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THE

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ART. I.—*Researches in Acoustics;* by ALFRED M. MAYER.

Paper No. 9, containing:

1. The Law connecting the Pitch of a Sound with the duration of its Residual Sensation.
2. The Smallest Consonant Intervals among Simple Tones.
3. The Durations of the Residual Sonorous Sensations as deduced from the Smallest Consonant Intervals among Simple Tones.

1. *On the Law connecting the Pitch of a Sound with the Duration of its Residual Sensation.*

IN October, 1874, I published in this Journal "Paper No. 6 of Researches in Acoustics," which contained an account of my attempts to establish the law connecting the pitch of a sound with the duration of its residual sensation. The law given in that paper was the expression of the results of the first experiments, extending through several octaves, ever made on the duration of sonorous sensations.

Subsequently, in April, 1875, I published in this Journal the results of similar experiments which Madame Ema Seiler had made at my request. She made a long series of experiments with the same apparatus I had used. Her determinations, though agreeing with mine in having approximately the same variation of the residual sensation with the pitch, yet differed considerably in the absolute quantities which she found for the durations of these sensations. That the two series of observations should differ was to be expected from the known variation of the sonorous sensations among different observers; but the principal cause of the difference is to be attributed to the apparatus, fig. 3, used in these experiments. This apparatus generated sounds in addition to the one to be specially observed, so that the determinations were difficult to make except by one whose hearing was peculiarly trained and naturally gifted in the power of excluding other sound sensations from the one alone to be studied. In the ability to analyze composite sounds Madame Seiler was noted, and I had no doubt at the time of the publication of her results that they were more worthy than mine to form the basis of a physiological law. This I stated in my paper of 1875, and the experiments described in the present paper, made with improved methods, show that the opinion then entertained was correct.

That there is a physiological law which gives the relation between the pitch of a sound and the duration of its residual sensation is shown by the numerous experiments contained in this paper. But those published in 1874 and 1875 sufficed to establish that fact; yet these experiments have never been repeated by physiologists.

I have waited nineteen years in the hope that others would make similar experiments, so that the combination of the results of various experimenters would give an expression of the law which might be regarded as general and accepted as expressing the average residual sensations of sounds.

It is true that Professor C. R. Cross and H. M. Goodwin published a series of similar experiments in "Some considerations regarding Helmholtz's Theory of Consonance." (Proc. Amer. Acad. Boston, June, 1891.) They obtained the smallest consonant intervals by blowing sheets of air across the mouths of resonators. The reciprocals of the differences of the frequency of the vibrations forming the intervals, thus found, are plotted in the curve, C, C, of fig. 1. I and I′ give their determinations of the durations of the residual sensations of UT_3 and UT_4, deduced from their observations of the coalescence of these sounds when interrupted by a perforated disk rotating between the resonator and its corresponding fork.

The curve, S, shows Madame Seiler's determination of the residual sonorous sensations; M, shows mine. It is evident that the meandering, undecided curve, C, cannot be the expression of a law, and that the data I and I′ cannot be combined with those contained in the curve, S, or, in the curve M. In a general way the curve, C, shows that the smallest consonant interval of two tones contracts as the pitch of the tones, forming the interval, rises.

The physicists Mr. Alexander J. Ellis and Professor J. A. Zahm have discussed the bearing of the law (as given by the experiments of 1874 and 1875), on the elucidation of many facts in consonance and dissonance, to which application of the law I referred in my paper of 1874.*

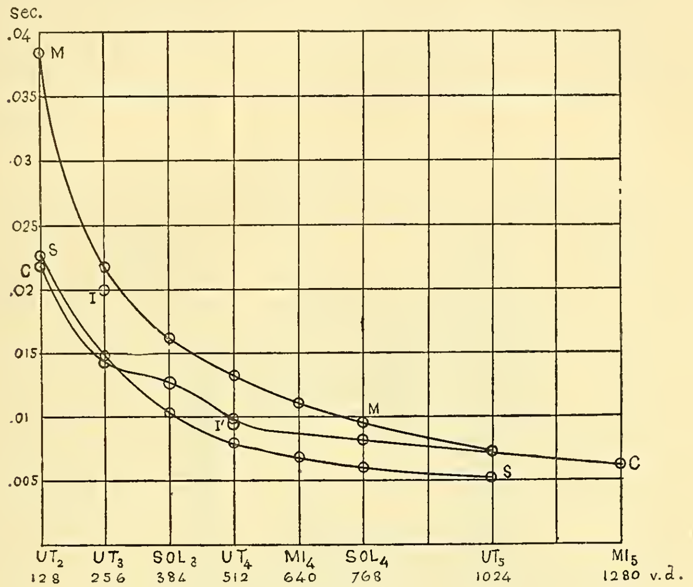

Fig. 1.

On the Duration of the Residual Sonorous Sensation.—The duration of a residual sonorous sensation is really the duration of the entire period in which a sensation of sound is perceived after the vibrations, outside the ear, giving rise to that sensation, have ceased to exist. While the total duration of the after-sensation produced by the stimulus of light can be measured (as in the case of an electric flash), the determination of the total duration or the after-sensation of a sound appears, in the light of our present knowledge and with the means of experiment at our command, to be a problem very difficult to solve.

The object of this research was not to determine the total duration of the after-sensation of a sound, but to measure that

*See Ellis' translation, of 1875, of Helmholtz's Lehre von den Tonempfindungen, pp. 173, 701, 795, and Ellis' Illustrations of Just and Tempered Intonation. Proc. Musical Assoc. of London, June 7, 1875. Zahm, Sound and Music; Chicago, 1892.

duration in which the after-sensation of a sound does not perceptibly diminish in intensity.

In fig. 2, D and E represent openings in a screen impervious to sound. The distance between these openings equals thrice the diameter of an opening. A tube, R, having the same interior diameter as the openings is supposed to convey

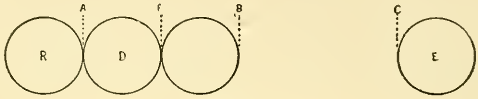

Fig. 2.

sound-vibrations against the screen, while the tube itself moves from left to right with its mouth sliding along the surface of the screen. In the position, A, the sound is just about to traverse the opening, D, to the ear on the other side of the screen. As R progresses over the opening, D, the sound traverses the opening till R has reached the position F B. Then, in the path of the tube from B to C no sound traverses the screen. When the edge B of the tube has reached the position C the sound is again just on the eve of traversing the screen through the opening E. As the distance A to B equals B to C, the periods during which the sound traverses the screen equal those in which it does not do so. If these alternations of sound and silence should succeed one another so rapidly that the sensation of the sound is uniform in its intensity; it may at first sight appear that during the time that the tube takes to go from B to C the after-sensation of the sound has not diminished in intensity. But is B to C to be taken as the measure of the duration of uniform sensation? As the tube, R, moves over D a sound with a varying intensity traverses the opening in the screen. We cannot suppose that the residual sensation caused by the stimulus of the sound traversing a minute opening in the screen equals that caused by the sound which traverses the screen when the circles R and D coincide. In such experiments, however, we are driven to take as the duration of the undiminished residual sensation the time that the center of the tube, R, takes to go from the center of D to the center of E.

In this illustration I have, for simplicity and conciseness, supposed the tube R to move over the openings D and E. In the actual experiments D and E are two of several holes in a disk, arranged in a circle, and the disk rotates while the tube R is fixed. Another tube placed in the prolongation of the tube R on the other side of the disk conveys the interrupted sound to the ear.

Evidently, the manner in which the tube conveying the sound to the disk is opened and closed by the revolving disk has to be considered in researches made with this apparatus. I give two cases whose discussion has led me to modify with marked efficiency the apparatus, shown in fig. 3, which was used in the researches published in this Journal in 1874 and 1875. In that apparatus the interruptions of sound were made by a perforated disk revolving in front of the mouth of a resonator while the interrupted sound was conveyed to the ear by a tube attached to the small opening in the nipple of the resonator.

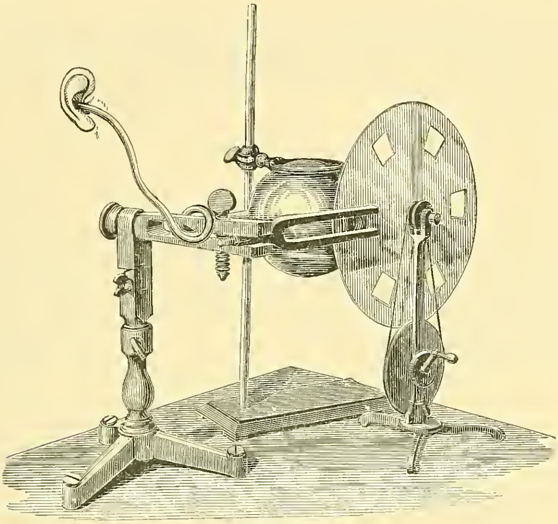

Fig. 3.

This mode of obtaining the interruptions of the sound is objectionable because the resonator is not in tune with the fork except when the former is fully opened and also because the perforated disk rotating across the mouth of the resonator gives rise to two secondary sounds and a resultant sound, fully described in my paper of 1875.* These sounds, from their intensity in this form of experiment, mask the proper sound of the fork, making the determination of the durations of the sonorous sensations both difficult and uncertain. Also, in these experiments the action of the interrupted sound on the ear is distressing; even injurious, for the hearing of one of my

*See a paper by Lord Rayleigh: Acoustical Observations, III, "Intermittent Sounds." Phil. Mag., April, 1880, in which the author gives an explanation, in mode and in measure, of the secondary sounds and of the resultant sound, observed by me in these experiments.

ears was permanently impaired by the experiments I made with this apparatus nineteen years ago.

In the apparatus, presently to be described, the fork vibrates in front of the mouth of the resonator and the interruptions in the flow of sound are caused by the perforated disk revolving in front of the small opening in the nipple of the resonator, as shown in fig. 7.

Discussion of the effects of the relative sizes of the openings in the revolving disk and of the opening in the tube conveying the sound to the disk.

First case.—Suppose that the opening of the nipple of the resonator and the openings in the disk have the same diameter. In the actual experiments these openings were 1^{cm} in diameter. The nipple of the resonator had a tube of that diameter adapted to it.

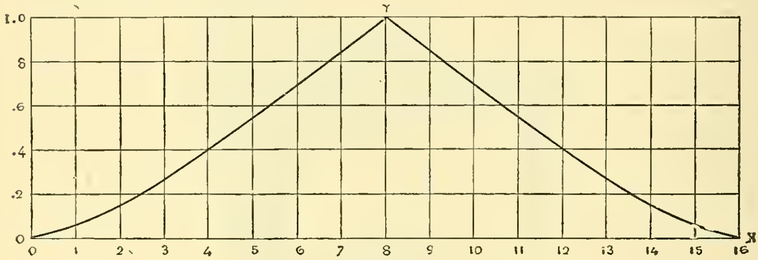

Fig. 4.

Fig. 4 is the graphic representation of the results of computing the varying areas of the opening of the tube of the resonator as an opening in the disk passes in front of it. This diagram is to be studied in connection with fig. 2. The entire length on the axis of abscissas, OX, gives the space A to B of fig. 2, divided into 16 parts. The ordinates of the curve give the relative areas of opening for corresponding positions on the axis of abscissas. The ordinate marked 8Y shows the full area of opening when the circles of the tube of the resonator and of the disk coincide. It will be observed that the tube is opened and closed slowly and is only instantaneously fully opened at 8.

Second Case.—The openings in the disk remain 1^{cm} in diameter, but the opening in the nipple of the resonator is $\frac{1}{2}^{cm}$ in diameter. Fig. 5 shows the relations between the areas of opening of the nipple of the resonator and the path A to B (fig. 6), of this opening, R, as it is supposed to move across the opening D in the disk. Fig. 5 is to be studied in connection with fig. 6. Fig. 5 shows that the opening and closing of the nipple of the resonator takes place rapidly and that the nipple remains fully opened from 4 to 8; that is, during one-third the time that the opening in the disk takes to traverse the opening in the resonator. The advantages gained by this mode of experimenting are considerable. The periods of sound and of silence are sharply marked and, as we shall now show, the fact that the hole in the resonator has half the

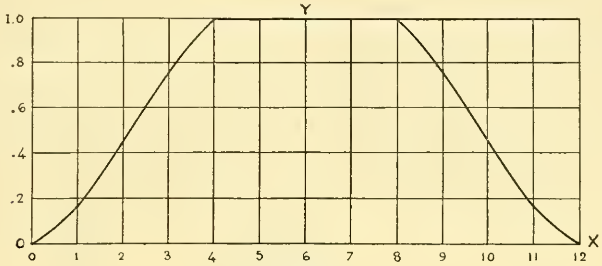

Fig. 5.

diameter of the hole in the disk gives us the means of approaching nearer to the measure of the veritable time during which we have an after-sensation of uniform intensity.

In fig. 6, R represents the opening in the nipple of the resonator, supposed to pass over the opening D in the disk. In this case, as in fig. 2, the space A to B in which sound traverses the revolving disk is equal to the space B to C in which silence supervenes, for the distance separating two holes on the disk equals twice the diameter of a hole, or, four times the diameter of the hole in the nipple of the resonator. But in this form of the experiment we are again in doubt as to what space should be taken as measuring the duration of the uniform residual sensation. The period from the full opening of the resonator in one position to the full opening in the succeeding one is equal to the time the disk takes to go from G to H, which is equal to the distance D to E between the center of the openings in the disk minus the diameter of the opening in the resonator, or, to DE minus $\frac{1}{6}$ DE. This distance, G to H, evidently measures the periods between maximum and maximum intensities of succeeding sound pulses, and we have taken this distance, in terms of velocity of rotation, as the measure of the period of uniform residual sound sensation because we have no certain knowledge of the relative durations of the residual sensations corresponding to

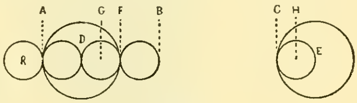

Fig. 6.

vibrations which pass the disk with increasing intensity, from 0 to 4, fig. 5, and with decreasing intensity from 8 to 12.

In our experiments we measured the number of flashes of sound entering the ear by knowing the number of revolutions of the disk per second and the number of holes in the disk. From this knowledge we compute the time it took the disk to go over D to E, in fig. 6, the distance between centers of two neighboring holes; then we reduced this time by $\frac{1}{6}$ which is the ratio of the diameter of the opening in the nipple of resonator to the distance, D to E, and took this reduced time as the duration of the uniform residual sensation. The duration of the sonorous sensation determined in this manner is evidently nearer the truth than that obtained with apparatus in which the hole in the tube conveying the sound to the disk and the holes in the disk have the same diameter.

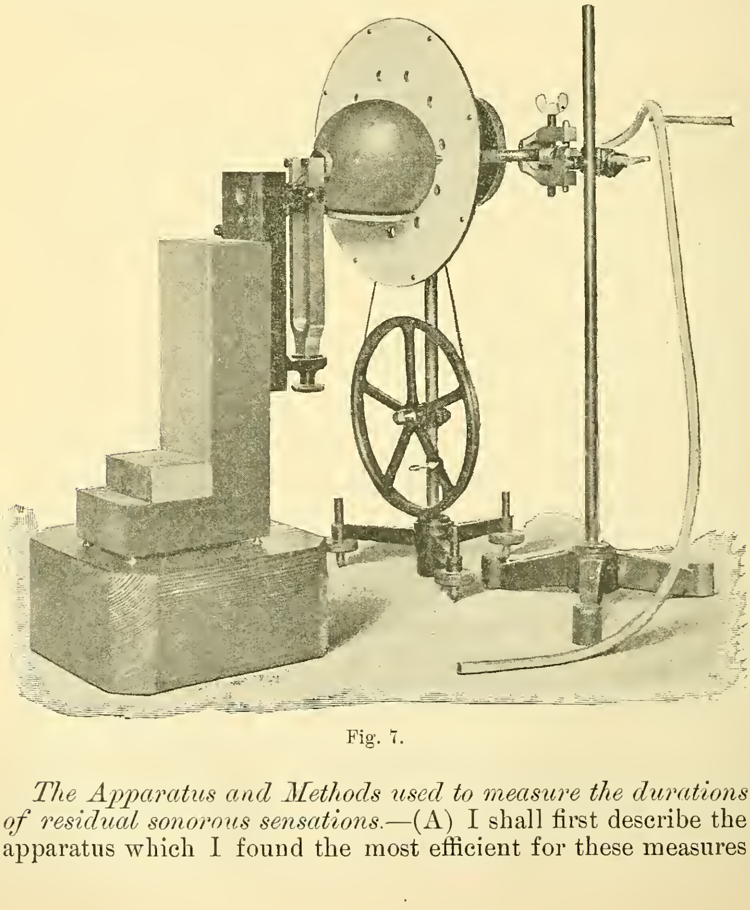

Fig. 7.

The Apparatus and Methods used to measure the durations of residual sonorous sensations.—(A) I shall first describe the apparatus which I found the most efficient for these measures and then describe three other forms of apparatus used. In fig. 7 is seen a perforated disk mounted on the axle of a rotator. In front of the disk is the resonator with its nipple close to the surface of the disk. A tuning-fork is opposite the mouth of the resonator. On the other side of the disk, with its axis in line with the axis of the nipple of the resonator, is the tube which conveys the interrupted sounds to the ear. The opening in this tube has the same diameter as the openings in the revolving disk. Behind the line of this tube is seen, on the end of the axle, a fly wheel of copper weighing a kilogram.

The bevelled face of the driving wheel of the rotator has three grooves cut in it, in steps. Corresponding grooves are cut in the pulley of the axle.

To run a rotator of this description smoothly, without jars, or vibrations, it is necessary that the cord which passes over the driving wheel and pulley should be very flexible and have a circular section of uniform area throughout its length. I obtained such a cord by soaking a cord of porpoise leather in neat's foot oil and then drawing it many times through wire-drawing plates. The ends of the cord are connected by a short hook and eye coupling. The driving wheel can be slid up or down the standard of the rotator to adjust the tension of the cord.

The driving wheel is turned by a handle of aluminum of the form shown in the figure. It is necessary to have a handle of small diameter in order to turn the wheel with a uniform velocity. The fingers which clasped the handle were coated with plumbago dust.

In all the experiments the driving wheel of the rotator was revolved either once in a second or twice in a second. This is accomplished, after some practice, in the following way. The rotator, on which is mounted the disk and fly-wheel, is placed near a clock giving loud beats of seconds, and the driving wheel is revolved by the guidance of hand and ear The results of the experiments showed that the velocities thus given to the disk were sufficiently uniform, and the measures of the durations of sonorous sensations sufficiently concordant and precise to obtain the data of the physiological law.

I adopted this method of rotation in preference to mechanical means for controlling and measuring the revolutions of the disks. To determine when the interrupted sounds have blended, requires, so to say, a flexible apparatus whose velocity is under the immediate control of the hand and ear. This is important in making the final judgment between sounds, one of which appears to have too few interruptions, the other a few more interruptions than are necessary to give a continuous uniform sensation. It is evident that when we can at once slightly increase or diminish the velocity of rotation of the disk we have the means of making comparisons rapidly succeeding one another. A rotator driven as described forms more a part of the observer than one driven and regulated by mechanism.

As there were three grooves in the driving-wheel and three on the pulley on the axle, and as the driving-wheel was revolved either once or twice in a second, 18 different velocities could be given to the rotating disk.

Disks were made having numbers of holes from 5 to 19, so that, with 18 velocities and the various numbers of holes in the disks it was easy to select a disk driven with a known velocity which gave the exact number of interrupted sounds per second to blend.

The 18 ratios of velocities of the driving-wheel and of the pulley on the axle of the rotator were obtained as follows: A circle of card-board, divided into 100 parts. was clamped on the rotator in front of a disk. The driving-wheel was rotated either once or twice in a second so that the conditions were the same as in the experiments. From 10 to 100 revolutions of the driving-wheel were made before the ratio was determined. The division to which a fixed index pointed on the divided circle gave the fraction of a revolution. The whole number of revolutions was given by a simple counter which moved with very little friction.

The rotating disks were made of mahogany, 5^{mm} thick, with disks of card-board about 2^{mm} thick screwed to the wooden disks. The circumference of the holes in the wooden and card-board disks exactly coincided. The circle of holes in the disk was placed 5^{cms} from its border. The rotator and disks were so carefully made that the nipple of the resonator was only $\frac{3}{10}^{mm}$ from the surface of the revolving disk. The mouth of the tube conveying the interrupted sounds to the ear was about the same distance from the surface of the other side of the disk. The disks were clamped on the axis of the rotator between smaller flat disks of brass, not shown in the figure.

The diameter of the holes in the disk and of the interior of the tube conveying the sounds to the ear was 1^{cm}. The diameter of the openings in the nipples of the resonators was $\frac{1}{2}^{cm}$.

The disks were made of mahogany which had been in my possession for thirty years. It was well seasoned and had nearly the thickness required for the disks. This wood was used because it holds the form given it better than any wood I have had experience with.

Sound passes through mahogany and other woods even when a centimeter in thickness. Sound also passes through card-board but not so readily as through wood. I found that by placing card-board on wood I formed a screen of heterogeneous materials which presented an effective obstruction to the passage of sound.

(B) In the second form of apparatus I replaced the resonators by resonant tubes as shown in fig. 8, where F is the fork, T, the tube with a tube of larger diameter, A, sliding on T, so that the air in the tube could be adjusted to vibrate with the fork. On the other side of the disk D, is the tube T′ to which is attached a tube of caoutchouc which leads to the ear. This arrangement is like that used by Dr. R. Kœnig and described on page 140 of his "Quelques Expériences d'Acoustique," Paris, 1882, and used by him for the observation of the sounds produced by interruptions of continuous sounds.

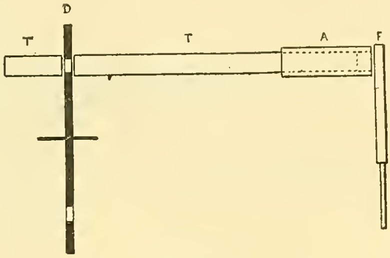

Fig. 8.

Experiments made with this apparatus gave the same results as those made with apparatus (A), but the sounds given are so feeble compared with those coming from the resonators (fig. 7) that the periods of sound and silence (or, rather of sound and much diminished sound) are not sharply separated. It followed that the judgment of a continuous sensation on the ear could not be so neatly made with the use of the resonant tubes as when the resonators were employed.

(C) To obtain sharper demarcation of sound and silence by having no aperture for the lateral escape of sound between the rotating disk and the nipple of the resonator and between the disk and the tube conveying the sound to the ear, I made the following apparatus, fig. 9.

I turned disks of brass flat and of uniform thickness. These disks were revolved on a rotator driven by gear wheels made of "fiberoid," so that the movement should be noiseless. The number of teeth on the wheels and holes in the disks were such that I was enabled to make three determinations corresponding in the number of interruptions of sound to those already obtained with apparatus (A).

Two brass tubes, T and T′, fig. 9, one having one interior diameter of $\frac{1}{2}^{cm}$, the other an interior diameter of 1^{cm}, slid accurately and with little friction in two tubes, A and B, with flanges on their ends. These flanges were pressed against the surfaces of the disk D by two delicate helical springs fitting over the tube at S and S′, between the flanges of A and B and the standards P and P′. The tubes T and T′ were as close as possible to the disk while it rotated. The flanges A and B were of such diameter that no sound could issue between them and the surfaces of the rotating disk, because the flanges

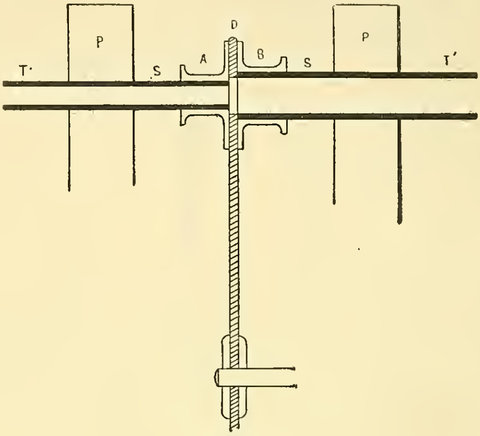

Fig. 9.

entirely covered the hole in the disk while this hole traversed the tubes T and T′. A tube of caoutchouc led from the tube T′ to the ear.

Although a film of oil was between the flanges and the disk and the disks were so accurately made that the greatest departure from uniformity of thickness amounted to only $\frac{1}{25}^{mm}$, yet the sounds produced by the sliding of the disk between the flanges caused much distraction in the perception of the sound from the resonator, which was adapted to the tube, T, of $\frac{1}{2}^{cm}$ in diameter. The results obtained with this apparatus agreed with those given by apparatus (A).

(D) I had formed great hopes of having the best apparatus for the determination of the duration of a residual sensation in the one shown in fig. 10. A is the lower drum of a Helmholtz double siren. D, the perforated disk of the siren, which was rotated by the driving-wheel W. The disk, D, was inclosed in the cover, C, of the form shown in fig. 10, clamped to the drum of the siren. The sound issued from the box, thus formed, and was conveyed to the ear by the tube E, to which was attached a tube of caoutchouc. The sound to be experimented on was conveyed from the fork, F, and resonator, R, through a long tube T to the drum of the siren. By placing pulleys, P, of various diameters on the axle of the disk of the siren and by opening one or another of the various circles of holes in the drum, A, I had the means of obtaining a considerable range in the numbers of interruptions of sounds per second.

The results given by this apparatus were the same as those obtained with (A), but the objection to its action is the produc-

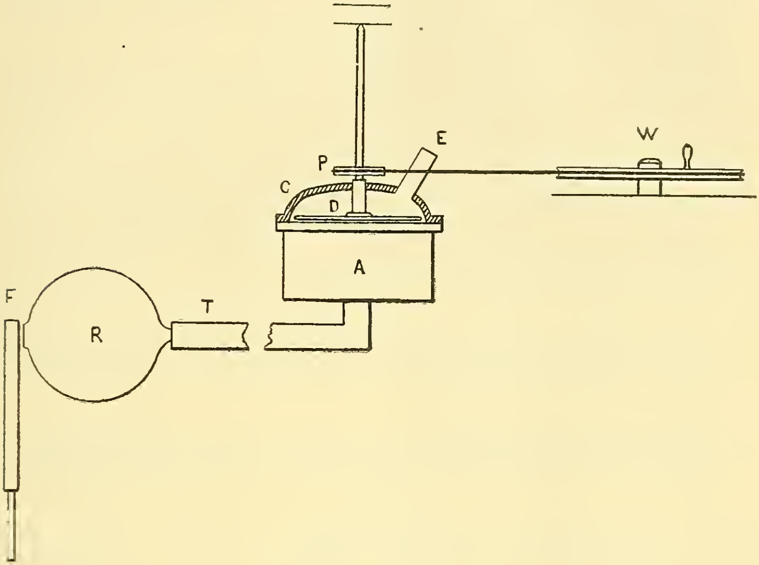

Fig. 10.

tion of sounds by the apparatus itself, caused by the rotation of the perforated disk. These sounds distracted the attention from the phenomenon of the continuous sensation produced by the interruptions of the sound from the fork and so masked it that I consider this apparatus the least efficient of any I have described.

These experiments on the blending of interrupted sounds are not pleasant to make. The ear soon becomes fatigued and the perception of sound is dulled. After an experiment the ear has to be rested during a considerable time before the experiment can be repeated satisfactorily. Thus much time is consumed and these experiments cannot be made in a few days, but weeks are required to arrive at satisfactory measures; also considerable time is consumed in gaining mastery over the apparatus. To make these experiments less tedious, fatigue of the ear is to be avoided. This is done by not allowing the interrupted sounds to enter the ear longer than during two or three seconds, then a rest of 5 to 6 seconds is taken while the fork is kept in action and the disk revolved with the same velocity ; then another three seconds period of sound is given the ear. This is best done by placing the rubber tube in the meatus of the ear and pinching the end of the tube between the fingers. By relieving the pressure more or less we can regulate the intensity of the sound which enters the ear, or we can shut the sound off. The other ear is tightly closed with beeswax softened with a little turpentine.

Within the limits of the intensities of sound used in these experiments I found no change in the duration of the sensation with change in the intensity of the sound. It seems probable that such connected changes exist. If they do exist, then it would appear, from the smoothness of the curve I have obtained from the experiments, that the relative mean intensities of the sounds used did not vary sufficiently to make apparent any change in the duration of the after-sensation with change in the intensity of the stimulus.

Table of results of experiments. The empirical formula which gives the relation of the pitch of a sound to the duration of its residual sonorous sensation.

The results of the experiments made with the various forms of apparatus just described are given in the following Table I.

TABLE I.

A	B	C	D	E	F	G	H	I	K	L
UT_1	64	23·1	$\frac{1}{26·9}$	·0361	·0369	—·0008				1·38
UT_2	128	36	$\frac{1}{43·2}$	·0231	·0228	—·0003	·0280	·0324	+·0044	1·77
SOL_2	192						·0232	·0237	+·0005	
UT_3	256	62	$\frac{1}{74·4}$	·0134	·0133	—·0001	·0190	·0189	—·0001	2·06
Mi_3	320	73	$\frac{1}{87·5}$	·0114	·0112	—·0002	·0160	·0158	—·0002	2·12
SOL_3	384	88	$\frac{1}{105·6}$	·0094	·0097	+·0003	·0137	·0137	·0000	2·18
UT_4	512	108	$\frac{1}{130}$	·0077	·0078	+·0001	·0110	·0109	—·0001	2·37
Mi_4	640	126	$\frac{1}{151·2}$	·0066	·0067	+·0001	·0092	·0092	·0000	2·53
SOL_4	768	143	$\frac{1}{171·6}$	·0058	·0059	+·0001	·0080	·0081	+·0001	2 68
UT_5	1024	170	$\frac{1}{204}$	·0049	·0049	—·0000	·0066	·0066	·0000	3·01
Mi_5	1280						·0057	·0057	·0000	
SOL_5	1536						·0052	·0052	·0000	
Ut_6	2048						·0045	·0044	—·0001	
Mi_6	2560						·0039	·0039	·0000	
SOL_6	3072						·0036	·0036	·0000	

Column A gives the names of the sounds, and B the numbers of their vibrations (v. d.) per second. C, the number of beats of interrupted sound received by the ear in a second to blend into a continuous uniform sensation. In column D are the durations of the residual sonorous sensations expressed in vulgar fractions. The numbers in column D are obtained, as already explained, by diminishing the reciprocals of the numbers in col. C by $\frac{1}{6}$. Under E are the fractions in column D in decimals. Under F are the durations of the residual sensations computed by the formula

$$D = \left(\frac{33000}{N+30} + 18\right) \cdot 0001$$

in which D = the duration of the residual sensation given by a sound of N number of vibrations per second. Under G are the differences between the computed and observed values of the residual sensations. These differences are so small, except in the case of SOL_3, that we may adopt the empirical formula as expressing the law, which connects the pitch of a sound with the duration of its residual sonorous sensation. This formula, however, only refers to my own auditory sensation. It is a physiological law and I imagine that the durations of these residual sonorous sensations will vary more with different observers than do analogous visual sensations. It is therefore to be wished that others will repeat these experiments and obtain determinations which, when combined, will give a law which may be accepted as the expression of the average durations of the residual sonorous sensations.

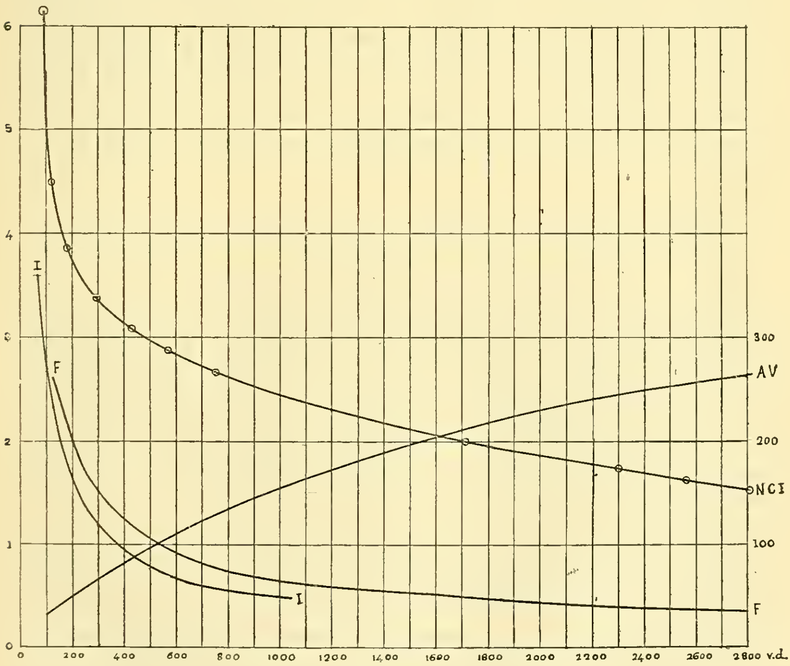

Fig. 11.

The results in column E are given graphically in the curve I of fig. 11. The unit on the axis of abscissas is 100 v. d. The unit on the axis of ordinates is ·01 second.

The determination of the duration of the residual sensation of UT_1 (64 v. d.) was very carefully made and made many times. The experiments gave ·0361 second for the duration of this sound. The formula gives ·0369, which is $\frac{1}{45}$ greater than the observed duration. The greatest difference existing between the observed and computed duration of the remaining sounds of the table is in the case of SOL_3 (384 v. d.) where the computed is $\frac{1}{31 \cdot 3}$ greater than the observed duration. In column L of Table I are given the number of wave-lengths of the sounds which pass into the ear through a hole in the rotating disks when these interrupted sounds blend into uniform sensations. The average number of wave-lengths which pass a hole is about $2\frac{1}{4}$. As the sound rises in pitch more wave-lengths pass the hole; thus while only 1·38 wave-length passes in the case of UT_1, 3 wave-lengths pass in the case of UT_5.

An examination of fig. 6 shows that sound passes to the ear while a hole in the disk passes over three diameters of the hole in the nipple of the resonator, while the distance between the centers of neighboring holes in the disk equals six diameters of the hole in the resonator; hence, to ascertain the number of wave-lengths which enter the ear during the passage of a hole in the disk across the hole in the resonator we must divide the number of vibrations per second of the sound, given in column B, by twice the corresponding number in column C.

