a result of injury to the outer surface, is not certain.

As compared with *Pupa vetusta* this shell is less than half the size, of a less cylindrical form, its whorls more rounded, and its body whorl much larger in proportion. Its sculpture is much finer. The conspicuous tooth in the aperture is of

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* Slightly modified from Bradley.

course also a strong mark of distinction. The shell is thin, and from its black color and failure to show structure under the microscope, I infer that it must have been of a horny or corneous texture, with little calcareous matter. The matrix is light colored and concretionary, and somewhat hard and calcareous.

As compared with modern American species, *P. Vermilionensis* is very near to several of the smaller forms with teeth in the aperture. In its form and aperture it approaches closely to *P.* (*Leucochila*) *corticaria* of Say, or to the immature shell of *P. rupicola.* It has also some resemblance to the western species *P. hordeacea* Gabb, from Arizona.

This shell was discovered by the late Mr. F. H. Bradley in 1869, in concretionary limestone accompanying the underclay of Coal No. 6, Wabash Valley Section, at Pelly's Fort, Vermilion River, Illinois. In the first notice, which appeared in the Report of the Geological Survey of Illinois, it was referred to *Pupa vetusta*, but was subsequently described by Mr. Bradley in the American Journal of Science, under the name above cited.

I am indebted for specimens of this shell to Mr. John Collett, of the Geological Survey of Indiana, and also to Mr. W. Gurley, of Danville, Illinois.

4. *Zonites* (*Conulus*) *priscus* Carpenter. (Figs. 10 and 11, and 14*d.*)

[Quarterly Journal of Geological Society of London, Nov. 1867. Acadian Geology, 2d edition, 1868, p. 385.]

*Description.**—Shell small, helicoid. Length two and five-tenths millimeters, width two and eight-tenths millimeters. Spire little elevated. Nucleus small. Whorls four, somewhat flattened, with the suture little impressed. Base somewhat excavated with large umbilicus. Aperture oblique, suboval, somewhat regularly rounded. Lip simple. Surface marked with uneven striæ and somewhat more conspicuous ridges of growth. Angle of divergence about 130°. Shell thin and probably horny.

This little shell was discovered in 1866, in the bed already referred to as the lowest of those at the South Joggins in which *Pupa vetusta* has been found. Shortly after I had discovered this bed, being impressed with the probability that it might hold other remains of land animals beside the *Pupa*, I had some excavations made in it, and a considerable quantity of material taken out. I found, however, that the thin layer containing the land shells was not continuous but in limited patches, and was rewarded only by the discovery of a few

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* Slightly modified from Carpenter.

specimens of *Zonites priscus* and a small and not determinable fragment of bone, in addition to specimens of *Pupa vetusta.*

The specimens found at this time were submitted to the late Dr. P. P. Carpenter, by whom the species was named and described. One or two crushed specimens have been subsequently found in the erect trees holding *Pupa vetusta* in group XV, but the species is extremely rare in comparison. This may however have depended on some difference in habitat or mode of life, rendering it less likely to be imbedded in the deposits in process of formation. It is also to be observed that the shell is much more delicate than that of *Pupa vetusta*, and therefore less likely to be preserved.

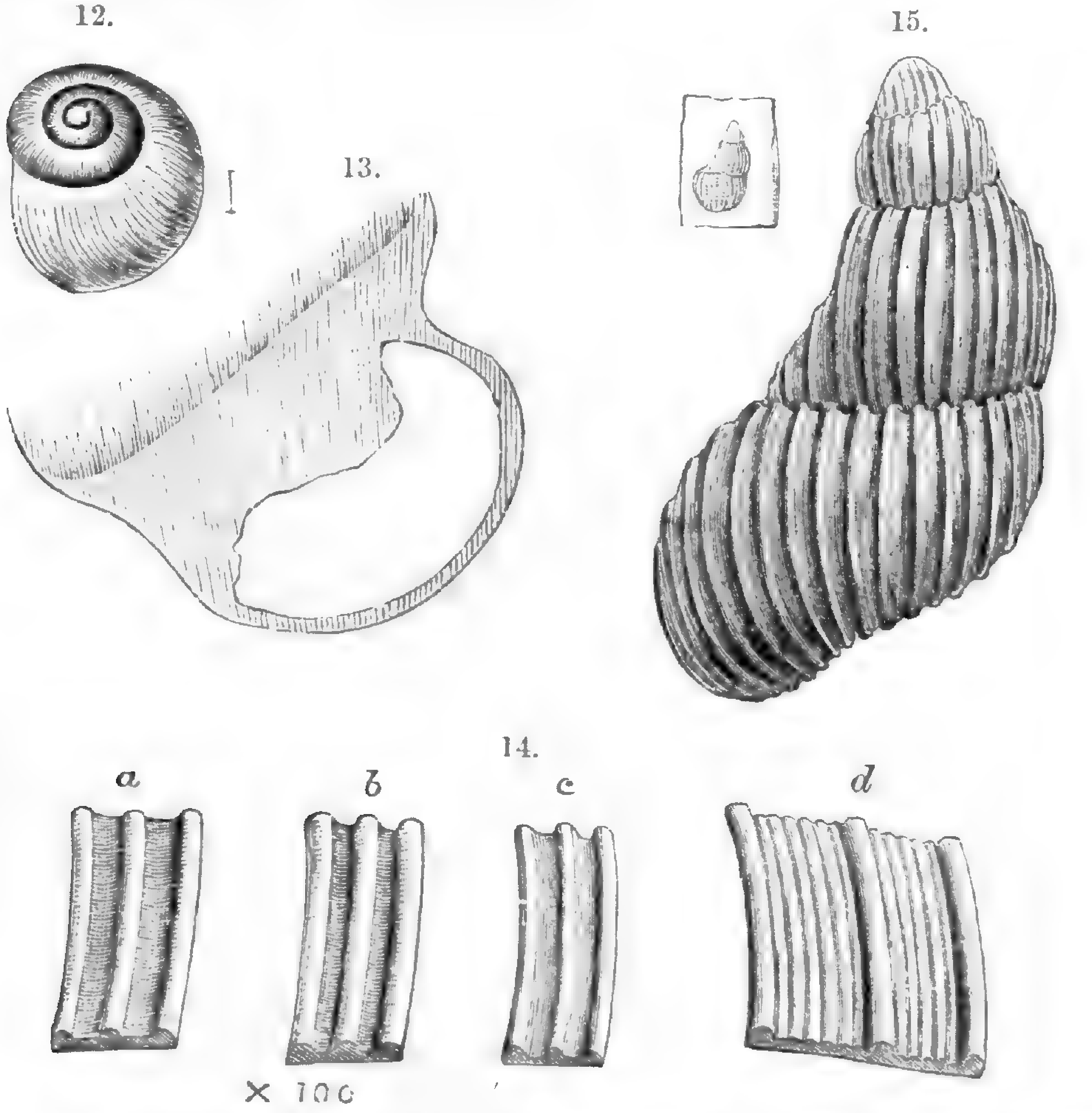

Fig. 12, *Dawsonella Meeki*, × 8; 13, same, section of aperture, × 16; the outer edge of the lamella is imperfect. 14, Markings of surface × 100: (*a*) *Pupa vetusta*; (*b*) *Pupa vetusta* var. *tenuistriata*; (*c*) *Pupa Vermilionensis*; (*d*) *Zonites priscus*; 15, *Strophites grandæva*, natural size and magnified 8 diameters.

With regard to its affinities, it was compared by Dr. Carpenter with the African species *Paryphanta Caffra* Fer., "on an extremely small scale." Dr. Carpenter also compared it with *Hygromia*, and stated that it might well be ranked under *Pseu-*

dohyalina of Morse, with the living species *minuscula* and *exigua.* He thought it best, however, to place it in the subgenus *Conulus* of the genus *Zonites*, as defined by Messrs. Adams. With regard to the subgeneric name, Dr. Carpenter explained that the subgenus *Conulus* of Fitz, 1833, appears to be synonymous with *Trochiscus* Held, 1837 (non Sby.); also with *Petasia* Beck, 1837; and with *Perforatella* Schlütt.; and according to Adams is a subgenus of *Zonites* Montf. (non Leach, Gray). Those who do not care to enter into these subgeneric distinctions, may designate the species as a *Zonites*, or even, speaking loosely, as a *Helix.* There seems nothing in its characters to separate it, more than specifically, from many of our smaller helicoid snails with thin shells and simple aperture.

5. *Dawsonella Meeki* Bradley. (Figs. 12 and 13.)

[Report of Geological Survey of Illinois, vol. iv, p. 254. Am. Journ. of Sci., III, vol. iv, p. 88. Ibid, vol. vii, p. 157.]

*Description.**—Shell broad, depressed, helicoid. Spire obtuse, consisting of three to three and one-half turns. Length three and two-tenths millimeters, width four millimeters. Surface smooth, but with fine microscopic lines of growth, about fifteen in a millimeter. Aperture oblique, oval, greatly contracted by a broad lamellar expansion of the columella, extending more than half way across, even in small individuals. Outer lip thickened, slightly reflexed. Suture little impressed, imperforate, but last turn slightly excavated in the umbilical region. The shell is usually black in color, and under the microscope shows no distinct structure, from which it may be inferred that it was corneous in texture. It is thicker than the shell of *Zonites priscus.*

This species is found along with *Pupa Vermilionensis*, and was discovered by Bradley, who was, however, at first disposed to refer it to genus *Anomphalus* of Meek; but subsequently, and with good reason, regarded it as distinct and as a land shell. In size and general form it resembles *Zonites priscus*, though expanding less rapidly and with rounder whorls; but it is at once distinguished by its want of the somewhat coarse sculpture of that species, and by the plate which partially covers its aperture. Its nearest modern allies in eastern America would seem to be such shells as *Helix* (*Triodopsis*) *palliata*, and *H.* (*Stenotrema*) *monodon.*

For specimens of this shell I am indebted to the persons above named as having furnished specimens of *Pupa Vermilionensis.*

6. *Strophites grandæva*, s. n. (Fig. 15.)

Description.—Shell cylindrical, with obtuse apex. Whorls four or more. Surface covered with sharp vertical ridges,

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* Modified from Bradley.

separated by spaces three times as wide. The body whorl about 4 millimeters in diameter, with about thirteen vertical ridges visible on one side. Length of a specimen probably not quite perfect, about 8 millimeters. The shell, which has disappeared, must have been very thin, and the surface remaining is smooth and shining. In general form, so far as can be ascertained from a very imperfect specimen, this shell must have closely resembled the modern Pupæ of the genus *Strophia* of Albers.

The only specimen known is from the Erian (Devonian) plant-beds of St. John, New Brunswick, which, besides affording great numbers of remains of land plants, have produced the only Erian insects as yet known. It was sent to me by Mr. G. F. Matthew, of St. John, along with specimens of fossil plants, several years ago, but I hesitated to describe it, waiting in hope of additional specimens. As these have not occurred, and I have now carefully examined the whole of the material from these beds to which I have been able to obtain access, I venture to name it as probably the oldest known land shell, the beds in which it is found being either middle or upper Erian.

If a land snail, it is larger in size and probably of higher type than any of those known from the Coal-formation. This would not be wonderful, when we consider the greater variety of surface and the high character of the vegetation, which, as I have elsewhere endeavored to show, distinguished the later Erian age in Northeastern America.

Concluding Remarks.

It may be proper to mention here the alleged Pulmonifera of the genus *Palæorbis* described by some German naturalists. These I believe to be worm-tubes of the genus *Spirorbis*, and in fact to be nothing else than the common *S. carbonarius* or *S. pusillus* of the Coal-formation. The history of this error may be stated thus. The eminent paleobotanists Germar, Gœppert and Geinitz have referred the *Spirorbis*, so common in the Coal-measures to the fungi, under the name *Gyromyces*, and in this they have been followed by other naturalists, though as long ago as 1868 I had shown that this little organism is not only a calcareous shell, attached by one side to vegetable matters and shells of mollusks, but that it has the microscopic structure characteristic of modern shells of this type.* More recently Van Beneden, Cænius and Goldenberg, perceiving that the fossil is really a calcareous shell, but apparently unaware of the observations made in this country by myself and Mr. Lesquereux, have held the *Spirorbis* to be a pulmonate mollusk allied to *Planorbis*, and have supposed that its presence on fossil

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* Acadian Geology, 2d edition, p. 205.

plants is confirmatory of this view, though the shells are attached by a flattened side to these plants, and are also found attached to shells of bivalves of the genus *Naiadites.* Mr. R. Etheridge, Jr., of the Geological Survey of Great Britain, has recently summed up the evidence as to the true nature of these shells, and has revised and added to the species, in a series of articles in the Geological Magazine of London, vol. viii.

If we exclude the alleged *Palæorbis* above referred to, all the Paleozoic Pulmonifera hitherto found are American. Since, however, in the Carboniferous age, Batrachians, Arachnidans, Insects and Millipedes occur on both continents, it is not unlikely that ere long European species of land snails will be announced. The species hitherto found in Eastern America, are in every way strangely isolated. In the plant-beds of St. John, about 9,000 feet in thickness, and in the Coal-formation of the South Joggins, more than 7,000 feet in thickness, no other Gasteropods occur, nor, I believe, do any occur in the beds holding land snails in Illinois. Nor, as already stated, are any of the aquatic Pulmonifera known in the Paleozoic. Thus, in so far as at present known, these Paleozoic snails are separated not only from any predecessors, if there were any, or successors, but from any contemporary animals allied to them.

It is probable that the land snails of the Erian and Carboniferous were neither numerous nor important members of the faunæ of those periods. Had other species existed in any considerable numbers, there is no reason why they should not have been found in the erect trees, or in those shales which contain land plants. More especially would the discovery of any larger species, had they existed, been likely to have occurred. Further, what we know of the vegetation of the Paleozoic Period would lead us to infer that it did not abound in those succulent and nutritious leaves and fruits which are most congenial to land snails. It is to be observed, however, that we know little as yet of the upland life of the Erian or Carboniferous. The animal life of the drier parts of the low country is indeed as yet very little known; and but for the revelations in this respect of the erect trees in one bed in the Coal-formation of Nova Scotia, our knowledge of the land snails and Millipedes, and also of an eminently terrestrial group of reptiles, the *Microsauria*, would have been much more imperfect than it is. We may hope for still further revelations of this kind, and in the meantime, it would be premature to speculate as to the affinities of our little group of land snails with animals either their contemporaries or belonging to earlier or later formations, except to note the fact of the little change of form or structure in this type of life in that vast interval of time which separates the Erian Period from the present day.

ART. XLIII.—*Extension of the Carboniferous Formation in Massachusetts;*[*] by W. O. CROSBY and G. H. BARTON. (Contributions from the Geological Department of the Massachusetts Institute of Technology: No. I.)

THE Carboniferous strata of Massachusetts and Rhode Island are all found within the limits of what is known as the Narragansett basin; the well-marked geological basin holding Boston and its environs being, in our opinion, entirely filled with rocks of Primordial age. The northern and western boundaries of the Narragansett basin have about the latitude and longitude, respectively, of the northeast corner of Rhode Island, tending to form a right angle at this point. But the angle is not closed, for the basin gives off a long, narrow branch or arm here which sweeps first in a northeasterly and then in an easterly direction to Braintree in Massachusetts, where, at a distance of more than twenty-five miles from its origin, it nearly, but probably not quite, connects with the Boston basin. The nearest outcrops in the two basins are about two miles apart, are entirely dissimilar lithologically, and are certainly widely separated in time. The intervening ground is a thick deposit of drift, and, although its contours are not unfavorable to the theory that the basins communicate, yet it is probably underlaid by granite, which is the predominant underlying rock of all this region. This elongated arm of the Narragansett basin lies wholly within the limits of Norfolk County; and, hence, it has received the local designation of the Norfolk County basin. Its breadth varies from a small fraction of a mile to two and one-third miles; and it is widest in the middle part, being very much contracted toward each end.