2. *On the Smallest Consonant Intervals among Simple Tones.*

When two simple tones, which differ slightly in pitch, are sounded simultaneously, beats are produced, which become more frequent as the difference in pitch increases, and with this increase in the interval between the tones the dissonance becomes harsher, reaching a maximum of dissonance (when the number of beats are about $\frac{4}{10}$ of the number required to blend), then becoming less dissonant as the interval increases till, at last, the two tones blend into a consonance. These are the phenomena observed from SOL_1 (96 v. d.) to the highest tones used in music.

Having the law which gives the number of beats (produced by the interrupted sounds of tones of various pitch), which blend, one might naturally infer that the consonant interval could be computed by that law. Given the pitch of a tone we compute by the law the number of interruptional beats of this tone which blend, and adding this number to the frequency of the given tone we should apparently have the pitch of the upper tone which makes with the lower the smallest consonant interval.* This however is not so. Take, for example, UT_3 (256 v. d.). The number of interruptional beats of this sound which blend is 62, and 256+62 = 318 which, according to the law, should make a consonant interval with UT_3. But experiment shows that a tone of 256+58 = 314 v. d. forms the smallest consonant interval with UT_3.

To render less tedious the comprehension of the results of many experiments on the smallest consonant intervals among simple tones I shall at once give a table (Table II) of the results of these experiments and then give the account of the experiments that furnished the data of the table.

In column A are given the lowest tones of the consonant intervals which were experimented on. In column B are the number of vibrations to be added to the tones of column A to form the higher note of the smallest consonant interval, as deduced from the experiments on the duration of the residual sensation of interrupted sounds. In column C the numbers of vibrations by which the tones in column A have really to be increased to form the higher notes of the smallest consonant intervals. In column D are the numbers of vibrations to be added to those of column A to form the smallest consonant intervals as computed by the formula

$$N : N + \frac{1}{\left(\frac{42500}{N+23} + 23\right) \cdot 0001}$$

in which N = the number of vibrations of the lower tone of of the interval and $N + \frac{1}{\left(\frac{42500}{N+23} + 23\right) \cdot 0001}$ = the number of vibrations of the higher tone of the interval. In column E are given the differences between the computed values (D) and the observed values (C). The formula gives quite closely the true values from SOL_2 (192 v. d.) to MI_6 (2560 v. d.). In column F are given the smallest consonant intervals, as determined experimentally, from SOL_1 (96 v. d.) to the tone of 2806 v. d., expressed in semitones of the equal-tempered scale.

In figure 11 these intervals, computed from the numbers in column C, are expressed graphically by the curve N. C. I. The units of ordinates (on the left of figure) are semitones and the units of abscissas are 100 vibrations. This curve

* Rigorously, we should take in the computation the number of beats which blend corresponding to a sound of a pitch which is the mean of the pitch of the lower and upper sounds of the interval.

TABLE II.

	A	B	C	D	E	F
Number of Experiment.	Tones.	Number of additional v. d. to form the smallest consonant interval as deduced from the experiments on the residual sensations of interrupted sounds.	Number of additional v. d. really required to form the smallest consonant interval.	Number of additional v. d. required to form the smallest consonant interval according to the formula $N : N + \frac{1}{\left(\frac{42500}{N+23} + 23\right) \cdot 0001}$	Differences between D and C.	Smallest consonant intervals in semitones of equal-tempered scale.
(1)	SOL (48)	19·	no consonant interval	16·		none
(2)	UT_1^{-1} (64)	23·1	no consonant interval	19·5		none
(3)	SOL_1 (96)	30·7	41	26·3	—14·7	$6\frac{15}{100}$ semitones.
(4)	UT_2 (128)	36	38	32·8	— 5·2	$4\frac{1}{2}$ "
(5)	SOL_2 (192)	49·7	48 +	47·4	— 0·6	$3\frac{86}{100}$ "
(6)	UT_3 (256)	62	58	57	— 1·0	$3\frac{53}{100}$ "
(7)	Mi_1^- (316)	72	68	67·4	— 0·6	$3\frac{34}{100}$ "
(8)	LA_3^- (432)	91·2	85·4	85·9	+ 0·5	$3\frac{12}{100}$ "
(9)	RE_4^- (575)	113·3	107·4	106·3	— 1·1	$2\frac{95}{100}$ "
(10)	SOL_4^- (766·2)	137·8	129·8	130·1	+ 0·3	$2\frac{70}{100}$ "
(11)	LA_5 (1706·6)	219·3	210·4	212	+ 1·6	2 "
(12)	RE_6 (2304)	251·4	245	242·3	— 2·7	$1\frac{76}{100}$ "
(13)	MI_6 (2560)	262·8	256	253·5	— 2·5	$1\frac{64}{100}$ "
(14)	Fork (2806)	272	266	263	— 3·0	$1\frac{54}{100}$ "

shows in a striking manner the contraction of the smallest consonant interval as we ascend the musical scale; while SOL_1 (96 v. d.) requires a sound separated from it by $6\frac{15}{100}$ semitones to give the smallest consonant interval, SOL_6 of 3072 v. d. forms a consonant interval with a higher sound separated from it by only $1\frac{1}{2}$ semitones. The curve AV, of fig. 11, which has the same units of abscissas as curve N. C. I, and the units of whose ordinates, in numbers of vibrations, are on the right of the diagram, shows graphically the number of vibrations to be added to the tones, on the axis of abscissas, to obtain the smallest consonant intervals.

The experiments which form the basis of the statements given in Table II, I shall now describe.

Having but few forks below UT_3 in pitch, and those not numerous enough to determine with accuracy the consonant intervals, I requested my friend Dr. Rudolph Koenig, of Paris, to determine for me the smallest consonant intervals among sounds below UT_3 in pitch. The numbers in the table referring to tones SOL_{-1}, UT_1, SOL_1, UT_2, and SOL_2, experiments Nos. 1, 2, 3, 4, and 5 of Table II, were furnished by Dr. Koenig's experiments. The account of these experiments, which Dr. Koenig so obligingly made for me, I give in his own words.

Dr. Koenig's Experiments.—"Paris, le 21 Mars, 1893 . . . Je veux maintenant repondre a vos questions concernant la consonance des intervalles formés de notes graves et pas trop fortes, et faire d'abord cette remarque générale, que la perceptibilité des roulements et raucités produits par des battements, qui depend avant tout de l'intensité relative des deux notes primaires, parait être presque entièrement indépendant de leur intensité absolue, quand elles sont graves, tandis que le rôle de l'intensité absolue augmente avec leur hauteur. En effet, les resultats des observations faites avec des diapasons relativement faibles, et sans résonateurs, sont pour les octaves graves presque absolument identiques avec les résultats donnés par les gros diapasons et résonateurs du grand tonomètre, et publiés dans le tableau, page 113, des "Quelques Experiences d'Acoustique," tandis que pour les intervalles avec les notes fondamentales UT_2 et SOL_2, les différences des résultats devient déja sensible. Je pourrais aussi résumer ces faits en disant que l'influence de l'intensité absolue des deux sons primaires sur la perceptibilité des battements, qui est absolument nulle pour les battements lents, augment pour les roulements et raucités avec les nombres des battements qui les produit, car, pour example, les 8 battements de UT_1 : RE_1 sont aussi distinctment entendus avec des notes UT_1 et RE_1 trés faibles, qu'avec des notes les plus fortes, tandis que le roulement des 32 battements de $UT_1 : SOL_1$, se fait beaucoup plus sentir quand les deux notes sont fortes, que quand elles n'ont q'une faible intensité.

Voici maintenant la liste de mes observations:

(1) *Intervalles avec la note fondamentale* $SOL_{-1} = 48$ v. d.

Les diapasons employés, du modèle de l'interrupteur universel, Cat. No. 253, ont des branches d'environ 9^{mm} d'épaisseur sur 15^{mm} de largeur.

On ne trouve dans toute l'octave pas un seul intervalle sans battements fortement perceptibles, soit séparément soit comme roulement. Le roulement parait le plus faible vers la sixte, $SOL_{-1} : MI_1$.

(2) *Intervalles avec la note fondamentale* $UT_1 = 64$ v. d.

Les diapasons employés du modèle, Cat. No. 234, ont des branches d'environ 10^{mm} sur 17^{mm}.

Tout se passe dans l'octave entière comme avec les gros diapasons avec resonateurs, seulement le roulement confus près de la quinte est faible et disparait presque devant les battements secondaires, mais il reparait au dessus de $SOL_1 + 4$ v. d. et devient plus fort en passant au roulement simple des battements supérieurs. A la quinte exacte, $UT_1 : SOL_1$, ou les battements secondaires manquent, on entend très bien le roulement des 32 battements, mais plus faible qu'avec des gros diapasons et resonateurs.

Les mêmes experiences répétées avec des diapasons à branches de 19^{mm} sur 15^{mm} donnent le même résultat.

En somme, ici aussi il n'y a pas d'intervalle consonant dans toute l'octave.

J'ai encore particulierèment examiné l'intervalle $UT_1 : MI_1$, mais on y entend le roulement des 16 battements même encore quand les sons premaires sont devenus déja si faibles qu'on ne les perçoit presque plus.

(3) *Intervalles ave la note fondamentale* $SOL_1 = 96$ v. d.

Diapasons employés à branches de 10^{mm} sur 17^{mm}.

SOL_1 : LA_1	10·6	battements	séparément	entendus.	
" : SI_1	24	"	roulement	simple fort.	
" : 124 v. d.	28	"	"	plus faible.	
" : UT_2	32	"	"	très faible.	
" : 134 v. d.				faible raucité.	
SOL_1 : 136 } " : 138 }	Peut être regardé comme consonant, mais				

à SOL_1 : 140 v. d. les battements secondaires deviennent déja sensibles et augmentent vit en intensité. Quand ils disparaissent à la quinte exacte.

$SOL_1 : RE_2$, celle ci fait entendre une raucité à peine perceptible. Au dessus de RE_2 les battements secondaires reparaîssent pour disparaitre vers 148 v. d.

SOL_1 : 150 v. d. Il y a encore un peu de raucité mais on pouvait à la rigeur regarder les intervalles d'ici à.

SOL_1 : 166 v. d. comme consonants. Au desus de 166 v. d. le roulement des battements superieurs commence, et augmente en intensité, et à partir de 180 v. d. les battements supérieurs sont séparément perceptibles.

En resumé, il y entre la quarte et la quinte une petite étendue, et au dessons et au dessus de la sixte une plus grande, ou se trouvent des intervalles consonants.

(4) *Intervalles avec la note fondamentale* UT_2 = 128 v. d.

Diapasons employés pour UT_2 jusqu'à UT_3, avec branches de 10^{mm} sur 17^{mm}, pour la note fondamentale UT_2 avec branches de $7\frac{1}{2}^{mm}$ sur 14^{mm}.

Tout se passe à peu près comme avec les gros diapasons et résonateurs (Cat. No. 197), seulement le roulement de $UT_2 : MI_2$ n'est plus qu'un simple raucité, qui diminue vit pour disparaitre à 166 v. d.

$UT_2 : FA_2$ est consonant, et la consonance persiste jusqu' à 188 v. d. ou les battements secondaires commencent à la troubler jusqu'à la quinte, $UT_2 : SOL_2$, qui est consonant. Quand ils ont troublé la consonance des intervalles au dessus de la quinte jusque vers UT_2 : 197 v. d. les intervalles sont de nouveau consonants et le restent jusque vers UT_2 : 222 v. d. ou alors le roulement des battements superieurs commence.

En resumé, les intervables d'un peu au dessau de la quarte jusqu' à près de la quinte, la quinte, et les intervalles d'un peu au dessus de la quinte jusque au dessus de la sixte sont consonants.

Avec des diapasons du modèle de Cat. No. 38*a*, aux branches de 15^{mm} sur 20^{mm}, montés sur caisses, le roulement des 32 battements de $UT_2 : MI_2$ est fort ; $UT_2 : SOL_2$ est consonant, mais comme $MI_2 : SOL_2$ donne le meme nombre, 32, de battements que $UT_2 : MI_2$, en faisant sonner ensemble UT_2, MI_2, SOL_2, les 32 battements do $UT_2 : MI_2$ et de $MI_2 : SOL_2$ se renforcent et produisent un roulement formidable.

(5) *Intervalle avec la note fondamentale* $SOL_2 = 192$ v. d.

Diapasons employés avec branches de 10^{mm} sur 17^{mm}.

$SOL_2 : LA_2$ Roulement simple assez fort.
" : 244 v. d. Raucité prononcé.
" : SI_2 Raucite faible.

La consonance commence encore avant $SOL_2 : UT_3$.

Il resulte de l'ensemble de ces observations, que pour les intervalles des notes très graves les faits ne s'accordent pas du tout avec votre loi, mais aussi que pour les intervalles des notes de plus en plus aigues, l'accord entre les faits et la loi devient toujours meilleur et finit par être presque parfait quand la note fondamentale atteint SOL_2."

I experimented on the hearing of twelve persons with all the forks at my command among which I could obtain consonant intervals. It is true that the number of intervals thus furnished, by 80 forks, did not amount to many. Many such intervals can only be obtained in the laboratory of Dr. Koenig where is his "grand tonomètre" giving the frequency of all sounds from 16 to 21845 complete vibrations per second. However, I secured, between UT_3 and SOL_6 enough intervals among the forks to establish the law and the facts given in Table II.

All the persons experimented on, except myself and one other observer, were accomplished musicians, several of them violinists of more than exceptional ability. Three were graduates of the Conservatory of Music of Leipzig.

These experiments were all made in the same manner, viz: by taking a fork giving the lower tone and sounding it successively with others which gave more and more beats per second, till these beats blended into a continuous smooth sensation, forming the smallest consonant interval. As musicians rather avoid than dwell on dissonant intervals I educated each one in the special subject of the roughness of the sensation given by beats, by making the beats more and more frequent till near consonance, then giving an interval which is admitted by every one to be consonant. In this way their hearing was trained in what I wished them to discern, viz: that separation in the pitch of two forks which just gives a consonant interval.

The variation among the decisions of these different observers never equalled two vibrations, generally they agreed exactly. This agreement among observers in the judgment of a consonant interval is remarkable. I give the mean of these experiments. The number of the paragraphs refer to the number of the experiment given in Table II.

(6) $UT_3 : MI_3 = 256 : 320$ gave a consonant interval. I narrowed the interval by lowering the pitch of MI_3 from 320 to 315, 314, 313·5 and 313

UT_3 : 315 consonant.
" : 314 just consonant.
" : 313·5 slightly rough.
" : 313 decidedly rough.

These experiments show that 256 : 256+58 = nearest consonant interval.

(7) $MI_3 : SOL_3 = 320 : 384$ is decidedly rough. Separated the interval by lowering the MI_3 fork from 320 to 916 then $MI_3 : SOL_3 = 316 : 384 = 316 : 316 + 68$ = smallest consonant interval.

(8) $LA_3 : UT_4 = 439 : 517{\cdot}4$ decidedly harsh. Separated interval by lowering LA_3 of 439 v. d. to 432 v. d. then $LA_3 : UT_4 = 432 : 517{\cdot}4 = 432 : 432 + 85{\cdot}4$ = smallest consonant interval.

(9) $RE_4 : FA_4 = 576 : 682{\cdot}65$ slightly rough. Increased the interval by lowering RE_4 of 576 v. d to 575 v. d. then $RE_4 : FA_4 = 575 : 682{\cdot}65 = 575 : 575 + 107{\cdot}65$ = smallest consonant interval.

(10) SOL_4 : Fork of 896 v. d. = 768 : 896 slightly rough. Increased the interval by lowering SOL_4 of 768 v. d. to 766·2 then $SOL_4 : 896 = 766{\cdot}2 : 896 = 766{\cdot}2 : 766{\cdot}2 + 129{\cdot}8$ = smallest consonant interval.

(11) $LA_5 : SI_5 = 1706{\cdot}6 : 1920$ consonant. Narrowed the interval by lowering SI_5 of 1920 to 1917 then $LA_5 : SI_5 = 1706{\cdot}6 : 1917 = 1706{\cdot}6 : 1706{\cdot}6 + 210{\cdot}4$ = smallest consonant interval.

(12) $RE_6 : MI_6 = 2304 : 2560$ consonant. Narrowed the interval by lowering MI_6 of 2560 v. d to 2549 then $RE_6 : MI_6 = 2304 : 2549 := 2304 : 2304 + 245$ = smallest consonant interval.

(13) Mi_6 : Fork No. $11_6 = 2560 : 2816 = 2560 : 2560 + 256$ is just perceptibly rough.

(14) Fork 11 : $SOL_6 = 2816 : 3072$ slightly dissonant. Increased interval by lowering Fork 11 of 2816 v. d. to 2806 then Fork 11 : $SOL_6 = 2806 : 3072 = 2806 : 2806 + 266$ = smallest consonant interval.

In the experiments just described the intervals of the tones that gave consonance were made by simple tones, of small intensity and free from the slightest trace of the upper partial tones of the forks, and the two forks were vibrated so that they gave, as near as I could judge, the same intensity of sound. The results given only refer to intervals so formed. To obtain them the forks were gently vibrated by strokes of rubber hammers that varied in hardness with the pitch of the forks. The lower the pitch of the fork the softer should be the hammer. A hammer of hard rubber striking low pitched forks will develop the upper partial tones of the forks and so vibrate the experiments that a really consonant interval might be judged as dissonant.

The results of all the experiments may be summed up as follows: From SOL_2 of 192 v. d. to MI_6 of 2560 v. d. the smallest consonant intervals are closely given by the formula

$$N : N + \frac{1}{\left(\frac{42500}{N+23} + 23\right) \cdot 0001}$$

For sounds below SOL_2 the interval as computed by the formula is too small to agree with the true interval. For sounds above MI_6 (2560 v. d.) the intervals computed by the formula, like those below SOL_2, are too small. That the experimental determination of the smallest consonant interval throughout four octaves, upward from SOL_2, or, throughout the tones given by the violin, should agree so closely with the formula indicates the existence of a law connecting the magnitude of the smallest consonant interval with its position in the musical scale.

Dr. Koenig has shown that a consonant interval does not exist among simple sounds of pitch below SOL_1 (96 v. d.), yet I have found that the sound of UT_1 (64 v. d.), when interrupted by a rotating perforated disk, blends perfectly, to my ear, when these interruptions occur 23·1 times in a second. It may appear strange that although 23·1 interruptions per second of the sound UT_1 blend, yet a consonant interval does not exist throughout the interval of UT_1 till the interval $UT_1 : UT_2$ is reached; but the beats produced by the rotating perforated disks are produced by the interruptions of one tone, whereas, when two simple tones are conjoined two sets of beats are produced, inferior and superior; thus, when UT_1 forms an interval with UT_1+23 v. d., the inferior beats are 23 per second and the superior beats are 41 per second, and the interaction of these inferior and superior beats produces secondary beats which give to the interval a confused rumbling sound.* Of this interval, $UT_1 : UT+23·1$, Dr. Koenig wrote to me as follows: "Your 23·1 interruptions of UT_1 correspond, in number, to the inferior beats of the simple tones $UT_1 : UT_1 +$

*See Quelques Expériences d'Acoustique, par Rudolph Koenig. Paris, 1882, pp. 89, 107, 113.

23·1, but it is just at this magnitude of interval that the superior beats begin to assert themselves, to produce with what remains perceptible of the inferior beats, the confused rumbling, which evidently would be but a slight roughness (disappearing entirely at a further increase of the interval), if the superior beats, whose intensity from this point increases with the interval, did not exist."

3. *The Durations of the Residual Sonorous Sensations as deduced from the Smallest Consonant Intervals among Simple Tones.*

If we assume that two simple tones form the smallest consonant interval because the beats produced by these conjoined sounds have blended into a smooth continuous sensation, then we may deduce the durations of the residual sonorous sensations from the observed smallest consonant intervals in the following manner. The reciprocals of the numbers in column C, Table II, are taken as expressing the durations of the sonorous sensations given by tones whose numbers of vibrations are the mean of those of the lower and higher tones of the corresponding consonant intervals, for, when two sounds of different pitch blend, there is no reason why the duration of their residual sensation, as given by the reciprocal in column C, should refer to the lower sound more than to the higher. Therefore we have taken these reciprocals from column C as expressing the durations of sounds having the mean pitch of the two associated sounds forming the interval. The residual sensations thus found were projected in a curve, drawn to a large scale. From this curve were obtained the durations of the residual sensations of the tones of the musical scale. These durations are given in column H of Table I.

In column I of Table I are given these durations as computed by the formula

$$D = \left(\frac{48000}{N+30} + 21\right) \cdot 0001$$

In column K are the differences between the durations computed by the formula and the durations given in column H. These differences show that the formula expresses closely the durations of the residual sensations thus deduced from the determinations of the smallest consonant intervals, except in the case of UT_2; for which tone the computed number of vibrations to be added to it to form the higher tone of its smallest consonant interval, as shown in Table II, is 5·2 vibrations less than the number of vibrations really required.

In figure 11 these durations, as determined from the smallest consonant intervals are plotted in the curve F so that the comparison of the durations of the residual sonorous sensations thus determined may be readily compared with those given (by the curve I), of the residual sensations as determined by the blending of sounds interrupted by rotating perforated disks.

The ordinates of the curve I and F of fig. 11 are obtained in fractions of a second by changing the numbers 1. 2 and 3 on the left of fig. 11 into ·01, ·02 and ·03.

These two curves of fig. 11 present the same general character of a rapid upward flexure at the points corresponding to about 600 v. d.

The durations of the sound-sensations thus deduced from the smallest consonant intervals average about $\frac{1}{3}$ greater than those given by the beats of interrupted sounds. It may be supposed that the durations of the sonorous sensations deduced from the smallest consonant intervals of simple tones are greater than those determined by sounds interrupted by the perforated disks because in the resultant actions of the vibrations of the tones, forming the smallest consonant intervals, the periods of silence, or, of the periods of great diminution of sound, are a fraction of the periods of sound, or, of the periods of maximum intensity of sound. To test this opinion I combined the sinusoids corresponding to the two tones of various smallest consonant intervals. On taking, as the residual duration of the sound, not the time from maximum to maximum of vibration (as in the deduction of the durations from the smallest consonant intervals), but the interval of time during which much diminished intensity of sound exists, as shown in the combined curves, I found that the durations of sonorous sensations were thus reduced, on the average, about $\frac{1}{2}$, whereas, the reduction in time should be only $\frac{1}{3}$ to make these durations agree with those determined by the rotating perforated disks. The explanation suggested is therefore not tenable.

For the period of much diminished intensity of sound I took that length (in time) of the resultant curve which is bounded, at each end, by an amplitude of vibration $\frac{1}{2}$ of the maxima amplitudes of the curve. We are here in doubt as to the relative intensities of the sensations given by two sound-vibrations whose amplitudes are 2 : 1 and whose energies are 4 : 1. We at once face an obstacle which, from our want of knowledge, is insurmountable; for, assuming that either the law of Weber, or the formula of Fechner deduced from it, correctly gives the relations existing between the intensity of a stimulus and its corresponding sensation, we cannot apply either of these laws, because we do not know the *absolute energies* of the sound-vibrations whose sensations are to be compared. Thus, if we adopt the law of Weber, with the least perceptible difference in the sensation of two sounds equal to $\frac{1}{3}$ of their energy, as given by the experiments of Volkmann,* we find that if 1 and 4 are the absolute energies of the sound-vibrations we get for the ratio of their corresponding intensities of sensations 1 : 2·6, but, if the absolute energies of the sounds are 10 to 40 (and their ratio is also 1 : 4), we get for their relative sensations 1 : 1·48. Or, what is the same, on the curve expressing the law of Weber, or, of Fechner, the ratio of the sensations of two sounds as given by their corresponding ordinates, depends on the number of units on the abscissas forming the ratio of the energies of these sounds.

Professors Cattell and Fullerton from extended experiments "On the Perception of Small Differences,"† very carefully

* In the investigations, of which I have knowledge, the experimenters have used either noises, or, sounds of complex composition mingled with noise, and the ways in which they have determined the relative energies of sounds, or, of noise-producing vibrations, are open to criticism. I do not know of similar experiments made with simple sounds, or, tones. I would suggest that the problem of determining the differences in the energies of two simple sounds to give a perceptible difference in the sensations they cause may be solved as follows: A fork, or, rod, is vibrated with a constant amplitude and this amplitude is measured with a micrometer-microscope. A second fork, or, rod, placed alongside of the first fork, or, rod, has a much smaller amplitude of vibration, which can be varied, and is also measured with a microscope. The second fork differs from the first slightly in pitch, so that, say, three beats per second are given. The amplitude of the second, or, of the first fork, is varied till the perception of beats just vanishes or just appears, while the ear is kept at a fixed distance from the forks. If we take for the relative energies of the sound-giving vibrations the ratio of the squares of the amplitudes of the forks, the least perceptible difference in sensation corresponding to the differences in the energies of the sounds may be computed. As example: suppose the second fork has $\frac{1}{20}$ of the amplitude of vibration of the first. Then the energy of the maximum sounds of the beats will be $\overline{20+1}^2 = 441$, and the energy of the minimum sound of the beating will be $\overline{20-1}^2 = 361$, and $\frac{441}{361}$ = the ratio of the stimuli giving the least perceptible difference in sensation. Sound vibrations of different amplitudes and of different pitch will have to be experimented with and the fork giving the greater amplitude of vibration should, in successive experiments, be lower in pitch and then higher in pitch than the fork giving the lesser amplitude of vibration, for reasons set forth in my research. "(1) On the obliteration of the sensation of one sound by the simultaneous action on the ear of another more intense and lower sound. (2) On the discovery of the fact that a sound even when intense cannot obliterate the sensation of another sound lower than it in pitch." (This Journal, Nov., 1876: Nature, Aug. 10, 1876). Such a research will be difficult and tedious and will require many precautions in arranging the experiments.

Any one may readily observe the phenomena described by sounding a fork with a large amplitude of vibration and gradually bringing up to the ear a second fork with a small amplitude of vibration, giving with the first three beats per second. As the latter fork gradually approaches the ear the beats become stronger, reaching a maximum of intensity, and then diminishing till they vanish in the more intense sensation of the more intense sound, to reappear when the faintly vibrating fork has been brought closer to the ear.

† Publications of the University of Pennsylvania. Philosophical Series, No. 2, May, 1892.

made and skillfully reduced, have formed the opinion that neither the law of Weber, nor Fechner's formula is correct, and *a priori* considerations lead them to the opinion that it is probable that the sensation is directly as the stimulus. If the sensation increases directly as the stimulus, then we can obtain the relative sensations of two sounds whose relative energies are known. Adopting this relation, we have 1 : 4 as the ratio of the maximum sensation in the periods taken for those of much diminished sound to the maximum sensation in the periods of much increased sound, as given by the measurements of the amplitudes of the resultant curves of the nearest consonant intervals.

In explanation of the facts and laws given in this paper I have no hypothesis to offer. It appears to me that the present condition of our knowledge of audition demands that we should ascertain more facts relating to it before we frame hypotheses on the mechanism and action of the apparatus of hearing.

Stevens Institute of Technology, Hoboken, N. J.

ART. II.—*Petroleum in its relations to Asphaltic Pavement*; by S. F. PECKHAM.

[Read at the World's Congress of Chemists, Chicago, Ill., Aug. 25th, 1893.]

THE chemical examination of petroleum has been conducted along two different lines of research. Sometimes one has been followed to the exclusion of the other and sometimes the two have been combined. The method most familiar to chemists is that of distillation, usually more or less destructive. The less well known method consists in separating the constituents of the petroleum by the successive application of solvents, in the use of which term I propose in this paper to exercise considerable latitude.

The earliest analysis of petroleum is described by de Saussure in a paper published in the Bibliothéque Universelle in 1817.* He examined the so-called naphtha of Amiano, a very light and almost colorless petroleum. He purified it by distillation and determined the percentage composition, as if it were an homogeneous substance. Twenty years later, in 1837,† Boussingault published his celebrated memoir on the composition

* Bibliothéque Universelle, iv, 116; Annales de Chemie et de Physique (2), iv, 314–340; London Journal of Science, iii, 411.

† Annales de Chemie et de Physique (2), lxiv, 141; Journal of the Franklin Institute, xxiv, 138; New Edinburg Philosophical Journal, xxii, 97.

of bitumens, in which he described his manner of separating, partly by distillation and partly by solution, what he supposed were two homogeneous substances from the petroleum, or more properly maltha, of Bechelbronn on the lower Rhine. He found that in making the separation by distillation it was necessary to keep the material heated in an air bath for from 45 to 50 hours, and in a note makes this pregnant observation: "By this method it is impossible to estimate the two principles of the bitumen; as at this temperature (250° C.) a part of the petrolene is oxidized and passes into the solid state, or asphaltene." These two substances, the petrolene or liquid part, and the asphaltene or solid part into which nearly all bitumens may be resolved in varying proportions, have not received the attention which they deserve, partly because as chemical compounds they are without significance and partly as they are separated from different bitumens, the petrolene in particular, they have very unlike properties.

On visiting southern California in 1865,* all the natural phenomena attending the passage of petroleum through maltha into asphaltum, were witnessed upon a very extended scale, and I was forced to consider as matters of economic importance, many problems that had not hitherto been brought to the attention of technologists. In what manner the changes, everywhere proceeding upon the surface were related to possible changes below the surface, led me to imitate in every respect, save the element of time, the operations of nature as far as possible. I therefore proceeded upon a synthetic rather than an analytic line of investigation, and treated the unchanged oil issuing from deep-seated strata, to the action of air and ozone. As the action of these reagents might be explained as due either to the addition of oxygen or to the substraction of hydrogen, I tried the effect of chlorine and found it to be in the main identical with that of the first named gases. The product of these reactions was a brilliant solid, apparently identical with pure asphaltum, and also with Boussingault's asphaltene.

In 1870, I stated the problem to Prof. J. D. Whitney as follows: "To discover if possible whether asphaltum is formed from petroleum by a change that adds oxygen or substracts hydrogen or both? To subject several typical varieties of petroleum to the action of ozone under conditions as nearly identical as possible. To study the residues of such action and establish the identity (if such identity exists) between the solid residues and native asphalts. To study the liquid and volatile products of such decomposition."

* Geological Survey of California, Geology, ii, Appendix, p. 73; Reports 10th Census U. S., vol. x, Petroleum, p. 185.

Since 1870 Le Bel and Muntz,* (1872) have treated Syrian asphalt and several other forms of bitumen to the solvent action of ethylic-ether. Ethylic-alcohol was then added to the solution and the bitumen precipitated. The solution and precipitation were repeated until the precipitated bitumen was quite pure. It appears as a brown powder. From solution in carbon disulphide it appears in brilliant black scales, which are insoluble in light petroleum naphtha (paraffines) but dissolve in the heavy distillates, which fact readily accounts for the difference in color between the light and heavy natural oils. These authors remark that, "Its (asphaltene) presence in natural bitumens proves that they have not been submitted to distillation, nor even the action of a high temperature, which corroborates the most generally received opinion respecting their origin, that they have been directly derived from coal or lignite."

Subsequent research by Le Bel showed that a resinous substance remained dissolved in the ether that was readily acted on by sulphuric acid. Distillation converted it into a residue of carbon, light oils and gas. These light oils when treated with iodohydric acid yielded compounds of the olefine series.

Later, Cabot† discovered that paraffines subjected to the action of sulphur at temperatures above their boiling points were converted into hydrogen sulphide and carbon. At about the same time Jenney,‡ aspirated air continuously for forty or more hours, through refined illuminating and lubricating oils, in presence of litharge and at a temperature of 100° C.–140° C. By this means he converted a portion of the oil into a solid oxidized residue, a portion distilled into the receiver, and a portion remained in the retort. These residues were either brilliant black solids or brownish flocculent precipitates, which were all soluble in carbon disulphide.

Lastly, I have lately found that a heavy fraction of a distillate, that was a transparent mobile fluid, obtained by distilling California petroleum at nearly a red heat, when left to stand in an open Becker glass for from 12–14 months, had become so charged with asphaltene, that the addition of petroleum naphtha or any of the liquids in which asphaltene is insoluble, at once produced a brown flocculent precipitate. This observation completely contradicts the conclusion reached by Le Bel and Muntz, and stated above, that natural oils containing asphaltene could not have been distilled or subjected to high temperatures.

*Bulletin de la Société Chemique de Paris, xvii, 156.

† American Chemist, vii, 20; Chemical News, xxxvi, 114; Wagner's Berichte, 1876, p. 1110.

‡ American Chemist, v, 309; Wagner's Berichte, 1875, p. 1060.

These researches show that the soluble and fluid portions of bitumens are converted into insoluble and solid forms, that may or may not contain oxygen, either by prolonged action of air and other oxidizing agents at ordinary temperatures, or at higher temperatures. They also show that the same effects are produced without the action of reagents by prolonged heating alone and the familiar process in technology known as "cracking," is a further illustration of the tendency of bitumens under the influence of heat alone, to break up into one series of compounds richer than the original in hydrogen and another compound or series of compounds richer than the original in carbon.

Now within a few years and since all of this work was completed, the laying of asphalt pavements has become an industry involving the expenditure of vast sums of money and consequently presenting technical problems of vast importance. The technology proceeds about as follows: A quantity of asphaltum is brought to New York from Trinidad. This asphaltum consists of water, 27 per cent; inorganic matter, consisting of fine aluminous sand, 27 per cent; organic matter insoluble in carbon di-sulphide, 8 per cent; bitumen 38 per cent. This crude asphaltum is put into large open kettles and melted, the temperature being raised and maintained for some time in the neighborhood of 400° F. By this treatment the water and lighter oils are expelled, and a portion of the mineral matter sinking out of the melted mass to the bottom of the kettles, a "refined pitch" is left, which is drawn off. This "refined pitch," consists in round numbers, of 56 per cent of bitumen, 36 per cent of mineral matter and 3 per cent of organic matter not bitumen. Of the 56 per cent of bitumen, 36 per cent is soluble in petroleum naphtha, leaving 20 per cent that may be obtained from solution in carbon di-sulphide in brilliant black scales. Properly interpreted the refined pitch consists of:

Petrolene		36 per cent.
Asphaltene	20 per cent.	
Organic matter not bitumen	8 "	
Mineral matter	36 "	
	64 "	36 "

64 per cent of material without cohesion; that is, dry solids for the most part, are held together by 36 per cent of a viscous adhesive tar. The 20 per cent of the asphaltene dissolves in the petrolene, the remaining 44 per cent being simply mineral and organic matter held together by the combined bitumens.

The next step in the process is the addition to the refined pitch of about 15 per cent of its weight of some heavy petroleum residuum, which renders the bitumen softer, and at the same time may or may not dissolve both petrolene and asphaltene. The mixture is made complete by blowing air through the melted mass for hours or even days. Sand is then added to the bituminous cement until the bitumen is only equal to 10 per cent of the mass. To incorporate the sand with the viscous mass, both are heated very hot and the sand and bitumen thoroughly mixed, when the mastic thus produced is put in its place and rolled.

Very great diversity is observed in the durability of the mastic thus prepared and laid, and to account for these diversities Mr. Clifford Richardson* would have us believe that it depends on the excavation on the Island of Trinidad from which the crude asphalt was taken. So too the Hon. Commissioner of Public Works of the City of New York, by the advice of Stevenson Towle,† Consulting Engineer, has reached a similar conclusion. Speaking of the Eighth Ave. pavement, a part of which "showed indications of disintegration" before it was accepted Mr. Towle says, "the asphalt used in this work was submitted by the contractor and analyzed and approved by chemical experts;" and yet, farther on in this same report it is stated that the asphalt was condemned because it was taken from one excavation on the island rather than another.

It is a very significant fact that an asphalt pavement should show signs of disintegration within a few weeks of the time of its having been laid. Especially is this the case when it is considered that some of the most enduring constructions of antiquity, which have withstood the ravages of time for at least 3000 years, are constructions of asphalt. Modern constructions of asphalt in Europe are said to remain intact for more than twenty years. The asphalt pavement laid upon Franklin Avenue in the City of Buffalo, has stood, with almost no expense for repairs, for fifteen years and I do not believe any one now knows from what exact spot the asphalt came. It is a very well known fact however that the material used to soften the asphalt was one that would dissolve both constituents of the bitumen, and form a chemical union or solution rather than a mechanical mixture with them. No one knows how old the asphaltic sandstones are that contain 10 per cent of bitumen, but they do not disintegrate; they are solid, impervious and tough.

* Report of the operations of the Engineer Department of the District of Columbia for the fiscal year ending June 30, 1892, pp. 96–123.

† Report of the Department of Public Works of the City of New York on Street Pavements, with special reference to Asphalt Pavements. Thomas F. Gilroy, Commissioner. 1892. pp. 9, and 11 et seq.

If sand could be cemented together with carbon, it would only be necessary to grind up anthracite slack and mix it with sand in order to produce a paving material. It is evident that the hydrogen combined with the carbon gives it adhesive properties, and this within certain limits, for the moment a sufficient amount of hydrogen is removed to convert the petrolene into asphaltene, or whenever the softening material is a petroleum or residuum that will not dissolve asphaltene, the elements of disintegration are present.

The observation made by Boussingault more than half a century ago, and quoted above, that prolonged heating at high temperatures, converts petrolene into asphaltene, which has no more adhesive properties than anthracite slack, appears to have been overlooked by Messrs. Richardson and Towle, for they do not appear to regard the manner of refining and blowing the asphaltic cement as of any importance. Neither for the same reason do they appear to appreciate the bearing of my own researches or those of Messrs. Cabot and Jenney upon this question, although they have been on record now more than twenty years. While it has been well known for years that bitumens occur in great variety, the selection of a proper material for softening the asphalt to the exclusion of others less desirable or wholly unfit, appears also to have escaped attention. A properly selected material for such a purpose would by entering into solution and chemical union with both the constituent parts of the bitumen of the asphalt, thereby increase its adhesive and binding properties upon the other constituents of the mastic. Added to all these omitted elements of the problem just enumerated, we have another of great importance, and that is the total proportion of bitumen to the total proportion of sand and other non-bituminous ingredients of the mastic. Experience proves that less than 10 per cent–11 per cent to 90 per cent–89 per cent gives too little stability to the mass, while a larger percentage of bitumen makes the pavement too soft.

One more element of a good asphaltic pavement is mechanical rather than chemical, and that is solidity. The pavement must be rolled as solid as asphaltic rock in order to keep out rain water and the action of the oxygen dissolved in it; for the effect of oxidation is to gradually convert the petrolene of the asphalt into ashpaltene, leaving the small amount of softening material as the only binding constituent of the mixture. When this softening material is not a solvent for asphaltene the pavement inevitably disintegrates.

I would therefore commend to the consideration of those who act as advisers to Commissioners of Public Works, not a less careful examination of the asphalt used, from whatsoever source it may be obtained; but in addition an equally careful exercise of judgment regarding the softening material used, the chemical effects of refining and blowing, with careless management of either, and the composition and mechanical structure of the surface pavement.

It is far from complimentary to this age of scientific achievement that the ancient world should have furnished constructions of asphalt that have survived to the present, centuries after their builders are forgotten, while with all our superfluities of refining and blowing, with penetrating machines and chemical analysis, of which they knew nothing, we are only able to prepare constructions that endure but a few months or even years, at longest.

I am aware that this paper is inconclusive, but from the nature and present status of the problem it must be so. I think, however, it is, as it was intended to be, suggestive.

University of Michigan, Ann Arbor, Mich., Aug. 16, 1893.

Art. III.—*The age of the extra-moraine fringe in Eastern Pennsylvania;* by Edward H. Williams, Jr.

At the Madison meeting of the Geological Society, the writer called attention to the existence of this deposit, and claimed that it was a true "fringe" and of recent origin. Subsequent study has afforded the material for this paper, which will attempt to prove that, as far as Eastern Pennsylvania is concerned, the extra-moraine fringe is of extremely recent origin and, as it antedates the formation of the great moraine, all glacial deposits in this region are of extreme recency.

A section of the formation near Bethlehem will be taken as typical of the average for the region at the same level. It shows a surface clay, unstratified and carrying rolled stones from the Blue Ridge and beyond (Oneida, Medina, Oriskany, Helderberg, Marcellus, Hamilton, etc.), and covering a till that varies widely in its nature; but is mainly of local stuff of angular shape mixed with a greater or less proportion of rolled material similar to that in the clay and, locally, with angular masses of the same. This latter rests uniformly on glaciated rock in place. This section may vary by the omission of the till, or by the introduction of local stratified deposits of sand and clay. In every instance noted, and in thousands of instances, the pre-glacial surface soil has been removed, and the subsequent deposit rests unconformably on the eroded country rock. As the ice-extension that produced the erosion antedated the formation of the great moraine, so also the upper clay is of the same age or younger than that formation. We have, therefore, a section that gives the extreme limits of the ice age in this region. In studying the till we notice—

First. The admixture of fresh and oxidized material at all levels, and the uniformity of oxidation at any point along a vertical section. The oxidized portion consists of angular masses of all sizes; or of angular fragments composing a ground moraine, and of fragments weathered to a spheroidal shape. The fresh portions are sub-angular and glaciated masses; or rolled bowlders, cobbles, pebbles and gravel. The latter are not found at a uniform level in the deposits; nor do they occur in a uniform proportion, as sections miles in length have contained but half a dozen of these foreigners and immediately adjacent to, and continuous with, this formation the foreigners would form an appreciable proportion of the whole deposit. This curious and persistent admixture proves that oxidation preceded glaciation and, while it may be taken as an evidence of the presence of part of the formation at or near the surface, it can in no sense be used as a criterion of the lapse of time since it was moved to its present position and mixed with the fresh and unoxidized part. This lapse, on the contrary, is to be estimated by the state of the fresh portion of the admixture.

Second. The following rule is universal. On going in the track of the glacier southward across the outcrops of slate, limestone and sandstone that make the floor of the great valley, we meet the ground moraine composed mainly of comparatively fresh fragments that, as in the case of the slate, pass gradually into the crushed and bent parts of the outcrop and rest on the solid rock. As we go to the south the slaty fragments become more decomposed and, as we pass from slate to limestone, they are rotted to a clay that retains, however, the cleavages of the small fragments. In the same way the till on the northern part of the limestone belt gradually loses its limestone fragments and retains only the chert at the south. The moraines south of the South Mountain have their southern border formed of weathered gneiss, while the Blue Ridge fresh rocks increase in proportion toward the northern border. This shows that the pre-glacial surface was scraped off by the glacier and exists along the southern part of the formation, where it is mixed with fresher local and foreign material.

Third. The surface outcrops, and those capped with clay, of gneiss, sandstone, slate and limestone are almost universally fresh and undecomposed. In the majority of cases there has been no change of color from oxidation. No matter what the dip and strike may be, they come sharply to the surface and the cap is usually unconformable, except where a steep slope has produced a local creep. For examples see Preliminary Reports, 2d Geol. Surv. Penna., DD, Plate I; D3, vol. i, Plates II and III. These show that the till and clay did not oxidize after deposition; but that the already oxidized deposit was laid upon a freshly glaciated surface. It also shows that the date of glaciation is so recent that the gneiss, limestone and slate have had no time to decompose or oxidize. In other words, the glaciation has been quite recent. There are thousands of such outcrops, and they exist at all elevations between 220–650 A. T., and under caps that vary from loose gravels to compact clays.

Fourth. There seems to have been but a short interglacial period—if any existed at all—as the surface clay in many cases shades gradually into the till; or lies in a highly oxidized state upon a glaciated surface of absolutely fresh country rock.

Fifth. There has been an unbroken continuity in the till from the crest of the Blue Ridge, west of the Lehigh Gap, to the South Mountain. It has been followed down to and under the flood plain deposits of the present river systems of the region. It has been a favorite amusement with some to argue about the length of the interglacial period from the standpoint of the time necessary for the Lehigh to erode a channel from a so-called bed over Bethlehem hill, at 340 A. T. to its present level at 220 A. T. It might have saved a great deal of bother if it had been ascertained that the Lehigh was flowing on a rock bottom. It has been ascertained that a deep gorge runs along the north side of the South Mountain (whether continuous or not is not yet determined) of extremely narrow section and with a bottom of fresh limestone at depths varying from sixty to over one hundred feet below the present surface, and this has been traced from Easton to within seven miles of Reading, or from the Delaware to the Schuylkill. The limestone on the north side drops almost vertically down to the maximum depth, and the south side rises at a sharp angle. The section of the deposits filling this depression *is identical in succession with those of the rest of the valley.* In other words we have a depression that is glacial or pre-glacial, and is filled with the same succession of sands, clays, till, etc., that cover the rest of the valley; but the individual members of the deposit (excepting the top one) are from five to seven times as thick. The post-glacial erosion of the Lehigh and tributaries is a myth.

There is but one conclusion to be derived from the above. Granting that all the glacial formations (infra- and extra-moraine) represent the whole work of the ice age in North

America, and that we have them all in Eastern Pennsylvania, we can conclude that the total time from beginning to end was small, and of so recent a date that the streams—though resting on beds of clays—have not not reached in all cases their pre-glacial bottoms, and the exposed rocks—in spite of greater or less exposure to the atmospheric agencies—have not had time to acquire signs of decomposition or even oxidation. In fine, we seem to have had but one ice age, and that a short and recent one.

Art. IV.—*Notes on the Cambrian Rocks of Pennsylvania, from the Susquehanna to the Delaware;* by Charles D. Walcott.

In a former paper a report was made of an examination of the lower Paleozoic rocks,* from the Susquehanna to the Potomac, and now attention is called to some observations, made during the past field season, relating to the basal quartzites and limestones of the lower Paleozoic rocks that extend across Pennsylvania, from the Susquehanna river to the Delaware river and across New Jersey to Orange county, New York, on the north, and into Chester county, Pennsylvania, on the east.

In the paper mentioned it is stated that *Hyolithes communis* and fragments of Olenellus were recognized in the material collected from limestones in Lancaster county, on the east side of the Susquehanna river,† and that, from the closely related stratigraphic arrangement of the rocks of Lancaster county, it is probable that all the Lancaster limestones will fall within the Cambrian, unless it be that some portion of the upper series may pass into the Ordovician. This generalization will also apply to the limestone in the adjoining counties of Berks and Chester, and, in fact, to the entire extension of this series northeastward, to the Delaware. All of the quartzites that have been referred to the Potsdam will necessarily fall into the lower Cambrian, as they are beneath the limestones.‡

Prof. A. Wanner, of York, Pa., accompanied me in the examination of the limestones about the city of Lancaster. His familiarity with the positions of the quarries and natural outcrops enabled us to make a rapid examination of the limestones along Conestoga creek, and, although no fossils were found, I saw no reason to think that the limestones were not of Cam-

* Notes on the Cambrian rocks of Pennsylvania and Maryland, from the Susquehanna to the Potomac, this Journal, vol. xliv, 1892, p. 469.

† Loc. cit, p. 474.

‡ Loc. cit, p. 475.

brian age. We next proceeded to the eastern side of the county, where the southern division of the limestone passes into Chester county. An examination was made of the lower quartzites and the superjacent limestones at Gap, Limeville and towards Compassville. A few Scolithus borings were noted in the quartzites northeast of Gap, and fragments of Olenellus and specimens of Obolella were found in sandy layers embedded in a shale one mile N.NE. of Gap. The section from the top downward, from a point a little east of Gap northwest, is:—

5. Massive-bedded, light-colored limestone with partings and small, interbedded, flattened nodules of mica schist.
4. Narrow belt of hydromica schist, with thin layers of hard calcareous sandstone containing Obolella and fragments of Olenellus.
3. Massive beds of bluish-black and nearly white limestone, extensively quarried at Limeville.
2. Narrow belt of shale altered to a hydro-mica schist.
1. Quartzite, in the hill northeast of Gap.

We next visited the extensive quarries at Bellemont, on the main line of the Pennsylvania railroad, four miles west of Gap. In the quarries the conglomerate limestone, so characteristic of the Cambrian at Stoner's station in York county, are beautifully exposed, and numerous photographs were taken of the conglomerate beds, showing their positions between the evenly-bedded limestones. The limestones and conglomerates belong to (3) of the Gap section, and are overlain by a belt of shale in which massive beds of a fine, limestone conglomerate occur. No time was given to searching for fossils.

The discovery of the Olenellus fauna in the limestone in the eastern portion of Lancaster county, north of Gap, taken in connection with the eastern section in York county, compels the reference of the so-called Potsdam rocks of Chester county with their superjacent limestones to the Cambrian. As mentioned in the previous paper, it is quite probable that the limestones towards the Triassic area, in the northern portion of Lancaster county, may be of Ordovician age, but this can only be proven by the discovery of the fauna.

Northern belt of Limestone.—As shown by the geological map of Pennsylvania (1884), the northern belt of limestone enters the State in Franklin county and then turns to the northeast in Cumberland county, crosses the Susquehanna at Harrisburg and extends on eastward across Dauphin, Lebanon, Berks, Lehigh and Northampton counties, to the Delaware river. The Olenellus fauna was found in the quartzites of South mountain in Adams county, as well as in the lower portions of the limestone in Franklin county.* From this and the fact that the lower portions of these limestones and the superjacent quartzites or sandstones were known to be of lower Cambrian age in their extension into New Jersey, I began the examination of them in the vicinity of Reading, where their relations to the Reading sandstone are well defined. The *Scolithus linearis* occurs abundantly in the quartzites of Penn mountain, east of Reading, and on the south side of Neversink mountain across the Schuylkill. In the upper layers of the sandstone or quartzite I obtained *Hyolithellus micans* and fragments of a species of Olenellus. This locality is about one-half mile above Klappenthal station, on the Philadelphia & Reading railroad, and the terminal station of the electric road running out of Reading over the Neversink mountain. West of the first railroad cut above the station thinner beds of quartzite are met with, between the cut and the stone-crusher that carry fossils. The quartzites are more or less contorted and folded, but their stratigraphic relations to the main quartzites of the mountain and to the adjoining limestones are readily determined. No fossils were observed in the limestones.

The sections in the vicinity of Allentown and Bethlehem were examined and found to be essentially the same as at Reading, the quartzites passing beneath the limestone. In the quarries at Catasauqua, four miles north of Allentown, I noted the occurrence of a large Pleurotomaria, of the type of *Pleurotomaria canadensis*, of the Calciferous horizon in New York and Canada. In the report of the Second Pennsylvania Geological Survey of Lehigh and Northampton counties the localities of fossils are all on the northern side of the outcrop of limestone, in the strata that dip to the northward beneath the superjacent shales. The Trenton horizon is represented in the limestone immediately beneath the shales (called "Hudson"), and lower down, in massive limestone, species of Maclurea or Euomphalus have been found that indicate the Chazy horizon. This distribution of faunas is the same as in Franklin county, where the lower Cambrian fauna occurs at the base of the limestone near the quartzites, and the Trenton fauna at the summit, near the base of the superjacent shales.

The limestones were examined in the vicinity of Easton, along Bushkill creek and the shores of the Delaware river. No fossils were found with the exception of a species of Cryptozoan: but from the similarity of the limestone to that of the lower portion of the series near Allentown, Reading and in Lancaster country, it is quite probable that they represent the lower or Cambrian portion of the section. Five or six miles north of Easton, in the vicinity of Churchville, fossils were

* Loc. cit., p. 478.

discovered by the Pennsylvania survey that indicate the Trenton horizon. I think it is only a matter of detailed search and patience to discover localities of fossils, both in quartzites and limestones throughout this belt, from where it enters the state from Maryland and crosses the Delaware into New Jersey.

If we follow on the line of the strike of the limestones across the Delaware into New Jersey, the same type of section is found to extend northeasterly across the state and into Orange county, N. Y. At Hardistonville, Sussex county, New Jersey, Dr. Beecher discovered the Olenellus fauna in the blue limestones resting on the basal quartzite.* The fossils are found on the southeastern side of the limestone belt; and on the northwestern side the limestones dip beneath the shales as in the Pennsylvania section. In the geological report of New Jersey for 1868, pp. 131, 132, numerous localities of the fossiliferous Trenton limestone are described, and a section given showing the limestone passing beneath the shales to the westward.

The discovery of the Olenellus or lower Cambrian fauna in the Reading sandstone practically completes the correlation of the South mountain, Chickis and Reading quartzites of Pennsylvania and establishes the correctness of the early correlations of McClure, Eaton, Emmons, and Rogers. They all considered the basal quartzite as the same formation from Vermont to Tennessee; and the discoveries of recent years have proven that the basal sandstone of Alabama, Tennessee, and Virginia (Chilhowee quartzite); Maryland, Pennsylvania and New Jersey (the Reading quartzite); New York and Vermont (Bennington quartzite); were all deposited in lower Cambrian time, and that they contain the characteristic Olenellus fauna throughout their geographic distribution. The superjacent limestones carry the Olenellus fauna in their lower portions, in northern and southern Vermont, eastern New York, New Jersey and Pennsylvania. To the south of Pennsylvania the lower portions of the limestones appear to be represented by shales, and the upper and middle Cambrian faunas are found in the lower half of the Knox dolomite series of Tennessee, and they will probably be discovered in the same series in Virginia and Maryland, when a thorough search is made for them. The same may be predicted, but with less assurance, for the Northern belt of limestone crossing Pennsylvania and into New Jersey, as the limestones between the Olenellus zone and the Trenton zone represent the intervals of the middle and upper Cambrian and the lower Ordovician, or the Calciferous and Chazy zones, of the New York section. The working out of

*Geol. Surv. New Jersey; Ann. Rep. State Geologist, 1890, pp. 31, 43, 49.

the details of this section in southeastern Pennsylvania is an interesting problem, left for solution to some geologist who has the necessary paleontologic training and who will not be discouraged by the prospect of a good deal of hard work before the desired result can be obtained.

The problem of where to draw the line in this series of limestones, on a geological map, between the Cambrian and Ordovician, is one that will seriously embarrass the geologist, but I anticipate that either lithologic or paleontologic characters will be discovered by which the two groups can be differentiated. If not, the limestones must be colored as one lithologic unit or formation and the approximate line of demarkation between the Cambrian and Ordovician indicated in the columnar section accompanying the legend of the map.

Art. V. — *The Internal Work of the Wind;** by S. P. Langley. (With Plates I–V).

Part I.—*Introductory.*

It has long been observed that certain species of birds maintain themselves indefinitely in the air by "soaring," without any flapping of the wing, or any motion other than a slight rocking of the body; and this, although the body in question is many hundred times denser than the air in which it seems to float with an undulating movement, as on the waves of an invisible stream.

No satisfactory mechanical explanation of this anomaly has been given, and none would be offered in this connection by the writer, were he not satisfied that it involves much more than an ornithological problem, and that it points to novel conclusions of mechanical and utilitarian importance. They are paradoxical at first sight, since they imply that under certain specified conditions, very heavy bodies entirely detached from the earth, immersed in, and free to move in, the air, can be sustained there indefinitely, without any expenditure of energy from within.

These bodies may be entirely of mechanical construction, as will be seen later, but for the present we will continue to consider the character of the invisible support of the soaring bird, and to study its motions, though only as a pregnant

* A paper read (by title only) to the National Academy of Sciences, in April, 1893. and subsequently (in full) at the Aeronautical Congress, at Chicago, in August, 1893.

instance offered by nature to show that a rational solution of the mechanical problem is possible.

Recurring, then, to the illustration just referred to, we may observe that the flow of an ordinary river would afford no explanation of the fact that nearly inert creatures, while free to move, although greatly denser than the fluid, yet float upon it; which is what we actually behold in the ærial stream, since the writer, like others, has satisfied himself by repeated observation, that the soaring vultures and other birds, appear as if sustained by some invisible support, in the stream of air, sometimes for at least a considerable fraction of an hour. It is frequently suggested by those who know these facts only from books, that there must be some quivering of the wings, so rapid as to escape observation. Those who do know them from observation, are aware that it is absolutely certain that nothing of the kind takes place, and that the birds sustain themselves on pinions which are quite rigid and motionless, except for a rocking or balancing movement involving little energy.

The writer desires to acknowledge his indebtedness to that most conscientious observer, M. Mouillard,* who has described these actions of the soaring-birds with incomparable vividness and minuteness, and who asserts that they under certain circumstances, without flapping their wings, rise and actually advance against the wind.

To the writer, who has himself been attracted from his earliest years to the mystery which has surrounded this action of the soaring bird, it has been a subject of continual surprise that it has attracted so little attention from physicists. That nearly inert bodies, weighing from 5 to 10, and even more, pounds, and many hundred times denser than the air, should be visibly suspended in it above our heads, sometimes for hours at a time, and without falling,—this, it might seem, is, without misuse of language, to be called a physical miracle; and yet the fact that those whose province it is to investigate nature, have hitherto seldom thought it deserving attention, is perhaps the greater wonder.

This indifference may be in some measure explained by the fact that the largest and best soarers are of the vulture kind, and that their most striking evolutions are not to be seen in those regions of the Northern Temperate Zone where the majority of those whose training fits them to study the subject, are found. Even in Washington, however, where the writer at present resides, scores of great birds may be seen at times in the air together, gliding with and against the wind, and ascending higher at pleasure, on nearly motionless wings. "Those who have not seen it," says M. Mouillard, "when they

* L. P. Mouillard, "L'Empire de l'Air," Paris. G. Masson.

are told of this ascension without the expenditure of energy, are always ready to say, 'but there must have been movements, though you did not see them;'" "and in fact," he adds, "the casual witness of a single instance, himself, on reflection, feels almost a doubt as to the evidence of his senses, when they testify to things so extraordinary."

Quite agreeing with this, the writer will not attempt any general description of his own observations, but as an illustration of what can sometimes be seen, will give a single one, to whose exactness he can personally witness. The common "Turkey Buzzard" (*Cathartes aura*), is so plenty around the environs of Washington that there is rarely a time when some of them may not be seen in the sky, gliding in curves over some attractive point, or, more rarely, moving in nearly straight lines on rigid wings, if there be a moderate wind. On the only occasion when the motion of one near at hand could be studied in a very high wind, the author was crossing the long "Aqueduct Bridge" over the Potomac, in an unusually violent November gale, the velocity of the wind being probably over 35 miles an hour. About one-third of the distance from the right bank of the river, and immediately over the right parapet of the bridge, at a height of not over 20 yards, was one of these buzzards, which, for some object which was not evident, chose to keep over this spot, where the gale, undisturbed by any surface irregularities, swept directly up the river with unchecked violence. In this ærial torrent, and apparently indifferent to it, the bird hung, gliding in the usual manner of its species, round and round, in a small oval curve, whose major axis (which seemed toward the wind), was not longer than twice its height from the water. The bird was therefore at all times in close view. It swung around repeatedly, rising and falling slightly in its course, while keeping, as a whole, on one level, and over the same place, moving with a slight swaying, both in front and lateral direction, but in such an effortless way as suggested a lazy yielding of itself to the rocking of some invisible wave.

It may be asserted that there was not only no flap of the wing, but not the quiver of a wing feather visible to the closest scrutiny, during the considerable time the bird was under observation, and during which the gale continued. A record of this time was not kept, but it at any rate lasted until the writer, chilled by the cold blast, gave up watching and moved away, leaving the bird still floating about, at the same height in the torrent of air, in nearly the same circle, and with the same aspect of indolent repose.

If the wind is such a body as it is commonly supposed to be, it is absolutely impossible that this sustention could have taken place in a horizontal current any more than in a calm, and yet that the ability to soar is, in some way, connected with the presence of the wind, became to the writer, as certain as any fact of observation could be, and at first the difficulty of reconciling such facts (to him undoubted) with accepted laws of motion, seemed quite insuperable.

Light came to him through one of those accidents which are commonly found to occur when the mind is intent on a particular subject, and looking everywhere for a clue to its solution.

In 1887, while engaged with the "whirling-table" in the open air at the Allegheny Observatory, he had chosen a quiet afternoon for certain experiments, but in the absence of the entire calm which is almost never realized, had placed one of the very small and light anemometers made for hospital use, in the open air, with the object of determining and allowing for the velocity of what feeble breeze existed. His attention was called to the extreme irregularity of this register, and he assumed at first that the day was more unfavorable than he had supposed. Subsequent observations, however, showed that when the anemometer was sufficiently light and devoid of inertia, the register always showed great irregularity, especially when its movements were noted, not from minute to minute, but from second to second.

His attention once aroused to these anomalies, he was led to reflect upon their extraordinary importance in a possible mechanical application. He then designed certain special apparatus hereafter described, and made observations with it which showed that "wind" in general, was not what it is commonly assumed to be, that is,—air put in motion with an approximately uniform velocity in the same strata; but that considered in the narrowest practicable sections, wind was always not only not approximately uniform, but variable and irregular in its movements beyond anything which had been anticipated, so that it seemed probable that the very smallest part observable, could not be treated as approximately homogeneous, but that even here, there was an internal motion to be considered, distinct both from that of the whole body, and from its immediate surroundings. It seemed to the writer to follow as a necessary consequence, that there might be a potentiality of what may be called "internal work"* in the wind.

* Since the term "internal work" is often used in thermo-dynamics to signify molecular action, it may be well to observe that it here refers not to molecular movements, but to pulsations of sensible magnitude, always existing in the wind, as will be shown later, and whose extent and extraordinary possible mechanical importance it is the object of this research to illustrate. The term is so significant of the author's meaning, that he permits himself the use of it here, in spite of the possible ambiguity.

On further study, it seemed to him that this internal work might conceivably be so utilized as to furnish a power which should not only keep an inert body from falling, but cause it to rise, and that while this power was the probable cause of the action of the soaring bird, it might be possible through its means to cause any suitably disposed body, animate or inanimate, wholly immersed in the wind, and wholly free to move, to advance against the direction of the wind itself. By this it is not meant that the writer then devised means for doing this, but that he then attained the conviction both that such an action involved no contradiction of the laws of motion, and that it was mechanically possible (however difficult it might be to to realize the exact mechanism, by which this might be accomplished).

It will be observed that in what has preceded, it is intimated that the difficulties in the way of regarding this even in the light of a theoretical possibility, may have proceeded, with others as with the writer, not from erroneous reasoning, but from an error, in the premises, entering insidiously in the form of the tacit assumption made by nearly all writers, that the word "wind" means something so simple, so readily intelligible, and so commonly understood, as to require no special definition; while, nevertheless, the observations which are presently to be given, show that it is, on the contrary, to be considered as a generic name for a series of infinitely complex and little known phenomena.

Without determining here whether any mechanism can be actually devised which shall draw from the wind the power to cause a body wholly immersed in it to go against the wind, the reader's consideration is now first invited to the evidence that there is no contradiction to the known laws of motion, and at any rate no theoretical impossibility in the conception of such a mechanism, if it is admitted that the wind is not what it has been ordinarily taken to be, but what the following observations show that it is.

What immediately follows is an account of evidence of the complex nature of the "wind," of its internal movements, of the resulting potentiality of this internal work, and of attempts which the writer has made to determine quantitatively its amount by the use of special apparatus, recording the changes which go on (so to speak) *within* the wind in very brief intervals. These results may, it is hoped, be of interest to meteorologists, but they are given here with special reference to their important bearing on the future of what the writer has ventured to call the science of Aerodromics.*

* From *ἀεροδρομεω*, to traverse the air; *ἀεροδρομος*, an air-runner.

The observations which are first given were made in 1887 at Allegheny and are supplemented by others made at Washington in the present year.*

What has just been said about their possible importance will perhaps seem justified, if it is remarked (in anticipation of what follows later) that the result of the present discussion implies not only the theoretical, but the mechanical possibility, that a heavy body wholly immersed in the air and sustained by it, may without the ordinary use of wind, or sail, or steam, and without the expenditure of any power except such as may be derived from the ordinary winds, make an aerial voyage in any direction, whose length is only limited by the occurrence of a calm. A ship is able to go against a head wind by the force of that wind, owing to the fact that it is partly immersed in the water which reacts on the keel, but it is here asserted, that (contrary to usual opinion and in opposition to what at first may seem the teachings of physical science) it is not impossible that a heavy and nearly inert body, *wholly* immersed in the air can be made to do this.

The observations on which the writer's belief in this mechanical possibility are founded, will now be given.

PART II.—*Experiments with the use of special apparatus.*

In the ordinary uses of the anemometer,—(let us suppose it to be a Robinson's anemometer, for illustration,—the registry is seldom taken as often as once a minute; thus, in the ordinary practice of the United States Weather Bureau, the registration is made at the completion of the passage of each mile of wind. If there be very rapid fluctuations of the wind, it is obviously desirable in order to detect them, to observe the instrument at very brief intervals, *e. g.* at least every second, instead of every minute or every hour, and it is equally obvious that in order to take up and indicate the changes which occur in these brief intervals, the instrument should have as little inertia as possible, its momentum tending to falsify the facts, by rendering the record more uniform than would otherwise be the case.

*It will be noticed that the fact of observation here is not so much the movement of currents, such as the writer has since learned was suggested by Lord Rayleigh so long ago as 1883, still less of the movement of distinct currents at a considerable distance above the earth's surface, but of what must be rather called the effect of the irregularities and pulsations of any ordinary wind, within the immediate field of examination, however narrow.

See the instructive article by Lord Rayleigh in Nature. April 5, 1883. Lord Rayleigh remarks that continued soaring implies "(1) that the course is not horizontal, (2) that the wind is not horizontal, or (3) that the wind is not uniform." "It is probable," he says, "that the truth is usually represented by (1) or (2); but the question I wish to raise is whether the cause suggested by (3) may not sometimes come into operation."

In 1887 I made use of the only apparatus at command,—an ordinary small Robinson's anemometer, having cups 3 inches ($7{\cdot}5^{cm}$) in diameter, the centre of the cups being $6\frac{3}{4}$ inches ($16\frac{3}{4}^{cm}$) from the centre of rotation. This was placed at the top of a mast 53 feet (16·2 metres) in height, which was planted in the grounds of the Allegheny Observatory, on the flat summit of a hill which rises nearly 400 feet (122· metres) above the valley of the Ohio river. It was, accordingly, in a situation exceptionally free from those irregularities of the wind which are introduced by the presence of trees and of houses, or of inequalities of surface.

Every twenty-fifth revolution of the cups was registered by closing an electric circuit, and the registry was made on the chronograph of the Observatory by a suitable electric connection, and these chronograph sheets were measured and the results tabulated. A portion of the record obtained on July 16, 1887, is given on Plate I, the abscissae representing time, and the ordinates wind velocities. The observed points represent the wind's velocities as computed from the intervals between each successive electrical contact, as measured on the chronograph sheets, and for convenience in following the succession of observed points, they are here joined by straight lines, though it is hardly necessary to remark that the change in velocity is in fact, though quite sharp, yet not in general discontinuous, and the straight lines here used for convenience do not imply that the rate of change of velocity is uniform.

The wind velocities during this period of observation ranged from about 10 to 25 miles an hour, and the frequency of measurement was every 7 to 17 seconds. If, on the one hand, owing to the weight and inertia of the anemometer, this is far from doing justice to the actual irregularities of the wind; on the other, it equally shows that the wind was far from being a body of even approximate uniformity of motion, and that even when considered in quite small sections, the motion was found to be irregular almost beyond conception,—certainly beyond anticipation; for this record is not selected to represent an extraordinary breeze, but the normal movement of an ordinary one.

By an application of these facts, to be presented later, I then reached by these experiments, the conclusion that it was theoretically possible to cause a heavy body wholly immersed in the wind to be driven in the opposite direction, *e. g.* to move east while the wind was blowing west, without the use of any power other than that which the wind itself furnished, and this even by the use of plane surfaces, and without taking advantage of the more advantageous properties of curved ones.

This power, I further already believed myself warranted by these experiments in saying, could be obtained by the movements of the air in the horizontal plane alone, even without the utilization of currents having an upward trend. But I was obliged to turn to other occupations, and did not resume these interesting observations until the year 1893.

Although the anemometer used at Allegheny served to illustrate the essential fact of the rapid and continuous fluctuations of even the ordinary and comparatively uniform wind, yet owing to the inertia of the arms and cups, which tended to equalize the rate (the moment of inertia was approximately 40,000 gr cm²) and to the fact that the record was only made at every twenty-fifth revolution, the internal changes in the horizontal component of the wind's motion, thus representing its potential work, were not adequately recorded.