President Hitchcock long ago established the Carboniferous age of the coal-bearing strata of the Narragansett basin. These are well developed on the island of Aquidneck, and also form a broad, semi-circular belt reaching from Warwick and Providence northerly by Valley Falls to Wrentham in Massachusetts, and thence easterly through Attleboro and Mansfield into Bridgewater.

South and east of this band of undisputed coal-measures is

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[*] This communication is an abstract embodying the more important results of an extended paper, illustrated with maps and sections, on the "Geology of the Norfolk County basin in Massachusetts." The original essay represents nearly four months of field and laboratory work, performed chiefly by Mr. Barton, and formed his thesis for graduation in the Class of 1880 of the Massachusetts Institute of Technology. We wish to acknowledge our great obligations to Professor W. H. Niles for material assistance rendered in many ways, and also to Hon. John Cummings and President W. T. Hart of the New York and New England Railroad for free transportation while engaged upon the field-work.

a wide area of conglomerate, extending to the limits of the basin. This great development of conglomerate was regarded by Hitchcock as underlying the coal strata, and as probably of Silurian age. While the stratified rocks lying to the northwest of the anthracite belt, and composing the attenuated Norfolk County basin, were finally referred provisionally by this distinguished geologist, and mainly upon lithological grounds, to the Devonian system, and Sir Charles Lyell, in a paper on the Worcester Anthracite,* appears to concur in this conclusion.

Of the former, if not the present, existence of Cambrian (Lower Silurian) strata in the Narragansett basin there can be but little doubt, since pebbles holding Primordial fossils—Scolithus and Lingula—are of common occurrence in the conglomerate at Newport, Fall River and Taunton; and yet this great conglomerate itself is now generally and, as we think, justly regarded as essentially a part of the Carboniferous series. That all previous determinations of the age of the Norfolk County beds have rested on insufficient evidence is obvious; and to improve this state of things was one of the principal objects of our investigation. A variety of opinions has been held concerning the horizon of this belt, it having been referred by different observers to the Primordial, Devonian, Carboniferous and Triassic systems. Almost the only argument for either the Devonian or Triassic age of these sediments is that derived from their color, red sandstones and shales occupying a prominent position in the basin; and the principal evidence of their Primordial age seems to be their proximity to the Boston basin, in Braintree; but, as already stated, the evidence is against the communication of the two basins in either past or present time. The Norfolk County beds are extensively folded, showing at most points high, and often vertical, dips; but in this respect they are as little contrasted with the Carboniferous on the one hand as with the Primordial on the other. In the almost complete absence of eruptive rocks among the beds in question, however, we find a sharp distinction between them and all the Primordial of Eastern Massachusetts.

We entered upon our work with a prepossession in favor of the Devonian age of the belt; but almost at the outset we were struck by the strong resemblance which it presented both lithologically and stratigraphically to the Carboniferous on the south. The Carboniferous of the main Narragansett basin, so far as we have been able to learn from our own observations, and from those of Hitchcock, consists essentially, beginning at the base, of the following groups of rocks:

(1.) A great thickness of conglomerate, which, at the bottom, is sometimes extremely coarse and irregular, holding bowlders

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* Jour. Geol. Soc. London, vol. i.

a yard or more in diameter, though the great mass of the rock is composed of pebbles not exceeding three inches in diameter. The higher portions, especially, include considerable sandstone, mostly in thin and irregular beds. All the crystalline rocks of the region are represented among the pebbles of the conglomerate, though granite, quartz and quartzite predominate. The paste is sometimes ferruginous, giving the red conglomerate described by Hitchcock.

(2.) The conglomerate gives way upward to red and gray or green sandstones which have in the aggregate a considerable thickness, certainly not less than six hundred feet. The differently colored sandstones do not appear to be always sharply separated stratigraphically, but it seems probable that in some cases the same horizon is represented by red sandstone at one point and green at another. Yet we are of the opinion that the red color is chiefly characteristic of the lower beds. Pebbly layers, and even considerable beds of conglomerate, sometimes appear in the sandstone; and these are much more abundant in some localities than in others. Both the red and the green sandstones frequently pass into true slates and shales; and in the red shales, especially, the ferruginous character is often very strongly marked.

(3.) Above the sandstone series, and forming the summit of the formation, come the true coal-measures, which, as well described by Hitchcock, consist very largely of a black, highly carbonaceous slate, but also include a large amount of green sandstone and shales, with comparatively little red rock. Conglomerate is rare in this series, though not entirely wanting.

Now, the important point to be made here is, that the first and second series described above agree perfectly in both composition and sequence with the rocks of the Norfolk County basin; that is, the Norfolk County beds are essentially similar lithologically and stratigraphically to the lower Carboniferous of the main basin; but we find in the smaller basin no trace of the highly carbonaceous, plant-bearing shales, and anthracite of the third series.

Furthermore, we have been able, in Wrentham, to trace a direct physical connection between the rocks of the Norfolk County belt, and the conglomerate and sandstone which underlie the coal-measures; so that, even in the absence of paleontological evidence, it seemed reasonably certain that the sediments of this narrow trough were the stratigraphical equivalents of all but the upper series of the Narragansett basin. But, before the close of our field-work, we were, fortunately, able to clinch the proof of their Carboniferous age by the discovery, near the middle of the belt, of characteristic Carboniferous fossils.

The precise locality is the place marked on the map as Rockdale, in the southeastern corner of the town of Norfolk. In this neighborhood there are many large, bold ledges of conglomerate and sandstone, as well as of the underlying granite; and this is, on the whole, the best exposure of the rocks which the belt affords. The fossils are found only in a small-pebbled or arenaceons conglomerate which lies near the top of the first or conglomerate series; and their occurrence along several lines of strike has assisted us in arriving at a knowledge of the structure of the region, the beds being clearly thrown into a series of closed folds. The fossils seem to consist wholly of the molds of Sigillaria, though many of them are so imperfect that, for aught that we could determine, they might be Calamites or Lepidodendron. The coarse texture of the rock has been unfavorable for the preservation of the finer and more characteristic features of the bark. Still, in several cases, enough remains to show that the specimens are unquestionably Sigillaria. The molds are all considerably flattened, and the flattening corresponds in direction with the imperfect cleavage of the rock. They are of various sizes, the smallest being one or two inches in diameter, while the largest observed was about twenty inches by six inches on the cross section. They are usually inclined to the horizon, and the extent to which the arenaceous material formerly filling them has been removed by the action of the weather is remarkable, some of the holes so formed having been probed to a depth of twenty feet or more. About thirty molds in all have been observed.

Although fossils have been found at only this one locality, yet we are not persuaded but that, having learned what kind of impressions are to be looked for, close observation would discover them at other points. Certainly, there is nothing peculiar in the character of the rock at Rockdale; and we feel that the fossils occurring here, taken in connection with the lithological and stratigraphical evidence already referred to, afford ample proof of the equivalence of the Norfolk County series and the conglomerate and sandstone underlying the coal-measures in the main Narragansett basin; and Hitchcock and Lesquereux have already satisfactorily referred these lower Narragansett beds to the horizon of the Millstone Grit. It is worthy of note, too, that the descriptions given by Dawson in his "Acadian Geology" of the Millstone Grit series of New Brunswick and Nova Scotia apply very closely to the rocks in question; and since our coarse conglomerate rests immediately upon the crystallines, it is apparent that Dawson's Carboniferous limestone and lower coal-measures, which taken together represent the Subcarboniferous of the Appalachian region, are probably entirely wanting in Massachusetts and Rhode Island.

We have observed many facts pointing to the conclusion that the Norfolk County beds were deposited in a narrow, elongated basin, similar to that which they now occupy, that is, that the present borders of the belt coincide approximately, at least, with the original shore lines, and that any narrowing which the belt may have experienced is due mainly to folding rather than to denudation.

Along the existing border of the belt, where, of course, the lowest beds of conglomerate outcrop, these are usually mainly, sometimes entirely, composed of pebbles of the immediately adjacent crystallines; and where the conglomerate rests upon granite, the first-formed beds are often a typical arkose which is distinguished with difficulty from the parent rock. This relation of the basal conglomerate to the crystallines is especially noticeable along the south side of the Blue Hills, in Quincy, Milton and Dedham. The carboniferous rocks here, as at most points, form low, level land, and for six miles the conglomerate plain meets abruptly the steep and sometimes almost cliff-like southern slope of this well-marked range of hills, which, on this side, is composed of fine-grained, slightly hornblendic granite, and a variety of petrosilex containing crystalline quartz and feldspar, a true quartz-porphyry or elvanite. Now we find that the conglomerate skirting the base of the Blue Hills is not only almost entirely composed of the débris of these two varieties of rock, but it is also, for the most part, exceedingly coarse, holding many bowlders from one to four feet in diameter, and these are often but imperfectly rounded. It is, in fact, just such material as accumulates on the adjacent coast to-day, where the sea beats against cliffs of granite and petrosilex; and, to our minds, the conclusion is irresistible that the Blue Hills, much higher then than now, towered cliff-like, above the Carboniferous sea, and marked then as now, the northern limit of the deposits of that age.

From the conclusions already stated, an inference of some practical importance may be drawn, viz: although the Norfolk County basin contains only beds of Carboniferous age, yet it is improbable that coal will ever be discovered within its limits, this narrow trough having become filled with sediments and converted into dry land, before the deposition of the true coal-measures began, and this later-formed series having been always, apparently, restricted to a comparatively small part of the main or Narragansett basin.

Art. XLIV.—*Discovery of a new Planetoid, and observations on Hartwig's Comet;* by Professor C. H. F. Peters. Communication to the editors, dated Litchfield Observatory of Hamilton College, Clinton, N. Y., October 13, 1880.

A bright *planetoid* was discovered on Oct. 10, and the following positions have been obtained:

1880.	Ham. Coll. m. t.	App. α (219).	App. δ (219).	Log. (p'' Δ).	No. of comp.
Oct. 10.	$14^h\ 18^m\ 12^s$	$1^h\ 27^m\ 9^s{\cdot}28$	$+9^\circ\ 6'\ 46''{\cdot}4$	0·553 0·705	10
Oct. 11.	13 19 58	1 26 27·86	+8 52 19·6	0·342 0·699	10

The position of Oct. 11 depends upon that of Dm. + 8°·252, a star of $8^m{\cdot}8$, but of which no accurate determination is found. It has been assumed for 1880·0:

$$\alpha = 1^h\ 29^m\ 45^s{\cdot}0 + c. \qquad \delta = +8^\circ\ 48'\ 20'' + c',$$

so that the planet's coördinates will receive corresponding corrections, when the star's place has been better determined.

The magnitude of the planet was estimated at $9^m{\cdot}3$, and its relatively great nearness to the earth is, besides, concluded from the great apparent motion, amounting to 43^s and 15′ 14″ in 24 hours.

I append such of my observations on the *Comet Hartwig*, as far as the comparison stars have been determined.

1880.	H. C. m. t.	α	δ	Log. ($p.''\Delta$)	No. of Comp.	Comp. star.
	h m s	h m s	° ′ ″			
Oct. 3.	7 18 29	15 27 12·46	+27 15 49·3	0·842 0·645	5	W_2. $15^h{\cdot}654$
" 3.	9 10 45	15 28 26·34	+27 11 54·7	0·862 0·767	5	*a* Coronæ.
" 8.	7 33 23	16 30 53·87	+22 40 57·3	0·803 0·651	10	W_2. 16^h 970 & 976
" 10.	8 27 55	16 49 17·68	+20 55 17·1	0·830 0·704	7	W_2.16^h1602

In Weiss's Catalogue the right ascension of $16^h{\cdot}970$ ought to be corrected by + 10^s.

On October 9, when the moon did not yet interfere, the tail could be followed, by a five-inch seeker, for three or four degrees. The nucleus, though not quite stellar, shows a good concentration for accurate pointing.

Art. XLV.—*The Discovery of Oxide of Antimony in extensive lodes in Sonora, Mexico;* by E. T. Cox, of Tucson, Arizona Territory.

[Read before the Boston meeting of the American Association for the Advancement of Science, August 27, 1880.]

Up to the present time the antimony of commerce has been mostly obtained by the reduction of the sulphide, and though this ore is widely distributed over the globe, it is, as a rule, associated with a variety of mineral substances that obstruct reduction and add to the cost of purifying the metal. These sulphides are also found in such sparse quantities, that the metal usually commands from three to four times the price of lead, and fully as much as that of tin or copper. At present the supply of sulphides of antimony for the English smelters is obtained from Algeria, Spain and Ceylon. Small quantities of oxide of antimony ores have been found in portions of Europe and in Ceylon, but at no time in such quantities as to elicit special attention. When, therefore, about a year ago, I called the attention of English metallurgists and smelters to the occurrence of vast lodes of almost pure oxide of antimony in the district of Altar, Sonora, Mexico, thirty miles from the Gulf of California, it seemed too marvelous for their belief.

A company of gentlemen of Boston, Mass., now have control of these antimony mines, and the ore will soon be in the hands of smelters.

The geological features of the country where this ore abounds are similar to those of Southern Arizona. The mountains are in short, narrow ranges, having for the most part a northerly and southerly trend. Their crests are either rugged or well-rounded cones, according to the nature of the rocks forming their mass. Between these ranges, we have what is called mesa or table land; the latter is formed of the debris of the mountains. This material is of so loose and porous a nature, that the small amount of rain which falls sinks through it and leaves the land dry and arid. As far as I have been able to make out the order of the rocks forming these mountain chains, we have first granite, and this is flanked by Subcarboniferous limestone, in most places so crystalline as to obliterate all traces of fossils. Protruding through these and forming the mountain peaks, we have porphyry, quartzites, basalt, diorites and trachytes.

The country rock in the immediate vicinity of the antimony mines is quartzite and limestone. The lodes are from four to twenty feet wide, and exploitation work, carried to a depth of thirty feet, shows that the fissures are filled from wall to wall with the oxide of antimony, almost pure and remarkably uniform in character. The course of the lodes is nearly north and south; the pitch is high to the east. The area over which the ore is found may be roughly stated to be five or six miles long and half a mile or more wide.

The Boston Company controls nine mines, each of which is a full Mexican claim, 800 meters (2624′ 8″) long and 200 meters (656′ 2″) wide. On three of the mines, the crop, which is solid oxide of antimony, stands up boldly above the general surface and may be traced along the claims for many hundred feet. As stated above, the ore, so far as explorations have exposed it, is almost pure oxide of antimony, the little impurity it contains being silica. The fire assays show it to contain from 60 per cent to 70 per cent of pure metal, and I have estimated the entire lode to average 50 per cent. By selection the average may be augmented. On going down to a greater depth in the lode, it is possible that the oxides may give place to sulphides, but thus far there is not the slightest evidence of any change.

This discovery is destined to produce a marked influence upon the production of metallic antimony and to greatly extend its uses.

Professor S. P. Sharples, of Boston, after an examination of many specimens of the oxide of antimony, received from me, has made the following statement: The mineral varies in color from almost white, to a very dark brown. The specific gravity of one of the purest specimens, is 5·07, and it contained 5 per cent of water, and 75 per cent of antimony. This composition and specific gravity approach very closely the same for *stibiconite.*

The mineral is only very slightly soluble in hydrochloric or nitric acid, or aqua regia. Fusion with bisulphate or soda, only partially resolves it. It is, however, readily and easily decomposed in a platinum crucible with carbonate of soda.

This oxide of antimony has hitherto been found only as a slight coating on other antimony minerals, and it has been difficult to get specimens of it, even a few grains in weight.

The mineral is not easily reduced before the blowpipe, but is very easily reduced in a crucible with powdered charcoal or cyanide of potassium, giving as a single operation buttons of star antimony.