In January, 1893, I resumed these observations at Washington with apparatus with which I sought to remedy these defects, using as a station the roof of the north tower of the Smithsonian Institution building, the top of the parapet being 142 feet (43·3 meters) above the ground, and the anemometers, which were located above the parapet being 153 feet (46·7 meters) above the ground. I placed them in charge of Mr. George E. Curtis, with instructions to take observations under the conditions of light, moderate and high winds. The apparatus used was, first, a Weather Bureau Robinson anemometer of standard size, with aluminum cups. Diameter to center of cups 34^{cm}; diameter of cups $10{\cdot}16^{cm}$; weight of arms and cups 241 grams; approximate moment of inertia 40,710 gr. cm².

A second instrument was a very light anemometer, having paper cups, of standard pattern and diameter, the weight of arms and cups being only 74 grams, and its moment of inertia 8,604 gr. cm².

With this instrument, a number of observations were taken, when it was lost by being blown away in a gale. It was succeeded in its use by one of my own construction, which was considerably lighter. This was also blown away. I afterward employed one of the same size as the standard pattern, weighing 48 grams, having a moment of inertia of 11,940 gr. cm², and finally, I constructed one of one-half the diameter of the standard pattern, employing cones instead of hemispheres, weighing 5 grams, and having a moment of inertia of but 300 gr. cm².

In the especially light instruments, the electric record was made at every half revolution, on an ordinary astronomical chronograph, placed upon the floor of the tower, connected with the anemometer by an electric circuit. Observations were made on Jan. 14, 1893, during a light wind having a velocity of from 9 to 17 miles an hour; on January 25 and 26 during a moderate wind, having a velocity of from 16 to 28 miles an hour; and on February 4 and 7, during a moderate and high wind ranging from 14 to 36 miles an hour. Portions of these observations are given on Plates II, III and IV. A short portion of the record obtained with the standard Weather Bureau anemometer during a high northwest wind is given on Plate V.

A prominent feature presented by these diagrams is that the higher the absolute velocity of the wind, the greater the relative fluctuations which occur in it. In a high wind the air moves in a tumultuous mass, the velocity being at one moment perhaps 40 miles an hour, then diminishing to an almost instantaneous calm, and then resuming.*

The fact that an absolute local calm can momentarily occur during the prevalence of a high wind, was vividly impressed upon me during the observations of February 4, when chancing to look up to the light anemometer, which was revolving so rapidly that the cups were not separately distinguishable, I saw them completely stop for an instant, and then resume their previous high speed of rotation, the whole within the fraction of a second. This confirmed the suspicion that the chronographic record, even of a specially light anemometer, but at most imperfectly notes the sharpness of these internal changes. Since the measured interval between two electric contacts is the datum for computing the velocity, an instantaneous stoppage, such as I accidentally saw, will appear on the record simply as a slowing of the wind, and such very significant facts as that just noted, will be necessarily slurred over, even by the most sensitive apparatus of this kind.

However, the more frequent the contacts, the more nearly an exact record of the fluctuations may be measured, and I have, as I have stated, provided that they should be made at every half revolution of the anemometer, that is, as a rule, several times a second.†

* An example of a very rapid change may be seen on Plate IV, at 12.23 P. M.

† Here we may note the error of the common assumption that the ordinary anemometer, however heavy, will, if frictionless, correctly measure the velocity of the wind, for the existence of "vis inertiæ" it is now seen, is not indifferent, but plays a most important part where the velocity suffers such great and frequent changes as we here see it does, and where the rate at which this inertia is overcome, and this velocity changed, is plainly a function of the density of the fluid, which density we also see reason to suppose itself varies incessantly, and with great rapidity. Though it is probable that no form of barometer in use does justice to the degree of change of this density, owing to this rapidity, we cannot nevertheless, suppose it to exceed certain limits, and we may treat the present records, made with an anemometer of such exceptional lightness, as being comparatively unaffected by these changes in density, though they exist.

I now invite the reader's attention to the actual records of rapid changes that take place in the wind's velocity, selecting as an illustration, the first $5\frac{1}{2}$ minutes of the diagram plotted on Plate III.

The heavy line through points A, B, and C, represents the ordinary record of the wind's velocity as obtained from a standard Weather Bureau anemometer during the observations recording the passage of two miles of wind. The velocity, which was at the beginning of the interval considered, nearly 23 miles an hour, fell during the course of the first mile to a little over 20 miles an hour. This is the ordinary anemometric record of the wind at such elevations as this (47 meters) above the earth's surface, where it is free from the immediate vicinity of disturbing irregularities, and where it is popularly supposed to move with occasional variation in direction, as the weather-cock indeed indicates, but with such nearly uniform movement that its rate of advance is, during any such brief time as two or three minutes, under ordinary circumstances, approximately uniform. This then may be called the "wind," that is, the conventional "wind" of treatises upon aerodynamics, where its aspect as a practically continuous flow, is alone considered. When, however, we turn to the record made with the specially light anemometer, at every second, of this same wind, we find an entirely different state of things. The wind, starting with the velocity of 23 miles an hour, at $12^{hrs}\ 10^{mins}\ 18^{secs}$ rose within 10 seconds to a velocity of 33 miles an hour, and within 10 seconds more fell to its initial speed. It then arose within 30 seconds to a velocity of 36 miles an hour, and so on, with alternate risings and fallings, at one time actually stopping; and, as the reader may easily observe, passing through 18 notable maxima and as many notable minima, the average interval from a maximum to a minimum being a little over 10 seconds, and the average change of velocity in this time being about 10 miles an hour. In the lower left hand corner of Plate III, is given a conventional representation of these fluctuations in which this average period and amplitude is used as a type. The above are facts, the counterpart of which may be noted by any one adopting the means the writer has employed. It is hardly necessary to observe, that almost innumerable minor maxima and minima presented themselves, which the drawing cannot depict.

In order to insure clearness of perception, the reader will bear in mind the diagram does not represent the velocities which obtained coincidently, along the length of two miles of wind represented, nor the changes in velocity experienced by a single moving particle during the interval, but that it is a picture of the velocities which were in this wind at the successive instants of its passing the fixed anemometer, which velocities, indeed, were probably nearly the same for a few seconds before and after registry, but which incessantly passed into—and were replaced by—others, in a continuous flow of change. But although the observations do not show the actual changes of velocity which any given particle experiences in any assigned interval, these fluctuations cannot be materially different in character from those which are observed at a fixed point, and are shown in the diagram. It may perhaps still further aid us in fixing our ideas, to consider two material particles as starting at the same time over this two mile course; the one moving with the uniform velocity of 22·6 miles an hour (33 feet per second), which is the average velocity of the wind as observed for the interval between 12^{hrs} 10^{mins} 18^{secs}—and 12^{hrs} 15^{mins} 45^{secs} on February 4; the other, during the same interval, having the continuously changing velocities actually indicated by the light anemometer as shown on Plate III. Their positions at any time may, if desired, be conveniently represented in a diagram where the abscissa of any point represents the elapsed time in seconds, and the ordinates show the distance in feet, of the material particle from the starting point. The path of the first particle will thus be represented by a straight line, while the path of the second particle will be an irregularly curved line, at one time above, and at another time below the mean straight line just described, but terminating in coincidence with it at the end of the interval. If, now, all the particles in two miles of wind were simultaneously accelerated and retarded in the same way as this second particle, that is, if the wind were an inelastic fluid, and moved like a solid cylinder, the velocities recorded by the anemometer would be identical with those that obtained along the whole region specified. But the actual circumstance must evidently be far different from this, since the air is an elastic, and nearly perfect fluid, subject to condensation and rarefaction. Hence the successive velocities of any given particle (which are in reality the resultant of incessant changes in all directions), must be conceived as evanescent, taking on something like the sequence recorded by these curves, a very brief time before this air reached the anemometer, and losing it as soon after.

It has not been my purpose in this paper to enter upon any inquiry as to the cause of this non-homogeneity of the wind. The irregularities of the surface topography (including buildings, and every other surface obstruction) are commonly adduced as a sufficient explanation of the chief irregularities of the surface wind; yet I believe that at a considerable distance above the earth's surface (e. g. one mile), the wind may not even be approximately homogeneous, nor have an even flow; for, while if we consider air as an absolutely elastic and frictionless fluid, any motion impressed upon it would be preserved forever, and the actual irregularities of the wind would be the results of changes made at any past time, however remote; so long as we admit that the wind without being absolutely elastic and frictionless, is nearly so, it seems to me that we may consider that the incessant alternations which it here appears make the "wind," are due to past impluses and changes which are preserved in it, and which die away with very considerable slowness. If this be the case, it is less difficult to see how even in the upper air, and at every altitude, we might expect to find local variations, or pulsations, not unlike those which we certainly observe at minor altitudes above the ground.*

Part III.—*Application.*

Of these irregular movements of the wind, which take place up, down, and on every side, and are accompanied of necessity by equally complex condensations and expansions, it will be observed that only a small portion, namely, those which occur in a narrow current whose direction is horizontal and sensibly linear, and whose width is only the diameter of the anemometer, can be noted by the instruments I have here described, and whose records alone are represented in the diagram. However complex the movement may appear as shown by the diagram, it is then far less so than the reality, and it is probable indeed, that anything like a fairly complete graphical presentation of the case is impossible.

I think that on considering these striking curves (Plates I, II, III, IV and V) we shall not find it difficult to admit, at least as an abstract conception, that there is no necessary violation of the principle of the conservation of energy, implied in the admission that a body wholly immersed in and moving with such a wind, may derive from it a force which may be utilized in *lifting* the body, in a way in which a body immersed in the "wind" of our ordinary conception could not be lifted, and if we admit that the body may be lifted, it follows obviously that it may descend under the action of gravity from the elevated position, on a sloping path, to some distance in a direction opposed to that of the wind which lifted it, though it is not obvious what this distance is.

We may admit all this, because we now see (I repeat) that the apparent violation of law arises from a tacit assumption which we in common with all others, may have made, that the

* In this connection, reference may be made to the notable investigations of Helmholtz, on Atmospheric Movements, *Sitzungsberichte*, Berlin, 1888–1889.

wind is an approximately homogeneously moving body, because moving as a whole in one direction. It is, on the contrary, *always*, as we see here, filled (even if we consider only movments in some one horizontal plane), with amazingly complex motions, some of which if not in direct opposition to the main movement, are relatively so, that is, are slower, while others are faster than this main movement, so that a portion is always opposed to it.

From this, then, we may now at least see that it is plainly within the capacity of an intelligence like that suggested by Maxwell, and which Lord Kelvin has called the "Sorting Demon," to pick out from the internal motions, those whose direction is opposed to the main current, and to omit those which are not so, and thus *without the expenditure of energy* to construct a force which will act against the main current itself.

But we may go materially further, and not only admit that it is not necessary to invoke here, as Maxwell has done in the case of thermo-dynamics, a being having power and rapidity of action far above ours, but that in actual fact, a being of a lower order than ourselves, guided only by instinct, may so utilize these internal motions.

We might not indeed have conceived this possible, were it not that nature has already, to a large extent, exhibited it before our eyes in the soaring bird* which sustains itself endlessly in the air with nearly motionless wings, for without this evidence of the possibility of an action which now ceases to approach the inconceivable, we are not likely, even if admitting its theoretical possibility to have thought the mechanical solution of this problem possible.

* "When the condors in a flock are wheeling round and round any spot, their flight is beautiful. Except when rising from the ground, I do not recollect ever having seen one of these birds flap its wings. Near Lima, I watched several for nearly half an hour without once taking off my eyes. They moved in large curves sweeping in circles, descending and ascending without once flapping. As they glided close over my head, I intently watched, from an oblique position, the outlines of the separate and terminal feathers of the wing; and if there had been the least vibratory movement these would have blended together, but they were seen distinct against the blue sky. The head and neck were moved frequently and apparently with force, and it appeared as if the extended wings formed the fulcrum on which the movements of the neck, body, and tail acted. If the bird wished to descend, the wings for a moment collapsed; and then when again expanded with an altered inclination the momentum gained by the rapid descent, seemed to urge the bird upwards, with the even and steady movement of a paper kite In the case of any bird *soaring*, its motion must be sufficiently rapid so that the action of the inclined surface of its body on the atmosphere may counterbalance its gravity The force to keep up the momentum of a body moving in a horizontal plane in that fluid (in which there is so little friction) cannot be great, and this force is all that is wanted. The movement of the neck and body of the condor, we must suppose is sufficient for this. However this may be, it is truly wonderful and beautiful to see so great a bird, hour after hour, without any apparent exertion, wheeling and gliding over mountain and river."—Darwin's *Journal of the Various Countries Visited by H. M. S. Beagle*, pp. 223–224.

But although to show how this physical miracle of nature is to be imitated, completely and in detail, may be found to transcend any power of analysis, I hope to show that this may be possible without invoking the asserted power of "aspiration" relative to curved surfaces, or the trend of upward currents, and even to indicate the probability that the mechanical solution of this problem may not be beyond human skill.

To this conclusion we are invited by the following consideration, among others.

We will presently examine the means of utilizing this potentiality of internal work in order to cause an inert body wholly unrestricted in its motion and wholly immersed in the current, to *rise;* but first let us consider such a body (a plane) whose movement is restricted to a horizontal direction, but which is free to move between frictionless vertical guides. Let it be inclined upward at a small angle towards a horizontal wind so that only the vertical component of the pressure of the wind on the plane will affect its motion. If the velocity of the wind be sufficient, the vertical component of pressure will equal or exceed the weight of the plane, and in the latter case, the plane will rise indefinitely.

Thus, to take a concrete example, if the plane be a rectangle whose length is six times its width, having an area of 2·3 square feet to the pound, and be inclined at an angle of 7°, and if the wind have a velocity of 36 feet per second, experiment shows that the upward pressure will exceed the weight of the plane, and the plane will rise, if between vertical nearly frictionless guides, at an increasing rate, until it has a velocity of 2·52 feet per second,* at which speed the weight and upward pressure are in equilibrium. Hence there are no unbalanced forces acting, and the plane will have attained a state of uniform motion.

For a wind that blows during 10 seconds, the plane will therefore rise about 25 feet. At the beginning of the motion, the inertia of the plane makes the rate of rise less than the uniform rate, but at the end of 10 seconds, the inertia will cause the plane to ascend a short distance after the wind has ceased, so that the deficit at the beginning will be counterbalanced by the excess at the end of the assigned interval.

We have just been speaking of a material heavy plane permanently sustained in vertical guides, which are essential to its continuous ascent in a uniform wind, but such a plane will be lifted and sustained *momentarily* even if there be no vertical guides, or in the case of a kite, even if there be no cord to retain it, the inertia of the body supplying for a brief period,

* See "Experiments in Aerodynamics," by S. P. Langley, *Smithsonian Contributions to Knowledge*, 1891.

the office of the guides or of the cord. If suitably disposed, it will, as the writer has elsewhere shown, under the resistance to a horizontal wind, imposed only by its inertia, commence to move, not in the direction of the wind, but nearly vertically. Presently however, as we recognize, this inertia must be overcome, and as the inclined plane takes up more and more the motion of the wind, the lifting effect must grow less and less (that is to say, if the wind be the approximately homogeneous current it is commonly treated as being), and finally ceasing altogether, the plane must ultimately fall. If, however a counter-current is supposed to meet this inclined plane, before the effect of its inertia is exhausted, and consequently before it ceases to rise, we have only to suppose the plane to be rotated through 180° about a vertical axis, without any other call for the expenditure of energy, to see that it will now be lifted still higher, owing to the fact that its inertia now reappears as an active factor. The annexed sketch (fig. 1) shows a typical representation of what might be supposed to happen with a model inclined plane freely suspended in the air, and endowed with the power of rotating about a vertical axis so as to change the aspect of its constant inclination, which need involve no (theoretical) expenditure of energy, even although the plane possess inertia. We see that this plate would rise indefinitely by the action of the wind in alternate *directions*.

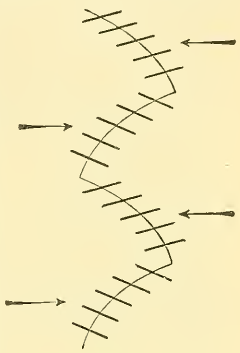

Fig. 1.

The disposition of the wind which is here supposed to cause the plane to rise, appears at first sight an impossible one, but we shall next make the important observation that it becomes virtually possible by a method which we shall now point out, and which leads to a practicable one which we may actually employ.

Figure 2 shows the wind blowing in one constant direction, but alternately at two widely varying velocities or rather (in the extreme case supposed in illustration), where one of the velocities is negligibly small, and where successive pulsations in the same direction are separated by intervals of calm.

A frequent alternation of velocities, united with constancy of absolute direction, has previously been shown here to be the ordinary condition of the wind's motion ; but attention is now particularly called to the fact that while these unequal velocities may be in the same direction as regards the surface of the earth yet as regards the *mean* motion of the wind, they are in opposite directions, and will produce on a plane, whose inertia enables it to sustain a sensibly uniform motion with the mean velocity of this variable wind, the same lifting effect as if these same alternating winds were in absolutely opposed directions, provided that the (constant inclination of the plane alternates in its aspect to correspond with the changes in the wind.

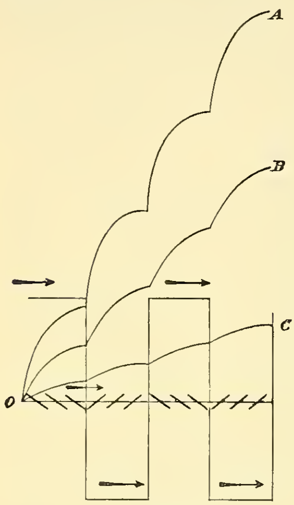

Fig. 2.

It may aid in clearness of conception, if we imagine a set of fixed co-ordinates X Y Z passing through 0, and a set of movable co-ordinates $x\ y\ z$, moving with the velocity and the direction of the mean wind. If the moving body is referred to these first only, it is evidently subject to pulsations which take place in the same directions on the axis of X, but it must be also evident that if referred to the second or movable co-ordinates, these same pulsations may be and are, in opposite directions. This, then, is the case we have just considered, and if we suppose the plane to change the aspect* of its (constant) inclination as the direction of the pulsations changes, it is evident that there must be a gain in altitude with every pulsation, while the plane advances horizontally with the velocity of the mean wind.

During the period of maximum wind velocity, when the wind is moving faster than the plane, the rear edge of the latter must elevated. During the period of minimum velocity, when the plane, owing to its inertia is moving faster than the wind, the front edge of the plane must be elevated. Thus the vertical component of the wind pressure as it strikes the oblique plane, tends in both cases, to give it a vertical upward thrust. So long as this thrust is in excess of the weight to be lifted, the plane will rise. The rate of rise will be greatest at the beginning of each period, when the relative velocity is greatest, and will diminish as the resistance produces "drift;" *i. e.* diminishes relative velocity. The curved line O B in the vignette, represents a typical path of the plane under these conditions.

* We do not for the moment consider how this change of aspect is to be mechanically effected; we only at present call attention to the fact that it involves, in theory, no expenditures of energy.

It follows from the diagram (fig. 1) that other things being equal the more frequent the wind's pulsations, the greater will be the rise of the plane, for since during each period of steady wind, the rate of rise diminishes, the more rapid the pulsations, the nearer the mean rate of rise will be to the initial rate. The requisite frequency of pulsations is also related to the inertia of the plane, as the less the inertia, the more frequent must be the pulsations in order that the plane shall not lose its relative velocity.

It is obvious that there is a limit or weight which cannot be exceeded if the body is to be sustained by any such fluctuations of velocity as can be actually experienced. Above this limit of weight the body will sink. Below this limit the lighter the body is the higher it will be carried, but with increasing variability of speed. That body, then, which has the greatest weight per unit of surface, will soar with the greatest steadiness, if it soar at all, not on account of this weight *per se*, but because the weight is an index of its inertia.

The reader who will compare the results of experiments made with any artificial flying models, like those of Penaud, with the weights of the soaring birds as given in the tables by M. Mouillard, or other authentic sources, cannot fail to be struck with the great weight in proportion to wing surface which nature has given to the soaring bird, compared with any which man has yet been able to imitate in his models. This fact of the weight of the soaring bird in proportion to its area, has been again and again noted, and it has been frequently remarked that without weight the bird could not soar, by writers who felt that they could very safely make such a paradoxical statement, in view of the evidence nature everywhere gave that this weight was indeed in some way necessary to rising. But these writers have not shown, so far as I remember, how this necessity arises, and this is what I now endeavor to point out.*

It has not here been shown what limit of weight is imposed to the power of an ordinary wind to elevate and sustain, but it seems to me, and I hope that it may seem to the reader, that the evidence that there is *some* weight which the action of the wind is sufficient to permanently sustain under these conditions in a free body, has a demonstrative character, although no quantitative formula is offered at this stage of the investigation. It is obvious that, if this weight is sustainable

*It is perhaps not superfluous to recall here that, according to the researches of Rankine, Froude and others, a body moulded in wave-line curves would, if frictionless, continue to move indefinitely against an opposed wind, in virtue of inertia and once acquired velocity, and also to recall how very small the effect of fluid friction in the air has been shown to be (by the writer in a previous investigation).

at any height, gravity may be utilized to cause the body (which we suppose to be a material plane) to descend on an inclined course, to some distance, even against the wind.

I desire, in this connection to remark that the preceding experiments and deductions showing that a material free plane,* possessing sufficient inertia, may in theory rise indefinitely by the action of an ordinary wind, without the expenditure of work from any internal source (as well as those statements, which follow), when these explanations are once made, have a character of obviousness, which is due to the simplicity of the enunciation, but not, I think, to the familiarity of the explanation, for though attention is beginning to be paid by meteorologists to the rapidity of these wind fluctuations, I am not aware that their effects have been so exhibited, or especially, that they have been presented in this connection, or that the conclusions which follow have been drawn from them.

We have here seen, then, how pulsations of sufficient amplitude and frequency, of the kind which present themselves in nature, may, in theory, furnish energy not only sufficient to sustain, but actually to elevate a heavy body moving in and with the wind at its mean rate.

It is easy to now pass to the practical case which has been already referred to, and which is exemplified in nature, namely, that in which the body (*e. g.* the bird soaring on rigid wings, but having power to change its inclination) uses the elevation thus gained to move against the wind, without expending any sensible amount of its own energy. Here the upward motion is designedly arrested at any convenient stage, *e. g.* at each alternate pulsation of the wind, and the height attained is utilized so that the action of gravity may carry the body by its descent in a curvilinear path (if necessary) against the wind. It has just been pointed out that if some height has been attained, the theoretical possibility of *some* advance against the wind in so falling, hardly needs demonstration, though it may not unnaturally be supposed that the relative advance so gained must be insignificant, compared with the distance traveled by the mean wind while the body was being elevated, so that on the whole the body is carried by the wind, further than it advances against it.

This however, probably need not be in fact the case, there being, as it appears to me from experiment and from deduction,

* I use the word "plane," but include in the statement all suitable modifications of a curved surface.

I desire to recall attention to the paragraph in "Experiments in Aerodynamics" in which I caution the reader against supposing that by investigating plane surfaces, I imply that they are the best form of surface for flight; and I repeat here that, as a matter of fact, I do not believe them to be so. I have selected the plane simply as the best form for preliminary experiment.

every reason to believe that under suitable conditions, the advance may be greater than the recession, or that the body falling under the action of gravity along a suitable path, may return against the wind, not only from Z to O, the point of departure, but further as is here shown.

I repeat however, that I am not at the moment undertaking to demonstrate how the action is mechanically realizable in actual practice, but only that it is possible. It is for this purpose, and to understand more exactly that it can be effected, not only by the process indicated, in the second illustration (fig. 2) but by another and probably more usual one (and nature has still others at command), that I have considered another treatment of the same conditions, of wind-pulsations always moving in the same horizontal direction, but for brief periods, interrupted by equal intervals of calm. In this third illustration (fig. 3) we suppose the body to use the height gained in each pulsation, to enable it to descend after each such pulsation and advance against the direction of the wind.

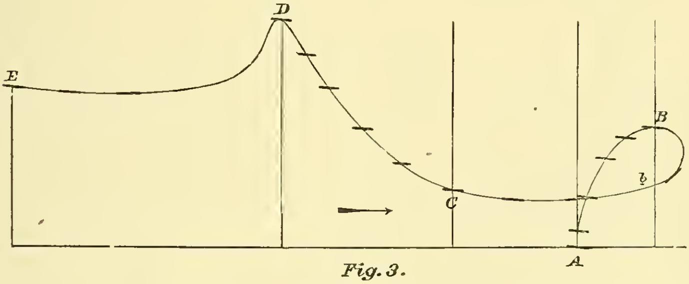

Fig. 3.

The portion A B of the curve represents the path of the plane surface from a state of rest at A, where it has a small upward inclination toward the wind. If a horizontal wind blow upon it in the direction of the arrow, the first movement of the plane will not be in the direction of the wind, but as is abundantly demonstrated by the writer in "Experiments in Aerodynamics" it will rise in a nearly vertical direction, if the angle be small. The wind, continuing to blow in the same direction, at the end of a certain time, the plane, which has risen (owing to its inertia, and in spite of its weight), to the successive positions shown, is taking up more and more of the horizontal velocity of the wind, and consequently opposing less resistance to it, and therefore moving more and more laterally, and rising less and less, at every successive instant.

If the wind continued indefinitely, the plane would ultimately take up its velocity, and finally, of course, fall, when this inertia ceased to oppose resistance to the wind's advance.

I have supposed, however, the wind pulsation to cease at the end of a certain brief period, and, to fix our ideas, let us suppose this period to be five seconds. At this moment the period of calms begin, and now let the plane, which is supposed to have reached the point B, change its inclination about a horizontal axis to that shown in the diagram, falling at first nearly vertically, with its edge on the line of its descent, so as to acquire speed, and this speed, acquired, by constantly changing its angle, glide down the curve B *b* C, so that the plane shall be tangential to it at every point of its descending advance. At the end of five seconds of calm it has reached the position C, near the lowest point of its descent, which there is no contradiction to known mechanical laws in supposing *may* be higher than A, and which in fact, according to the most accurate data the writer can gather, *is* higher, in the case of the above period, and in the case of such an actual plane, as has been experimented upon by him.

Now, having reached C, at the end of the five seconds' calm, if the wind blow in the same direction and velocity as before, it will again elevate the plane on the latter's presenting the proper angle, but this time under more favorable circumstances, for at this time the plane is already in motion in a direction opposed to that of the wind, and is already higher than it was in its original position A. Its course, therefore, will be nearly that along the curve C D, during all which time it maintains the original angle α or one very slightly less. Arrived at D, and at the instant when the calm begins, it falls with varying inclination, to the lowest position E (which may be higher than C), which it attains at the end of the five seconds of calm, then rises again (still nearly at the angle α) to a higher position, and so on; the alternation of directions of motion, at the end of each pulsation, growing less and less sharp, and the path finally taking the character of a sinuous curve. We have here assumed that the plane goes against the wind and rises at the same time, in order to illustrate that this is possible, though either alternative may be employed, and the plane, in theory at least, may maintain on the whole a rapid and nearly horizontal, or a slow and nearly vertical course, or anything between.

It is not meant, either, that the alternations which would be observed in nature are as sharp as those here represented, which are intentionally exaggerated, while in all which has just preceded, by an equally intentional exaggeration of the normal action, the wind-pulsations have been supposed to alternate with absolute calm. This being understood, it is scarcely necessary to point out that if the calm is not absolute, but if there are simply frequent successive winds or pulsations of wind of considerably differing velocity (such as the anemometer observations show, are realized in nature), that the same general effect will obtain,* though we are not entitled to assume from any demonstration thus far given that the total advance will be necessarily greater than that of the whole distance the mean wind has traveled. It may also be observed that the actual actions of the soaring bird may be and doubtless are, more complex in detail than those of this diagram, while yet in their entirety depending on the principles it sets forth.

The theoretical possibility at least will now it is hoped, be granted, not only of the body's rising indefinitely, or of its descending in the interval of calm to a higher level C, than it rose from at A, but of its advancing against the calm or light wind through a distance B C, greater than that of A B, and so on. The writer however repeats that he has reason to suppose from the data obtained by him, that this is not only a theoretical possibility, but a mechanical probability under the conditions stated, although he does not here offer a quantitative demonstration of the fact, other than by pointing to the movements of the soaring-bird and inviting their reconsideration in the light of the preceding statements.

The bird, by some tactile sensibility to the pressure and direction of the air, is able, in nautical phrase, to "see the wind"† and to time its movements, so that without any reference to its height from the ground, it reaches the lowest portion of its descent near the end of the more rapid wind pulsation; but the writer believes that to cause these adaptive changes in an otherwise inert body, with what might almost be called instinctive readiness and rapidity, does not really demand intelligence or even instinct, but that the future ærodrome may be furnished with a substitute for instinct, in what may perhaps allowably be called, a mechanical brain, which yet need not, in his opinion, be intricate in its character. His reasons for this statement, which is not made lightly, must however be reserved for another time.

It is hardly necessary to point out that the nearly inert body in question may also be a human body, guided both by instinct

* The rotation of the body about a vertical axis so as to change the aspect of the inclination as in the first figure, may be illustrated by the well-known habit of many soaring-birds, of moving in small closed curves or spirals, but it may also be observed, in view of the fact that even in intervals of relative calm during which the body descends, there is always some wind,—that in making the descents, if the body, animate or inanimate, maintain its direct advance, this wind tends to strike on the upper side of the plane or pinion. Mr. G. E. Curtis offers the suggestion that the soaring-bird avoids such a position when possible, and therefore turns at right angles to or with the wind, and that this may be an additional reason for his well known habit of moving in spirals.

† Mouillard.

and intelligence, and that there may thus be a sense in which human flight may be possible, although flight depending wholly upon the action of human muscles be forever impossible.

Let me resume the leading points of the present memoir in the statement that it has been shown :

(1) That the wind is not even an approximately uniform moving mass of air, but consists of a succession of very brief pulsations of varying amplitude, and that, relatively to the mean movement of the wind, these are of varying direction.

(2) That it is pointed out that hence there is a potentiality of "internal work" in the wind, and probably of a very great amount.

(3) That it involves no contradiction of known principles to declare that an inclined plane, or suitably curved surface, heavier than the air, freely immersed in, and moving with the velocity of the mean wind, can, if the wind pulsations here described are of sufficient amplitude, and frequency, be sustained or even raised indefinitely without expenditure of internal energy, other than that which is involved in changing the aspect of its inclination at each pulsation.

(4) That since (A) such a surface, having also power to change its inclination, *must* gain energy through falling during the slower, and expend energy by rising during the higher, velocities; and that (B) since it has been shown that there is no contradiction of known mechanical laws in assuming that the surface *may* be sustained or *may* continue to rise indefinitely, the mechanical possibility of some advance against the direction of the wind, follows immediately from this capacity of rising. It is further seen that it is at least possible that this advance against the wind may not only be attained relatively to the position of a body moving with the speed of the mean wind, but absolutely, and with reference to a fixed point in space.

(5) The statement is made that this is not only mechanically possible, but that in the writer's opinion, it is realizable in practice.

Finally, these observations and deductions have, it seems to me an important practical application not only as regards a living creature like the soaring bird but still more as regards a mechanically constructed body, whose specific gravity may probably be many hundred or even many thousand times that of the atmosphere. We may suppose such a body to be supplied with fuel and engines, which would be indispensable to sustain it in a calm, and yet which we now see might be ordinarily left entirely inactive, so that the body could supposably remain in the air and even maintain its motion in any direction without expending its energy, except as regards the act of changing the inclination or aspect which it presents to the wind, while the wind blew.

The final application of these principles to the art of aerodromics, seems then to be, that while it is not likely that the perfected aerodrome will ever be able to dispense altogether with the ability to rely at intervals on some internal source of power, it will not be indispensable that this aerodrome of the future, shall in order to go any distance—even to circumnavigate the globe without alighting—need to carry a weight of fuel, which would enable it to perform this journey under conditions analogous to those of a steamship, but that the fuel and weight need only be such as to enable it to take care of itself in exceptional moments of calm.

Smithsonian Institution,
Washington, D. C., August, 1893.

Art. VI.—*Post-Glacial Eolian Action in Southern New England*; by J. B. Woodworth.

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The following paper is an account of some detached observations made by the writer while engaged in the survey of the pleistocene deposits of southern New England. The matters touched upon here are too detailed and of too little economic importance to find a place in the short descriptive text accompanying the forthcoming atlas sheets, and are hence published in this form. The field work during which the observations were made extended over the years 1889–1892, and was done under the supervision of Mr. N. S. Shaler, geologist in charge of the Atlantic Coast Division, to whom I am primarily indebted for the privilege of making this independent statement of my observations.

The action of the winds in New England in their geological bearing has been described in several communications. The most significant of these papers is that published in this Journal, in 1886, by Geo. H. Stone.* In this paper, Prof.

*III, vol. xxxi. pp. 133–138. The following is a list of papers by American authors in which carved and polished rock surfaces are described, and generally though not always ascribed to eolian action.

1855. W. P. Blake: Report of a Reconnaissance in Colorado. House Doc. 129, p. 27, and Pacific Ry. Reports, v. pp. 91, 117, 229–232, and this Journal, II, xx. pp. 178–181. 1861. C. H. Hitchcock: Report on Geology of Maine, pp. 266–268; 1870. Gen. Benj. Tilghman: U. S. Patent, No. 108,408; 1875. G. K. Gilbert: U. S. Geog. Surv. 100th Meridian, III, pp. 82–84; 1886 N. S. Shaler: Geology of the Island of Nantucket, U. S. Geol. Survey, Bull. 53; 1886.

Stone for the first time recognized the agency of wind-driven sand in carving rock surfaces. His studies were carried on in the State of Maine, where, he states, "in numerous places, both in Bethel and elsewhere near the mountains, I found bowlders and even small stones which are now being sand-carved by the wind as plainly and incontestably as in Colorado."

The competency of blown-sand to carve rock surfaces.—There can be no question that sands driven by the wind have the power to cut away the surface of rocks on which they impinge. The observations of Blake in San Bernardino Pass, of Gilbert in the Great Basin, of Blanford and Oldway in India, and of numerous observers in the desert regions of the Sahara, the Sinai peninsula, and less arid tracts, point conclusively to the view that by means of this subtle agency the hardest rocks are reduced to detritus and receive a form peculiar to the manner of erosion.

Prestwich, in his Geology (vol. i, page 145, says: "On a land freshly emerged from the sea, both rain and wind had necessarily an infinitely greater effect than now, when it is covered with soil and vegetation. Soft and incoherent strata were then subject to rapid wear by surface waters, and loose materials to easy removal by strong winds, as sands now are on the coast, or on bare tracts inland by the like cause. In the same way volcanic ashes, Diatomaceæ, and seeds are transported for hundreds of miles, and so dispersed over wide areas. Sand, when carried by winds over rocks, is known to wear them smooth, and even to line their surface with scratches and furrows. In some cases, hard rocks, such as granite, quartz, and limestone, have been polished, and quartzite pebbles worn into symmetrical forms by this means. This occurs in countries where certain winds prevail at different times of the year, so that different sides of the pebbles are alternately exposed to the wind-action. In this manner regular pyramidal-shaped pebbles have been fashioned in New Zealand and Egypt."

This quotation sets forth in brief the class of effects which are sparingly observed in the district to which this paper relates. The explanation of the pyramidal-shaped pebbles given by Prestwich differs somewhat from that advanced by Walther, whose account of his observations and the history of opinion in Germany is so good that I venture to quote from his valuable monograph.*

Alex. Winchell: Geological Studies, p. 284; 1886. N. H. Winchell: Geology and Nat. Hist. Survey of Minn., i, p. 541. R. D. Salisbury, Annual Rep't, N. J. Geol. Survey, for 1892, p. 155.

* Die Denudation in der Wüste und ihre geologische Bedeutung. Abhandlungen der math.-physisch. Classe der Königl. Sach. Gesell. der Wissenschaften. Band. xvi, No. iii, 1891, pp. 445–448.

The following are some of the foreign papers relating to the formation of carved pebbles:

"It was so far as I know on the 5th of April, 1876, that G. Berendt for the first time called the attention of North German geologists to peculiar facets which are seen on pebbles in the glacial drift. Since this time, these so-called 'drei-kanter, or 'Kantengerölle' have interested geologists, and a great deal has been written on this subject. They were regarded as the work of ice, of great pressure, etc., until Mickwitz in his treatise gave the right key to the puzzle, in that he proved that these facets are merely a phenomenon of smoothing by sand (Sandschliffer-scheinung), a view which since then has merely been confirmed by Credner, Heim, Sauer, and others. Views at present differ only concerning the manner in which these planes were cut. I have collected a number of such edged pebbles in different parts of the desert: first I found them in Wady Araba in the Arabian desert, then between Giseh and Abu Roasch on the border of the Libyan desert; and Dr. Sarasin has found them in the Sinai peninsula.

"According to my observations," continues Walther, "it is limestone of the Cretaceous formation, of fine, compact, very uniform grain, which in Egypt forms dreikanter. I have not found other varieties of rock in this form. The Eocene limestones may be too soft, the Nummulitic rock too unequally hard, and the crystalline rocks, as I have to show in the following pages, so quickly decompose in the desert that they are not adapted for forming dreikanter.

"The number of corners ground on varies as much as does the size of the pebbles, and neither are causally connected. I found einkanter (pebbles with one edge or arris) a foot in diameter (fussgrosse) and nut-sized stones with five edges (fünfkanter) and conversely.

"The edges are of unequal sharpness, and I believe I have observed that the edges are merely due to the fact that two ground flat surfaces intersect each other so that the expression 'facetted pebbles' (Facettengerölle) appears to me to be more correct than edged-pebbles (Kantengerölle).

"A connection between the direction of the edges and the direction of the wind could not be found, and this seems to me easily understood since I did not observe constant winds, and

Johannes Walther: Kantengeröllen in der Galalawüste; Berichte der math. phys. Klasse der Sachs. Gesell. der Wissenschaft, Nov. 14, 1887; E. Geinitz: Ueber Kantengeröllen; Neues. Jahrb. für Min. Geol. and Pal. Stuttgart, 1887 (II), p. 78. Heim: Kantengeschiebe aus dem norddeutschen Diluvium; Viertel-jahrsch r. d. Furcher. Natur. Gesellsch., 1888. F. Wahnschaffe, Beitrag. zur Lössfrage; Jahrbuch d. König· Preuss. Geol. Landesanstalt, Berlin, 1890, pp. 328–346. A. Sauer und C. Chelim: Die Ersten Kantengeschiebe im Gebiete der Rheinebene; Neues Jahrb. f. Min., etc., 1890, ii. A. Sauer: Ueber due æolische Enstehung des Löss am Rande der norddeutschen Tiefebene; Zeitschr. für Naturwissenschaften, Bd. lxii, Halle, 1889; Neues. Jahrb. f. Min., 1888, Bd. ii, s. 300–304. Dames und Wahnschaffe: Zeitschrift d. Deutsch. Geol. Ges., 1887, s. 226–227 und 229. A. Geikie in the 3d edition of his text-book refers to other papers.

since the direction of the wind in the desert often changes every hour.

"On the other hand, I have never found the facetted pebbles isolated, but always distributed among ordinary desert pebbles, which lay close together. The annexed drawings show the position of facetted pebbles with reference to other pebbles.* I have frequently observed the movement of the sand between such pebbles with strong wind (sandwind) and have come to the following conclusion concerning the formation of the facettes:

"The sand flows along in little streams over the ground and the pebbles lying on the surface form just so many obstructions and resistances to the small sand-courses. In front of a large pebble the sand-stream is parted, so as often to reunite behind the obstruction; often the divided streamlets run, isolated, some distance further, finally reuniting with neighboring ones. In consequence of this bifurcation and reunion of the small sand-streams, caused by the stones lying on the ground, such stones upon which two converging sand-streams strike, become provided with two facettes, of which each has been formed by a sand-stream. Since these facettes continually enlarge, they come finally to an intersection (gegenseitigen Schneiden) and form thereby an edge. Pebbles which are constantly washed by similar sand-streams, receive sharp edges; but if the direction of the sand-stream changes, then the edges and facettes will become indistinct and again effaced.

"In other words, planes are cut on the pebbles, whose development forms edges, and on this account the word 'facetted-pebble' (Facettengerölle) it seems to me best expresses the process of their formation, for the edge is secondary."

The attention which is paid to this subject in Germany and the indications which point to even the slight action of wind-blown sands are evident from what Karl v. Fritsch says in his Allgemeine Geologie (Stuttgart, 1888), p. 302.

"Wir können in Norddeutschland die grossen erratischen Blöcke an den Wegen, Brückenfeilern, etc., nicht betrachten, ohne wahrzunehmen, dass sie fast alle auf der nach der herrschenden Windrichtung (meist Nordwest) liegenden Seite hin eine eigenthümlich flachgrubige oberfläche und einen stärkeren Glanz als liewärtz zeigen. Giebt es auch solche Feldsteine bei denen das erwähnte Verhältnisse nicht wahrnehmbar ist, so kann man die Ursache ihrer Rauhigkeit fast jedesmal erkennen. Sobald ein erratischer Block eine längere Reihe von Jahre unverändert liegen geblieben, fehlen diese spuren der Winderosion nicht."

Localities in which eolian action was observed in southern New England: Island of Martha's Vineyard.—At a number

* The drawings are not reproduced in the present paper.

of points on the highlands of this island wind-bared spaces were found, in some of which occur polished and worn pebbles. Such places are common on the east side of Menemsha Creek near the road which goes southward to Chilmark. At other points on the island, both in the highland region and on the morainal plain, I found carved and polished pebbles in positions where sands are not now blowing. One carved and polished pebble was found with its carved faces uppermost by the side of an old cart road in a field surrounded by woods, and in a location where no winds have blown sand since the foresting of that portion of the island. The facets still retain their peculiar polish. Another pebble partially buried in the soil had been covered over by a lichenous growth. It, too, had long been exempted from the action of the wind by the forest and soil. Near the mouth of Paint Mill Brook, on the north shore of the island, and at an elevation of about 20 feet above the sea, the glacial gravels underlying the soil, for the depth of 3 or 4 inches contain numerous examples of pebbles with a high polish and the facets and edges peculiar morainal plain near West Tisbury, all indicating the former to eolian pebbles. Similar pebbles were found on the activity of the process here described at a time before the growth of forests and the soil prevented the blowing of sand.

The section in Matakeset Creek.—The most important occurrence of facetted-pebbles known to me in this field was met with in September, 1889, in the extreme southeastern part of the island in the banks of a ditch opened between Matakeset Pond and Katama Bay, and which is known as Matakeset Creek. In this ditch, then newly opened, there was exposed to view a continuous line of sculptured and polished pebbles lying at an average depth of from one to two feet beneath the surface. The pebbly layer rested upon a semistratified deposit of sand and gravel constituting the marginal portion of the broad plain which fronts the Martha's Vineyard moraine on the south. The pebbly layer was overlaid by a deposit of fine, wind blown beach sand, stained black by humus, and surmounted by a thin layer of mould which nourished a growth of stunted beach grass. These sands are no longer blowing, but immediately to the south of the ditch at the distance of an eighth of a mile is a line of dunes fringing the shore, the inward migration of whose sands has not suffused the beach grass on the old wind-blown deposit. The layer of sand-carved pebbles is about three inches thick. The pebbles vary in size from the very smallest polished pebbles to bowlderets six inches in diameter. Many of these show no carving or polishing on one side, this being particularly the case with the underside where it was in contact with the underlying gravels. This layer could be traced for a long distance either side of the point where I crossed the ditch, and thousands of characteristic facetted pebbles may be obtained from the layer. It was a noticeable fact that no facetted or polished pebbles occurred in the exposed faces of the underlying gravel section. The geological conditions of this section lend support to the idea that facetted pebbles are the product of eolian action. The location of this eolian pebble bed out on the southern margin of the frontal plain of the Martha's Vineyard moraine and on a surface which bears no marks of ice-advance excludes, it seems, the agency of strictly glacial causes from effecting the shape of these pebbles. They are evidently glacial stream pebbles reshaped *in situ*.

In the many instances on this island of soil-covered surfaces which have evidently undergone exposure to wind-blown sands, I am not certain of the time of the action, for it is obvious that since the process is now going on in places so it may have been active at any time in the past, the process being interfered with by the renewal of the vegetative coating. But the wide spread occurrence of buried or partially inhumed eolian pebbles, with worn sand, points strongly to the conclusion that the process has been more active than it now is.

Providence atlas sheet.—On the surface of the sand-plain in East Providence, R. I., is a bowlder 3 feet in length and 2 feet high, the southern face of which has been scored, worn and polished, evidently by the long continued action of blowing sand. The surface about the bowlder is now grass-covered. South of Providence in Auburn, bowlders exhibit traces of the same action. In many places on the west side of Narragansett Bay, the surface is covered by blown sand.

Boston atlas sheet.—Eolian pebbles occur in the soil near Fresh Pond in Cambridge. The pebbles of the Roxbury conglomerate, in a ledge, in Dorchester, exhibit the peculiar spoon-shaped and polished surface due to wind-erosion. Carved slates occur on the surface of kames in the soil along the Charles River in the vicinity of Mt. Auburn cemetery.

Boston Bay atlas sheet.—A bowlderet 6 inches in diameter bearing crateriform faces and possessing a high polish was found on Grover's cliff in Winthrop, the cobble having come evidently from the upper surface of the drumlin.

Narragansett Bay atlas sheet.—Eolian pebbles occur near the head of a glacial sand-plain half a mile north of the Warwick Neck Station in Warwick, R. I.

Dedham atlas sheet.—I found a pitted eolian pebble on the surface of a kame at Holbrook station on the Old Colony railroad.

Rate and Angle of Wear on Pebbles.—The observations made by W. P. Blake early led to the use of the artificial sand-blast in the arts. The conditions under which erosion takes place in the arts have been studied experimentally by Thoulet and are set forth in his paper, "Experiences synthetiques sue l'abrasion des roches par le sable."* The results of these experiments include observations relating to the rate of wear at certain angles of incidence which appear to me to be significant when compared with some of the pebbles which I am about to describe. "The abrasion," states Thoulet, "is so much the more energetic when the rock upon which it acts is more nearly vertical with reference to the direction of the sand which strikes (horizontally), and it diminishes very rapidly in intensity directly as the inclination becomes lower than 60 degrees." "Oblique incidence too (from 30° to 45°)† increases the rapidity of the cutting effect, probably because the issuing particles of sand are not met and their force deadened by the rebounding ones." From these experiments we should be led to expect the wear on a nearly vertical surface of a pebble to proceed slowly in nature, to go forward more rapidly after a time when a surface had been worn down to a plane inclined about 30° to the vertical, and again to wear very slowly when the plane had been worn down to an angle of 60 degrees with the vertical. The result of this varying rate of wear would be that on a pebble plain exposed to sand-blasting, the carved pebbles would soon pass through the maximum rate of cutting and would remain long near the angle of 30° of inclination to the horizon. An examination of several well-facetted pebbles from Martha's Vineyard shows this feature in a marked way. It is necessary, however, in order to ascertain this mature state of erosion, to establish the soil-line or horizontal plane in which the pebble lay at the time of its carving. This can frequently be done with pebbles found *in situ*. The smaller pebbles by the erosion of the sand and gravel about their bases have frequently been overturned, and eroded on all sides. It is evident that where inversion takes place regularly and frequently that facets may fail to develop and that the pebble may slowly waste away in the manner of those described by Gilbert on the plains of Colorado.

Lithological characters of the pebbles.—There is a certain relation between the sand blown upon the rocks and their

*Compt. Rend. Acad. Sci., t. civ, p. 381; also Annales des mines, Mars-Avril, 1887, pp. 199–224.

† The experiments conducted by Gen. Tilighman in connection with his patent are described by G. F. Barker in Johnson's New Universal Cyclopedia, vol. iv, pp. 62–65.

mineralogical constitution. The most perfectly symmetrical pebbles are a variety of compact quartzite, or even vein quartz. Finely crystallized granitic rocks also exhibit good facets, but the quartz is apt to stand out above the feldspar. Quartz-porphyries, felsites and other massive rocks exhibit forms related with original fragmental contour and mineralogic construction. Pits are reamed out where minerals have decomposed, and grooves are worn often regardless of structure but commonly along lines determined by weakness in the rock. Facets show no prevalent relations to joint-planes or bedding; but often one can see that a joint-face has been cut and polished.

The symmetry of the pebbles gives them an artificial appearance in many instances. The original symmetry of rounded water-worn pebbles has been preserved by the production of balanced planes on opposite sides of the fragment. Pyramidal, triangular pebbles are common. The smaller pebbles by reason of the facility with which they may be undermined and overturned by the wind, are more generally carved on all sides than the larger ones.

Nomenclature.—In Germany sand-blasted pebbles receive specific names depending upon the number of edges which are developed by the intersection of facettes. The term facetted-pebble proposed by Walther has already been given in this country to a product of glacial action.* Since some of the sand-carved pebbles are facetted, some grooved, and others merely pitted, I would suggest that "glyptolith" (*glyptos*, carved; *lithos*, stone) might be employed, in the sense of a rock surface carved by wind-blown sand. "Eolite" has already been appropriated for a rock made by the deposition of sand by æolian action.†

That the blowing of sand by wind must have been wide spread in the interval between the disappearance of the last ice-sheet and the occupation of the land by plants, is shown by the fact that even now wind-blown sand and sand-blasting is to be observed at numerous points on the sand-plains in this district. The question is to determine whether the glyptoliths found in grass-covered tracts or in wood-lands are due to a phase of general deflation preceding the incoming of the recent flora, and are, therefore, indicative of an eolian phase succeeding the deglaciation of the district, or whether they are due to secular wind erosion acting now and then as the opportunity is offered by the removal of the soil and the exposure of sand to the wind. My own observations have not been sufficiently extended to come to a definite conclusion in regard to this matter, particularly since in many places the

* Chamberlin: 7th Annual Report, U. S. G. S., p. 209, 1888.
† T. M. Reade: Geol. Mag., dec. ii, vol. ii, pp. 587, 588.

process of sand-carving is now evidently going on; but I am led by the distribution of many of the pebbles which I have collected to think that sand-blasting was formerly more prevalent than it now is in this district.

Relation of land to sea-level.—It is obvious that the carving and polishing of rock surfaces by the sand-blast is essentially a subærial phenomenon. Although the sand carried by water-currents as in the case of the Colorado, shown by Newberry, furrows and polishes the rock of its bed, the sands of the littoral are not known to produce the facets and polish characteristic of the typical glyptoliths. This is probably due to the frequent turning and rubbing of pebbles even where they lie in the zone of sands driven by wind along the beach. It follows that where we have these eolian pebbles carved at any time in the past, we have evidence to show that at that time the land was above the level of the sea. As yet the coast region of New England along which submergence at the close of the last glacial epoch has been suspected has not been examined with this point in mind.* The evident antiquity of the Matakeset examples on Martha's Vineyard and the direct superposition of the eolian pebbles on the wind-eroded surface of the overwash or frontal plain indicates that next after the deposition of the glacial gravels it was subjected to wind-erosion. This evidence indicates that if the land there was submerged after the retreat of the ice, the period of depression was brief and is locally without any trace of its geological effects.

Among the problems which these eolian pebbles may be looked to for a solution is the question of the former elevation of the continental shelf in recent geological times. It is therefore of the utmost importance that the pebbles and bowlders occasionally dredged up from the surface of the "banks" off the New England coast should be carefully scrutinized with the view of determining whether or not they bear marks of eolian erosion. If, as there is reason to believe, these banks were during late Tertiary or in the pleistocene period, like Martha's Vineyard and Nantucket now, above the sea-level, we should find on them the kind of evidence which occurs on the islands named.

Cambridge, Mass.

*Since this was written, Prof. W. M. Davis has presented in the current volume of the Proc. Boston Soc. Nat. Hist. a paper announcing the occurrence of facetted eolian pebbles at numerous points on Cape Cod in geological situations showing the subærial deposition of at least a part of the glacial gravels of that peninsula. See also paper by the same author read at the December meeting of the Geol. Soc. Am., held in Boston, 1893.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Production of Silver hyponitrite from Hydroxylamine.*—The fact that on mixing at ordinary temperatures hydroxylamine sulphate and sodium nitrite in concentrated aqueous solution, mutual decomposition takes place with the evolution of nitrogen monoxide, was first pointed out by V. Meyer. If the solutions be dilute, the same reaction takes place on heating; but if the temperature be not raised the decomposition proceeds slowly and if silver nitrate be added to this solution a yellow precipitate of silver hyponitrite is thrown down which may be purified by dissolving it in cold dilute nitric acid and reprecipitating with ammonia. W. Wislicenus has shown that this reaction may readily be used as a lecture experiment. For this purpose two or three grams of hydroxylamine sulphate and the equivalent quantity of sodium nitrite are dissolved separately in about 100^{cc} of water, the solutions are mixed, and a portion is tested with silver nitrate. A white precipitate of mixed silver sulphate and silver nitrite results. The rest of the solution is heated rapidly to 50° on the water bath for a few moments, the evolved gas being shown to be nitrogen monoxide by means of a glowing splinter. On adding now silver nitrate to the solution, a yellow precipitate of silver hyponitrite $Ag_2N_2O_2$ will be thrown down. Experiment will determine the time of heating necessary to secure the best results.—*Ber. Berl. Chem. Ges.*, xxvi, 771, April, 1893. G. F. B.

2. *On the Electrolysis of Alkali Salts.*—From recent experiments by Arrhenius, it appears that upon electrolyzing an aqueous solution of an alkali salt, using mercury as the cathode, a considerable time elapses after the passage of the current before hydrogen makes its appearance. From this fact it would appear that hydrogen is not a primary result of the electrolysis, but is due to the secondary action of the water of the solution upon the alkali amalgam produced primarily by the discharge of the positive ion; i. e. the alkali metal. The time required before the first bubble of hydrogen appears, increases very slowly as the strength of the current diminishes, and, when the current is maintained constant at one-twentieth of an ampere, increases as the concentration increases and as the temperature decreases. For equivalent solutions of electrolytes having the same positive ion, this time is practically constant; but it is found to be much larger for potassium salts than for those of sodium and lithium. Theory indicates that the electromotive force required for electrolysis increases, at the outset, with the amount of electrolytic products already separated. But when secondary reactions take place, preventing the continuous accumulation of these products if the electrolysis goes on very slowly, the electromotive force required

for electrolysis is determined almost solely by these secondary reactions. Evidently if the result of the secondary actions is the same as it is in the case of alkali salts, the electromotive force required for the decomposition will be practically the same also; thus confirming the experiments of Le Blanc and not requiring us to assume the primary decomposition of the water. From Shields' data, showing that a decinormal solution of sodium acetate is hydrolyzed to the extent of 0·008 per cent, the author calculates that the electrical conductivity of pure water at 25° is $0{\cdot}56\times10^{-11}$; this conductivity being greatly diminished in the presence of electrolysis. A salt of a strong acid and a strong base is hydrolyzed to the extent of $1{\cdot}21\times10^{-4}$ per cent in decinormal solution, the absolute quantity hydrolyzed being nearly independent of the concentration. The author has also calculated from the electromotive force required for the electrolytic dissociation of pure water, the value of this force required to develop hydrogen and hydroxyl ions from water in a liquid already containing as many of these as are in normal solutions of strong acids or bases. His value thus found is 0·81 volt, that obtained experimentally by Le Blanc being 0·76 volt.—*Zeitschr. physikal. Chem.*, xi, 805, June, 1893. G. F. B.

3. *On the Preparation of Chromium, Manganese and Uranium in the Electric Furnace.*—The electric furnace of Moissan and Violle consists of a carbon vessel in which an arc from two horizontal electrodes is made to act upon any substance desired. This vessel is a portion of a carbon tube, of a height equal to its diameter, standing on a carbon plate and covered with a disk of the same material. The electrodes are also of carbon; all the carbon parts of the apparatus being prepared from powdered gas carbon and tar, no boric acid being used. The carbon cylinder and electrodes are enclosed in a block of lime, being supported on props of magnesia and separated from the sides of the block by a layer of air five millimeters thick. The dimensions of the furnace and its various parts vary according to the current which is to be used and the temperature desired; a temperature of 3000° being obtained without difficulty. If manganous oxide be mixed with charcoal and heated by the arc given by a current of 300 amperes and 60 volts, the reduction is complete in five or six minutes; but twelve to fifteen minutes is necessary if only 100 amperes and 50 volts is used. If the carbon be in excess, the reduced metal contains 6·4 to 14·6 per cent of this substance, but if the manganous oxide be in excess, only 4 or 5 per cent of carbon is contained in the metal. With a low content of carbon, the metal is unaltered when exposed in open vessels; but when the proportion of carbon is increased, it is attacked by moist air. In water, small fragments are oxidized, hydrogen and hydrocarbons being evolved. Chromium oxide mixed with carbon and subjected to a current of 350 amperes at 50 volts, is reduced in from 8 to 10 minutes, 100 grams of the metal being obtainable at one operation. With 100 amperes and 50 volts, fifteen min-

utes are required for the reduction. The metal contains from 8·6 to 12·85 per cent of carbon; but if placed in fragments in a carbon crucible brasqued with chromium oxide and again subjected to the arc, the metal is obtained quite free from carbon. If chromite be thus treated an alloy of chromium is obtained. If the mixture of oxides obtained by calcining uranium nitrate be mixed with a slight excess of carbon, strongly compressed in a crucible of carbon, imbedded in magnesia, and submitted to the arc produced by a current of 450 amperes at 60 volts, reduction takes place at once, an ingot of 200 to 220 grams being obtained in 12 minutes. The metal is very hard, has a brilliant fracture, and contains from 5 to 13·5 per cent of carbon. Although its fusing point is higher than that of platinum, it decomposes water at the ordinary temperature.—*C. R.*, cxvi, 347, 349, 549, Feb., March, 1893. G. F. B.

4. *On the Production of Sarcolactic acid by the Fermentation of Inactive Lactic acid.*—Having obtained a bacterial growth possessing the power of exciting an active fermentation in solutions of calcium lactate, FRANKLAND and MACGREGOR have studied the resulting products. They find that by the interrupted bacterial formation of ordinary inactive calcium lactate a liquid may be obtained which shows a negative rotation in the polarimeter. From this liquid they have extracted the residual lactic acid and by converting it into the zinc salt have obtained by fractional crystallization a lævorotatory zinc lactate proved by its chemical composition and its specific rotation to be pure zinc sarcolactate. By converting this into the calcium salt, it was found to possess the same specific rotation as calcium lactate. If the fermentation was interrupted too early a large quantity of the inactive acid remained mixed with the active one; while if too long continued, the active lactate was destroyed.—*J. Chem. Soc.*, lxiii, 1028, Aug. 1893. G. F. B.

5. *On the Heats of Combustion of Gaseous Hydrocarbons.*—Carefully purified gaseous hydrocarbons have been burned by BERTHELOT and MATIGNON in a calorimetrical bomb by means of compressed oxygen and their heats of combustion in this way determined. Preliminary experiments made with hydrogen gave 68·15 large calories at constant volume and 68·99 large calories at constant pressure; the values obtained for carbon monoxide being 67·9 and 68·2 respectively. This gives +26·1 for the heat of formation of this latter substance. For the hydrocarbons, the values obtained were as follows:—

		Methane.	Acetylene.	Ethylene.	Ethane.
Heat of combustion	Const. vol.	----	----	340·05	370·9
	Const. press.	213·5	315·7	341·1	372·3
Heat of formation		+18·7	+58·1	−14·6	+23.3

		Propane.	Allylene.	Propylene.	Trimethylene.
Heat of combustion	Const. vol.	526·7	472·4	497·9	505·6
	Const. press.	528·4	473·6	499·3	507·0
Heat of formation		+30·5	−52·6	−9·4	−17·1

It will be observed that the difference between the heats of combustion of two homologous and contiguous hydrocarbons is practically constant, being about 157 Calories; while the corresponding difference between the heats of formation is about 5·5 Calories. In the methane series therefore the heats of combustion at constant pressure are $213·5+157·5n$, in the ethylene series $341·2+157.5n$ and in the acetylene series $315·5+157·5n$; the corresponding heats of formation being respectively $+18·7+5·7n$, $-14·6+5·5n$, and $-58·1+5·5n$. When a member of the acetylene series is converted into the corresponding olefine, 43·3 Calories is set reef; and the conversion of the olefine into the paraffin develops 39 Calories. The heat of combustion of trimethylene does not accord with the hypothesis that it is a closed chain hydrocarbon. The heat of formation of trimethylene dichloride, 4·3 Calories, shows that the substitution of Cl_2 for H_2 produces a thermal disturbance similar to that observed in the methane series.—*C. R.*, cxvi, 1333; *J. Chem. Soc.*, lxiv, ii, 444, Oct. 1893. G. F. B.

6. *On the Action of a Lævolactic Ferment on Dextrose, Rhamnose and Mannitol.*—In the course of observations on the nature of the micro-organisms which attack the ripe pear, TATE succeeded in isolating one which produced marked lævolactic fermentation of dextrose and mannitol. He has now studied this fermentation and gives the following conclusions: The organism which produces this lævolactic fermentation is anaërobic and is characterized by forming two kinds of growth upon solid media —a white growth of moist appearance consisting chiefly of rods and cocci, and a tough, tapioca-like growth consisting of ascococci. The fermentations brought about by this organism under aërobic conditions in solutions of dextrose, mannitol and rhamnose are fairly constant in character. From 9 molecules of dextrose the organism produces alcohol 2 molecules, succinic acid 1, lævolactic acid 7 to 8; and acetic and formic acids in smaller and variable proportions. If the organism has grown in the ascoid form, the amount of lævolactic acid is slightly less probably from secondary changes. From 9 molecules of mannitol are obtained 6 of alcohol, 1 of acetic acid, 2 of formic acid and 12 of lævolactic acid, together with some succinic acid. From 9 molecules of rhamnose, 4 molecules of *inactive* lactic acid and 5 of acetic acid are produced, alcohol being absent. This cultivation in rhamnose solutions, producing inactive lactic acid, does not cause the organism to use any of its activity in causing lævolactic fermentation of dextrose. The study of dextrose fermentations, in the opinion of the author, tends to indicate that the attack of the organism is directed simultaneously against nine or other multiple number of molecules—that is against a group of molecules—rather than against single molecules.—*J. Chem. Soc.*, lxiii, 1263, Oct. 1893. G. F. B.

7. *On Lead Tetracetate.*—It has long been known that red lead dissolves in hot glacial acetic acid yielding a colorless solution which on cooling deposits crystals. HUTCHINSON and POL-

LARD have examined these crystals with considerable care. They were purified by recrystallization from hot glacial acetic acid and were dried over sulphuric acid. When free from acetic acid the substance is extraordinarily sensitive to the presence of water, which at once converts it into lead peroxide and acetic acid. This fact was made use of to analyze the substance, the lead peroxide being collected on a tared filter and the acetic acid titrated with alkali. The results leave no doubt that the compound is lead tetracetate $Pb(C_2H_3O_2)_4$. The crystals begin to melt at 175° and decompose a few degrees above this. They dissolve in concentrated hydrogen chloride, producing lead tetrachloride; as is shown by the fact that when a cold saturated solution of ammonium chloride is added, a characteristic yellow double ammonium salt is precipitated. An analogous crystalline tetrapropionate may be similarly obtained.—*J. Chem. Soc.*, lxiii, 1136, Sept. 1893.

G. F. B.

8. *On the Thermochemistry of Chloracetic acid.*—It has been observed by TANATAR that the unstable modification of chloracetic acid (fusing point 52°) changes into the stable modification (fusing point 63°) with an evolution of heat of 0·65 calory per gram-molecule. The heat of dissolution of the unstable acid was found to be −2·77 calories, that of the stable acid −3·47 calories; the difference being 0·70 calory, nearly the same as the heat of transformation directly observed. Both acids show a normal molecule in aqueous solution and a double molecule in solution in benzene.—*J. Russ. Chem. Soc.*, xxiv, 694; *J. Chem. Soc.*, lxiv, i, 624, Nov. 1893. G. F. B.

9. *A method of using the arc light for reading rooms and libraries.*—Mr. Benjamin A. Dobson, a manufacturer at Bolton, England, has lately made experiments in regard to the best method of lighting his workshops which are very suggestive in regard to the disposition of lights in reading rooms and libraries. It was found that incandescent lamps were not much superior to gas while the arc lamp threw sharply defined shadows. It therefore occurred to Mr. Dobson to invert the ordinary arc lamp, so that the positive carbon from which most of the light proceeds was below the negative carbon. The light which was thus thrown upward by the positive carbon was received on a well whitewashed ceiling and was thus reflected downward and the room was flooded with a well diffused light. One could stand in any part of the rooms thus lighted and read a book or paper without being troubled with shadows. When the strength of the light is considered the system is cheaper than that of gas.—*Nature*, Nov. 2, 1893, p. 18. J. T.

10. *Application of light waves to metrology.*—Michelson in a preliminary communication states that two complete and independent determinations give for the numbers of waves of red light in one meter of air at 15° C. and 76^{mm} pressure the following:

1st series	1553163.6
2d series	1553164.6

The difference from the mean is half a wave, or about one-fourth of a micron. We can thus compare two standards by means of light waves with the same order of accuracy that we can at present compare the meter bars, and the comparison is based upon an unchangeable unit.—*Nature*, Nov. 16, 1893. J. T.

11. *Radiation of heated gases.*—F. Paschen, by means of a bolometer, has conducted a series of experiments upon the radiation of heated air, oxygen, carbonic acid and steam. The gases were heated by passing over a platinum spiral which was raised to incandescence by a storage battery. A heat spectrum was formed and wave-lengths as long as $5{\cdot}2\mu$ were measured. It was found that gases can emit a discontinuous spectrum. In the case of CO_2 and steam, there was a displacement of the intensity within the emission maxima, with decreasing temperatures. No explanation is given of this phenomenon.—*Ann. der Physik und Chemie*, No. 11, 1893, pp. 409–443. J. T.

12. *Electric radiations in Copper Filings.*—At a meeting of the Physical Society, London, Oct. 27, Mr. W. B. Craft stated that if a battery-galvanometer and tube containing copper filings were joined in series under ordinary conditions no current passed; but a current was immediately produced by an electric spark, produced many feet distant by an electrical machine. Iron filings were inferior to copper, and carbon always allowed the current from the battery to pass.—*Nature*, Nov. 9, 1893, p. 46. J. T.

13. *Absorption of Electrical waves.*—I. Klemenčič has applied his method of the thermal junction to the question of the absorption of the energy of electrical oscillation on wires of different material and confirms the results of Bjerknes, J. J. Thomson and Trowbridge in regard to the damping effect of iron. For wires made of iron, german silver, brass and copper of 6^{cm} long and $0{\cdot}018^{cm}$ diameter he finds the development of heat can be expressed relatively as $10{\cdot}5 : 1{\cdot}75 : 1 : 1$. The observations showed that in the case of the ramification of electrical waves of very short duration the factor of self-induction is more potent than that of resistance.—*Ann. der Physik and Chemie*, No. 11, 1893, pp. 456–475. J. T.

14. *A new form of Contact maker.*—In a paper read before a late meeting of the American Institute of Electrical Engineers, Messrs. Bedell, Miller and Wagner describe a new form of contact maker. A fine jet of water was projected upon a needle which is inserted into a revolving disc, and thus contact was made between a voltmeter and a circuit. The nozzle of the water jet is carried by a disc which is capable of being rotated and has its edge graduated into degrees. The voltmeter could thus be connected with the circuit of a transformer at any required part of a cycle. The needle cut the water jet before it broke into drops. A little salt was put into the water, for conduction. J. T.