ART. XLVI.—*Experiments made to determine the "Drag" of Water upon Water at Low Velocities;* by the Rev. SAMUEL HAUGHTON and J. EMERSON REYNOLDS, M.D.*

A SPHERICAL ball of granite, unpolished, was suspended by a pianoforte wire, and allowed to hang freely; from the brass collar by which the ball was suspended an index projected on each side, the pointed ends of the indices traversing a graduated horizontal circle, whose center corresponded with the line of suspension. The suspended ball was immersed in water contained in an iron tub.

The weight of the granite ball was 22452·85 grams, and its mean diameter was 251·46 millimeters. The length of the

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* From the Proceedings of the Royal Irish Academy, read Feb. 23, 1880. The term "Drag" is to be understood as signifying the combined effects of friction and viscosity

wire of suspension was 610·8 centimeters, and its diameter was 0·889 millimeter. The diameter of the iron tub was 2 feet 4 inches, and the depth of water contained in it was 1 foot 9 inches.

The method of observation was as follows: the indices of the ball having arrived at the zero of rest, the ball was then displaced by a torsional movement of the wire, and allowed to regain its position of rest by a succession of vibrations of diminishing amplitudes.

The quantities observed were, the time of vibration and the rate of diminution of the amplitude.

The equations of motion of the apparatus are thus found:—

$$\frac{d^2x}{dt^2} - X = 0; \qquad (1)$$

where x=the varying amplitude of any point of the surface of the ball measured from the zero of rest; X = the tangential forces of torsion and "drag" acting at the point x.

If we assume that for low velocities the friction will be proportional to the velocity, we shall have

$$X = k^2x - f\frac{dx}{dt}; \qquad (2)$$

where k is a coefficient depending on torsion, and f is a coefficient depending on "drag."

It is easy to see that the complete integral of the equation of motion,

$$\frac{d^2x}{dt^2} + f\frac{dx}{dt} + k^2x = 0, \qquad (3)$$

must be of the form

$$x = ae^{mt}\cos nt + be^{mt}\sin nt, \qquad (4)$$

where a and b are arbitrary constants, and where m and n have the values

$$m = -\frac{f}{2}; \quad n = \sqrt{k^2 - \frac{f^2}{4}}. \qquad (5)$$

If we reckon the time from the commencement of the oscillation, equation (4) reduces to

$$x = ae^{mt}\cos nt. \qquad (6)$$

If T denote the time of a complete double oscillation, we find from the above

$$\theta_n = \theta_0 e^{-\frac{fnT}{2}}, \qquad (7)$$

where θ_n=amplitude of the $(n+1)^{th}$ vibration; θ_0=amplitude of the first vibration.

From (7) we obtain the following working equation, for use in the calculations to determine the coefficient of friction:—

$$f = \frac{2}{nT}\log_e\left(\frac{\theta_0}{\theta_n}\right). \qquad (8)$$

Also, we have $n=\frac{2\pi}{\mathrm{T}}=\sqrt{k^2-\frac{f^2}{4}}$;

from which we obtain, after some reductions,

$$\mathrm{T}=\frac{4\pi}{\sqrt{4k^2-f^2}}. \tag{9}$$

If we introduce into this equation the value of f determined by (8), we obtain k, which depends on the torsion only.

From careful experiments made by means of the apparatus described at the beginning of this paper the following value has been obtained for the coefficient of "drag":

$$f=\frac{1}{307{\cdot}057}$$

From this value of f we can determine the relation between the slope of a water-surface and its velocity. We have, for the equation of motion of the surface,

$$\frac{d^2x}{dt^2}=g\sin i-f\frac{dx}{dt}; \tag{10}$$

where g denotes the force of gravity, i the slope of the surface, and x the distance of any particle from the origin measured in the direction of the motion. If v denote the velocity of a particle, equation (10) becomes at once

$$\frac{dv}{dt}+fv=g\sin i; \tag{11}$$

which gives, by integration,

$$e^{ft}(g\sin i-fv)=\text{const.} \tag{12}$$

This indicates that the velocity will increase from zero up to the value given by

$$g\sin i-fv=0, \tag{13}$$

after which it will remain constant forever.

The final constant velocity given by equation (13) is

$$v=\frac{g\sin i}{f}=32{\cdot}2\times 307{\cdot}057\sin i. \tag{14}$$

If we express the velocity in feet per second, and call h the slope per mile, we find

$$v=1{\cdot}8726\times h\text{ ft. per second}; \tag{15}$$

which is equivalent to

$$v=30{\cdot}642\,h\text{ miles per day}. \tag{16}$$

Dr. Carpenter has proposed to explain the phenomena of ocean circulation by the greater height of the water at the equator as compared with that at the poles.

If we call the distance from the equator to the pole 6,000 miles, and suppose the velocity of the surface current toward the pole to be only one mile per day, we find from equation (16), that this would require a head of water at the equator

$$h = 195{\cdot}80 \text{ feet.}$$

No such difference of level can be admitted between the equilibrium levels of the equatorial and polar oceans. The latest accurate estimate of the difference is that made by Mr. Croll, viz., 4½ feet. This head of water, if it could produce an oceanic flow at all, would be one at the rate of one mile in 42·567 days; or a flow that would occupy 700 years to pass from the equator to the poles.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the determination of Carbon dioxide in expired air.*—**Marcet** has described a modification of Pettenkofer's apparatus for determining the amount of carbon dioxide contained in expired air. He uses a cylinder of thick glass, of about two liters capacity, ground flat at both ends and closed by disks of thick glass, closely fitting the openings and kept in place by brass collars. The upper glass disk is perforated with three holes, to contain respectively a thermometer and two stopcocks. The lower disk has one opening, for the insertion of a stopcock. The cylinder is supported on a tripod. The air to be analyzed is collected in a rubber bag, those used by Marcet holding 39·3 and 64·8 liters under the pressure of one inch of water. The bag is connected to the cylinder by one of the upper openings, and the cylinder is put in communication with the air-pump by the lower one. After exhausting to 20 or 30 mm. pressure the air from the bag is allowed to enter the cylinder; this operation being repeated till the cylinder is filled with air from the bag. By means of the thermometer and a manometer attached to one of the stopcocks, the temperature and pressure are noted. The stopcocks are now closed and communication interrupted with the bag and the air-pump. In place of the tube to the bag, a pipette containing 100 c.c. of normal barium hydrate solution is connected to the cylinder; and in place of the manometer a small bag of vulcanized rubber is inserted to receive the air expelled by introducing the barium solution. On opening the stopcocks of the pipette and the connecting tube, the solution passes into the cylinder. After agitation, the milky liquid is drawn off into a 100 c.c. bottle and closely corked. Subsequently, at convenience, 25 c.c. of this liquid is removed with a pipette, 100 c.c. of distilled water is added, the solution is placed in a burette and added to 5 c.c. of an oxalic acid solution of such strength that 1 c.c. corresponds to one milli-

gram of CO_2, until neutralization is effected. From the data thus given the weight of the carbon dioxide is calculated.—*J. Chem. Soc.*, xxxvii, 493, July, 1880. G. F. B.

2. *On the Atomic Weight of Ytterbium.*—Nilson has continued his researches upon the rare elements of the mineral euxenite, having had the good fortune to receive from Professors Nordenskiöld and Waage more than ten kilograms of this substance. The earth from it, which was formerly called erbia and supposed to be the oxide of a single element, he now finds to contain not less than seven different oxides, scandia, ytterbia, thulia, erbia, terbia, the earth which Soret calls *x*, and yttria. To extract them, the finely pulverized mineral was placed in a platinum dish, in quantities of about 400 grams, mixed with four times its weight of hydropotassium sulphate, and fused over a powerful gas lamp. The fusion was completely extracted with cold water, decanted from the undissolved metallic acids, precipitated with ammonia, the hydrates thus obtained washed out, dissolved in nitric acid, boiled, again decanted from the metallic acids, precipitated with oxalic acid, washed, dried and ignited. In this way 2½ kilograms of the mixed earths was obtained. After boiling with water to free it from potassium carbonate, it was dissolved in nitric acid and the nitrate evaporated and fused until the weight was twice that of the mixed earths. On solution in water, a residue remained of basic nitrates of thorium, cerium, uranium and iron. The filtrate gave a beautiful fused nitrate, which was subjected to the long series of partial decompositions already previously described. The strongest bases, didymium, yttrium and terbium accumulated in the first mother-liquors so that the principal solution after seven decompositions, contained no didymium. In the mother-liquors from 8 to 30 the absorption-bands of the so-called erbia increased successively in intensity, the solution containing finally nearly the whole of the earths which are characterized by absorption bands. Cleve having worked up 15 kilograms of gadolinite at the same time, these two chemists had at least 6–7 kilograms of the earths between them. So they divided the work, Cleve taking erbia proper and thulia, and Nilson ytterbia and Soret's earth *x*. The latter's present paper is upon ytterbium. After 68 decompositions, the syrupy nitrate solution showed not a trace of any absorption band, and, after the scandia had been separated, contained only pure ytterbia.* The solution of the nitrate was treated with H_2S, and the filtrate precipitated with oxalic acid. The oxalate was ignited, the earth converted into nitrate and divided by partial decompositions into seven fractions. Each of these was converted into sulphate by dissolving a weighed quantity of the earth in nitric acid, adding sulphuric acid in excess, and evaporating till no more fumes appeared. The atomic weight of ytterbium as obtained from these seven fractions, calling ytterbia Y_2O_3, is as follows: 173·21, 173·03, 173·08, 173·00, 173·01, 172·84,

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* Series 61–68 contained, beside ytterbia, only the oxide of a metal to which Cleve has given the name of thulium.

172·91; or 173·01 as a mean. The author also describes ytterbia, and its hydrate, nitrate, anhydrous and hydrated sulphates, selenite, and oxalate.—*Ber. Berl. Chem. Ges.*, xiii, 1430, July, 1880. G. F. B.

3. *On the Atomic Weight of Scandium.*—Nilson has also communicated the results of his researches upon the atomic weight of scandium. For its separation from ytterbium, two methods may be used: the first, based upon the fact that scandium nitrate is far more easily decomposed by heat than the corresponding ytterbium salt; and the second, which rests on the behavior of scandium sulphate to a saturated solution of potassium sulphate; a double sulphate $(K_2SO_4)_3$. $Sc_2(SO_4)_3$ being deposited, while ytterbium sulphate is easily soluble in such a solution. Three grams of the mixed earths were dissolved as neutral sulphate in a few c.c. of water, and the solution was gradually saturated with potassium sulphate by hanging fragments of this salt in it in a platinum basket. In a few hours the walls and bottom of the vessel were covered with the crystalline double salt. After a couple of days, it was collected and washed. A weighed quantity of the earth from the filtrate converted into sulphate gave an atomic weight of 172·88, showing this filtrate to contain pure ytterbium. The potassium-scandium sulphate itself was converted into nitrate and fractionally decomposed. Four products were obtained which gave atomic weights of 80·07, 49·47, 49·72, and 46·70; showing that some ytterbia had come down with the scandium. From this last fraction, four further fractions were obtained and the pure scandia prepared by igniting the oxalate. This was weighed, dissolved in nitric acid and evaporated with sulphuric acid in excess till fumes no longer appeared. These fractions gave atomic weights of 43·99, 44·07, 44·05, and 44·02 respectively; or 44·03 as a mean. This atomic weight, 44, coincides exactly with that which Mendelejeff derives from his periodic law for ekabor, with the predicted properties of the oxide of which, scandium oxide Sc_2O_3 coincides. The author describes this oxide, and also the hydrate, nitrate, sulphate, selenite and oxalate. The molecular heat of Sc_2O_3 is 20·81.—*Ber. Berl. Chem. Ges.*, xiii, 1439, July, 1880. G. F. B.

4. *On a new Cymene in Rosin oil.*—Kelbe has examined the lighter oils obtained from the distillation of rosin and finds that they contain a new cymene. After washing with sodium hydrate solution, and fractioning, several products are obtained of constant boiling points. One of these boiling at 170°–178° C., was agitated with concentrated sulphuric acid, in which it dissolved almost completely. On dilution, two layers separated, the upper of which contained the sulpho-acids. This, neutralized with barium carbonate while hot, deposited on cooling brilliant pearly plates of barium α-cymene-sulphate, almost insoluble in cold water, insoluble in alcohol and yielding, when treated with phosphoric chloride and ammonia an α-cymene-sulphamide fusing at 73° C. Further evaporation of the mother liquor gave a second salt, barium

β-cymene-sulphate, as an indistinctly crystalline mass, easily soluble in absolute alcohol. β-cymene-sulphamide prepared from this salt, fuses at 106°–108° C. The cymene prepared from the α-sulpho-salt is a colorless highly refractive liquid of agreeable odor boiling at 173°–175°. By oxidation it gives an acid of high fusing point, probably isophthalic acid. This cymene is distinguished from the parapropytoluenes of Jacobson by the fact that while the sulphamides of these bodies fuse, the one at 112° C., the other at 97°–98° C., this one melts at 73° C. Orthocymene is excluded since it does not yield isophthalic acid on oxidation. Metacymene differs from it in the crystal-form of its barium β-sulpho-salt, and in the ease with which this is converted into the sulphamide. Hence the author is inclined to regard this cymene, at least provisionally, as meta-isopropyltoluene.—*Ber. Berl. Chem. Ges.*, xiii, 1157, June, 1880. G. F. B.

5. *On the preparation of normal Ethyl sulphate.*—VILLIERS has succeeded in obtaining a larger yield of normal ethyl sulphate $(C_2H_5)_2SO_4$, by effecting the distillation under diminished pressure. To prepare this ether, 200 grams of absolute alcohol is distilled slowly with twice its volume of concentrated sulphuric acid, in as good a vacuum as possible. The yield is 25 to 30 grams. Two layers of liquid appear in the receiver, the lower of which is the ether. It is rectified in vacuo, and boils under a pressure of 5 mm. at 2·5° C. It crystallizes at —24·5°, and alkalies convert it at once into sulphethylate.—*Bull. Soc. Ch.*, II, xxxiv, 25, July, 1880. G. F. B.

6. *On Homatropine.*—Atropine, as is well known, breaks up into tropic acid and tropine. LADENBURG succeeded in reversing the process and in producing atropine from tropic acid and tropine. This led him to the synthesis of an entirely new class of alkaloids, which he called tropeines, produced by the action of acids upon tropine in presence of hydrochloric acid. The tropeine of mandelic or oxytoluylic acid, which he calls oxytoluyltropeine or homatropine, while possessing equal mydriatic power with atropine, yet passes off much more rapidly, in 12 to 24 hours. Merck has obtained it crystallized from solution in absolute ether. It fuses at 95·5° to 98·5°, and has the formula $C_{16}H_{21}NO_3$.—*Ber. Berl. Chem. Ges.*, xiii, 106, 1081, 1340, July, 1880. G. F. B.

7. *On Carbonyl Hæmoglobin.*—WEYL and VON ANREP have proposed to use the behavior of oxy-hæmoglobin and of carbonyl-hæmoglobin toward oxidizing agents as a means of detecting the latter in blood poisoning. While 1 c.c. iodine solution (1 grm. KI, 0·05 grm. I, 1 liter water) produces in blood containing oxygen the bands of methæmoglobin immediately, in blood containing carbonous oxide these bands appear only after four days. In oxygenated blood, ½ c.c. of permanganate solution (0·025 per cent) gives the bands at once, the blood remaining clear and becoming yellowish-green in color. Blood containing CO remains red, becomes turbid and shows no bands. The quantity of the oxidizing agent required to produce the bands increases with the

quantity of CO present. A one per cent aqueous solution of pyrocatechin or of hydroquinone also causes the appearance at once of the methæmoglobin bands in blood containing oxygen; while carbonyl blood is unchanged. In this test, the blood is heated with the phenol to 40° for 15 minutes.—*Ber. Berl. Chem. Ges.*, xiii, 1294, July, 1880. G. F. B.