II. Geology and Mineralogy.

1. *Geological Survey of Georgia.* The Paleozoic group. The Geology of ten counties of northwestern Georgia and resources; by J. W. Spencer, state geologist, pp. 406 and one map, Atlanta, Ga. 1893.—The Paleozoic formations of northwestern Georgia are described under the following nomenclature, viz: Cambrian, Oostanaula formation; Ordovician, Knox dolomite, Chicamauga (including Rockmart slate); Silurian, Redmountain; Devonian, Chattanooga Black shales; Carboniferous, Fort Payne chert, Floyd shales, Mountain limestone and Coal measures. Part II describes the Economic Resources of the Paleozoic group, coal, iron, manganese, bauxite, kaolin and building materials, graphite, etc. The report is a valuable compendium of the local geology of this corner of the state. w.

2. *The Geology of Mexico.*—The following maps and charts illustrating the geology of Mexico have been published recently by the *Comision geologico Mexicana*, prepared under the direction of Antonio del Costillo, director of the Escuela n. de Ingenieros and of the Comision geologico:—A small geological map of the whole Republic on the scale of 1:10,000,000, entitled Bosquejo de una Carta geologica de Republic Mexicana; a map on a scale of 1: 2,000,000, on which the distribution of the following minerals is shown, viz: gold, platinum, mercury, copper, iron, lead, bismuth, zinc, antimony, coal, sulphur, kaolin, lignite. Carta los meteritos de Mexico, scale 1 : 10,000,000. Cartes geologicas de Pozos Artesianos abiertos en la gran Cuenca de Mexico. Plans of the Peñon de los Baños, scale $\frac{1}{4000}$: of the mining regions of S. Antonio and Triumfo in lower California, scale $0\cdot^{m}001$ per 40^{ms};—of the iron mines of Encarnacion and of S. Jose del Oro, scale 1: 20000, and a detailed plan of the geological and petrographical structure of the environs of the city of Mexico, scale 1: 200,000. In the same series appears a large engraving of the geyser in the vicinity of Puebla described by Antonio del Castillo.

A valuable summary of the present state of knowledge regarding the geological formations and their fossils for Mexico is given in *Datos para la Geologia de Mexico*, by Jose G. Aquilera and Ezequiel Ordoñez of the Escuela de Ingenieros, Mexico, 8vo, 87 pp. The following systems are recognized: Archæan, Permo-Carboniferous, a small outcrop near the border of Guatemala, compact limestone with a *Productus ? semireticulatus*, and certain tracts in the northeastern part of Mexico, which furnish fossil Lamellibranchs, which may be Carboniferous. Triassic, in numerous localities, determined to be upper Triassic. From this system in Ros Bronco in Sonora, Dr. Newberry described a flora of 23 species of plants. The Jurassic system is recognized by a fauna of 37 species distributed among the Sponges, Echinoderms, Vermes, Brachiopods, Lamellibranchiata and Cephalopoda.

Among the latter are *Arietites* indicating the inferior Lias and *Stephanoceras* indicating a middle Jurassic horizon.

The Cretaceous system is indicated by a rich fauna including species of lower, middle and upper Cretaceous age. This fauna includes 3 species of Rhizopoda, 38 Anthozoa, 16 Echinoidea, 2 Vermes, 95 Lamellibranchiata, 54 Gastropoda, 24 Cephalopoda, 1 Thoracostraca, 8 Pisces, 1 Reptile, a total of 242 species.

The Tertiary system is recognized by 67 species of ? Eocene and Miocene age, including 3 Echinodermata, 53 Lamellibranchiata and 11 Gastropoda.

Hippotherium peninsulatum Cope and *Protohippus Costilloi* Cope, are from the Upper Miocene, and from the Pliocene and Quaternary are the following genera of vertebrates; *Spheroma ?*, *Glyptodon*, *Sceledoterium*, *Rhinoceros ?*, *Equus*, 5 species, *Platigonus*, 2 species, *Palauchenia*, *Auchenia*, 2 species, *Holomeniscus*, *Eschatius*, *Bison*, *Aphelops*, *Mastodon*, (1 *Trilophodon*, 2 *Tetralophodon* species), *Elephas*, 2 species. W.

3. *Geological Survey of New Jersey.* (Ann. Rept. 1892. 367 pp. 8vo and two folded maps.)—This report includes Pt. I, Surface Geology by Rollin D. Salisbury; Pt. II, Preliminary Report on the Cretaceous and Tertiary, W. B. Clark, with a geological map of portions of Monmouth and Middlesex Counties, scale 1 mile to the inch. Lists of the invertebrate fossils are given for the Lower Marl, Middle Marl, Upper Marl, and Shark River Marl beds, and Heilprin's list of the Neocene fossils. A chapter is devoted to discussing the origin of Greensand, and three plates of colored illustrations of the mode of formation of Glauconite grains are reproduced from the Challenger Report on Deep Sea Deposits. Part III, is on the Water supply and Water power by C. C. Vermeule and is accompanied by a map of the state. Part IV, Artesian wells of southern New Jersey by Lewis Woolman. V. Notes on Sea Dikes of the Netherlands and Reclamation of the Lowlands of the Netherlands by the state geologist. W.

4. *Elementary Paleontology for geological students*; by Henry Woods, B.A., F.G.S. pp. 222, small 8vo, 1893. (Cambridge University Press, London).—This little hand-book places before the British geologist a concise account of the chief characters of the hard parts of invertebrates, sufficient for the recognition and the classification of fossils into their proper class, order and sub-order, and for some of the more important genera brief diagnoses of their characters are given and the geological range of each. Except that the subdivision of the geological systems are in terms of British geology, the book will be a useful one to the American geologist who is chiefly interested in identifying the age of rocks by their fossils.

5. *Geology of Boston Basin*; by Wm. O. Crosby. Vol. i, Part I, Nantasket and Cohasset, 177 pp., 8vo. (Occasional Papers Boston Society of Natural History, IV).—This is a contribution to the detailed structural geology of Eastern Massachusetts illustrated by maps and numerous figures and sections. A chapter is included on the microscopic examination of the newer eruptive Rocks of Nantasket by Geo. P. Merrill. W.

III. Miscellaneous Scientific Intelligence.

1. *The Wilder quarter-century Book.*—A collection of original papers dedicated to Prof. B. G. Wilder at the close of his 25th year of service in Cornell University by some of his former students (D. S. Jordon, Mrs. A. B. Comstock, J. H. Comstock, E. R. Corson, L. O. Howard, Theob. Smith, W. C. Krauss, Mrs. S. P. Gage, H. M. Biggs, P. C. Branner, Y. A. Moore, G. S. Hopkins, P. A. Fish, W. R. Dudley, S. H. Gage). 8vo, pp. 493, 1893.

The articles are original investigations, in many cases beautifully illustrated, in Anatomy, Histology, Bacteriology, Pathology, Embryology, Botany, and Geology; some of them studies of problems of Evolution. Prof. J. C. Branner (Leland Stanford University), contributes valuable observations upon an Erosion in the hydrographic basin of the Arkansas River above Little Rock, Ark. From observations extending from Oct. 1887 to Sept. 1888, it is estimated that the amount of material carried past Little Rock by the river in one year is 28,299,929 tons, not including the mud and sand pushed along the bottom. At this rate of transportation it is estimated that the Arkansas River would remove an average of one foot from its total hydrographic basin in 9433 years.

Prof. J. H. Comstock (Cornell University) contributes a suggestive article on Evolution and Taxonomy, in which a minute comparison of the venation of the wings of insects is made the basis of their classification and of determining their genetic relations and evolution.

Prof. S. H. Gage (Cornell University) discusses the habits and structure of the Lampreys of the fresh water lakes of New York, assumes that the lake Lamprey is a landlocked species and recent offshoot from the true anadromous sea Lamprey. In order to account for this mode of origin the hypothesis is advanced that the ancestors of the Cayuga lake Lamprey were spawn deposited by the sea Lamprey which ascended the Susquehanna River at the geological time when Cayuga Lake emptied through it to the Atlantic; that they were landlocked by the opening of a lower exit for the waters through the Mohawk and retreat of the glacier northward, and then became adjusted to completely fresh water habitat. W.

Obituary.

Dionys Stur, the veteran geologist and paleontologist of Vienna, and late director of the K.K. geologische Reischsanstalt of Austria, died at Vienna October 9th, 1893.

John Tyndall, the famous physicist, whose lucid and graceful style has made the reading public familiar with many of the abstruse problems of modern science, died at Haslemere, England, on December 4th, 1893, age 73 years.

Erratum.—On page 54, line 14, read *in* for *to*.

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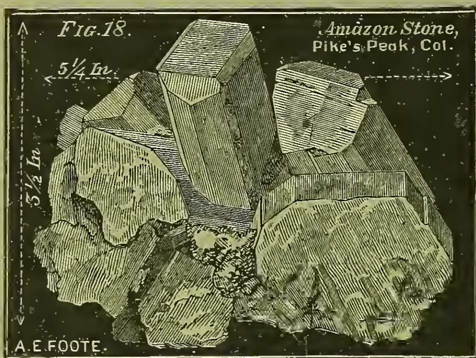

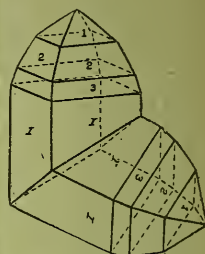

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Amateur's size, 2¾ x 2 in.	..	...	...	10 00	20 00	45 00
High School or Academy size, 2½ x 3½ in., Shelf Specimens	...	...	...	25 00	50 00	125 00
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AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. VII.—*On the Chemical Composition of Staurolite, and the regular arrangement of its Carbonaceous Inclusions*; by S. L. Penfield and J. H. Pratt.

Historical.—In the early analyses of staurolite, especially those of Jacobson* and Rammelsberg,† a great variation was found in the chemical composition, especially in the amounts of silica, which varied all the way from 27 to 50 per cent. The iron oxide, moreover, was regarded by some investigators as ferric, by others as ferrous, while still others considered that it existed in both states of oxidation.

In 1865 Lechartier‡ observed that pulverized staurolite from Brittany and Bolivia, when examined with the microscope, showed both brown and colorless grains. On treatment with hydrofluoric acid, it was found that the colorless ones dissolved, while the staurolite was very slightly attacked. Furthermore, material purified by this treatment was found to be nearly uniform in specific gravity and gave amounts of SiO_2 varying from 28–29 per cent, agreeing with the purest staurolite from St. Gothard. He also proved that water was an essential constituent of the mineral.

In 1872, von Lasaulx§ showed, from a microscopic examination of staurolite from various localities, that all crystals are more or less impure from mechanical admixtures, especially of

* Pogg. Ann., lxii, p. 419, 1844 and lxviii, p. 414, 1846.
† Pogg. Ann., cxiii, p. 599, 1861.
‡ Bull Soc. Chemique, iii, p. 378.
§ Min. Mittheilung, 1872, p. 173.

quartz, while garnet, cyanite, magnetite and mica were also observed. These inclusions of quartz, amounting sometimes to 30–40 per cent of the total weight of the crystal, account for the great variation of the silica percentages in the older analyses.

In 1873 Rammelsberg* reëxamined the exceptionally pure staurolite from St. Gothard and also the impure material from Pitkäranta and Brittany, in which he had previously found over 50 per cent of silica. After purifying these latter by treatment with hydrofluoric acid, only from 29 to 30 per cent of silica was found and the analyses agreed with that of the St. Gothard mineral. From these analyses he deduced the formula $H_2Fe_3Al_{12}Si_6O_{34}$, the iron being regarded as ferrous and replaced in part by magnesia.

In 1885 Friedl† investigated carefully selected material from St. Gothard and Tramnitzberg in Mähren, which by examination with the microscope had been found to be free from foreign inclusions. From the results of his analyses he deduced the formula $H_4Fe_6Al_{24}Si_{11}O_{66}$. In the same year Coloranio‡ analyzed the St. Gothard staurolite, which had been carefully selected and digested with hydrofluoric acid, the formula deduced by him being $H_2Fe_2Al_{12}Si_5O_{31}$.

It is interesting to note the variations in the proposed formulæ, each investigator in turn finding a smaller amount of silica as shown below, where the formulæ of Rammelsberg and Coloranio have been doubled for more ready comparison.

Rammelsberg	$H_4Fe_6Al_{24}Si_{12}O_{68}$
Friedl	$H_4Fe_6Al_{24}Si_{11}O_{66}$
Coloranio	$H_4Fe_4Al_{24}Si_{10}O_{62}$

From a consideration of the analyses of Friedl and Coloranio Groth§ concludes that staurolite has a still simple formula and suggests a basic orthosilicate $(AlO)_4(AlOH)Fe(SiO_4)_2$.

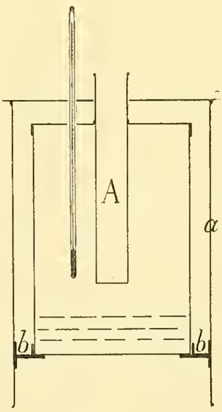
Selection and preparation of material for analysis.—In the present investigation, material of exceptional purity was selected from the four following localities: St. Gothard, Switzerland; Windham, Maine; Lisbon, New Hampshire and near Burnsville, North Carolina. The material from the first of these is too well known to need special description. Some crystals from the Brush collection were available. At Windham, Maine, it occurs in crystals measuring up to 25^{mm} in diameter, imbedded in mica schist, as represented by an excellent suite of specimens in the Brush collection. This has

* Zeitschr. Deutsch. Geol. Gesell., xxv, p. 53.
† Zeitschr. Kryst., x, p. 366.
‡ Bull. Soc Chemique, xliv, p. 427.
§ Tabellarische Uebersicht der Mineralien, 1889, p. 104.

never been previously analyzed. The material from Sugar Hill in Lisbon, N. H., was collected in the summer of 1893 by Prof. G. J. Brush. As observed by him extensive ledges of gray, staurolitic mica schist occur, extending several miles north from Pearl Lake, better known as Mink Pond, and including the ledges on Garnet Hill and Cowen Hill. In the ledges on Cowen Hill unusually large and fresh crystals are found, measuring up to 115^{mm} long by 40^{mm} broad. Thin sections of these crystals revealed the fact that they are remarkably free from inclusions of quartz and garnet, which are so common in staurolite, but they contain carbonaceous material arranged in certain definite planes, as described later. The staurolite from near Burnsville was collected by the writers in the summer of 1892, while engaged in work for the North Carolina Geological Survey. It was found at and near a prospect pit on the property of Mr. D. M. Hampton, which had been dug in exploiting for iron ore. The associated minerals are magnetite, menaccanite and corundum. The staurolite occurs in crystalline aggregates, often intimately associated with the iron ores.

In the preparation of material for analysis the carefully selected crystals were pulverized and sifted to a uniform grain. In the case of the North Carolina mineral the magnetite and menaccanite were removed by means of an electro-magnet. In order to separate a powder of uniform specific gravity the use of fused silver nitrate, which can be diluted with potassium nitrate was resorted to, as recommended by J. W. Retgers.* It was found convenient to use a double walled, cylindrical, copper air bath, shown in section in the accompanying figure. The outer cylinder *a* stands on legs which are not represented. The inner bath is supported by brackets, *b*, and is provided with several perforated discs near the bottom, which serve to disseminate the heat of the lamp. The well *A* holds a test tube containing the silver nitrate, which can readily be kept in a state of fusion and at a constant temperature for any desired length of time; this latter condition being very essential in order to avoid circulating currents. The fusing point of silver nitrate is 198° C. but the temperature which was found most convenient for work was about 250° C. The specific gravity of fused $AgNO_3$

1.



* Jahrb. f. Min., 1889, ii, p. 190.

is about 4·1 which can be lowered by addition of KNO_3. The fused salt is a clear mobile liquid, through which the particles of mineral move freely, and separations can be made in this as accurately as in any of the heavy solutions. On cooling, the fusion solidifies to a cake with the heavier and lighter portions at the bottom and top respectively. The test tube readily breaks away from the fused mass, the cake can be cut in two and the minerals separated by dissolving the nitrates in water. The latter can be reclaimed by evaporating the solutions to dryness on a water bath and finally fusing. By eliminating the heavier and lighter portions and repeating the separation remarkably pure products were obtained, of nearly uniform specific gravity. The manipulations are very simple and the results extremely satisfactory. A preliminary experiment that was made showed that staurolite does not suffer any decomposition or loss in weight when exposed to a temperature of 250° C. The separated material, when examined with the microscope, was found to be homogeneous and very free from visible inclusions.

Method of analysis.—The silica and bases were determined by well known methods. The evaporations were carried on in platinum, the purity of the silica tested by evaporation with hydrofluoric acid and account taken of the small quantity of silica carried along and weighed with the sesquioxides. Especial pains was taken in the determination of ferrous and ferric iron. The very finely pulverized mineral was treated in a small platinum bottle with a mixture of strong hydrofluoric and sulphuric acids and boiled vigorously for about twenty minutes, the neck of the bottle being covered by a cone of platinum foil. The contents of the bottle were then diluted with cold, boiled water, washed into a casserole and titrated with potassium permanganate. Preliminary experiments were made by treating known weights of ferrous sulphate in the same manner and it was found that no appreciable oxidation from the air took place. As the staurolite is very slowly attacked by hydrofluoric acid only a portion in each experiment went into solution. After titration, the insoluble portion was filtered off and the filtrate evaporated in a platinum dish till all the hydrofluoric acid was expelled. After diluting, the iron was reduced by hydrogen sulphide, the excess of the latter removed by boiling and the total iron determined by means of potassium permanganate. The determinations give the ratio of ferrous to ferric iron in that portion which had been dissolved by the hydrofluoric acid, and the total iron in the mineral having been previously found in that portion used for silica and bases, the percentages of ferrous and ferric iron are readily calculated. Direct determinations of water were made in all cases, as loss by ignition would naturally give too low results, owing to the oxidation of the ferrous iron.

Analytical results.—The results of the analyses are given below, together with the specific gravity determinations which were made very carefully by means of the pyconometer.

St. Gothard, Switzerland.

Specific gravity = 3·748.

	I.	II.	Average.
SiO_2	27·80	27·65	27·73
Al_2O_3	53·23	53·35	53·29
Fe_2O_3	2·83	2·83	2·83
FeO	11·21	11·20	11·21
MnO	·63	·44	·53
MgO	1·77	1·85	1·81
H_2O	2·19	----	2·19
			99·59

Windham, Maine.

Specific gravity = 3·728.

	I.	II.	III.	Average.
SiO_2	27·81	27·88	----	27·84
Al_2O_3	54·44	54·51	54·36	54·46
Fe_2O_3	2·81	2·90	2·80	2·83
FeO	10·52	10·85	10·44	10·60
MnO	·59	·62	·56	·59
MgO	1·83	1·87	----	1·85
H_2O	2·24	----	----	2·24
				100·41

Lisbon, New Hampshire.

Specific gravity = 3·775.

SiO_2	27·81
Al_2O_3	54·09
Fe_2O_3	2·76
FeO	12·48
MgO	1·92
H_2O	1·70
	100·76

Burnsville, North Carolina.

Specific gravity = 3·773.

	I.	II.	III.	IV.	Average.
SiO_2	27·80	27·65	27·59	27·77	27·70
Al_2O_3	53·09	53·30	----	53·27	53·22
Fe_2O_3	4·81	4·81	4·83	4·85	4·82
FeO	9·70	9·68	9·74	9·79	9·72
MnO	·27	·38	·33	·36	·34
MgO	2·64	2 65	2·70	----	2·66
H_2O	1·99	1·96	----	----	1·97
					100·43

For a better comparison of the above results the average analyses are given below, after recalculating Fe_2O_3 as Al_2O_3, MnO and MgO as FeO and bringing the whole to one hundred per cent.

	St. Gothard, Switz.	Windham, Me.	Lisbon, N. H.	Burnsville, N. C.
SiO_2	27·70	27·60	27·44	27·47
Al_2O_3	55·04	55·75	55·16	55·83
FeO	15·07	14·43	15·72	14·74
H_2O	2·19	2·22	1·68	1·96
	100·00	100·00	100·00	100·00

The ratios in these analyses are as follows:

	SiO_2 : Al_2O_3 : FeO : H_2O	
St. Gothard	·460 : ·540 : ·209 : ·121	= 2·12 : 2·50 : ·967 : ·560
Windham	·460 : ·546 : ·200 : ·122	= 2·11 : 2·50 : ·915 : ·557
Lisbon	·457 : ·540 : ·218 : ·093	= 2·11 : 2·50 : 1·01 : ·430
Burnsville	·458 : ·547 : ·205 : ·109	= 2·07 : 2·50 : ·934 : ·497

The above ratios approximate closely to 2 : 2·5 : 1 : 0·5 which would give the formula $HAl_5FeSi_2O_{13}$, in which the aluminium is partly replaced by ferric iron and the ferrous iron by magnesium and manganese. This is, moreover, the formula suggested by Groth, and, as previously stated, may be written as a basic ortho silicate, $(AlO)_4(AlOH)Fe(SiO_4)_2$ or equally well, $(AlO)_4Al(FeOH)(SiO_4)_2$. The percentage composition required by the formula is the following:

SiO_2	26·32
Al_2O_3	55·92
FeO	15·79
H_2O	1·97
	100·00

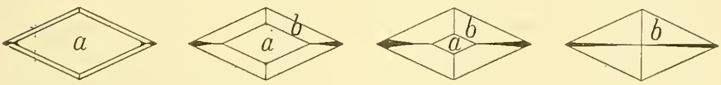
From a comparison of the ratios, or of the analyses, as reduced, with the theory, it will be observed that the silica is uniformly a trifle high, amounting to something over one per cent. This cannot be referred to an analytical error, as the distilled water and reagents were pure, and platinum vessels were used for the evaporations. It was not derived from the agate mortar in which the mineral was ground, for in the analysis of the mineral from Lisbon a steel mortar was used, the powder being afterwards purified by treatment with hydrochloric acid. From the careful selection of nearly pure mineral to start with, and the special precautions that were taken to eliminate all heavier and lighter portions by the specific gravity separation, it was not expected that the staurolite grains would still contain inclusions of quartz, nor were they visible in the fragments, when examined with the microscope; from the results of the analyses, however, it is evident that they were not wholly eliminated. To test this point more carefully, the following experiments were made on some of the finely powdered minerals left over from the regular analyses. After digesting with cold, strong hydrofluoric acid for twelve hours and washing, silica determinations were made, which are given below, along with the determinations from the previous analyses.

	St. Gothard.	Windham, Me.	Lisbon, N. H.
SiO_2 after treatment with HF.,	27·52	27·36	27·15
" from regular analyses....	27·73	27·84	27·81

It will be observed that hydrofluoric acid has removed some silica, but still the percentages are higher than the theory. We should infer, therefore, that quartz is an impurity in the mineral and that it is present as very minute inclusions. If, for example, the inclusions are as fine or finer than the acicular crystals of rutile in quartz, they could not be removed by a specific gravity separation, nor, being enclosed in the staurolite, would they be wholly accessible to the action of hydrofluoric acid. That the formula suggested by Groth is correct is well established by our analyses and, surely, its simplicity is one of the strongest arguments that can be advanced for its acceptance.

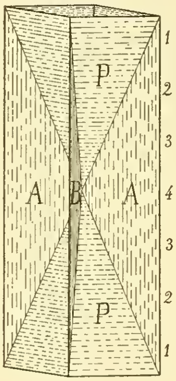
On the regular arrangement of inclusions in staurolite crystals.—In examining orientated thin sections of crystals from Lisbon, N. H., it was observed that they all contained dark inclusions, arranged in certain definite planes, resembling the phenomena so common in andalusite. That the inclusions are carbonaceous material was proved by the fact that, on separating the pulverized mineral by specific gravity, the dark portion was found to be lighter than the clear staurolite, and on igniting it in a current of air, purified by passing over caustic potash, carbon dioxide was abundantly evolved. These inclusions can only be clearly seen in plates ground sufficiently thin to be transparent and can best be studied in basal sections.

1. 2. 3. 4.



Figures 1 to 4 represent the arrangement of the inclusions in plates cut from a simple prismatic crystal 50^{mm} in length by 11^{mm} broad from which eleven basal sections were cut. Near the ends the impurities are arranged as in fig. 1; at the middle the appearance is that of a simple dark cross, fig. 4; while intermediate sections show the rhomb diminishing in size as the sections approach the middle of the crystal, figs. 2 and 3. A number of crystals were cut showing this same phenomena and the symmetrical arrangement of the rhomb and cross was always well marked. The central portions *a* and the outer ones *b*, up to the very edges of the section, are remarkably pure staurolite. The dark bars running parallel to the macro axis broaden as they approach the outer angle of the section and are more regular and better defined than the brachy-diagonal ones. From a series of sections, then, it is evident that each staurolite prism contains two skeleton or phantom pyramids P, outlined by carbonaceous material, whose bases correspond to the basal planes of the staurolite and whose apices join at the center, while from the acute and obtuse pole edges of the

5.



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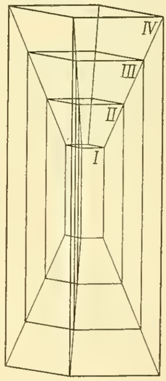

pyramids the inclusions extend as films or fins A and B to the vertical edges of the prism, fig. 5, the numbers at the side of the figure indicating where sections should be cut to give the phenomena corresponding to figures 1 to 4 respectively. Regularly arranged inclusions have previously been observed in staurolite* but apparently they have never been studied from a series of sections from a single crystal.

In seeking for an explanation of these inclusions, it must be borne in mind that staurolite is a mineral occurring essentially in the crystalline schists, which were probably derived from former mud or clay deposits. The crystals were formed by metamorphic agencies, under great pressure, in rocks which

* C. T. Jackson, Alger's Phillips Mineralogy, 1844, p. 112; Dana's Min., Sixth edition, p. 560: S. Webber, Proc. Nat. Institution for the Promotion of Sci., Bull. 2, p. 197, 1842; A. Lacroix, Min. de la France, 1893, p. 11.

were probably quite firm and solid while the staurolite was forming. The crystals, therefore, must have exerted great force in crowding away the surrounding rock material in order to make room for their growth, and we must take into consideration their inability to exclude foreign matter under these conditions, as well as their tendency to take it up. Large crystals have surely resulted from a growth about smaller ones and the beginnings of the crystals under consideration were undoubtedly at the centers, where the apices of the pyramids P, fig. 5, join. In the development of a large crystal from a small one it is imagined that at various points on the crystal faces the growth commences. The addition of particles or of crystal molecules must then advance, forcing foreign matter to one side until the crystal surfaces are complete. The particles, however, which meet to form the edges of the crystals may come together in such a way that they cannot exclude certain foreign materials. It would, moreover, seem reasonable to expect that the more obtuse the angle at which the faces, or the crystal molecules forming the faces, meet to form an edge, the less tendency there would be to hold impurities, while the more acute the edge the greater this tendency would become. If these conclusions are correct, then inclusions would be taken up by the edges, and being largely of carbonaceous material, as in the staurolite under consideration, the result would be that, in the development of a large crystal from a smaller one, the inner prism I, fig. 6, as it enlarged to form II, III and IV, would leave a dark deposit along the paths described by its advancing edges, corresponding to the planes A, B and P of fig. 5. In examining many basal sections it has, moreover, been generally observed that the bars running parallel to the macro-axis, representing the impurities taken up at the acute edges of the prism, are the heaviest, those parallel to the brachy axis are the lightest and in some sections practically fail, while the outlines of the inner rhomb, representing the impurities taken up along the edges of 90° between prism and base, are intermediate as regards the quantity of included matter. Also the inclination of the phantom pyramid P, fig. 5, seems to be wholly dependent upon the relative development of the prism and base during the growth of the staurolite crystal and to be in no way connected with the length of the vertical axis as expressed by the axial ratio $\breve{a} : \bar{b} : \dot{c}$.

The considerations given above seem sufficient to account for the curious arrangements of the impurities in the crystals under consideration and doubtless by a similar explanation the impurities in some andalusite crystals could be accounted for.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, November, 1893.

ART. VIII.—*The Carboniferous Insects of Commentry, France;* by SAMUEL H. SCUDDER.

ALTHOUGH only a very few fossils have yet been fully described or figured from Commentry it has been known for some years that it is the richest locality for paleozoic insects yet discovered. Commentry lies in central France, in the Department of Allier and the horizon is Upper Carboniferous. Mining is there carried on in the open air and this offers the best possible opportunity for recognizing and preserving the fossils.

Besides some brief notices of the richness of the insect fauna at Commentry and the description of some highly remarkable forms, M. Charles Brongniart of the Paris Museum, to whose hands all the material has been entrusted, published a few years ago a summary notice of the entire collection, which, without entering into details, indicated at once the astonishing variety and abundance of forms at this locality.

Within the last two or three days I have had the opportunity through the kindness of M. Brongniart of seeing not only a considerable part of this collection but also the illustrations prepared by M. Brongniart himself from the choicest specimens; illustrations made with a care and exactitude which leave nothing to be desired, and which are now nearly completed after a labor of ten years, so that we may hope soon to be favored with his final work. Leaving the cockroaches out of account, to which M. Brongniart will give his attention later, the number of these illustrations, their variety, the extraordinary character of the insects themselves and their rare perfection, leave not the least room for doubt that when his work appears, our knowledge of paleozoic insects will have been increased three- or fourfold at a single stroke and an entirely new point of departure for the future opened. No former contribution in this field can in any way compare with it, nor even all former contributions taken together. Besides it will offer such a striking series of strange forms as cannot fail to awaken the attention of the least incurious. One may not enter into details, but mention may simply be made of one species, regarded by M. Brongniart as one of the forerunners of the dragon flies, in which the wings have an expanse of considerably more than two feet (or about 70 centimeters) and of which several specimens are preserved. It is a veritable giant among insects.

Paris, Dec. 2, 1893.

ART. IX.—*On the Cæsium-Cupric Chlorides;* by H. L. WELLS and L. C. DUPEE.

As a continuation of the work done in this laboratory on double halogen salts, we have taken up the cæsium-cupric chlorides, which had never been thoroughly investigated. The result has been the discovery of four double salts belonging to three different types. The beauty of the crystals in size and form, and the magnificent and unexpected colors of some of them have made the investigation a very interesting one. The colors of the anhydrous salts, yellow and red, were perhaps not very remarkable since anhydrous cupric chloride is reddish brown, but since water of crystallization is supposed to give green and blue colors to cupric salts, we were considerably surprised to find that a brown salt, $Cs_3Cu_2Cl_7 . 2H_2O$, was hydrous. The color of this hydrous salt is, however, not without analogy, for a garnet-red, hydrous lithium-cupric chloride is known, $LiCuCl_3 . 2\frac{1}{2}H_2O$ according to Chassevant,* or $LiCuCl_3 . 2H_2O$ according to Meyerhoffer;† moreover Engel has described‡ a garnet-red compound $HCuCl_3 . 3H_2O$, and Sabatier's red salt $H_2CuCl_4 . 5H_2O$,§ is similarly exceptional in color.

In this connection, it should be noticed that cupric chloride, when dissolved in water with an excess of cæsium chloride gives a bright yellow solution when it is hot and concentrated. It is well known that solutions of cupric chloride in concentrated hydrochloric acid have the same yellow color.

A list of the formulæ of the salts to be described, with their colors, is given below. The first salt has already been described by Godeffroy.‖

Cs_2CuCl_4	Brilliant yellow.
$Cs_2CuCl_4 . 2H_2O$	Bluish green.
$Cs_3Cu_2Cl_7 . 2H_2O$	Brown.
$CsCuCl_3$.	Garnet-red.

The previously described cupric double halides containing alkali-metals and ammonium belong to two of the types which we have found in investigating the cæsium-cupric chlorides. A list of all those that we have been able to find is given below. Four of the double fluorides have been recently described by von Helmont.¶

* Compt. Rend., cxiii, 646.
† Monatshefte, xiii, 716.
‡ Compt. Rend., cvi, 273.
§ Compt. Rend., cvi, 1724.
‖ Berichte, viii, 9.
¶ Zeitschr. Anorgan. Chem., iii, 115.

2 : 1 Type.	1 : 1 Type.
$(NH_4)_2CuCl_4 . 2H_2O$	$NH_4CuCl_3 . 2H_2O$
$K_2CuCl_4 . 2H_2O$	$NH_4CuF_3 . 2\frac{1}{2}H_2O$
K_2CuF_4	$KCuF_3$
$(NH_4)_2CuF_4 . 2H_2O$	$RbCuF_3$
	$LiCuCl_3 . 2H_2O$

It is to be noticed that this list contains salts which correspond exactly to three of the cæsium compounds, and that the group of 2 : 1 salts with two molecules of water is a conspicuous one.

The salt $Cs_3Cu_2Cl_7 . 2H_2O$ is an interesting one because it is apparently the only known double halide of an alkali metal with a bivalent metal, which has the 3 : 2 ratio.

The cæsium salts were investigated systematically by starting with a solution of 50 g. of cæsium chloride and adding to this from 3 to 5 g. of cupric chloride at a time, evaporating after each addition and observing the products. At the same time another series of experiments was made by beginning with a solution of 50 g. of cupric chloride, adding cæsium chloride to this gradually and operating in the same manner as in the other case. Many additional experiments were made, sometimes with the use of as much as 200 g. of cæsium chloride, and a number of crystallizations were made in the presence of hydrochloric acid of various strengths. It is believed that no double salt capable of existence either in warm solutions or at ordinary temperatures has been overlooked.

The salts were so well crystallized and so distinct in form and color that there was no difficulty in selecting pure products for analysis. The usual precautions, often mentioned in communications from this laboratory, were taken for the removal of mother-liquor from the crystals.

In analyzing the salts copper and cæsium were determined in one portion, the first as subsulphide, the other as normal sulphate. The chlorine was determined in separate portions, by the usual gravimetric method.