8. *Change of wave length by movement of the source of light.*—M. L. Thollon points out the peculiar fitness of a group of iron lines in the spectrum for observation on changes in wave length produced by the approach or recession of the sources of light. The wave length of these iron lines are $b=5976·1$ and $c=5974·6$; to the left of b is a telluric line $a=5976·35$ and to the right of c a telluric line $d=5974·36$. When the edge of the solar disc is observed it is found that the iron lines change while the telluric lines remain in the same position they assume when the center of the solar disc is observed.—*Comptes Rendus*, No. 7, 1880, p. 368. J. T.

9. *Successive transformations of the photographic image by prolonged action of light.*—M. J. Janssen states the following facts in extension of those previously communicated by him: (1.) The ordinary negative image. (2.) A first neutral state. The plate becomes uniformly obscure under the action of the developer. (3.) A positive image which succeeds the first neutral state. (4.) A second neutral state, opposite to the first, in which the plate becomes uniformly clear under the action of the developer. (5.) A second negative image, resembling the ordinary negative image, but differing from it by intermediate states and by the enormous difference of the luminous intensity which is necessary to obtain it. (6.) A third neutral state—in which the negative image of the second order has disappeared, and is replaced by a dark uniform tint.—*Comptes Rendus*, No. 4, 1880, p. 199.

Captain Abney enters into an explanation of the reversal of the developed photographic image in the Philosophical Magazine, September, 1880, p. 200. J. T.

10. *Change of the zero point of a thermometer.*—Professor J. M. Crafts shows (1.) that the zero point rises more rapidly in thermometers made of French crystal than in those made from glass without oxide of lead. (2.) The elevation of the zero point is much more rapid at first, and probably tends toward a limit under long heating at a fixed temperature. (3.) The zero point which has risen under prolonged heating at a high temperature retains this elevation when the thermometer is kept at the ordinary temperature; and the effect produced by the elevated temperature renders the thermometer more stable under the influence of lower temperatures. Professor Crafts shows that the theory of Depretz is sustained by his own experience. In other words the changes in glass are due to the interior work of the molecules in coming back to positions of equilibrium, and probably not to the effects of pressure.—*Comptes Rendus*, Nos. 5 and 7, 1880, pp. 291–370. J. T.

11. *On the electric discharge in Rarefied gases.*—Dr. EUGEN GOLDSTEIN, in a preliminary paper on a new differentiation of Electric Rays maintains the following points: (1.) The production of light by an electric ray from the negative pole in highly rarefied gas, takes place only when the ray strikes upon a solid obstacle. (2.) It is not the whole length of the ray which produces the light, but only the end of it furthest from the negative pole. (3.) The cause of the production of the light is to be sought in an optical action. (4.) The modification of the end of the ray is produced, not only when the ray impinges on a fluorescent wall, but also whenever it falls on any solid substance. (5.) The differentiation in question is not associated with a particular pressure. (6.) The phenomenon is not associated with any particular intensity of discharge. (7.) The same differentiation occurs with the "secondary negative light," a name given to the light produced at any point of the discharge at which a contraction of the tube is introduced. (8.) The excitation of light by the ends of the negative rays is not of the same kind as the illumination called forth in the surrounding walls of the tubes by the stratification of the positive light when the rarefaction is small.—*Phil. Mag.*, September, 1880, p. 173.

Dr. Goldstein's paper is to be continued and will prove of great interest in connection with Crookes' experiments in the same direction. J. T.

12. *Heat theory of the development of Electricity.*—H. J. L. HOORWEG maintains the theory that the development of electricity is due to a redistribution of kinetic energy in the form of heat. Electricity results from thermo-dynamic relations between the points of contact of heterogeneous substances. Peltier's phenomena—the development of electricity from evaporation, from diffusion, from osmose, from capillarity are, in turn, discussed from the point of view of this theory.—*Annalen der Physik und Chemie*, No. 9, 1880, p. 133.

13. *Introduction to the study of Chemical Reactions;* by Dr. PHIL. EDMUND DRECHSEL. Translated by N. Fred. Merril, Ph.D. New York: John Wiley & Sons. 138 pp. 12mo.—This volume is occupied with the application of the most recent and advanced chemical philosophy to the elucidation of the chemical changes that are involved in elementary qualitative analysis. The work of both author and translator is excellently done. The terms Molecules, Atoms and Reactions are first defined; Valence and its laws; Oxidation and Reduction; Solution of Metals and Metallic Oxides; Manner in which Reagents work; Characteristic and Special Reactions of Bases and Acids, are the titles of the remaining chapters. The book must be very serviceable to students of analytical chemistry in acquiring familiarity with the theory of their work. S. W. J.

14. *Water analysis for Sanitary purposes, with hints for the interpretation of results;* by E. FRANKLAND. 149 pp. 8vo. Philadelphia, 1880 (Presley Blakiston).—This little volume gives

in clear and concise form the methods employed in the analysis of water for sanitary purposes, and the determination of the various ingredients which may be present. It contains much useful information in regard to the sanitary effect of different kinds of water, the comparative danger arising from the various possible impurities, and concludes with the Report of the Rivers Pollution Commissioners of Great Britain.

II. GEOLOGY AND NATURAL HISTORY.

1. *On the Geological action of the Humus acids;* by ALEXIS A. JULIEN, of New York. 100 pp. 8vo. From the Proceedings of the American Association, vol. xxviii, Saratoga Meeting, 1879. Salem, 1880.—This extended memoir treats of the "acids existing in humus" according to chemists, or rather some chemists, and of their distribution through surface and subterranean waters; and then of the action of organic acids in taking up iron oxide, silica and other mineral ingredients, and producing changes in minerals and rocks and making mineral depositions. Under the long-recognized principle that iron is taken up by such acids and thus removals, bleachings and depositions are made, he brings forward the case of the bleaching of sands on the New Jersey coast and elsewhere, which he attributes to this agency. The reader will derive from the memoir an enlarged view of the efficiency of this agency in geological operations, but in the case of consolidations, mineral formations, silicifications and many other of its alleged results will wish that the suggestions had been fortified by experiment.

2. *Catalogue of Minerals and Tables of Species;* by A. E. FOOTE. 97 pp. 8vo. 1880. Philadelphia, Penn.—This catalogue, besides containing a list of mineral species, a tabulation of some of their character, and republications of descriptions of several new American minerals, gives some excellent original figures (from photographs) of crystals of the amazon stone from Colorado, rutile and brookite from Arkansas, and some other species.

3. *Bulletin of the Nuttall Ornithological Club*, Cambridge, Mass.—No. 4 of the fifth volume of the Ornithological bulletin has recently been issued. It contains a large variety of interesting matter and shows great enthusiasm in its numerous contributors. In an article by Dr. Coues, "Behind the Veil," we are treated to much of peculiar interest, not only in the personal history of Wilson and Audubon, but also in the early history of American Ornithology itself. A. E. V.

4. *Life on the Seashore, or Animals of our Coasts and Bays;* by JAMES H. EMERTON. 138 pp., 12mo. 161 cuts. George A. Bates, Salem, Mass. 1880.—In this book the author has given very interesting and popular accounts of the more common forms of animal life occupying the shores; the surface; and the bottoms of our northern sea-coast, with good illustrations of a large number of them. The large amount of information concerning the habits and transformations of many of these animals

gives additional interest to the book. Descriptions of the apparatus and the modes of capturing and preserving specimens of marine invertebrates are also given. It is an admirable introduction to the study of marine zoology. A. E. V.

5. *The Natural History of the Agricultural Ant of Texas, a Monograph of the Habits, Architecture and Structure of Pogonomyrmex barbatus;* by HENRY CHRISTOPHER McCOOK. 310 pp. 8vo, with 24 photolithographic plates. Philadelphia, 1880. (J. B. Lippincott & Co.)—This volume gives at great length the final results of an enthusiastic study of the life-history of the agricultural ant of which some accounts were published nearly twenty years ago by Buckley and Lincecum. Considerable doubt has been expressed in regard to the accuracy of these early observations, and Mr. McCook, in 1877, visited Texas for the purpose of settling the questions which Buckley's and Lincecum's reports had raised. The later observations in the main confirm the earlier ones, but are far more complete and minute and add many new facts to the remarkable history. The present work is eminently popular in style and certainly very readable and thoroughly interesting, though often exceedingly diffuse, and deserves a wide circle of such readers as have been delighted with the somewhat similar work of Moggridge, "Harvesting Ants and Trap-door Spiders." It may add to the interest in Mr. McCook's volume to call attention to a note, by the Rev. G. K. Morris, in the American Naturalist for September, p. 669, ascribing harvesting habits to an ant (a species of *Pheidole*) in New Jersey. S. I. S.

III. ASTRONOMY.

1. *Photographs of the Nebula in Orion;* by Professor HENRY DRAPER, M.D.—During the night of September 30, 1880, I succeeded in photographing the bright part of the nebula in Orion in the vicinity of the trapezium. The photographs show the mottled appearance of this region distinctly. They were taken by the aid of a triple objective of eleven inches aperture made by Alvan Clark and Sons, and corrected especially for the photographic rays. The equatorial stand and driving clock I constructed myself. The exposure was for fifty minutes. I intend at an early date to publish a detailed description of the negatives.

New York, Oct. 2d, 1880.

2. *Astronomical Observatory at Rochester N. Y., under the charge of* Professor SWIFT.—The new Astronomical Observatory, at Rochester, is to have the third largest telescope in size in America. The telescope will be twenty-two feet in length and its lens sixteen inches in diameter. The Observatory is named after Mr. H. H. Warner, by whom it has been most liberally endowed, and its locality is one of the most commanding in Rochester. With Professor Swift as its observing astronomer, great results may be expected from the new Warner Observatory.

IV. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *Manual of Cattle-Feeding. A Treatise on the Laws of Animal Nutrition and the Chemistry of Feeding-Stuffs in their application to the feeding of Farm Animals. With illustrations and an Appendix of useful tables;* by HENRY P. ARMSBY, Ph.D., Chemist to the Connecticut Agricultural Experiment Station. New York: John Wiley & Sons. 1880.—This volume of 525 clearly printed 12mo pages is divided into three parts, viz: Part I. The General Laws of Animal Nutrition, comprising eight chapters, treating respectively on the Composition of the Animal Body; Components of Fodders — Nutrients; Digestion and Resorption; Circulation, Respiration and Excretion; Methods of Investigation; Formation of Flesh; of Fat; Production of Work. Part II, on Feeding Stuffs, in three chapters, discusses Digestibility; The Coarse Fodders; Concentrated Fodders. Part III treats of the Feeding of Farm Animals, in seven chapters, viz: Feeding Standards; Feeding for Maintenance; Fattening; Feeding Working Animals; Production of Milk; Feeding growing animals; Calculation of rations. An Appendix includes four tables: I. Composition of Feeding Stuffs; II. their Digestibility; III. Feeding Standards for farm animals; IV. Proportions by weight of the various parts of cattle, sheep and hogs.

It may be safely asserted that Dr. Armsby's work contains the most complete and satisfactory exposition of the present state of knowledge on the subjects it treats of, that is extant. Not only is it very far in advance of anything that has hitherto appeared in the English language, but no other tongue, not excepting the German, can to-day offer its equal. The book treats of a difficult and complicated subject, but the difficulties are approached in a manner adapted to make their mastery easy to the careful reader who possesses a moderate knowledge of chemistry and physiology. The method and spirit of the book deserve the highest praise as in evident accord with the best tendencies of exact science. The whole field of investigation has been surveyed. Excellent discrimination is shown in the selection of illustrative experimental data, and to a great degree all essential facts are so presented that the reader cannot fail to see their force. The author fairly presents the claims of rival or opposing theories, and clearly indicates where his conclusions rest on solid facts, and where, in default of accurate knowledge, it is for the present necessary to accept probabilities as our guide, or even to remain quite in the dark. The student of physiology will find in this work the results of a vast amount of investigation undertaken in the German Experiment Stations, with which our physiologists are imperfectly acquainted; and the farmer who is exercised on the practical questions of cooking fodder, the use of concentrated foods, fensilage, compounding of rations, exclusive meal feeding, influence of food on milk, etc., can read in Dr. Armsby's pages the essence of what is positively known on these subjects. S. W. J.

2. *Contributions to the Archæology of Missouri* (30 pp. 4to.) by the Archæological Section of the St. Louis Academy of Science. Part 1, *Pottery*, 30 pp. 4to, with 23 plates.—This valuable and well-illustrated contribution to archeology consists of two memoirs: one, a general sketch of the archeological remains in southeastern Missouri by W. B. POTTER; the other, on the ancient pottery of the same region, by Dr. EDWARD EVERS, in which the large number and often quite artistic forms represented in the plates are treated of as to locality, conditions of occurrence, and other particulars.

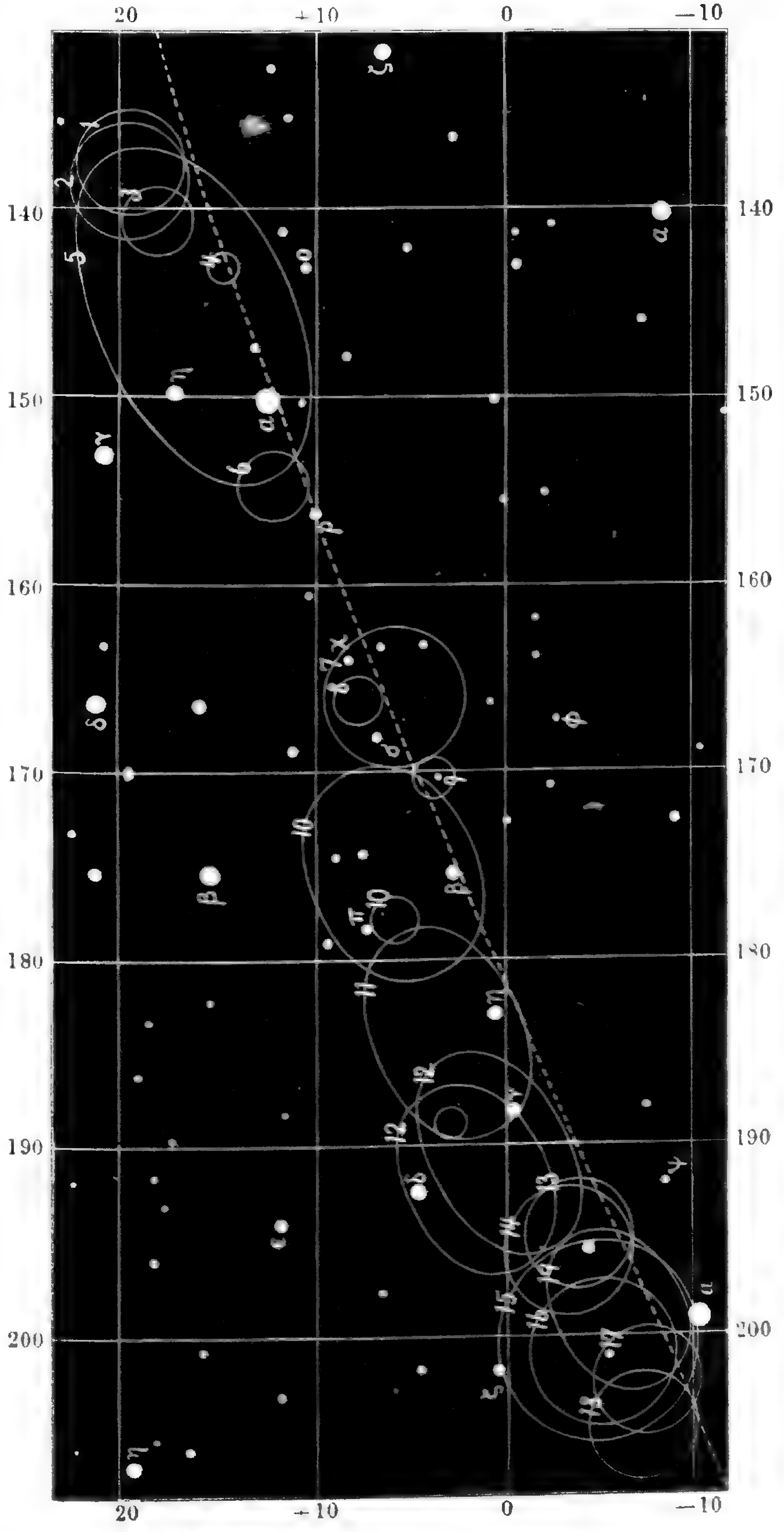
3. *Spectroscopic Notes by Professor Young.*—In this article, in the 8th line from the top of page 358, the letter Y should be G.

OBITUARY.

Professor **BENJAMIN PEIRCE**, LL.D., F.R.S., Perkins Professor of Astronomy and Mathematics at Harvard University, died at his home in Cambridge, Oct. 6, in the seventy-second year of his age, and the fiftieth of his connection with the University. His father and mother were both distinguished for their acuteness of mind, and his instructor, Nathaniel Bowditch, predicted that the boy Peirce would be one of the first mathematicians of his day—a prediction fully realized. In 1831, two years after graduation at Harvard College, he was appointed mathematical tutor, in 1833, professor, and in 1842 he was appointed to the chair he filled and honored until his death. He found it consistent with his devotion to science to do much work in connection with other institutions than Harvard during his professorship. Among these services, in 1849 he undertook the revision of the American Ephemeris and Nautical Almanac, for which he prepared his valuable lunar tables. In 1855 he was one of the commission to organize the Dudley Observatory. From 1867 to 1874 he was in charge of the United States Coast Survey and rendered great service to the country and to science by recruiting the languishing financial strength of that service and impressing upon Congress the duty of effectually reorganizing and pushing forward the work so much retarded by the civil war. He was one of the original members of the National Academy. He threw all his influence into the organization and successful development of the American Association, which he always held should be free from class distinctions, and to which he would never be elected in the higher class of fellows but was a member only. He contributed very largely to make the American Academy of Boston what it is, and throughout the whole of the scientific literature of the past fifty years Peirce's name frequently occurs as a contributor upon mathematical and physical topics. In his own department of the University he thoroughly impressed the concise methods of thought so effectually used in his greater works. The teaching at Harvard is based upon his methods and notation, and these methods are models of perspicuity and elegance. In physical astronomy perhaps his greatest works were in connection with the planetary theory, his analysis of the Saturnian system, his researches regarding the lunar theory, and the profound criticism of the discovery of Neptune following the investigations of Adams and of Leverrier. As a mathematician, his work on Analytical Mechanics, his treatise on Curves, Functions and Forces, and his memoir on Linear Associative Algebra all evince extraordinary originality and genius. Many of his detached papers, relating to the theory of observing, and the solution of special problems, show an appreciation of the needs in applied mathematics which perhaps has not been exhibited by the same order of genius since the death of his friend and admirer, Gauss. His originality was fostered by his habit of examining a new mathematical question for himself, and only referring to the work of other geometers after he had first fairly exerted his own powers of analysis.

His genius was early recognized abroad and elections to the Royal Societies of London, Edinburgh and Göttingen and to various continental societies were awarded him. The versatility and breadth of his mind is partly shown by the scope of his papers; but to those who came in daily contact with him he showed such a penetrating discernment of the conditions of a problem, he made such sagacious suggestions regarding the inferences to be drawn from the data before him, he showed such a wonderful power of generalization, that the papers he has given to the world only seem to indicate the quality of work his mind had constantly before it, and to afford no idea of the multitudinous problems he had been interested in and discarded as soon as the solution became evident to himself. He habitually ascribed to his listener a power of assimilation which the listener rarely possessed. He assumed his readers could follow wherever he led; and this made his lectures hard to follow, his books brief, difficult and comprehensive, and his best work only when his listeners were students trained in his methods who had already attained some skill as mathematicians. He was personally magnetic in his presence. His pupils loved and revered him, and to the young man he always lent a helping hand in science. He inspired in them a love of truth for its own sake. His own faith in Christianity had the simplicity of a child's; and whatever radiance could emanate from a character which combined the greatest intellectual attainment with the highest moral worth, that radiance cast its light upon those who were in his presence. His works are already scarce and some of them hardly obtainable; notably the second volume of his "Curves, Functions and Forces," and his memoir on "Linear Associative Algebra." It is much to be desired that the manuscripts he has left be completed so far as possible and made accessible; and this work could devolve on no person so well qualified as is his distinguished son, Professor James Mills Peirce. L. W.

William Lassell, F.R.S., the distinguished astronomer, and eminent in connection with the history of reflecting telescopes, died on the 4th of October, in the 82nd year of his age.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THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XLVII.—*Note on the Zodiacal Light;* by HENRY CARVILL LEWIS. With Plate VI.

[Read before the American Association for the Advancement of Science, Boston, August 28, 1880.]

It is designed in the present paper to make a brief record of the results obtained from observations of the zodiacal light extending over a period of nearly five years.* The facts here presented are deductions from a large number of closely accordant observations, the publication of which in detail must be reserved for some future opportunity.

The discordant results obtained by different observers have induced the writer to take special precautions in his method of observation. To map correctly such very faint objects, as those parts of the zodiacal light here called the zodiacal band and the gegenschein, requires absolute freedom from bias on the part of the observer. An atlas (Heis' Atlas Cœlestis), on which the ecliptic was not marked, was therefore used, and the gegenschein was plotted always without reference to the sun's longitude. Its angular distance from the sun was not calculated until after the close of the whole series of observations. In order to train the eye to more acute vision, it has been customary before each observation to use it in the detection of stars of the sixth magnitude and under.† It has been found that such practice is not only a good preparation for accurate observing, but that an idea of the comparative transparency of the atmos-

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* A short notice of the writer's work was published in the Annual Record of Science and Industry for 1878.

† The writer has frequently seen twelve stars in the Pleiades with his naked eye.

phere is thus obtained. In all cases the observations were made in perfect darkness, and recorded as soon after as possible.

Nearly all of the observations were made in Germantown, Pa. (lat. 40°); but a few, especially those upon the "horizon light," were made at the sea-shore, on board ship, or on the mountains.

The zodiacal light may be divided into three portions:—the *Zodiacal Cone*, the *Zodiacal Band* and the *Gegenschein*. This division, in addition to its convenience, saves confusion in description, and may be, in part at least, a natural one.

The Zodiacal Cone.—This, the zodiacal light proper of most authors, and by far the most conspicuous of its three portions, has frequently been described and its outlines mapped. It is, however, often misrepresented in popular works on astronomy. It is the only part of the zodiacal light which varies in appearance. Its height above the horizon and its brightness are directly connected with the duration of twilight and the obliquity of the ecliptic. The most favorable time for viewing it is always immediately after the last trace of twilight has disappeared. It would be more frequently noticed, but that it is often confounded with twilight. While the last trace of twilight is a lateral expansion of light along the western horizon, the evening zodiacal cone, of about the same shade of color, rises obliquely as a cone which is more or less pointed according to the season. Its apex occasionally attains a distance of 100° from the sun.

In this latitude, the zodiacal cone is not a symmetrical figure, its southern side being more vertical than its northern side. Its southern side is also the more sharply defined of the two, and is the side more nearly parallel with the ecliptic. Its axis of greatest brightness does not correspond with its axis of symmetry, but lies south of it. There is a very small angle between these two axes. The axis of greatest brightness appears to lie precisely upon the ecliptic. The lateral extension of the base of the zodiacal cone, often observed, is probably a purely atmospheric effect.

The brightness of the zodiacal cone depends upon the season of the year and the time of the night when observed. Its brilliancy increases rapidly as it approaches the sun, and at such times as it can be seen nearest the sun it always appears brightest. The time of shortest twilight coincides with the greatest brilliancy of the zodiacal cone. In each of the five years the evening zodiacal cone was most brilliant from the middle of February to the middle of March. Several observations have proved it to cast a distinct *shadow* at that time.*

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* Zodiacal light shadows were noticed on Feb. 12, 1877, at 7.15 P. M., and on Feb. 21, 1879, at 7.20 P. M. On the latter night snow covered the ground, on which distinct zodiacal light shadows were cast.

Numerous comparisons have been made between the brightness of the zodiacal cone and that of different parts of the Via Lactea, with the result that early in December of each year it becomes as bright as the Via Lactea, soon outshining it in brilliancy, until in April it again begins to become the fainter of the two objects. During July and August the cone, now lying on one side along the horizon, can only be seen from positions whence there is a very perfect horizon, and at that season has generally been confounded with twilight.

At the period of its maximum brightness an *inner cone* of much greater brilliancy can be detected near the horizon. This short inner cone is less pointed in shape than the outer one, although fading by degrees into it. It is many times brighter than the Via Lactea, and is slightly colored by atmospheric absorption. This inner cone appears directly above, and is suddenly obscured by the dark atmospheric *absorption band*, which is on the horizon.

Neither in this *inner cone* nor in the zodiacal cone in general has any color, except what can be explained by atmospheric absorption, been proved by the observations under discussion. Although a decidedly warm color has frequently been observed, it is found that this color, like that of the moon and planets at low altitudes, is variable, and depends upon atmospheric conditions. Comparison between the zodiacal cone and the last traces of twilight or the glow preceding moonrise, shows them to have a similar color when equally bright. The zodiacal cone in the morning is frequently more pale than that in the evening, for the same reason that sunrise has generally less deep colors than sunset.

Several observations indicate that the light of the zodiacal cone has a great penetrating power. Even under atmospheric conditions in which the Via Lactea is made nearly invisible, the zodiacal cone appears to lose but little of its light. The light is dense, though dull and ill-defined, and the impression is given that the matter producing it has great depth.

Careful watch has been made for any pulsations in the zodiacal cone. Although aware of the statements of some observers as to their existence, the writer, during the whole of his observations, has never once been able to detect any certain pulsations, any movement, or any sudden change in brightness in any part of the zodiacal light; and he believes that all such apparent effects are due either to atmospheric changes or to changes in the eyesight of the observer. Since frequently an apparent diminution in brightness ensues after the observer has been looking at another part of the sky, and especially after recording a note by lamplight, it has been found necessary to compare directly the brightness of the cone at a certain altitude with a definite portion of the Via Lactea; and it was then always noticed that the diminution in brightness of the zodiacal cone was accompanied by a corresponding change in the Via Lactea. Any change in the transparency of the atmosphere or in personal judgment affects equally both phenomena.

Not only have no pulsations been observed, but as yet no periodic variations in the appearance or brightness of the zodiacal cone have been noticed. The photometric observations were only approximate, but, so far as could be judged, the zodiacal cone each year went through the same series of changes; attaining each winter, at the time of its maximum brilliancy, an equal degree of brightness, and becoming equally faint each summer. The statements, which others have given of its remarkable brilliancy during the appearance of certain comets or other noticeable phenomena, may be accounted for on the hypothesis that at such times special attention is directed towards a certain class of celestial objects,—and a phenomenon generally ignored is thus brought to special notice. The observations of the writer tend to prove the invariability of the zodiacal light. The difference in its appearance is thought to be due merely to the different positions of the earth in reference to it.

Nor has the *moon* been discovered to have any action upon the appearance of the zodiacal cone. The zodiacal cone is frequently sufficiently bright to enable it to be seen when the moon is either in it or higher in the heavens. The presence of the moon does not appear to alter its shape. When the moon is above the zodiacal cone, but not on the ecliptic, it has been frequently observed that the axis of the cone points away from the moon, making with it a considerable angle. Again, the cone is found to preserve its shape, both while the moon lies within it, or on one side of it, or when, after having passed its first quarter, the moon illuminates it from above. The widening of the base of the zodiacal cone, as the moon lights up the horizon, is an atmospheric effect caused by the brightening of the "horizon light."

The writer has taken several observations upon the *spectrum* of the zodiacal cone. Three different spectroscopes, of different make,* have been used with accordant results. It was of interest to find that, notwithstanding the brilliancy of the cone when observed, nothing whatever could be seen when using a narrow slit,—a fact proving the truly continuous character of the spectrum. When a slit of over a millimeter in width was used, there appeared a faint, pale, continuous spectrum, brightest and most abruptly ending at the less refrangible end, and gradually

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* Browning's one prism, Browning's direct vision, Eaton's direct vision,—the last being the most satisfactory.

fading at the other extremity. The slit was too wide to permit Fraunhofer lines to appear. The spectrum was of a pale greenish-gray color throughout, and was not unlike that given by late twilight. It was much shorter than that given by reflected moonlight. The peculiar ashy-gray color of this spectrum, which lies between the yellow and the green of the solar spectrum, and forms its most luminous portion, is probably characteristic of all very faint polychromatic lights. It is the last portion of the spectrum to disappear, and is nearer white than any other color. The spectroscopic observations of the writer agree with the more careful work of Smyth and Wright, and point to reflected sunlight as the source of the light of the zodiacal cone.

The Zodiacal Band.—The zodiacal band is one of the faintest visible objects in the heavens, and has thus escaped the attention which it deserves. It may be described as an extremely faint zone of light, somewhat wider than the milky way, which, like a narrow strip of gauze, is stretched across the sky along the zodiac from horizon to horizon, and which can be seen at all times of the year and at all times of the night. It is a belt with parallel sides, of nearly equal width throughout, which, as though a second and much fainter milky way, forms a faint prolongation of the zodiacal cone across the sky. It is most favorably situated for observation at the same season of the year in which the zodiacal cone is best seen, when it forms a high and perfect arch from east to west. It is so faint that in order to detect it at any time it is necessary for the observer to seek out first the darkest places in the sky, shifting the eyes rapidly and continuously along the sky from north to south and the reverse, and thus by degrees to narrow the vision down to the faint band of light upon the zodiac. It is most easily seen late in the evening, after the zodiacal zone has sunk below the horizon; since the brightness of the latter is apt to dim it by contrast. It is also of course best seen when it makes a large angle with the Via Lactea, or when the latter is on the horizon.

The zodiacal band is brightest along an inner line, whence it fades off very gradually toward the edges. When most favorably situated, it seems to be more sharply defined on its southern than on its northern edge, and in this respect is similar to the zodiacal cone. Toward midnight the zodiacal band is decidedly brightest at the highest portion of the arch, where it contains the third division of the zodiacal light,—the gegenschein.

The width of the zodiacal band can only be very approximately estimated. As generally seen, it has perhaps a width of about 12°. When low down toward the southern horizon, this width is apparently greatly increased, and, the horizon light interfering, the whole southern sky beneath the Via Lactea may seem illuminated. On rare occasions it is possible to detect an inner zone of greater brightness, some 2° wide. At such times the principal band of light has a width of 5°–6°, while beyond and on either side a very diffuse portion measures from edge to edge as much as 20°. This diffuse portion is particularly noticeable on the northern edge. It must be understood that each of these portions shade by insensible degrees one into the other, and that probably no two observers would give the same widths.

The zodiacal band lies in the zodiac, upon or close to the ecliptic. The observations appear to show that while its axis of greatest brightness is either on or very slightly north of the ecliptic, the axis of symmetry is decidedly north of that line. Probably in the southern hemisphere the reverse would be the case.

The zodiacal band is generally quite obscured in the presence of the moon, but two or three observations are recorded, in which the zodiacal band has apparently been seen by moonlight. That such an extremely faint object as the zodiacal band should be seen by moonlight, as though illuminated by it, is an interesting fact, which, however, is not as yet sustained by sufficient observation.

The Gegenschein.—The term gegenschein, given by Brorsen to a light which appears opposite to the sun, but which has been confused by others with the eastern part of the zodiacal band, is here limited to the round or oval spot of light which nightly appears at that place in the zodiacal band which is 180° from the sun.