Anhydrous 2 : 1 Cæsium-Cupric Chloride, Cs_2CuCl_4:—This salt, which Godeffroy first described, forms magnificent, yellow, orthorhombic prisms, which were often obtained several centimeters in length and several millimeters in thickness. The crystals are usually attached at one end, and they often arrange themselves in parallel position, forming flat clusters. Doubly terminated, short crystals were occasionally observed. Its formation was observed, with 50 g. of cæsium chloride, in the presence of from 5 to about 25 g. of cupric chloride. It can be recrystallized from water if the solution is made so concentrated that crystals form on cooling, but with more dilute solutions one or both of the hydrous salts are usually deposited on standing or on spontaneous evaporation. The following analyses represent different crops made under considerable differences of conditions:

	Found.				Calculated for Cs_2CuCl_4.
Cs	-----	56·33	56·14	56·18	56·42
Cu	13·52	13·45	13·47	13·48	13·46
Cl	30·07	29·99	30·04	30·03	30·12
		99·77	99·65	99·69	100·00

Hydrous 2:1 Cæsium-Cupric Chloride, $Cs_2CuCl_4 . 2H_2O$: —This salt is bluish green in color, and it loses its water very rapidly on exposure to the air with a change of color to bright yellow. It is a well crystallized, transparent salt, but its form was not made out on account of its instability. It is difficult to prepare it, at least at summer temperatures under which this investigation has been made, and we have only occasionally observed it. It is formed by allowing solutions containing nearly the required proportions of cæsium and copper chlorides to evaporate spontaneously. A sample quickly pressed on paper gave the following analysis:

	Found.	Calculated for $Cs_2CuCl_4 . 2H_2O$
Cæsium	51·28	52·40
Copper	12·53	12·50
Chlorine	----	28·00
Water	7·20	7·10

Another sample, which had been exposed to the air too long, gave 6·02 per cent of water, and the dehydrated compound gave the following analysis:

	Found.	Calculated.
Cæsium	56·09	56·42
Copper	13·68	13·46

3:2 Cæsium-Cupric Chloride, $Cs_3Cu_2Cl_7 . 2H_2O$: —This compound was obtained from solutions of nearly the required proportions of cæsium and cupric chlorides. It usually forms only at ordinary temperatures, and if the solution is too concentrated, one or both of the anhydrous salts will be deposited while it is warm. The salt forms triclinic crystals, often one or two centimeters in diameter. The large crystals are deep brown in color, small ones and fragments are very much paler while the powder is yellow. It is nearly stable at ordinary temperatures, but gradually loses its luster on long exposure. All the water goes off readily at 100°. The following analyses of separate crops were made:

		Found.		Calculated for $Cs_3Cu_2Cl_7 . 2H_2O$.
Cæsium	----	49·36	48·96	49.23
Copper	15·68	15·90	15·74	15·67
Chlorine	30·84	29·90	30·69	30·66
Water	4·22	4·38	4·41	4·44
		99·54	99·80	100·00

1:1 Cæsium-Cupric Chloride, $CsCuCl_3$:—This is formed under wide variations of conditions, up to the point where the solution is saturated with cupric chloride. It can be recrystallized from water. It forms slender hexagonal prisms terminated by pyramids. The color is a deep garnet-red, and all except very slender crystals appear black by reflected light. The following analyses of separate products were made:

		Found.		Calculated for $CsCuCl_3$.
Cæsium	43·67	-----	43·58	43·89
Copper	21·16	21·17	21·06	20·96
Chlorine	35·25	35·22	35·00	35·15
	100·08		99·64	100·00

Sheffield Scientific School, September, 1893.

ART. X.—*On the Cæsium-Cupric Bromides*; by H. L. WELLS and P. T. WALDEN.

WE have made a systematic investigation of the cæsium-cupric bromides, following the plan, described in the preceding article, which was used for the corresponding chlorides. Although the work has been very thorough, we have found only the following two salts:

Cs_2CuBr_4 and $CsCuBr_3$.

These salts correspond to the two common types of cupric double halides. The fact that no hydrous salts could be obtained was unexpected, because it has been pointed out by Remsen* in the case of certain double halides, and it has been observed by one of us in the case of the alkaline-lead halides,† that the tendency to combine with water seems to increase with the atomic weight of the halogen. The fact that hydrous

* Am. Chem. Jour., xiv, 88. † This Journal, xlvi, 37.

double chlorides of cæsium and copper exist, while no corresponding bromides were obtained indicates that the rule does not apply in all cases.

2 : 1 Cæsium Cupric Bromide, Cs_2CuBr_4:—This compound forms opaque, black crystals having a greenish tint. The powder is black. In form and habit it resembles the corresponding chloride and is evidently orthorhombic like that salt. Elongated prisms, usually not over 5 to 10^{mm} in length, commonly occurring in groups in parallel position, were observed where an excess of cæsium bromide was used. When the proportion of cupric bromide was increased, small short crystals made their appearance.

With 50 g. of cæsium bromide the compound is formed in the presence of from 5 to about 70^{g} of cupric bromide. The range of conditions under which it is formed are considerably wider than in the case of the corresponding chloride.

Of the analyses given below, A, B, C, D and E represent a series of preparations in which copper bromide was gradually increased from 5^{g} in A to 46^{g} in E, while the cæsium bromide remained constant at about 50^{g} and the volume increased from 100^{cc} in A, to 150^{cc} in E. The sample F was obtained by recrystallizing the salt from water, while G resulted from recrystallizing $CsCuBr_3$.

	Cs.	Cu.	Br.	
A	40·80	9·46	49·38	= 99·64
B	----	9·68	----	
C............	40·75	9·74	48·97	= 99·46
D............	40·88	9·69	48·95	= 99·52
E............	----	9·78	49·40	
F............	41·11	9·66	----	
G............	----	10·00	----	
Calculated for Cs_2CuBr_4	40·96	9·77	49·27	= 100·00

1 : 1 Cæsium-Cupric Bromide, $CsCuBr_3$.—This salt forms short, hexagonal crystals which are strung together end to end. They are dark and opaque, giving a bronze-colored reflection, while their powder is nearly black. When recrystallized from water the compound gives the 2 : 1 salt, thus differing from the chloride. It was obtained from a solution containing 50^{g} of cæsium bromide and 70^{g} of copper bromide with sufficient water to form a volume of 200^{cc}, and it continued to be produced as cupric bromide was added until the solution became saturated with that compound.

The following analyses were made of separate preparations which were obtained under wide variations of conditions.

	Found.				Calculated for $CsCuBr_3$.
Cs	29·93	29·09	....	30·43	30·48
Cu	14·72	15·09	14·73	14·81	14·53
Br	55·09	54·96	....	64·96	54.99
	99·74	99·14		100·20	100·00

Sheffield Scientific School, September, 1893.

Art. XI.—*On the Cæsium-Cuprous Chlorides;* by H. L. Wells.

The salts to be described were prepared by heating solutions containing cæsium chloride and cupric chloride with copper wire, and sufficient hydrochloric acid to prevent the formation of basic salts; then, after the copper in solution was chiefly in the form of cuprous chloride, cooling to crystallization.

When the solutions were dilute, cæsium chloride being in in excess, very slender white prisms were obtained under wide variations of conditions. The crystals became yellowish while being dried with paper, but they were apparently nearly stable in the air when dry. It was found that the salt was decomposed by water. Two different products were analyzed.

	Found.		Calculated for $CsCl . Cu_2Cl_2$.
Cæsium	36·93	36·36	36.29
Copper	34·33	34·17	34·64
Chlorine	28·95	28·87	29·07

The results show that the formula $CsCu_2Cl_3$ belongs to this salt.

On using more concentrated solutions, also with an excess of cæsium chloride, thin, rectangular, colorless plates were produced, sometimes 10 or 20^{mm} in diameter. The range of conditions under which this salt is produced is wide, and large crops of it are easily prepared. As the concentration of the cæsium chloride solutions was increased the same compound appeared in the form of blade-like crystals with pointed ends. By dissolving this salt in water the previously described compound is produced by crystallization. The surface of the crystals becomes yellow on drying, but when dry it appears to be very stable. The first two analyses represent separate crops of the rectangular plates, the third a crop of the blade-like crystals.

	Found. I.	II.	III.	Calculated for $3CsCl . Cu_2Cl_2$.
Cæsium	56·81	56·66	56·84	56·72
Copper	17·95	17·89	17·84	18·05
Chlorine	25·03	25·08	25·13	25·23

It is evident that this salt has the formula $Cs_3Cu_2Cl_5$.

With nearly or quite saturated cæsium chloride solutions containing comparatively little cuprous chloride, prismatic crystals are formed on cooling. The crystals are very pale yellow in color and their luster is less brilliant than that of the preceding compound. Crystals having a diameter of two or three millimeters and a length of several centimeters were sometimes observed. This salt forms under very narrow limits of conditions and it is very difficult to obtain it free from the preceding salt, and especially from cæsium chloride which usually crystallizes with it when the conditions are right for its formation. After a great many trials three crops which were satisfactory were obtained for analysis. The third analysis represents crystals which were picked out of a solution one at a time and separately pressed between smooth filter-papers. All the preparations were carefully examined under the microscope and were evidently pure.

		Found.		Calculated for $6CsCl . Cu_2Cl_2 . 2H_2O$.
Cæsium	64·77	65·07	64·09	64·10
Copper	9·38	9·42	10·04	10 20
Chlorine	22·70	22·83	---	22·81
Water (difference)	3·15	2·69	3·14	2·89

The analyses show that the salt has the formula $Cs_3CuCl_4 . H_2O$.

The previously described cuprous double halogen salts, with the new cæsium salts for comparison, are given below:

Cæsium Salts.	Previous Salts.
$CsCl . Cu_2Cl_2$	$4NH_4Cl . 3Cu_2Cl_2$
$3CsCl . Cu_2Cl_2$	$2NH_4I . Cu_2I_2 . H_2O$
$6CsCl . Cu_2Cl_2 . 2H_2O$	$4KCl . Cu_2Cl_2$
	$4NH_4Cl . Cu_2Cl_2$

It is remarkable that there is no correspondence in type between the cæsium compounds and the others, and that such a variety of types appears to exist. The formula $4NH_4Cl . 3Cu_2Cl_2$ may be considered somewhat doubtful on account of its complex ratio, and because with one-fourth less ammonium chloride it would correspond to the first cæsium salt.

The salt $Cs_3Cu_2Cl_5$ is noticeable on account of its rather complex formula and because it has the same ratio of cæsium to copper as the previously described cupric salt $Cs_3Cu_2Cl_7 . 2H_2O$. Since the latter has a ratio that is unique among the bivalent metal double halogen salts, a close structural relation between the two compounds is suggested.

These cæsium-cuprous chlorides show a decided lack of conformity with Remsen's law* concerning the composition of double halides. Two out of three of them fail to correspond to the law, while one of these, instead of not containing more than one CsCl for one CuCl, actually contains three times as much cæsium chloride as Remsen's law allows.

My thanks are due to Mr. L. C. Dupee, who prepared and analyzed one sample of the salt $CsCu_2Cl_3$

Sheffield Scientific School,
New Haven, Conn., September, 1893.

ART. XII.—*The Harrisburg Terraces;* by HARVEY B. BASHORE, West Fairview, Pa.

IN 1889 I began a study of the gravel deposits at Harrisburg, Pa.; at the suggestion of Prof. G. F. Wright, I made special effort to discover, if possible, some facts which might be of value in settling the much-debated question as to the origin of the deposits in this valley; and I shall, in this paper, confine myself to the statement of facts only, leaving all theorizing to others.

The river at this point flows between high slate hills, the distance between which is generally one mile but in the neighborhood of Harrisburg the interval is increased to a mile and a half, and this additional one-half mile, on the eastern side has been filled by successive deposits of gravel and clay, forming the plane for the building of the city of Harrisburg.

The deposit, which is about one-half a mile wide and between two and three miles long, consists of four terraces, differing somewhat in their characteristics: it is necessary, therefore, to describe each separately. The first and lowest terrace is about 28 feet above low water (river 290 A. T.): it is composed of a fine brick-making clay and contains many bowlders of large size (4–5 feet in diameter), mostly of local origin, composed of sandstone and conglomerate from the mountains beyond; this deposit is distinctly marked on both sides of the river and forms the gradient for the public highways: in most cases, too, it is the bed of the railways up and down the river.

*Am. Chem. Jour., xi, 296; xiv, 85.

The second terrace, 46 feet above the river, is not very plainly marked: one of the city streets however was originally graded from its level. The bed is composed of gravel, some granite and gneiss,* and contains large and small bowlders all rounded, and is capped by two or three feet of fine loam.

The third terrace, 90 feet above the river forms the plane for two of the city streets (Fifth and Sixth). This deposit, which gives a good perpendicular exposure of 15 feet, is composed of fine gravel and contains some granite and gneiss; a few rounded bowlders, two to three feet in diameter appear in it and the whole deposit is capped by four or five feet of fine clay: almost all the bowlders occur in the gravel.

The three terraces just described are placed in the interval between the river and the hill, but the highest or fourth terrace is situated on the brow of the hill itself.

The fourth terrace, 130 feet above the river—420 A. T.—is well exposed by the cutting of several streets and shows the gravels resting upon the slate. The deposit is about 20 feet thick and is capped by fine brick clay. The gravel bed, especially at its upper part, presents a peculiar white appearance compared to the overlying clay—the line of junction between the gravel and clay being very distinctly marked. The gravel contains considerable quartz, some granite and gneiss pebbles, but none were found more than two or three inches in diameter; some rounded bowlders, two to three feet in diameter occur in the deposit, mostly in the gravel, although several were found in the clay. Above this joint, 420 A. T., on the eastern side of the river there was not found any further evidence of water action although careful search was made over the adjoining hills: on the western side, however, as I stated in a former report to the State Geologist of Pennsylvania, I found, on a slate hill at 148 feet above the river, a number of small rounded pebbles, one of which was of gneiss; it is possible, however, that their transportation was due to human agency. I may add that the mountains both north and south of the city were carefully searched for "shore-lines" but the result was negative in every instance.

West Fairview, Pa., Nov. 1, 1893.

* Granite and gneiss do not occur in the Susquehanna Valley above this point except as transported rock from regions farther north.

ART. XIII.—*Additional Species of Pleistocene Fossils from Winthrop, Mass.*; by RICHARD E. DODGE.

ANY note concerning the discovery of additional species of shells in the drift of the last Glacial period is interesting because we thus obtain a fuller conception of the richness and distribution of the oceanic fauna previous to the advent of the ice sheet. For that reason, I venture to note here the finding of a few additional species in the drumlin in Boston Harbor, locally known as Winthrop Great Head. This drumlin is the most important of several in Boston Harbor that have furnished fragments of shells, from time to time, for of the twenty-six species thus far found, it has given us twenty-three, and the others together but three. Furthermore only three of the species found in this locality have been found in the other drumlins of the harbor.

The first note of the finding of fragments of shells, in more or less perfect condition, in the clayey till of Winthrop Great Head was made by Dr. Stimpson,* who reported the following species: *Balanus crenatus* Brugière, *Chrysodomus decemcostatus* Say, *Tritia trivitatta* Adams, *Urosalpinx cinerea* Stimpson, *Mya arenaria* Linné, *Ensatella americana* Verrill, *Mactra solidissima* Chemnitz, *Venus mercenaria* Linné, *Cyclocardia borealis* Conrad, *Astarte undata* Gould, *Astarte castanea* Say, *Mytilis edulis* Linné, *Modiola modiolus* Turton, *Ostrea virginiana* Lister. In 1888 Mr. W. W. Dodge† reported the finding of species of the genera *Lacunea*, *Tapes*, and *Cardium*. In 1888 Mr. Warren Upham, in a paper before the Boston Society of Natural History,‡ from which the above list has been taken, reported *Cliona sulphurea* Verrill, from the same locality.

So far as I can find out, these are the only species reported from this locality up to the present time. Other drumlins in the harbor have furnished occasional specimens of the following additional species: *Lunatia heros* Adams, *Saxicava arctica* Deshayes, *Pecten islandicus* Chemnitz.

Of the specimens mentioned above, the only ones that are at all common in the drift are *Venus mercenaria*, *Cyclocardia borealis* and *Cliona sulphurea*. The other specimens are rare and very fragmentary, so that identification is frequently difficult if not impossible.

To the above list I wish to add the following, which I have been fortunate enough to find during recent short trips to the

* Proc. Bost. Soc. Nat. Hist., vol. iv, p. 9.
† This Journal, III, vol. xxvi, p. 56, July, 1888.
‡ Proc. Bost. Soc. Nat. Hist., vol. xxiv, pp. 127–141.

cliff at Winthrop: *Lunatia groenlandica* Stimpson, *Scapharca transversa* Adams, *Buccinum undatum* Linné, *Ilyanassa obsoleta* Stimpson. Of the above, all but the last are undoubtedly new discoveries. The last has however been noted by Verrill* as coming from this locality, having been discovered by Dr. Stimpson. I have examined all the references I could find to discover where Dr. Stimpson has announced the finding of the species, but without success. Even in the article,† in which he changes the generic name from Nassa to *Ilyanassa*, he makes no mention of its occurring as a fossil either in this locality, or anywhere along the shore of Massachusetts Bay.

I have also found a small fragment of shell, the species of which I have thus far been unable to have determined. Prof. Verrill, to whom the specimen was referred for identification, states in a letter, "I have compared it with all similar living shells of our Eastern Coast fauna and find nothing just like it in sculpture. It probably belongs to the *Veneridæ* or *Lucinidæ*, but there is too little of it to be sure even of the family. It may be Tertiary or even Cretaceous, for I have had specimens of soft limestone bowlders from the drift of Cape Cod containing well preserved Cretaceous shells." Mr. J. B. Woodworth has shown me some specimens which he has collected from the Miocene of Squibnocket, Martha's Vineyard, which this fragment resembles in a marked degree. If this species should prove to be not now known on the Atlantic seaboard, it would be the first instance, as far as I know, of a species found as a fossil in the Glacial drift but not now living. Mr. Upham says:‡ "All these species which remain from the marine fauna that existed before the formation of the last ice sheet, are found living at the present time in the adjoining waters of Massachusetts Bay." *Venus mercenaria* however is more truly a southern form and is only found scatteringly in the Bay. It is thus very similar in its distribution to *Scapharca transversa*, which is not found north of Cape Cod. Finding thus this species as a fossil in Massachusetts Bay, which now lives only in the warmer waters south of Cape Cod, we have a strong bit of additional evidence to help prove that the waters of Massachusetts Bay, just previous to the advent of the last ice sheet, were somewhat warmer than at present, an hypothesis which is now pretty generally conceded to be true.

Recent discoveries of Post-glacial fossils from dredgings in Boston Harbor, noted by Mr. Upham,§ show us conclusively

* Report upon the Invertebrate Animals of Vineyard Sound, U. S. Fish Commission Report, 1871–72.

† Am. J. Conchol., vol. i. p. 61.

‡ Proc. Bost. Soc. Nat. Hist., vol. xxiv, p. 134.

§ Proc. Bost. Soc. Nat. Hist., vol. xxv, pp. 305–316.

that the waters immediately at the close of the Glacial period were warmer than at present. Of twenty-five species thus far reported from the dredgings, many of which are the same as in the Glacial drift, fourteen are distinctly southern in their distribution, according to Mr. Upham. Thus, as far as we can determine by the testimony of fossils, the ocean waters of Cape Cod both immediately before the advance of the ice sheet and just after the retreat were warmer than at present. Whether these changes in temperature were due to the presence or absence of melting glaciers in the neighboring oceanic waters or whether they were due to slight oscillations of land, it is difficult to determine. The existence of elevated shore lines and fossiliferous clays to the north of Massachusetts Bay, noted by Prof. Shaler and others, would seem to show that the changes of temperature were due to oscillations of the continent which at one time gave access to the warmer southern waters into Massachusetts Bay, and at others shut them out more than at present.

Inasmuch as the direction of ice movement during the drumlin-making stage must have been from a generally northwesterly direction in this region, as shown by the striæ, the fragments of shells now found in the drumlins must have occupied a position, at the beginning of the ice advance, somewhere to the northwest of the spot where they are now found, otherwise they could not have been taken up and carried by the ice in such a manner as to be deposited in their present position. As I have already stated, all these species of fossils but two are now found living in the waters of Massachusetts Bay, and if the necessary conditions for their existence have always been the same, it would appear that, at the time the ice sheet overrode this portion of the coast, there must have been somewhere in the western portion of Boston Harbor, probably near the present estuary of the Charles River, an extensive colony of shells of many different species. Yet we find no evidence, other than the shells themselves, of the existence of any such colony of invertebrates, in the localities I have noted. It would seem very strange however that all the more important discoveries of pleistocene fossils from the drift of this region have been from one drumlin, while the several drumlins in the immediate vicinity have furnished but a very few species. It is especially difficult to understand why we find but four different species of fossils in the large drumlin, called Grover's Cliff, about a mile to the northeast of Winthrop Great Head, while Great Head itself has given us twenty-three species.

It would seem furthermore as if the distance of travel which these fragments underwent must have been considerable, and this for the reason that they are found in the eroded face of the drumlin often at a height of over fifty feet above the present sea level. Even if dead they would not probably have been elevated much above the present level of the sea in their original resting place, when set in motion by the ice sheet, and a somewhat lengthy journey in the ice would seem requisite in order to allow them to have risen so high above sea level as we now find them. In spite however of the long journey, apparently necessary for elevation in the ice, the fragments, with few exceptions, show little evidence of Glacial wear. Mr. J. B. Woodworth has shown me two small fragments of *Venus mercenaria* from the Winthrop Great Head cliffs that still present faint glacial striæ on the inside, yet the shells have not been sufficiently worn to lose their surface markings or the gloss of the interior. The specimens of *Buccinum* and *Ilyanassa* are especially well preserved, being but slightly worn at the apex of the spire and retaining their delicate surface markings.

I found each of these two shells filled with compact till containing small pebbles, and in one case a fragment of the shell of *Venus mercenaria.* If the shell had died in place previous to being taken up by the ice, it might be reasonably expected to retain in its chamber, even to the present time, some of the bottom on which it had lived. Therefore I carefully removed the filling from the outer chamber of the *Buccinum* but failed to find within any other material than clayey till like that in which it was lying when found.

The large number of small fragments of shells scattered through the till in the lower half of the drumlin of Winthrop Great Head would seem to indicate that much of the material of which the drumlin is composed came from the same place as the shells, for we cannot conceive how the onward moving glacier could remove the shells without taking at the same time a large part of the bottom on which the shells were growing. If so, then the materials of this drumlin and of much of our drift, not only represents the amount of bed rock removed by the ice sheet, but such rock waste plus a large amount of the previously accumulated soil, river and shore deposits. It may in this case even include much of the drift deposited by the first ice epoch which has been undergoing secular decay during all of interglacial times. At any rate the physical character of the material in the face of this drumlin seems to indicate the presence of much fine clayey matter, greatly decayed and appearing very similar in nature to the brick clays of Cambridge and Somerville, Mass. These brick clays on fresh exposure present to view innumerable small vertical joints which allow the clay to break up into small cubes. This tendency to break along incipient joint planes appears much more conspicuously in the clays of the drumlins of Boston Harbor than in any of the inland drumlins I have had an opportunity to note in Western Massachusetts and Connecticut. The possible presence of such a large amount of previously eroded material in the deposits laid down during the last stages of the ice age relieves us from considering that a moving continental ice sheet is such a great erosive agent as we are wont to believe it.

Mr. W. O. Crosby,* believes that "possibly as much as one-fourth and quite certainly not more than one-third of the detritus composing the till of the Boston basin was in existence before the ice age, and that the remaining two-thirds or three-fourths must be attributed to the mechanical action of the ice-sheet and its accompanying torrents of water." Comparing this estimate of the amount of erosion by the ice sheet in Boston Harbor with the scant amount of work done by the ice sheet in Western Massachusetts and Connecticut, as shown by the very conspicuous bed rock topography formed in preglacial times and but little affected by the ice advance, the estimate seems to be very large indeed.

The most interesting problem suggested by the presence in our drift of such fossil fragments as I have described is, however, that of the relative positions of land and sea in the different epochs of pleistocene times. For that reason, even the evidence of one small fragment like that of *Scapharca transversa* is important, though it gives us but one small bit of proof of the warmer waters in Massachusetts Bay in the times immediately previous to the last ice age. It only remains in conclusion to say that similar assemblages of pleistocene shells have been found in our glacial drift in other localities, but mainly on the southern shores of New England. The most important discoveries have been those of Desor† and Verrill and Smith‡ from the apparently interglacial beds of Sankaty Head, Nantucket. At this locality more than a score of species have been found, occurring in two distinct beds. The lower beds contain warm water forms and the upper mostly worn fragments of northern forms. On our northern shores no section so rich in pleistocene fossils has as yet been found as that of Winthrop Great Head, although similar deposits have been found by Prof. Shaler at Gloucester, Mass., and by others at different localities on the coast of Maine. The reason for the occurrence of so many different species of fossils in this one drumlin in Winthrop, situated as it is among so many neighboring unfossiliferous drumlins, still remains a mystery.

Harvard University, Cambridge, Mass.

* Proc. Bost. Soc. Nat. Hist., vol. xxv, p. 115–140.
† Quar. Jour. Geol. Soc. Lond., vol. v, pp. 340–344.
‡ This Journal, III, vol. x, 1875, pp. 364–370.

Chas. D. Walcott

Art. XIV.—*The Amount of Glacial Erosion in the Finger-lake Region of New York;* by D. F. Lincoln, M.D., Geneva, N. Y.

[Read before the Am. Assoc. for the Advancement of Science, Madison, August, 1893.]

The Lake-region proper does not extend beyond the Devonian belt; it will, however, be instructive to include in our consideration the closely-related "drumlin-belt" of level country adjacent on the north, which covers the upper Silurian area between Rochester and Syracuse, nearly. Within this region occurs the well-marked, though low, Corniferous escarpment, besides some local escarpments to the south: the Niagara exposures being hardly worthy of that name. Most of the formations are exposed at great numbers of points in brooks, and complete sections across the Devonian are afforded by some of the lakes. Beginning at the north, the formations in ascending order are as follows:*

The Medina sandstone along Lake Ontario is thickly enveloped with drift and lake deposits. Five exposures in the beds of brooks are mentioned by Hall in Wayne County. (Report for the Fourth District, 1843). In the Clinton shales and limestone Hall names twelve exposures, adding that "almost every stream north of the road from Wolcott to Rochester exposes one or more members of this group." The Niagara shale is soft, and forms very gentle slopes. It is exposed, though not deeply cut, in "all the small streams which flow into the lake" (Hall).

The Niagara limestone occupies a tract a mile or two wide, crossing the middle of the lake counties from west to east. Its position is marked by a line of lime-kilns across the country. Little cascades or rapids occur wherever the streams pass from it to the shale. It is characterized by frequent low anticlines, with axis approximately N.–S., the backs of which come within a foot or two of the surface. Broad levels, underlain by sheets of this rock, with only a foot or two of soil, have been observed at Sodus. On the whole, the contour of the landscape is not distinctly affected by this formation.

The Salina formation, being to a great degree composed of weak rocks, is probably excavated and buried more deeply than the others. The Clyde, the present outlet of the Finger lakes, runs through it lengthwise (W.–E.); for several miles west of Lyons its valley is deserted by its wandering occupant; the banks are there 30 feet high exclusive of drumlins, and rock is not exposed.

Distinct evidence in regard to the depth of the drift-covering is less easily had in this formation than elsewhere. The

* For a sketch map of the Lake region, see this Journal, October, 1892.

drumlins are numerous, and intercept the drainage to such an extent that the low grounds between them are largely filled with alluvium, and often swampy. Hall, however, mentions 16 localities where the rock is exposed. A comparatively continuous series of exposures is seen along the line of contact with the next following rock.

The Corniferous limestone makes itself seen in many places along the south side of the Auburn branch of the New York Central railroad. It comes close to the surface at many quarries; and its low escarpment, resembling an old stone wall, west of Geneva, has forced the railway to diverge four miles to the north. Upon this escarpment, a mile south of the New York Central, runs the new line of the Lehigh Valley road, cutting through some low anticlinals of rock resembling those mentioned in the case of the Niagara limestone, and with a similar (N.–S.) axis. Both roads run for some miles west of Geneva over broad levels of Corniferous limestone covered with a little soil and occasionally swampy. The Lehigh road has found it impossible to plant posts in the usual way, and stone-laden cribs are used to support the fences.

With the Corniferous begins the series of exposures belonging to the lake-region proper. In this region no other escarpment of equal development exists. Locally, however, we may name that due to the Tully limestone, a sheet of rock a dozen feet or more in thickness, surmounting the Hamilton group. At its outcrop in the rising land between Seneca and Cayuga Lakes, just north of Ovid, there is a shoulder or upward jog in the landscape, quite well seen at a distance of eight miles. The "basal limestone" (J. M. Clarke), which forms the lowest layer of the Hamilton shale, parting it from the Marcellus, is the cause of the bluff northerly termination of a certain detached hill, four miles south of the outlet of Seneca Lake; the soil is very thin over a large tract, and the coral reef is bare in spots. Many hundreds of little ravines, entering the Finger Lakes from the sides, and cutting through the Devonian series, have made the region classic ground for the collector of fossils. The drift-coating, as shown in these cuts, is usually thin (1–5 feet) at least within a mile or two of the lakes. In many places, however, the delta-terraces are prominent, and where cut through by the railways might mislead the observer's estimate. It is fair to presume that these accumulations of drift were not, for the most part, taken from the general surface, but from those surfaces which have now been converted into ravines and gullies. The general sweep and slope of the country is not towards the ravines, as a rule; the upland contour is broken abruptly by the line of the gorge, and there plunges at an angle of from 20° to 90°. Hence, little general loss of drift has probably taken place through stream-action.

The *general topography* of the district—its hills, valleys, and slopes—furnish important aids to determining the amount of drift. On the whole, these features are formed of rock, veiled under a very few feet of drift. Although the country along the lower (northern) reaches of the lakes is in general level, yet it is not without marked features. The hill of coral limestone just described is one of several, similarly elongated parallel to the lake-axes, and formed of shale. They are described in this Journal for October, 1892. Other hills and ridges may be added to their number. Farther south, towards the neighborhood of the moraine of the second Glacial period, as defined by Professor Chamberlin, the country rises very considerably, forming for the most part a series of broad backs, plateau-like, intersected at short intervals by straight, trough-like valleys, running nearly N.–S. Most of these valleys contain lakes. The moraine is very weak on the high lands, over which it lies in loops bending northward. It crosses the valleys a short distance south of the present lakes, and has evidently determined their position. In the valleys, the accumulations are vast, with extensive overwash deposits southwards towards the Susquehanna, and northwards towards the lakes (?) Over a great part of the rolling uplands it is safe to say that the rock lies within from one to ten feet of the surface. They are in places characterized by rock-flats covered with thin soil; in other parts they undulate in broad clumsy lines, forming certain high hills and a few transverse or E.–W. valleys with rock sides. A good example of the latter is found at Dundee, which lies about ten miles north of a locality named by Chamberlin as belonging to the moraine. The existence of such a valley at such a point is not suggestive of a heavily drift-blocked country. Several other valleys, in similar situations north of the moraine, remain as the last survivals of a topography which is clearly *not post-glacial*; they appear in harmony with the valley system of the Allegheny plateau of western Pennsylvania.

These remarks, however, must be understood as limited to the high lands lying southward; whose topography in fact much resembles that south of the moraine. The lower lands, including the northerly reaches and the troughs of the lakes, produce the impression of a typically glaciated country, with few prominent features. The forms are smooth and flattened, even when demonstrably due to rock-structure. Any long stretch of horizon tends to resemble a line drawn with a ruler. Looking east or west, the sky-line is nearly level; looking north or south we have broad planes inclining to the lakeside.

On the lower levels—say up to 900 feet above tide—a good deal of the land between the lakes is provided with drumlins of moderate size, and of a different aspect from the bolder and larger forms of the parts nearer Lake Ontario. The material of these small drumlins, if spread over their own neighborhood, would not exceed 10 or 20 feet in thickness.

Kames and osars have been observed in three counties, but not with sufficient system to enable an estimate to be offered. It is not believed that the material they contain would add very greatly to the total.

The deepest parts of the lakes may be assumed, with probability, to be nearly free from drift. On the south they are prolonged in alluvial plains, reaching several miles, which may not be all Post-glacial. The northern ends of several lakes also appear to be choked with Glacial deposits. At Geneva several wells have been sunk at the water's edge, passing through gravel, sand, clay, and till, with many large bowlders, and striking bed-rock at 205, and 240 (?) feet. Adjacent drumlins rise to the height of 90 feet. A mile from the lake, at an elevation of 100 feet, the drift is 60 feet thick; half a mile further, on higher ground, shale crops out in several spots. This drift-mass extends six or eight miles to the southward, occupying the width of a mile on the west bank of the lake, and very probably shoaling a corresponding portion of the lake. On the whole, it may be estimated that $\frac{2}{5}$ of the surface of land lying between the Finger Lakes and extending to (but not including) the terminal moraine, is covered with drift, averaging from 1 to 5 feet in thickness. Another $\frac{2}{5}$ may average from 5 to 30 feet. The remainder may be included, for the most part, between 30 and 100.

In close connection with the above study, a question of great interest awaits solution—that of the origin of the trough-like lake-basins. The reader will not fail to recall the diversity of opinion, which has been recently developed by the discussions upon the origin of mountain lakes, in the pages of "Nature" for 1893. It is not my present purpose to enter into this discussion. Certain facts, however, in part new, may well be mentioned here, as deserving to be weighed before we take sides. In part, these favor the theory of deepening by Glacial erosion; in part, that of tilting or differential uplifts, whereby valleys that once ran continuously to the sea have been bent so as to hold water like a spoon. For the sake of simplicity, let us confine the presentation to Seneca Lake, which will serve as a type. Situated in the axis of the system known as the Finger Lakes, this valley has been cut down to a depth considerably greater than either of its neighbors; in addition to which, it is the one about whose rock-contours we have most definite information. We will consider it as incidental to a valley, 58 miles long, running from the flat land at Geneva south to a junction with the Chemung Valley at Elmira; of which valley the lake occupies the northern 36 miles, and the terminal moraine with its dependent deposits occupies the remaining 22 miles.