The writer has paid particular attention to the observation and careful mapping of this object. He has made more than forty maps of its position among the stars at different times, and upon subsequent calculation, he has found that almost without exception, the center of the gegenschein, thus mapped, lies within 1° or 2° of a point in the heavens 180° in longitude from the sun.

The gegenschein is an extremely faint spot of light some 7° in diameter, lying in the zodiacal band. It is best placed for observation about midnight, and can be detected by shifting the eye backward and forward along the zodiacal band. Anyone who looks for it in February and March, when the Via Lactea is low on the horizon, cannot fail to find it, first in Leo and afterwards in Virgo. Night after night it shifts its place among the stars, so as to keep opposite to the sun. It is of course invisible when crossing the Via Lactea.

The gegenschein is decidedly brighter than the zodiacal band, although always much fainter than any central portions of the Via Lactea. It often appears to form an oval whose major axis is parallel to the ecliptic. At such times its major axis may be 15° in length. This effect is probably caused by the brightness of the zodiacal band on either side of it, for careful observations show that the brighter portion is approximately circular.

Sometimes a *nucleus* of greater brightness has been noticed in the center of the gegenschein. This nucleus is a small definite circular spot of about 2° in diameter, and is only to be detected under favorable atmospheric conditions. Several maps have been made of the position of this nucleus. Generally the gegenschein appears as a nebulous patch of equally diffused light.

Perhaps the most interesting fact concerning the gegenschein which is clearly deduced from the maps of its position, is that it always lies some 2°± *north of the ecliptic.* While a number of observations place its center 3°–4° north of the ecliptic, not a single one makes it south of that line. This fact will be of importance in a theory of the gegenschein.

The extreme faintness of both the gegenschein and the zodiacal band made it impossible to obtain any spectrum other than that given by diffuse star-light.

Explanation of Plate.—Plate VI represents those observations of the gegenschein which were taken while it was near the vernal equinox. These observations, made at different times and upon different maps, are here for the first time plotted on one map and the line of the ecliptic added. The bounding lines of the different gegenscheins represent boundaries of more or less diffuse portions; and the various circular figures on the plate are not to be regarded as showing difference in size and shape of the gegenschein. They are merely indices to locality.

The dates of observations were as follows:—

1. Feb. 4, 1880.
2. Feb. 4, 1878.
3. Feb. 7, 1880.
4. Feb. 9, 1877.
5. Feb. 14, 1879.
6. Feb. 21, 1879.
7. Mar. 5, 1880.
8. Mar. 5, 1877.
9. Mar. 9, 1877.
10. Mar. 15, 1877.
11. Mar. 25, 1879.
12. Mar. 31, 1880.
13. Apr. 5, 1877.
19. Apr. 5, 1880.
14. Apr. 6, 1877.
15. Apr. 6, 1878.
16. Apr. 7, 1880.
17. Apr. 10, 1877.
18. Apr. 14, 1877.

The Moon Zodiacal Light.—A phenomenon is described under this head by Rev. George Jones,* in his interesting series of observations upon the zodiacal light, as a short, oblique cone about in the plane of the ecliptic, seen in the immediate proximity of the moon. He observed it several times just before moonrise. It may have been owing to an inferior horizon, but, although careful search was made, at no time has the present writer been able to detect any such appearance. The light which precedes the rising of the moon is found uniformly to rise at right angles to the horizon. This light

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* U. S. Japan Exped., iii, 329, et seq.

spreads out laterally along the horizon, and appears to be a purely atmospheric effect.

Another kind of "moon zodiacal light" is described in a recent paper with the above title in the Proceedings of the American Acad. of Arts and Sciences.* Here the observer describes comet-like tails extending on each side of the moon to a distance of 8–10 times its diameter. The sky was soon after overcast with dense vapors, and after all such vapors had disappeared, these appearances also vanished. They were supposed to have a connection with both the zodiacal light and the aurora.

Similar appearances have been observed by the present writer only upon similarly cloudy evenings, at which time diffraction caused by floating vapor might have explained what was seen. Since such phenomena have not been seen on clear evenings, it is thought that these effects are probably purely atmospheric.

The writer has not, as yet, been able to recognize in his observations any direct connection between the zodiacal light and the moon.

The aurora appears to have no influence whatever upon any portion of the zodiacal band.

The Horizon Light.—More than once in this paper, reference has been made to a light which it has been found convenient to designate by the above name. It has no connection whatever with the zodiacal light; but since it is continually observed with that phenomenon, and at certain seasons of the year blends with and is apt to be confounded with portions of it, it is necessary to take it into account. Unlike the zodiacal light, it is a terrestrial effect.

The horizon light is a faint band of white light with parallel sides, lying all around and parallel to the horizon, and separated from it by an interval of darkness. It is seen on every clear night and at all times of the night. This band of light is most bright and terminates most abruptly on its lower edge. Its upper edge fades off very gradually into the sky. Its comparatively sharp lower edge is at an altitude of some 5° above the horizon. The diffuse upper edge varies in altitude with the state of the atmosphere. On clear nights it has probably a mean altitude of 20°±, the horizon light being therefore some 15° broad. The clearer the night the narrower is the horizon light. On hazy nights it reaches far up toward the zenith. At such times it is possible that artificial earth-lights aid in its extension. The horizon light disappears when the sky is overcast.

Its brightness is variable. At times its lower portion seems

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* Proc. Amer. Acad. Arts and Sc., Nov., 1877, p. 183.

as bright as the Via Lactea and at other times is fainter than the gegenschein. When the moon is in the sky it becomes exceedingly bright and wide, far surpassing the Via Lactea. Just before the time of the rising of the moon it widens out on both the east and west horizons. Stars are readily seen through the horizon light and are but slightly dimmed in luster. The horizon light can most easily be detected by inclining the head toward the shoulder and glancing from the zenith to the horizon.

The horizon light appears to be caused by reflected starlight. That diffuse skylight is sufficiently bright may be proved by noting its power to cast a shadow.

Below the horizon light and resting upon the horizon is a dark space which we may designate the *Absorption Band.* It is darker than the sky at the zenith, and quenches all faint celestial lights. The Via Lactea ends abruptly at its upper portion and the zodiacal cone, even when very bright, extends only slightly into it. Their comparative brightness may be estimated by noting how low down they penetrate the absorption band. No stars can be seen through its lower portion and rarely through its upper part, at such times being deeply colored. The moon and the larger planets are colored red while in it. The absorption band is some 5° broad, and is of course only seen when the observer has a perfect horizon.

In the study of the zodiacal light it is important that both the horizon light and the absorption band should be recognized. In the summer, when the ecliptic is low, and the zodiacal band lies far down toward the southern horizon, the horizon light frequently blends with it, greatly interfering with its determination. The two illuminate the southern sky, and it is difficult if not impossible at times to separate one from the other.

Conclusion.—Other observers have contributed much of importance concerning the phenomena of the zodiacal light, and several theories of its origin have been proposed. No theory is advanced in the present paper, and, as the observations are being continued, these partial results alone are presented as a contribution to the store of facts already collected on this interesting phenomenon.

Germantown, Pa., August, 1880.

ART. XLVIII.—*The early stages of Renilla;* by EDMUND B. WILSON. With Plate VII.—Note from the Chesapeake Zoological Laboratory of the Johns Hopkins University.

DURING the past summer, while at Beaufort, N. C., I had an opportunity to study the development of the colony of *Renilla reniformis* Cuv., from the simple free-swimming young to the adult stage. Since very little is known concerning the growth of the colony in the *Pennatulacea* and the mode of budding in *Renilla* is somewhat remarkable, a brief abstract of the observations may be worth recording. In a fuller paper, to be elsewhere published, the intermediate stages will be figured and the anatomical details fully described.

The young polyp (fig. 1) is ciliated, and at first swims actively at the surface. Two slight elevations, *a*, *a*, indicate the rudiments of the first pair of zooids. The septa (indicated by dotted lines) are of unequal lengths and are disposed in accordance with a perfect bilateral symmetry. Thus, the pair on the opposite side from the zooids (which may be called the lower side) are the shortest, not extending as far back as the level of the pair of zooids; the upper pair extend to the zooids; the upper lateral pair are apparently continuous with the longitudinal septum (*s*) which extends to the extremity of the body; and the lower lateral pair extend some distance beyond the pair of zooids. This arrangement of the septa is very constant and may be traced up to a late stage. And the mesenterial filaments, which appear later, are of corresponding lengths.

Figure 2 represents the young polyp some time (probably about two weeks) after the free-swimming life has been abandoned. Eight pinnate tentacles have appeared, the lateral zooids have become divided into chambers by the development of rudimentary septa, and a median zooid (*h*) has appeared on the upper side in front of the lateral zooids. The small or "ventral" compartment of each lateral zooid is on its outer side, that is, the lower side when the zooid is horizontally extended. The corresponding chamber of the median zooid is on its posterior side, that is, the side opposite to the oral end of the primitive polyp. The median zooid ultimately becomes the peculiar central zooid through which the contained water of the colony is mainly discharged; and hence the term "Hauptzooid," which has been applied to it by German writers, is inappropriate. The characteristic spicules make their appearance about a week after the free-swimming life is abandoned at a considerably earlier stage than fig. 2.

Figure 3 represents a much later stage. The lateral zooids,


1.
a
a
s
2.
h
a
a
3.
h
d
r'
c
r''
a
e
b
4.
d
c
g
k
d
i
b
f
5.
6.
h
7.
a
h
i
p
8.
d
h
a
d
o
a
p
c
9.
p
d
f
p
a
a
a

(*a*, *a*, of the last figure,) have now well-developed tentacles, and four new pairs of zooids have appeared. Of these the first to appear are the pair *b*, *b*, behind the primary pair; they are followed by *c*, *c*, in front of the primary pair, and these by *d*, *d*, still farther forward. The fifth pair *e*, *e*, appear in the angle between *a*, *a*, and *b*, *b*. Besides these, which all develop into sexual zooids, a pair of rudimentary zooids, r', r', have appeared, and also an odd one, r'', which, however, has normally a fellow on the opposite side.

The subsequent development consists in the growth of these sexual zooids, the constant development of new ones in the angles between contiguous preëxisting sexual zooids, and the appearance of a series of rudimentary zooids on the upper side of each sexual zooid. And at length each rudimentary zooid, with exception of the median "Hauptzooid," multiplies to form a group of similar zooids.

Comparison of the foregoing figures with fig. 4 (which represents a much later stage in a state of contraction) will make this process clear. The zooids are lettered as before. There are six pairs in front of the primary pair, and likewise six pairs behind them. Each zooid of the primary pair is now directed more or less upward, and the two adjacent zooids, *g* and *i*, have nearly met behind it. The oral extremity of the primary polyp, *p*, is at the edge of the disc and is still directed straight forward. In time, however, it is gradually directed upward, and the two adjacent zooids uniting behind, it becomes wholly included in the disc which continues to expand beyond it. By a similar process each of the marginal zooids is gradually included in the disc and comes to arise from its upper surface. Exception must however be made in the case of the posterior pair, *f*, *f*; these remain always marginal because no zooids are developed in the angles between them and the primary polyp. From this circumstance results the posterior interruption in the continuity of the margin of the disc and the consequent reniform shape of the colony.

The mode of budding exhibited by the rudimentary zooids is curiously like that of the entire colony; so that each group of rudimentary zooids is, in a certain sense, a miniature repetition of the whole colony. As might be expected, there is some irregularity in the multiplication of these zooids; and the following description applies to the most usual method as determined by the study of a large number of cases.

Figure 5 gives an enlarged view of one of the simple zooids shown in fig. 4. The small median chamber (which may as before be called the lower chamber) is always turned approximately toward the center of the disc, that is, *away* from the oral extremity of the sexual zooid on which it is situated.

In fig. 6, the rudiment of a new zooid, *h*, has appeared on the upper side of the primary one. In fig. 7 this is fully developed and two lateral zooids, *a*, *a*, have appeared.

The group may now be compared with the entire colony as shown in fig. 2. In both there is a larger primary zooid with a pair of lateral zooids and a central zooid on the upper side. Moreover, it is important to observe that, in both, the lower (or smaller) chamber is turned *away* from the center of the group. In other words, the zooids are not only grouped in the same manner but their axes have the same relation to each other.

In the next typical stage, fig. 8, four new zooids, *c*, *c*, *d*, *d*, have appeared in the angles between the four preëxisting zooids, and in these, also, the small chamber is turned away from the center of the group.

Very soon after this stage, many of the individual zooids become themselves centers of multiplication and according to the same law as before. A study of figure 9 (which represents an almost fully developed group) will show this. Thus *p* is the primary zooid, *h* the central or upper zooid (which might be compared to the "Hauptzooid" in respect to its relation to the group), and *a*, *a* the primary lateral pair which are still undivided.

As in fig. 8, *d* and *d* are simple; but *c* and *c* have themselves become secondary centers of multiplication. On one side, *c* has become a group of four (exactly like the entire group in fig. 7); and on the other side the corresponding zooid is represented by a group of two. Besides these, two incomplete groups, *e* and *f*, have appeared.

Briefly summarizing the points of interest:

1. The larva exhibits a strongly marked bilateral symmetry.
2. The colony is perfectly bilaterally symmetrical up to a late stage.
3. Both sexual and rudimentary zooids bud in the same way.
4. The peculiar central zooid of the colony is not the primary polyp but a secondary zooid; the term "Hauptzooid" is therefore a misnomer.
5. The posterior (*i. e.* aboral) part of the body of the primary polyp persists as the peduncle of the colony.

ART. XLIX.—*Geological relations of the Limestone Belts of Westchester County, New York;* by JAMES D. DANA. (With Plates VIII and IX.)

[Continued from page 375.]

3. *The Limestones and the conformably associated rocks of Westchester County and New York Island are Lower Silurian in age—the Cambrian or Primordial being here included.*

No evidence with regard to the age of the Westchester County and New York Island limestones, and the conformably associated rocks (gneisses of various kinds, mica schist, hornblende schist, etc.), can be wholly satisfactory that is not based on fossils. But the fossils may exist at points outside of the region if only they are within the same system of conformable strata or formations. This kind of evidence as to the age of these rocks is afforded in three ways:

First: by the relations which exist between the limestone areas and schists of this county and those of Western New England and Eastern New York to the north.

Secondly: by the special relations between the areas of northwestern Westchester County, south of the Putnam County Archæan, and those of Dutchess County, north of it.

Thirdly: by the relations of both the Westchester and Dutchess County rocks to those *west* of the Hudson in Southern New York and Northern New Jersey.

The age to which the facts from these different sources point is the Lower Silurian. The Cambrian or Primordial era is here included with the Lower Silurian because in the geology of the region there is no possibility of separating them; moreover, no stratigraphic or paleontological reason for the separation is afforded by the geology of North America, and little too by that of Great Britain where the separation was first made.

1. *Relations to the limestone areas and associated schists of the regions to the north.*—In order that the facts under this head may be appreciated, I have brought together in one map (Plate VIII) the southern portion of the Green Mountain region, from the northern boundary of Connecticut to New York Island. The northern portion of the map was published with my paper on Dutchess County;* the rest is the Westchester County map (Plate V) reduced to the same scale, or that of ten inches to the mile. The limestone areas of the Connecticut portion, east of Dutchess County, N. Y., are mainly from

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* This Journal, III, xvii, 375. May, 1879.

Percival's map of Connecticut, as stated in my former paper But those of the vicinity of Danbury and Ridgefield, which have eminent importance because they are the connecting links between the two portions, I give from my own observations.[*]

In the first place, this map seems to announce most emphatically a unity of system from the north to New York Island. The limestone formation which comes down from Vermont and enters Connecticut in great force, continues on, with every appearance of oneness, to the belts of New York Island; and the special facts with regard to the relative positions of the associated schists prove that what is true of the limestone is true also of them.

Now, to the north in the western half of Vermont, where these limestones and schists are least crystalline, they have afforded many fossils, including Corals, Crinoids, Brachiopods, Gasteropods and Trilobites, of Trenton, Quebec and Calciferous age, so many kinds and under forms so little disguised by metamorphism that the Lower Silurian age of the limestone and of the associated schists is placed beyond reasonable question.[†] Again, along what may be called the middle of the range, in its western half over Dutchess County, where again the limestones and schists are least crystalline, that is, least altered, the limestones have afforded, at various points between Poughkeepsie and the Taconic range, numerous Trenton and Calciferous fossils—Corals, Crinoids, Brachiopods, Gasteropods, Orthocerata, Receptaculites and Trilobites;[‡] and, besides, the associated schists of Poughkeepsie have yielded several species of Hudson River Brachiopods;[§] so that a Lower Silurian age for the limestones and schists has become a certainty. In addition to the facts already published I have learned from Professor W. B. Dwight, in a letter dated October 26th, of his recent discovery of fossils (*Orthis testudinaria*, *O. pectinella*, *Chætetes compacta*, *crinoidal columns*, etc.) in the Wappinger valley limestone three miles directly south of Vassar College.

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[*] Percival's limestone areas often embrace, as has been explained, large areas of comformable schist (all that are contained within the outer limits of the limestone); and in the Ridgefield part of the map the positions of the areas, as a consequence, wholly fail to be indicated. There are similar interpositions of schist in his broad Canaan area; but these follow the line of strike of the area, and hence the absence of detail does not affect the question before us. I purpose to work out the limits of the formations in Canaan and the adjoining towns another season; and, at the same time, to attempt to map the Archæan which exists in isolated areas to the south of Canaan, and is the occasion of the abnormally curving courses in the vicinity of Danbury and Ridgefield.

[†] This Journal, III, xiii, 332, 1877.

[‡] J. D. Dana, ibid., xvii, 378; W. B. Dwight, ibid., xvii, 393, xviii, 50, 1879.

[§] T. Nelson Dale, ibid., xvii, 57, January, 1879.—It cannot be inferred from these fossils from the vicinity of Poughkeepsie that the hydromica and mica schists or slates of Dutchess County, or even the argillyte-like kinds, are wholly of the Hudson River group; on the contrary, part may be Primordial.

If the Green Mountain limestone formation is to this extent Lower Silurian, it is probable, in view of the apparent unity of system, that this is true down to its most southern limit in New York Island.

2. *Special relations between the limestone areas of Northwestern Westchester County and those of Dutchess County.*—The northwestern limestone areas of Westchester County are normal in trend, and are plainly of the same general system with the others of the county. They afford the following facts.

(1) The limestones and associated slates of northwestern Westchester County are closely like those of western and southwestern Dutchess County in their semi-crystalline condition and aspect, so closely, *that, were the intervening Archæan away, no one would suspect any difference of age or system.* The southern of these two regions looks, as regards its rocks, like an uninterrupted continuation of the northern. This resemblance descends to details. For quartzyte occurs with the slightly crystalline limestone and slate of each, adjoining the Archæan: as if precisely the same seashore work were then going on simultaneously on the north and south sides of the Highland peninsula now known as Putnam County. Further, some of the quartzyte in both regions is granitic or gneissic through the presence of feldspar and some mica, showing just those variations in the character of the material transported by torrents from a region of gneiss and granite that would naturally have taken place.* Such a correspondence in the rocks of the two regions is in harmony with the idea of identity in age; and the fossils of Dutchess County would make it identity in Lower Silurian age.

The evidence of Lower Silurian relations becomes the more remarkable the closer these are studied. In Dutchess County, in the Fishkill limestone belt, at points between East Fishkill (E, map, Plate VIII) and Shenandoah Corners (S), the limestone is partly a white fine-grained variety, and partly a bluish gray scarcely crystalline rock; and the latter (at a place $\frac{1}{3}$ mile N. of Shenandoah Corners) afforded me (in an excursion made since the publication of my Dutchess County article) large shells, of a Strophomena, like *S. alternata*, distinct in form though disguised by pressure and slight alteration, indicating for the beds a Trenton age. A little to the south, between Shenandoah Corners (S) and Hortentown (H), where the limestone extends up a valley, openings have been made for limonite and kaolin (as elsewhere along belts of Green Mountain limestone), and near Hortentown beds of quartzyte have been exposed in the excavations. The quartzyte (like that east of Matteawan, nearer the Hudson) lies between the limestone and the Archæan.

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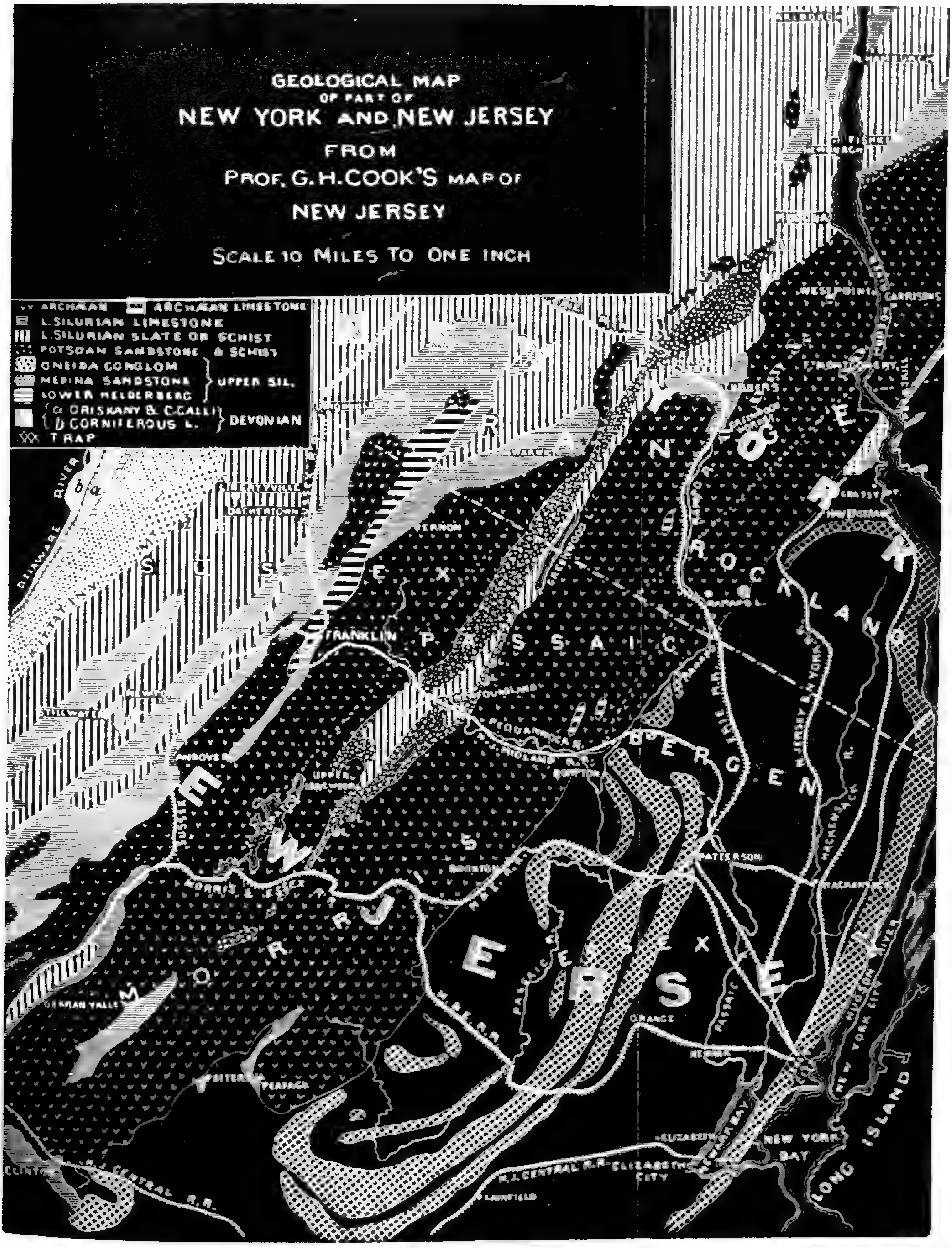
* This Journal, xvii, 386, 1879, and xx, 24, 214, 1880.

Plate VIII


LIMESTONE AREAS
OF
DUTCHESS
WESTCHESTER
AND
PUTNAM COUNTIES
NEW YORK
AND
OF PART OF
WESTERN
CONNECTICUT
WITH THE
ARCHÆAN
OF
PUTNAM CO.
AND THE
PALISADE
TRAP RANGE
5
10 m
LIMESTONE
ARCHÆAN
PALISADE TRAP
NEW YORK
MASS
CONNECTICUT
NEW JERSEY
WAPPINGER VALLEY BELT
FISHKILL AND MILLERTON BELT
GREAT CENTRAL BELT
TACONIC MTS.
KENT
NEW MILFORD BELT
ARCHÆAN HIGHLANDS
LONG ISLAND SOUND
Hudson R.
Housatonic R.
Germantown
Copake Iron-works
Copake
Sheffield
MOUNT WASHINGTON
Ancram
Canaan
Salisbury
Pine Plains
Millerton
Stissing
Sh.
Bangall
KINGSTON
Rhinebeck
Sharon
W. Cornwall
Col. Br.
Mabbettsville
P. Valley
POUGHKEEPSIE
Verbank
Warren
Kent
New Preston
Clove
Washington
Poughquag
New Hamburgh
Stormville
Pawling
New Milford
Roxbury
Fishkill
Fishkill on H.
NEWBURGH
Towners
Brookfield
New Fairfield
Dykeman
Cold Spring
CARMEL
WEST POINT
BREWSTER
GARRISONS
DANBURY
RIDGEBURY
BETHEL
NEWTOWN
ANTHONY'S NOSE
STEPNEY
PEEKSKILL
RIDGEFIELD
BRANCHVILLE
TRUMBULL
CRUGERS
BEDFORD
SING SING
CHAPPAQUA
TARRYTOWN
HOUSATONIC R.R.
TUCKAHOE
NEW ROCHELLE
YONKERS
ENGLEWOOD
HACKENSACK
KINGSBRIDGE


GEOLOGICAL MAP
OF PART OF
NEW YORK AND NEW JERSEY
FROM
PROF. G. H. COOK'S MAP OF
NEW JERSEY
SCALE 10 MILES TO ONE INCH
ARCHÆAN
ARCHÆAN LIMESTONE
L. SILURIAN LIMESTONE
L. SILURIAN SLATE OR SCHIST
POTSDAM SANDSTONE & SCHIST
ONEIDA CONGLOM
MEDINA SANDSTONE
LOWER HELDERBERG
UPPER SIL.
a ORISKANY & C. GALLI
b CORNIFEROUS L.
DEVONIAN
TRAP
DELAWARE RIVER
KITTATINNY MT.
SUSSEX
PASSAIC
FRANKLIN
VERNON
DECKERTOWN
NEWTON
STILLWATER
ANDOVER
UPPER GREENWOOD
BOONTON
MORRIS & ESSEX R.R.
MORRIS
GERMAN VALLEY
NEW JERSEY
ROCKLAND
BERGEN
ESSEX
ORANGE
NEWARK
PATERSON
HACKENSACK
ELIZABETH CITY
ELIZABETH
N.J. CENTRAL R.R.
PLAINFIELD
CLINTON
NEW YORK BAY
LONG ISLAND
NEW YORK CITY
HUDSON RIVER
ORANGE
WEST POINT
GARRISONS
NEWBURGH
FISHKILL
HAVERSTRAW
PEQUANNOCK R.
RAMAPO
PASSAIC R.
HACKENSACK R.

Passing south from Hortentown over Archæan rocks for fifteen miles (in a direct line) the first of the limestone outcrops up Peekskill Hollow is reached; and the rock where most crystalline is undistinguishable from the white fine-grained limestone of East Fishkill; moreover, it is accompanied by a well-bedded quartzyte, which affords good slabs for the floors of furnaces. The limestone may have once—before denudation began its long work—extended farther northward toward Dutchess County. But whether so or not, the similarity of the limestones of the two regions, and especially the similar association with quartzyte, add weight to the argument for sameness of geological age. Like the quartzyte of Dutchess County, that to the south is, in all probability, the Potsdam sandstone; and as the limestones of Dutchess County include beds of the Calciferous as well as the Trenton, as proved by fossils, so the limestones of Westchester County may have the same range; or, if not the whole, may cover at least the earlier part of the Lower Silurian. This true, the conformably associated schists of Westchester County are Lower Silurian in age, whatever their coarseness of crystallization, whether mica schist, gneiss, or anything else.

3. *Relations of the Westchester and Dutchess County areas to those west of the Hudson in Southern New York and Northern New Jersey.*—To illustrate these relations I have introduced a map (Plate IX) representing the latter region. This map is reduced from the excellent geological atlas of New Jersey published by Professor George H. Cook, the director of the geological survey of that State.* For the small northern portion about Newburgh, I am indebted to Professor W. B. Dwight of Poughkeepsie. Its areas are explained underneath the title. The part *between the Hudson River and the Archæan* which is left in black is Triassic.

On comparing the two maps (Plates VIII and IX), it is at once obvious that the slates and limestones of Dutchess County are continued southwestward in those west of the Hudson. This is so lithologically. More than this, it is so stratigraphically and paleontologically; for Lower Silurian fossils like those of Dutchess County have been found in both the slates and limestones between Poughkeepsie and the Newburgh region.† Professor Dwight, in his letter of October 26th, above referred to, states that he had that day found, three-fourths of a mile south of Washington Lake (the lake in which the Newburgh limestone terminates), the gritty beds of the slate crowded with fossils, among which *Orthis testudinaria* was most abundant.

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* Geology of New Jersey, George H. Cook, State Geologist. 900 pp. 8vo, with a geological Atlas. Newark, 1868.

† T. Nelson Dale, this Journ., xvii, 59, 1879; W. B. Dwight, ibid., xix, 50, 451, 1880; R. P. Whitfield, ibid., xviii, 227, 1879.

From the map (Plate IX) it is also obvious that these same slates and limestones, along with more or less quartzyte, stretch on almost continuously southwestward through New Jersey. Much of the limestone is bluish "magnesian limetone," uncrystalline or slightly crystalline, described by Professor Cook as Calciferous, and not yet found to be fossiliferous; but, besides this, there are Trenton beds, in which fossils have been detected at various points.*

Further, the two belts of limestone and slates of Dutchess County are separately continued along and through the New Jersey Highlands. The Wappinger Valley (or Barnegat) belt, passing within a mile of Newburgh on its southwestward course, is continued, though with interruptions, in the large limestone area lying partly along the western side of the Archæan and partly within its great western longitudinal valley, and reaches the Delaware River near Belvidere; and it is described by Professor Cook as having Trenton fossils near Middleville, Branchville, Newton, Huntsville, Stillwater, Belvidere, and at other places. So again, the Fishkill belt with its associated quartzyte (the latter outcropping at several points between the limestone and the Putnam County Archæan), is plainly continued in the limestone, slates and quartzyte of the nearly central longitudinal valley of the Highland Archæan, the great valley that includes Greenwood Lake and German Valley and ends in the limestone on the southern border of the Archæan about Clinton. Only a little limestone is indicated along the belt on the map; yet it outcrops at several points (marked L) besides in other larger areas, notwithstanding the losses from ages of denudation; and, at Upper Longwood and Newfoundland it has afforded Trenton fossils.†

The extension of Dutchess County belts southwestward through old longitudinal valleys of the New Jersey Highlands, and along the west side of the Highland Archæan, has its parallel in connection with Westchester County belts. For the Canopus Hollow and Fishkill Hollow belts occupy northeast-and-southwest Archæan valleys of Putnam County; and thence the rocks of these belts, but slightly crystalline near Peekskill, extend southwestward along the eastern border of the New Jersey Highlands, outcropping as magnesian limestone or the Calciferous (as so-called by Cook) along by Tompkin's Cove, and also farther southwest, in spite

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* Geol. Rep. N. Jersey, p. 131: and on the "Magnesian limestone which is the Calciferous sandstone of the New York Geologists," pp. 90–130.

† Loc. cit., p. 133, 134. The fossils reported from the impure limestone associated with Hudson River slate at Upper Longwood are *Chætetes lycoperdon, Orthis testudinaria* and *Strophomena alternata.* The Lower Silurian rocks of this Archæan valley are accompanied, west of Greenwood Lake, by shale and conglomerate, which are referred by Professor Cook to the Upper Silurian.

of the thick covering of Triassic, east of Ramapo, and beyond in the large limestone area of Pepack. These "magnesian limestones" have not yet afforded fossils, but their Lower Silurian age is unquestioned.

New Jersey thus throws light upon Westchester rocks as well as those of Dutchess County; and, in fact, into all Green Mountain geology, for these New York and New Jersey beds are but western and southwestern prolongations from the Green Mountain region.

CONCLUSIONS.

From the distributional, stratigraphic and paleontological facts which have been presented the conclusion appears to follow that—

The limestone of Westchester County and New York Island and the conformably associated metamorphic rocks are of Lower Silurian age.

Should it be made certain that all the *magnesian* limestone of the New Jersey Lower Silurian is Calciferous, there will be some reason for the inference that the limestone of Westchester County, since it is magnesian, is Calciferous or of the earlier part of the Lower Silurian. The schists may be either earlier or later than the limestone.

Finally, in view of all the facts from the length and breadth of the Green Mountain region which are brought out in this and previous papers, comes the broader conclusion:

The limestone and the conformably associated rocks of the Green Mountain region from Vermont to New York Island are of Lower Silurian age.

The evidence which has been adduced, though then but partly discerned, led Professors W. B. and H. D. Rogers and Professor W. W. Mather, forty years since,* nearly to the result here reached. The discoveries of fossils, together with the study of the stratigraphical facts, have now cleared the way for a safe scientific deduction.

These Westchester County rocks have been pronounced *Montalban.* I know of no facts sustaining such a conclusion. If true, it would follow, from the above, that the original Montalban rocks—those of the White Mountains—also are Lower Silurian.

It remains to add a few words on the origin of the rocks of the "Cortlandt Series."

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* Professors Rogers, Amer. Phil. Soc., Jan. 1, 1841, and this Jour., iv, 1872, p. 363; Mather, Rep. Geol. N. York, 4to, 1842, pp. 438, 464, 628, and this Jour., xvii, 388, 1879.

Supplementary note on the Distribution of the belts of Limestone.—I have given, on page 363, probable evidence that the limestone area of northern New York Island has an eastern division extending down Harlem River to Eighth Avenue. I have since learned, from Mr. Benjamin S. Church, Resident Engineer in charge of the New York Croton Water Works, the confirmatory fact that three of the piers of High Bridge (the Croton aqueduct bridge over the Harlem, crossing it near the middle of this part,) *stand on limestone in place.* I propose to publish, in connection with the Appendix to this paper, an enlarged map of the north end of the Island and of the southern part of Westchester County, giving my observations in detail.

(To be continued.)

ART. L.—*Abstract of some Paleontological studies of the Life History of* SPIRIFER LÆVIS *H.*; by Professor H. S. WILLIAMS, of Cornell University.*

A CAREFUL study of the character and mode of occurrence of *Spirifer lævis* H., of the Portage group of New York State, and comparison of it with other species of the genus, has led to the observation of some interesting facts bearing upon the probable history of the species in geological time. The original article embodying the results of my study was read before the Cornell Philosophical Society last spring. Only a brief abstract of some of the important points will be attempted in the present article, hoping at some future time to publish the results in full detail.

The important characters of the species were gathered under seven heads, each of which could be examined and compared separately with like characters in other species.

These were: (1) Form and proportions of the shell; (2) the size; (3) the prominence and over-arching of the beak; (4) the short and high cardinal area; (5) the triangular aperture covered by an arched pseudo-deltideum; (6) the smoothness (not plicated) of the surface; (7) the concentric series of minute radiating lines covering the surface.

A careful determination of these characters as found in *Spirifer lævis* was made, and the last character was specially noted and described.

These concentric series of fine radiating lines have not been recorded as characteristic of the species, and so far as I know have not been observed by any writers on the Devonian Brachiopods. Nevertheless it is an all-important character to be ob-

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served in making comparison with other forms. After pointing out the specific characters of *S. lævis* I give the results of a minute comparison of them with those of *S. fimbriatus* of the Hamilton and earlier formations.

This comparison has left little doubt that a genetic relationship exists between *S. lævis* and the earlier form, *S. fimbriatus.*

Then an examination was made of the relationship of several species of the preceding geological formations to the typical form as characteristic of each of the former species, and thus representatives of the type were discovered in each of the fossiliferous formations back to the Niagara.

In the Niagara group was found the earliest trace of the combination of characters found to be essential in *S. lævis* and *fimbriatus* and the other representatives seen in the intermediate formations.

The species which appears to be the central type of the original primitive species is *Spirifer crispus* Hisinger, of the Niagara formation, of which I presume *S. bicostatus* H. may be regarded but an extreme variety, and *S. sulcatus* His. (at least in part as referred by Hall), the extreme variety on the other side. The peculiarities of this species (*S. crispus* His.) are *very great abundance* and *wide distribution* in the formation in which it first appears. It being a characteristic species of the formation wherever represented, in England and at several localities in Europe.

Where it does appear, it also assumes *great variation of characters*, so that the three species in America, *S. crispus, S. bicostatus* and *S. sulcatus*, while good species in small collections, are recognized, even by Hall as bordering on each other in some of their varietal forms.

Also the three species recognized by Davidson in Great Britain (*S. sulcatus, S. elevatus* Dalman and *S. crispus*), corresponding in the main to the extreme forms identified by Hall in this country, are regarded by Davidson as doubtfully distinct species (see Brit. Sil. Brach., pp. 91 to 98) on account of the variations and intermediate forms. I have also traced out, as well as the limited material at hand would allow, the relationship to *S. glaber* Martin and other Carboniferous forms.

The study of the facts has led me to the following conclusions. Whatever theoretical description we may give to species, here are, in the first place, an abundance of individual organisms whose remains are found in the Upper Silurian rocks of Europe, Great Britain and America, presenting a few clearly marked distinctive characters, which are found variously developed in the individual forms, but so grading in the various varieties as to cause careful naturalists to associate them as varieties of a single species. There are well marked typical characters distinguishing all the individuals from other forms of the same genus, together with great variability of the characters themselves. In the upper part of the Upper Silurian we find the same typical characters, with a greater permanence of one or other of the variations; but still, in the variations occurring later in the Corniferous and Hamilton, we have the main type represented with some variations strongly marked and seeming to be fixed, but still recognized as varieties simply.

In the Portage, we see under peculiar conditions a solitary race of the type with greatly exaggerated size, a luxuriant form, but still presenting the typical characters of the second varietal type.

In the Carboniferous we meet with several well marked varieties, but no feature which did not appear in the early form except large size, which is evidently a mark of good nourishment and other good conditions of growth. This latter seems to be a character of most of the Carboniferous forms of Brachiopods which have lived on from earlier times. There may be unknown characters to distinguish these forms, but of the characters that are preserved we have evidence that in the earliest form, the type, *S. crispus* His. of the Niagara, etc., are found all those which afterward appeared in the later representatives.

These characters appeared in combination in a single group of individuals, living in one class of conditions, in such circumstances as seem to warrant our calling them one physiological species in the sense of being able fertilely to cross with each other, this being the explanation of the gradation of one form into the other noted by Davidson. This presumed—that we had a single species to begin with—we have, by intercrossing and by local conditions modifying the offspring, well defined groups, which would be called races if we knew their history but which are called species because they appear at so widely divided geological periods.

These separate groups, however, *develop no new characters*, but in those appearing at each stage are seen fixed and apparent only varietal characters of the original form, with such modifications as poor, or rich, or variety of food give to animals we now may modify. There is nothing of a specific character evolved in this series of forms which did not appear in the first forms, but, there is every evidence for the belief that the species has lived through this long geological time without losing its character, and that all that has resulted from great time and change of conditions has been the fixing into race groups of the original variable characters of the species.

The species, at its first appearance in the Silurian presented a decidedly new combination of characters for the genus and also much variation. When once these specific though variable forms appeared, they lived till the variations which could be played on them were exhausted; and the species ceased to live and became extinct either near the close of the Carboniferous or not till later in the Mesozoic.

Some of the races or varieties may die out but they reappear again and again till there are such strong contrasts that it is difficult to see even generic resemblance between them.

The following is a tabular view of the relations of the Silurian and Devonian forms of which *Spirifer crispus* of the Niagara in New York is the type; the tracing of the history through the European forms and higher into the Carboniferous is reserved for further study. In the table, lateral extension is expressive of the morphological variations; each line represents one of the geological formations, which are arranged in their natural order; and the name of each species is placed in the position on the line representing its supposed relation to the typical form of *Sp. crispus.*

Chemung						prematurus		
Portage							lævis	
Hamilton				fimbriatus				subumbona
Corniferous				fimbriatus				
Oriskany			tribulis					
Lower Helderberg	N. Y. & Tenn.		Saffordi (pars.)					
	Maryland				octocostatus			modestus
	New York		cyclopterus (pars.)					
	New York		vanuxemi					
Niagara	shale					crispus		
	limestone	sulcatus (pars.)		crispus		bicostatus		

A History of the Jetties at the Mouth of the Mississippi River, by E. L. Corthell, C. E., Chief Assistant and Resident Engineer during their construction. 384 pp. 8vo. Illustrated by numerous maps and sections, and with a portrait of Mr. J. B. Eads as its frontispiece. New York. (J. Wiley & Sons.)

Röutgen's Principles of Thermodynamics, with special applications to hot-air, gas and steam engines. Translated, revised and enlarged by A. Jay DuBois. xviii and 641 pp. 8vo. New York, 1880. (J. Wiley & Sons).

Degeneration: a Chapter in Darwinism; by Prof. E. Ray Lankester, F.R.S., Fellow of Exeter College, Oxford. 76 pp. 12mo. London, 1880. (Macmillan & Co.) The discourse of the learned author before the British Association at Sheffield, in August, 1879, aiming to show especially that the Ascidians are degenerate instead of *prototype* Vertebrates.

History of North American Pinnipeds: a Monograph of the Walruses, Sea-lions, Sea-bears and Seals of North America: by Joel Asaph Allen, Assist. Mus. Comp. Zool. Cambridge. 786 pp. 8vo. With a number of wood cuts. 1880. Constitutes No. 12 of the "Miscellaneous Publications" of the U. S. Geological and Geographical Survey of the Territories under F. V. Hayden, Geologist-in-Charge, of which Survey Mr. Allen was Special Collaborator in Zoology. A very thorough work in all directions—Zoological, Historical and Economical, and as interesting to the popular reader as it is valuable to science.

Second Treatise on the decrease of Water in Springs, Creeks and Rivers, cotemporaneously with an increase in height of floods in cultivated countries, by Sir Gustav Wex, Chief Engineer of the Improvement of the Danube, at Vienna. From the papers of the Society of the Austrian Engineers and Architects, 1879, Nos. 6–9, translated by G. Weitzel, Major Engineers, Brevet Maj. Gen. U. S. A.

42 pp. 8vo. Washington, 1880. A paper of wide interest to the people of America, illustrating the evils coming from the destruction of forests.

The Geological and Natural History Survey of Minnesota. The 8th Annual Report, for 1879, of Prof. N. H. Winchell. 184 pp. 8vo. Saint Paul, 1880. Contains Reports on the Cupriferous series at Duluth, and the Trenton and Hudson River groups in Minnesota, by N. H. Winchell; a Report on the Geology, and especially the glacial phenomena, of Central and Western Minnesota, by W. Upham; on the Zeolites of the vicinity of the Grand Marais, by S. F. Peckham and C. W. Hall, and other papers. Prof. Winchell, speaking of the Cupriferous series, concludes that these rocks (the Keweenian, as they have been recently called), including the associated igneous, were "correctly assigned to the Potsdam by Messrs. Foster, Whitney and Hall, in 1849."

Bulletin of the Philosophical Society of Washington, (D. C.). Vol. i, March, 1871, to June. 1874; ii, Oct., 1874, to Nov., 1878; iii, Nov, 1878, to June, 1880.

Museum of Comparative Zoology. The following publications of the Museum have been recently issued: (1.) The Auriferous Gravels of the Sierra Nevada and California, by J. D. Whitney, vol. vi, No. 1 of the 4to memoirs, 289–570 pp.; being the completion of the author's work on the subject, the preceding portion of which appeared in 1879. (2.) The Climatic Changes of Later Geological Times, a discussion based on observations made in the Cordilleras of North America, by J. D. Whitney, vol. vii, No. 2, Part 1 of the 4to memoirs, 120 pp. (3.) On some points in the structure of the Embryonic Zoëa, by W. Faxon, vol. vi, No. 10, of the Bulletin.

Die Spongien des Meerbusen von Mexico und des Caraibischen Meeres, von Oscar Schmidt. 2nd Heft. 4to, with plates 5 to 10. Jena, 1880. One of the reports of the dredging under the supervision of Prof. Agassiz and the direction of the Coast Survey.

On the Zoological position of Texas, by E. D. Cope. 52 pp. 8vo. Bulletin No. 20 of the U. S. National Museum, Washington, 1880. Also, by the same, Genera of the Creodonta, Proc. Amer. Phil. Soc., 1880.

Supplement I to a Catalogue of Official Reports on Geological Surveys of the United States and British North America, by F. Prime, Jr., late Asst. Geol. Survey of Pennsylvania. 13 pp. 8vo. Cedar Point Iron Co., Baltimore, July 31, 1880.

Report of the Dearborn Observatory (Chicago) for 1880, G. W. Hough, Director. 16 pp. 8vo. 1880.

Album of Anthropological Types of the Islands of the Pacific Ocean, with 28 photographic plates, explanatory text, and an ethnological map of the Ocean, just published at Hamburg, by the Museum Godefroy. 4to, 1881. (L. Frederichsen & Co.) Also, from the same Museum, a Treatise on Pacific Ocean Ethnography and Ethnology. 650 pp. 8vo, and 46 plates. 1880.

Examination of the Double-Star Measures of the Bedford Catalogue, by S. W. Burnham. (Monthly Not. Astron. Soc., vol. xl, No. 8.)

Observations on the Satellites of Mars, by Asaph Hall. (Monthly Not. Astron. Soc., vol. xl, No. 5.)

Science. This New York Weekly Journal of Science has announced that its size will be doubled with the commencement of next year.

American Entomologist, a monthly devoted to Practical and Popular Entomology, edited by C. V. Riley. Washington, D. C. Vol. iv commences with January. $2.00 a year.

Annals of the Astronomical Observatory of Harvard College, vol. xii. Observations made with the Meridian Circle during the years 1874 and 1875, and prepared for publication under the direction of Joseph Winlock and E. C. Pickering, Successive Directors of the Observatory, by Wm. A. Rogers, Assist. Prof. Astron. in the Observatory. xcii, and 272 pp. 4to. Cambridge, Mass., 1880. Also, by the same, Catalogue of 618 Stars, extracted from volume xii of the Annals of the Observatory. Cambridge, 1880.

Nachtræge zur Dyas I., von Dr. H. B. Geinitz. 44 pp. 4to, with 7 plates. (Fossil plants, fishes and footprints.) Mittheilungen of the Royal Mineralogico-geological and Prehistoric Museum of Dresden. Cassel, 1880. (T. Fischer.)

Memoirs of the Geological Survey of India. Sind Fossil Corals and Alcyonaria, by P. Martin Duncan. vol. i, 110 pp. 4to, with 28 plates. (Tertiary and Upper Cret. Fauna of Western India, Ser. xiv.) Calcutta, 1880.