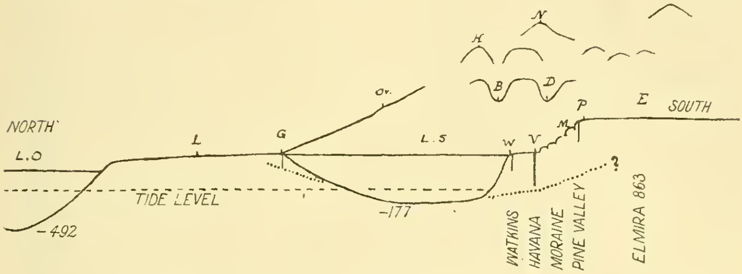

FIG. 1. Section from Lake Ontario southward through Seneca Lake to Elmira. LO, Lake Ontario, bottom 492 below tide level; L, Lyons, 407 above tide level; G, Geneva; O, Ovid, 1061; LS, Seneca Lake, surface 441, bottom —177; H, Hector (summit) 1805; B, Burdette; N, Newfield, 2095; D, Odessa; W, Watkins; V, Havana; M, Moraine; P, Pine Valley; E, Elmira, 863.

The greatest depth of the valley is at and to the south of the middle of the lake, where the bottom lies 150–176 feet below tide. At the north end, the lake comes to an abrupt end, choked with drift and alluvium; the valley also disappears to the eye and is not traceable farther north. The apparent depth of the lake at this part is 40 feet; its true depth is probably not much in excess of 200 feet, as may be inferred from the section (fig. 2) in which the borings are shown to represent two localities, distant 1700 feet in a line at right angles with the channel, and near its probable axis. The lake-level being 441 A. T., the buried channel would be at 241 A. T.

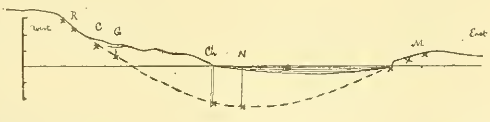

FIG. 2. Section across Seneca Lake at Geneva, from west to east, showing probable depth of buried channel. R, Reservoir; C, Castle Creek; G, Geneva Nat. Gas Spring Co.; Ch, Chase's well; N, Nester's well; M, outcropping of Marcellus shale.

For the part of the valley lying south of the lake the following data have recently been obtained. At the mouth of the "inlet" at Watkins, near the middle of the valley, a well has been driven "by blows from a sledge" 224½ feet in the alluvium. Four miles south, at Havana, a well was sunk at Cook Academy, near the middle of the valley, which passed through 435 feet of sand without reaching rock. Six miles farther south (one mile beyond Millport) a well was sunk by Mr. U. Hall to the depth of 186 (?) feet in sand, without touching rock; the site of the well was near the brook, which has cut its gorge to the depth of 100 feet (estimated) below the level of the drift at that point, which indicates 300 ± feet of drift in all. At Elmira the valley is two miles and a half wide; the Erie road runs near the middle; borings have been made at the Table factory, just west of the road, giving *less* than 200 feet of gravel, and at the Rolling mills, just east of the road, striking rock at less than 60 and 120 feet; while at the Blast furnace, in the same region, I am informed by a former official that their well could not have gone more than 100 feet in depth before striking rock. These data are all that seem at present available. We may therefore assume that the drift deposits of the valley equal or exceed 300 feet in thickness until we approach Elmira, where they probably become less than 200, perhaps less than 100 feet thick. This places the southern end of the valley at 680–780 feet above tide = 850–950 feet (in round numbers) above the deep parts of the lake-floor; the northern end of the valley being about 400 feet above the lake-floor.

In the valley of the Susquehanna, between Wilkesbarre and Bloomsburg, a similar state of inversion has been shown to exist (2d Geol. Rep. of Pennsylvania, G 7). Wilkesbarre is 124 miles down-stream from Elmira; Bloomsburg is 40 miles further. At Wilkesbarre the existing river deposits have been pierced by boring to the depth of 180 and 185 feet before striking rock, showing the existence of a buried bed at 340 feet above tide; while at Bloomsburg the rock-bed is exposed in the stream at a height of 450 feet above tide, giving a tilt of 110 feet in a direction contrary to the present course of the river.

The hypothesis of crust-bending is obviously available to explain such differences of level as the above. It seems to me however, that the arguments for the other side are of great importance. There are three principal ones.

1. The magnitude of the valleys of Seneca and Cayuga Lakes demands an explanation which has not yet been offered. The Seneca valley at its wider and deeper parts greatly exceeds in dimensions that of the Ohio below Pittsburg; this would not be inconceivable, if we supposed both the Susquehanna and the Chemung to have flowed north past Elmira and Geneva Ontario-wards; but it is less easy to account for a second valley, that of Cayuga Lake, parallel with it at twenty miles' distance, and nearly as large as the first. Further, the character of the valleys of these lakes changes in going south to the moraines; they become narrower, and assume the aspect of cols. See fig. 3.

2. A much more important group of objections exists, which may be summed up under the title of Incompatibility of Levels.

a. To the east and west of the Seneca valley, at a distance of 6–12 miles, there run two upland valleys; on the east, that of Cayuta Creek, 26 miles long and half a mile wide; to the west, that of Pine Creek, about half that length. They begin opposite Watkins and run southward. In this situation it is hardly conceivable that a general flexure, capable of affecting the beds both of Seneca and Cayuga Lakes, should fail to affect similarly the valley of these creeks; especially as Cayuta valley lies between the south extensions of Cayuga and Seneca valleys. But in point of fact, this is what has occurred :—the valley of Seneca falls *northward*, its probable bed descending nearly 900 feet in 30 miles (Elmira 700 ± A. T., lake-bottom 176 below tide]. The valley of Cayuta Creek falls *southward*, descending probably 300 feet in 26 miles (and doubtless considerably more, if its rock-bed were uncovered at its lower part). Pine Creek similarly falls 337 feet *southward* in 13 miles from Beaver Dam (1279) to Corning (942). It is of course quite possible that streams should interlock in this way over a divide, flowing in opposite directions for a time. But it is unlikely that a large river (by supposition, the upper Susquehanna) should have run from Elmira north with a descent of 30 feet to the mile for 30 miles. If such were the state of things, a deep narrow gorge with vertical sides would have been produced, extending back at a relatively rapid rate far down into Pennsylvania. The actual outlines of the section of the lake (fig. 3) are absolutely contradictory of this view.

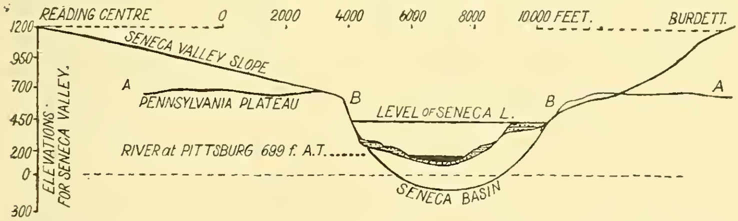

FIG. 3. Combined sections of Seneca Lake and the Ohio River, on the same scale (vertical 4 times the horizontal). The lake is taken near the southern end, on line III of Cornell University map; from Reading Centre east to hill at Burdett. The river (ABBA) is an average section within 12 miles below Pittsburg obligingly furnished by Prof. F. W. Very of Allegheny, Pa. Width of lake 6250 feet; width between the Ohio bluffs (B–B) 7000 feet; width of lake-valley between high points 22,000 feet. Depth of water in lake 540 feet. (The greatest depth is 2 miles north of section = 618 feet.) Depth of Seneca valley, from level of bluffs 800 feet; from level of plateau (Reading Centre), 1400 + feet. Depth of Ohio valley, from plateau at bluffs (B–B), near 500 feet.

2*b*. The incompatibility between the Seneca valley and those of the high land appears further in this: that if they had coexisted, the deeper must have "robbed" the less deep.

The smaller upland creeks above named, lying nearly 1000 feet higher than the Seneca bottom, and distant only 4 or 5 miles, without obstructing elevations of ground, must inevitably have become its tributaries. But not the first step seems to have been taken towards this end. The upland systems were uninfluenced, during their formation, by such an attraction; hence we may infer its non-existence.

3. Probably the most important argument in this direction is drawn from the *absence of side valleys* along Seneca and Cayuga Lakes. In this respect, the lake-scenery presents a remarkable contrast to that of the valleys lying beyond the line of moraine, which are entirely typical in this respect. The contrast is observed immediately on crossing the moraine, e. g. to the south of Havana; still better, along Cayuta Creek. While the latter valleys are notched down to the flood-plain level, every mile or two, the lake-side for stretches of 10–15 miles seems like an artificially smoothed garden-slope.

Professor Chamberlin noticing this, suggests as a probable view, that at least one-half of the depth of the old side-valleys has been lost through the shearing action of the glacier upon the projecting bluffs. The remainder of the effect is due to filling with drift. This is exactly in the direction of the present line of thought. But it seems necessary, in view of certain conditions, to carry this observer's views to a somewhat more radical conclusion. These conditions are the following:

The upper twenty miles of Seneca Lake is bordered by a continuous line of cliff, varying from 20 to 100 feet in height, but presenting only very gradual changes in level. As the coast forms almost a straight line, the inference is clear that no deep incisions exist at that level, or from 500 to 600 feet above the lake-bottom—practically, about half-way up the valley-side, where the side-notches would have made the deepest incisions. These remarks are intended to apply only to such small, but deeply cut notches as would correspond to streams of half-a-dozen miles in length: such, for instance, as may be seen by following the valley ten miles southwards from Watkins. Larger valleys, joining the lake at near the present water-line, may be instanced; Seneca Lake has one such at Dresden, which seems to have formed the original outlet of Keuka (Crooked) Lake; the Post-glacial gorge follows the same route. Cayuga Lake has the valley of Salmon Creek, opening at Ludlowville, near Ithaca, and running some 16 miles midway between Cayuga and Owasco Lakes. The bottoms of these valleys contain a very heavy deposit of drift, but not enough to prevent their forming impressive features of the landscape. Other than these, no important valleys enter the two lakes. The fluctuations in the height of the lake-cliffs suggest that we may yet trace the residue of the old side-notches in degraded forms. The same is suggested in places by curves in the higher landscape.

As representing several aspects of this discussion, let us consider the case of the valley at Dundee, which lies ten miles north of Watkins. Its banks are composed of Chemung sandstone, thinly coated with drift; they rise several hundred feet above the little valley at a moderate angle. The stream runs in a tolerably direct course towards the lake for about five miles, with a moderate fall of 4–20 feet per mile. Passing the village of Dundee—where it runs over rock for a mile—the stream cuts under the viaduct of the Fall Brook railroad, and at once begins a plunge of 500 feet, which it accomplishes in less than two miles by a line of post glacial gorges. If it could descend to the bed of the lake, the remaining 600 feet of fall would be accomplished in one mile. Such a case appears to show (1) the loss, through lateral shearing, of the Dundee valley, beginning at the point where its plunge commences. The modern landscape suggests the same. (2) The deepening of the main channel of Seneca, to an extent sufficient to enable us to bring it into correlation with such tributaries as this upland stream. Obviously, this implies a large figure—several hundreds of feet both laterally and horizontally.

In conclusion, it is worth notice that Dundee valley, and other valleys at corresponding heights across Seneca Lake, on the east side, agree very fairly in elevation with the system of petty valleys antedating Glacial time which empty into the Chemung near Elmira. The trough of Seneca Lake (with that of Cayuga) stands an exception to the harmony, and its excessive depth is from several points of view irreconcilable with the hypothesis of pure river-erosion, with or without crust-bending.

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Art. XV.—*On the Basalts of Kula*; by Henry S. Washington, Ph.D.

The following pages are a resumé of an inaugural dissertation presented by the writer last July at the University of Leipzig for the degree of Ph.D. The original dissertation being of too great a length and containing too much matter (historical and topographical) foreign to the scope of the Journal this paper was prepared embodying the chief and most interesting petrographical facts and conclusions. This being the case, the reader will pardon conciseness and the omission of much detail, and for further information may be referred to the original which is to appear shortly in New York as a separate pamphlet.

The rocks treated of were collected by the writer in the spring of 1892 near Kula, a small town of Asia Minor, lying about 125^{km} E. by N. of Smyrna in a part of what formed the ancient country of Lydia. This special district was called by the Greeks Katakekaumenē—the Burnt Country. It is a tract, about 18 miles long by 8 wide, on the left bank of the Hermos River (now Gediz Chaï); three basins of tertiary limestone, separated from each other and bounded to the south by ridges of mica (and hornblende) schist, while to the north are limestone hills. These basins, and the schistose ridges, are covered with well shaped volcanic cones and large lava streams and fields, which belong to three distinct periods of activity. The earliest is represented by large basaltic sheets, much denuded in places, lying rather outside the basins proper, and not treated of here. The second period is represented by over thirty cones, mostly on the schistose ridges, the forms denuded and somewhat rounded and lowered, and covered with vegetation, as are also their lava streams. To the third period belong three large volcanic cones—one in each basin—in an exceedingly fresh and unaltered state, their slopes of scoriæ bare of vegetation, and the lava streams as black, fresh, and rugged as those of the modern outflows of Vesuvius or Etna.

The large cone of the Kula Basin (the easternmost) is known as *Kula Devlit*, or Kula Inkstand, the black lava streams looking like ink running from an overturned inkstand. It has a height above sea level of 885 meters, above its base of 165 meters, and its outer sides slope at an angle of 30° 30′. It is a typical cinder cone, and shows two craters, one smaller in the southwest corner of the larger, and both extremely well preserved. No emanations or other signs of present volcanic activity are to be noticed. It has several lava streams, the largest running north to the Hermos River, a distance of about 10^{km}. A few smaller third period cones are to be found in the basin, and the Turks call the whole field of cones and black lava *Janyk Tash*, Burnt Rock.

As to the date of their eruption we know nothing, historically or traditionally; but as is evident from their fresh and unaltered state, it must have been within historical, or very recent quaternary, times. For the ancient description of the district the reader is referred to Strabo,* and of the very scanty modern notices the best are those of Hamilton,† Hamilton and Strickland,‡ and Tchihatcheff.§

The lavas of both the second and third period outflows are to be classed as hornblende-plagioclase basalts, distinguished by the constant presence and great relative quantity of the hornblende, its peculiar magmatic alteration, the small quantity of both plagioclase and olivine, and the large amount of glass basis. They form a distinct (and in some points new) type of the group, so much so as to be worthy of a distinctive name, that selected being *Kulaite*, the definition and characteristics of which being given later. They are all very fine grained compact rocks, gray or iron-black in color, and of low specific gravity. Hornblende, presenting the usual features of basaltic hornblende, olivine and augite, are visible megascopically, as porphyritical crystals. Occasional enclosed fragments of quartz, clear and with the usual fringe of augite needles, are to be found, some reaching a diameter of several centimeters. These are most certainly foreign enclosures.‖ The lava—especially of the third period—is vesicular and in some of the outflows shows a decided columnar structure, in one place on the Hermos River the columns attaining a length of six meters.

An interesting mineralogical feature of two of the Kula Devlit streams is the presence of leucite in small characteristic crystals. This is only the second time that it has been observed in Asia Minor, Lacroix¶ having found it in rocks from Trebizonde. These leucitic basalts seems to have their continuation in Persia. It is also to be noted that this is the first recorded case of its occurrence in hornblende basalts; nepheline, which is a very frequent constituent, not having been here observed.

* Geography, xiii, 411.

† Researches in Asia Minor, etc. London, 1842, i, 136–140, ii, 130–150.

‡ Trans. Geol. Soc., 2d Ser., vi. 81.

§ Asie Mineure, Pt. IV, Geologie. Paris, 1867, I, 7.

‖ Throughout the paper the word "enclosure" is used for such foreign masses accidentally enclosed in the lava stream, while "inclusion" is reserved for crystals, etc., structurally included in the other component minerals.

¶ Bull. Soc. Geol. de France, xix, 1891, 732.

The component minerals may be now described and we begin with

Feldspar.—This is constantly a plagioclase, and is sparingly present. In the second period Kulaites it is found in leptomorphic grains forming, with the glass basis, the groundmass of the rock. In the latest flows, on the contrary, it is constantly in the form of lath shaped microlites in the glass basis, generally very minute, but in some cases attaining a length of $0{\cdot}1^{mm}$. They show fluctuation structure and seem to have been among the last products of crystallization, being very sparingly present in the tachylitic forms. This plagioclase, but very rarely porphyritic, is shown by optical examination to be bytownite.

Augite.—The largest, megascopically visible crystals are light greenish yellow, and generally fragmentary. The greater part though is in well formed crystals, from $0{\cdot}1$–$0{\cdot}4^{mm}$ long, generally elongated parallel to $\dot{c}$, and showing the usual planes. They are either colorless or of a very pale fawn gray, sometimes with a core of greenish gray. The extinction is normal, though in one case as high as 43°. The prismatic cleavage is not well developed. As inclusions were seen glass and groundmass, rarely hornblende, and still more rarely magnetite, the latter in a few cases arranged in small grains parallel and close to the plane $s\,(\bar{1}11)$. Twins are not common. The well known "hourglass" structure was well developed and some interesting modifications were noticed. A zonal structure is very frequent. Augite is also present as a microlitic constituent of the groundmass, scattered thickly through the glass basis, and showing fluctuation structure.

Hornblende.—This, of all the constituent minerals, is the most constant and characteristic, and offers the most points of interest. It is present in relatively large quantity in all the lavas examined, in the leucitic, as well as in the non-leucitic, in the pure tachylytes and in the basalts of a normal structure—it is in fact the stamp and seal of the Kula basalts. Megascopically it is more frequent and prominent than either the augite or olivine, the crystals sometimes reaching a length of 8^{mm}, showing all the usual characters of basaltic hornblende—dark brown color, rounded edges and pitted surfaces.

Under the microscope it is seen that it is always porphyritic, never forming part of the groundmass. It is well formed, in short stout crystals, showing the usual planes, and with the cleavage well marked. The color is usually yellowish brown, but occasionally, and this as a rule in the more glassy specimens, it is greenish yellow. Pleochroism strong; $(\mathfrak{c})$ = dark yellowish brown; $(\mathfrak{b})$ = yellowish brown, $(\mathfrak{a})$ very pale gray, $(\mathfrak{c}) > (\mathfrak{b}) > (\mathfrak{a})$. The angle of extinction varies from 4° to 14° 30′, in one case being 23°. Zonal arrangement of the color is very common in the larger brown crystals, a dark core being surrounded by a light zone, or rarely several zones alternately light and dark. The dark core occasionally shows a corroded outline. Inclusions are not common, being chiefly glass, which are frequently arranged parallel to the outer planes of the crystal, or make up a central core of shape similar to that of the host. Augite is sometimes seen.

The alterations undergone by the hornblende are of great interest and will be described at some length. Of cases of mechanical distortion or simple corrosion nothing need here be said. The chemical alterations—to be ascribed to magmatic action—fall under three heads. The first, observed almost exclusively in specimens of scoriæ, consists of a simple darkening and reddening of the original crystal, without any change of form. It need not detain us here. The other two seem to be more or less connected with one another, and may be separate stages of one process, or two similar processes. The first consists of the replacement of the hornblende substance by a reddish brown mineral, in small elongated crystals, accompanied by grains of colorless augite and black "opacite;" in the other the outer part, or it may be the whole, of the hornblende crystal is changed into a mass of augite and opacite grains. This last is of very frequent occurrence in all eruptive rocks, though more common in the basic ones, and affects the biotite as well as the hornblende. The nature of the black grains of the so-called "augite-opacite aggregate" is not definitely known, but, with most observers, the writer is inclined to think them magnetite. Though very frequently the original form of the crystal is scarcely changed, yet in some specimens from a second period stream, obtained from a well-digging, at a depth of about 35^m, the hornblende "pseudomorphs," as they have been called, have lost their original shape, and are reduced to spheroidal or ovoidal masses, or as one writer puts it, looks "as if they had melted and run"—a natural consequence of the action of a moving lava stream on the granular, and probably not very coherent, mass of alteration products.

The alteration to "brown mineral aggregate," on the contrary, is of quite rare occurrence, only thirteen references to it having been found in the range of petrographical literature. Its geographical range is large, though, as first noticed by Zirkel,* in 1870, in some Eibel basalts, it has since been found (always in hornblende basalts) in Saxony, the Rhone, Palma, Syria, Madagascar, Kilimandjaro, and Cabo de Gata in Spain. It has never been observed in biotite.

* Basaltgesteine, p. 26. Cf. Rosenbusch Mik. Phys., 3[te] Aufl., i, 560.

The characteristic feature of this alteration is a reddish brown mineral in small "club-shaped" crystals, not scattered pell-mell through the accompanying augite and opacite grains, but forming a sort of network, the crystals lying at angles of about 60° with each other, and two sets also at the same angle with the prismatic edges of the hornblende crystal. At the end of the hornblende crystal the small brown bodies are generally arranged in slightly diverging fan-shaped tufts, spreading inwards. Definite crystallographic planes cannot be made out, though the blunt pointing of the terminations indicates a dome. The pleochroism is very strong, vibrations parallel to the long axis olive green (the least absorption), and at right angles to this respectively light brown, and very dark red brown (the greatest absorption). The extinction noted was, in every case, parallel to the long axis—in this point alone my observations differing from those previously made, other writers noting extinction angles of from "parallel or little inclined* (Palma) to maxima of 20°† (Kilimandjaro) and 25°‡ (Syria)." It must be remarked that in the Kulaites the opportunities for observation seem to have been far superior to any others, the crystals being of fair size, quite distinct from each other, and, the slides being well made, of fairly light color. Filling the interstices between the brown crystals are grains of colorless augite and opacite.

This form of alteration, like the other, begins at the surface of the hornblende, or along cracks, and thence spreads inwards. It seems to show a preference for the dark variety of brown hornblende (the green never being so altered), and frequently the dark core is altered while the outer light zone is unchanged,—apparently having been deposited after alteration took place in the core. A striking fact in connection with this, as with the preceding, form of alteration is the perfect manner in which the hornblende crystal has, as a rule, preserved its form, while undergoing such a profound change of substance. This will be referred to later.

It has already been said that these two forms of alteration seem to be separate stages of one general process. It is certainly true that the simple augite opacitic type follows on the other in many cases, and numerous examples were noted where are to be seen a core of unchanged hornblende, then a zone of the "brown mineral aggregate," and last on the outside a simple augite-opacite border. Or again, the central core of hornblende has entirely disappeared, giving place to the

* van Werveke, Neues Jahrb., 1879, 825.

† Hyland. Min. pet. Mitth., x, 1888, 238.

‡ Doss. Min. pet. Mitth., vii, 1886, 515.

"brown mineral aggregate" with a surrounding augite-opacite zone.

Two questions present themselves for solution, and answers to them are now attempted. What is this peculiar "brown mineral?" What is the cause of the alterations, and of the difference in the two "stages?"

Brown mineral.—In regard to the first it may be premised that the nature of the mineral is so far not certain. Nearly all observers call it hornblende, with more or less confidence, basing this conclusion chiefly on the usually observed slightly oblique extinction. As has been seen, in the Kula basalts the extinction was always parallel, and, however the discordant results of other observers may be explained (as they can be to some extent), the writer gives it as his opinion that the mineral in question is hypersthene, basing this conclusion on the following facts:

a. The unanimous results of all experiments made show that melted hornblende on cooling crystallizes invariably as augite.* "It is hard to see how this tendency can be overcome."

b. The color and pleochroism of the brown crystals agrees perfectly with that of hypersthene, calling the axis of greatest length $\dot{c}$, as is also usually the case with hypersthene.

c. The constant parallel extinction observed by me indicates an orthorhombic mineral and points to hypersthene.

d. On the theory that the crystals are hornblende the arrangement at angles of 60° with one another is very difficult of explanation. In hypersthene however we find that the dome 101 is a twinning plane, giving an angle between the two $\dot{c}$ axes of 60° 58′, and such twinned needles of hypersthene have been observed† in andesite from Bukowina. The case of similarly twinned rutile needles (sagenite) may be recalled.

e. Augite and hornblende tend to crystallize, when together, in parallel position, and when we use the pleochroism as a means of orientation we find that if the crystals are hypersthene their a(100) corresponds with that of the hornblende when the $\dot{c}$ axes are parallel.

f. The alteration of hornblende to hypersthene (along with feldspar, augite and magnetite) has been several times observed, as in andesites from Mexico, Arequipa in Peru, and Cabo de Gata, the rhombic pyroxene in the latter case being called bronzite.

It must be added that the unsatisfactory and indeterminative result of a chemical analysis of a dark spot containing

* Cf. Becker, Zeits. d. d. geol. Ges., xxxvii, 1885, p. 10.
† Becke, Min. pet. Mitth., vii, 93.

much brown mineral was, if anything, rather against the hypersthene theory.

Causes of alteration.—We now come to the question of the causes of the two kinds of alteration. The limits of the present article will not allow us to go into detail on this subject but some space may be devoted to the phenomena to be explained and a sketch of the possible explanation proposed. The facts are as follows: The brown hornblende is more subject to both forms of alteration than the green, and it is often, but not necessarily, changed first to "brown aggregate," and this to the simpler augite-opacite aggregate. The changes begin at the surface, or along cracks, of the hornblende, and thence work inwards, and when along cracks no contact with the molten magma exists. Both alterations occur with necessarily no marked change of form in the original crystal. A layer of fresh hornblende can be deposited on substance altered to brown aggregate, but has not been observed on that otherwise altered. Both alterations are more common in the basic volcanic rocks, and are the more marked the less glassy the groundmass. The "brown aggregate" alteration seems to have taken place at a greater depth than the other.

A number of explanations have been given varying from the vague general idea of "corrosive action of the molten magma" to the statement that the hornblende crystal has been melted or dissolved, and the new alteration product (?) deposited in its place. Lack of space forbids an examination of them here, but it may be remarked that the perfect preservation of the crystalline form precludes, in the writer's mind, any possibility of fusion or solution of the hornblende in a molten moving magma. To sum up it may be stated in brief that all the theories proposed are too vague or too improbable to be admitted as true.

The writer's idea in regard to the formation of the brown aggregate is that occluded hydrogen (produced by dissociation of the water almost always present in lavas) acts as a powerful reducing agent, changing the Fe_2O_3 of the original brown hornblende to FeO, and under certain conditions of high temperature and pressure (with probably others) giving rise to a mixture of the ferrous magnesian silicate, hypersthene, along with augite and magnetite. This process, it will be observed, requires no fusion or solution of the hornblende.

A chief factor in the formation of the augite-opacite aggregate the writer looks for in a simple molecular change (similar to that of monoclinic to rhombic sulphur, etc.) under certain conditions, among which are probably the chemical constitution of the magma and a slow rate of cooling, with certainly a high temperature.

These theories are, it is admitted, but probable, not certain, and for the further discussion of the subject the reader must be referred to the original dissertation.

Other minerals.—The other mineral constituents need not detain us long. The olivine is very sparingly present, and offers no special features of interest. Two cases of inclusions of black trichites, in groups, were noticed—a rare occurrence in basaltic olivine. The magnetite of the groundmass is always in very small grains, rarely reaching a diameter of $0{\cdot}1^{mm}$. The most interesting feature of its occurrence is that in the least glassy Kulaites the magnetite grains are very abundant and the glass basis perfectly colorless, while as the rock becomes more glassy the quantity of magnetite decreases and the glass assumes a brown hue, till finally in the pure tachylytes no magnetite is to be seen and the glass is of a clear dark chocolate brown color. This seems to show that in these rocks the magnetite is among, if not quite, the last of the minerals to crystallize out. Its rarity as an inclusion points the same way. It may be noted that Judd* observed exactly the opposite state of affairs in the Tertiary gabbros and basalts of western Scotland. The leucite offers no special features of interest. That apatite is present is shown by the presence of P_2O_5 in the analyses, but crystals of it were not certainly seen, except a few large ones, which are certainly derived from enclosures of foreign rock.

General description of the rocks.—All the basaltic rocks of the Kula district are very similar to one another in composition —chemical and mineralogical,—as well as in the habit of their mineral components, and form a good, though small, example of a so-called "petrographical province." Structurally they may be divided into normal, hyalopilitic, semi-vitreous, and tachylytic basalts, these subdivisions shading off into one another.

To the first of these belong the specimens of the second period streams—light gray, rough fine grained rocks, of average sp. gr. 2·756, with porphyritic augite and olivine. Under the microscope they show a groundmass of glass and leptomorphic plagioclase grains containing many microlites and magnetite, with small porphyritical augite and olivine crystals, and numerous hornblende crystals, which have all, without exception, undergone alteration, generally completely to a mass of augite and opacite. Rounded forms are quite common.

The third period basalts are more glassy, and a hyalopilitic structure, of quite typical development, is common, the microlites being plagioclase laths, augite needles, and magnetite

*Q. J. Geol. Soc., 1886, 79.

grains, with some trichites. Phenocrysts, of hornblende, augite and olivine, are abundant, the first being generally altered to the "brown aggregate" stage. Those of a "semi-vitreous" structure have a pitchy luster. In them the ground-mass shows a largely preponderating quantity of clear cinnamon brown glass, and they have lost, with reduced number of microlites, the hyalopilitic structure of the preceding. Some greenish hornblende appears, but this, as well as the brown, is commonly free from alteration, and the alteration when present is always to "brown aggregate." The tachylytes are very compact, jet black, with a vitreous luster, many specimens looking like anthracite. They consist almost wholly of a clear dark chocolate brown glass, often streaked. Very few microlites and no magnetite are present. Phenocrysts are represented by large augites and hornblende crystals, the latter frequently showing a zonal structure, but always fresh and unaltered, both brown and green, the latter having become more frequent. Olivine is very rare. The average sp. gr. of the hyalopilitic type was found to be 2·655, of the semi-vitreous 2·704, and of the tachylytes 2·721. Two lava streams of Kula Devlit are leucitic. They are both hyalopilitic in structure, and, apart from the presence of leucite in not very abundant, small crystals, are not markedly different from the non-leucitic type. Their sp. gr. is 2·719.

The following may be selected as typical analyses out of those made for me by Dr. A. Röhrig of Leipzig.

	A.	B.	C.
H_2O (Ign.)	0·02	0·46	0·04
SiO_2	48·24	47·50	47·74
Al_2O_3	20·64	19·32	20·95
Fe_2O_3	4·63	4·75	3·29
FeO	5·55	5·20	6·32
CaO	7·94	8·37	7·56
MgO	5·02	4·36	5·16
Na_2O	5·08	7·63	7·12
K_2O	1·88	2·31	1·21
P_2O_5	0·97	0·21	0·13
	99·97	100·11	99·52

A = Second period Kulaite from well-digging in Kula. Sp. gr. = 2·733.

B = Third period. Early stream of Kula Devlit. Sp. gr. = 2·704.

C = Third period. North stream of Kula Devlit. Leucitic. Sp. gr. = 2·736.

The mutual similarity is most marked, but nothing special need here be said, except to call attention to the small quantity of K_2O in the leucitic specimen, analysis C.

A few words on the bestowal of a name on these rocks. While deprecating the too free use of new names, yet in this case the writer deems it justifiable. In all the Kula basalts the hornblende plays the leading rôle, surpassing in constancy, invariability, and quantity the augite, olivine or feldspar. It is not of secondary importance, as in most hornblende basalts, but of the first importance among all the mineral constituents. The name chosen is Kulaite, and by this we may understand a sub-group of the basalts which is characterized by the invariable presence of hornblende as an essential constituent, which also, both in quantity and petrographical importance, surpasses the augite; in other words to a large extent replaces the latter. We can call such a plagioclase-basalt kulaite, having the further subdivisions of leucite-kulaite (as just seen), and nepheline-kulaite.

In addition to the volcanic rocks just described a number of metamorphic schists, serpentine, diorite from a dyke in the schist, and foreign rock enclosed in the basalt were examined. It may be added that the writer hopes to revisit the region the coming spring, when a longer stay will be made, and data and specimens from the whole of the Katakekaumenē will be collected. The writer desires to return his warmest thanks to Prof. Dr. Zirkel of Leipzig for his very kind advice and assistance and to Prof. E. S. Dana for his kind advice.

Navesink, N. J , Nov. 11, 1893.

Art. XVI.—*The Fishing Banks between Cape Cod and Newfoundland*; by Warren Upham.*

Along a distance of about a thousand miles east-northeastward from Cape Cod the submarine border of the North American continent presents very remarkable irregularities of contour. The sea bed there in its descent from the present coast lines to the abyssal depths of the North Atlantic Ocean differs entirely from the smooth and gently inclined plane of the submerged continental slope along its next thousand miles south to the Strait of Florida and the Bahama Islands. Instead we find by soundings from Cape Cod to the Grand Bank of Newfoundland that this section of our coast has a profusion of submerged hills and broad plateaus, elevated from 100 to 1000 feet above the intervening valleys and adjacent low portions of the sea bed, from which they rise nearly to the sea

* From the Proceedings of the Boston Society of Natural History, vol. xxvi, pp. 42–48, for March 15, 1893.

level but only in a single instance reach above it, forming Sable Island. These plateaus, covered by water ranging mostly from 10 to 50 fathoms in depth, sustain luxuriant submarine vegetation, abundant molluscan life, and vast schools of cod, haddock, mackerel, halibut, and other food fishes, which almost from the time of first discovery and exploration of this coast have caused its submerged plateaus to be the site of important fisheries and thence to be known as Fishing Banks.

In their order from southwest to northeast, the more extensive of these plateaus are the St. George's, Western or Sable Island, Banquereau, St. Pierre, and Green Banks, and, most northeastern and by far the largest, the Grand Bank of Newfoundland.

St. George's Bank, more frequently called simply George's Bank by the Gloucester fishermen whose fleet of hundreds of schooners is mostly employed in fishing there, extends a hundred and seventy five miles east from Nantucket and Cape Cod, being connected with the Nantucket shoals by an isthmus which has about 40 fathoms of water. The area of St. George's Bank above the 50 fathom contour line exceeds that of the State of Massachusetts, and has a width of about a hundred miles from northwest to southeast. George's Shoal, on the northwestern part of this plateau, has two spots with only 12 feet of water; while twenty miles west from that highest portion of St. George's Bank, it rises again in the Cultivator Shoal to 18 feet, or only 3 fathoms, below the sea level. About these shoals the ground swells of great storms break with nearly as much grandeur and danger to shipping as on a coast line. The surface of the bank, as shown by the soundings of the U. S. Coast Survey, "is covered with pebbles and small stones, excepting shallow portions and pot-holes, where the material ground down by the sea has accumulated."*

North of St. George's Bank, the Gulf of Maine occupies an area of about 36,000 square miles, of which nearly a third part exceeds 100 fathoms in depth, the average for the whole being estimated not less than 75 fathoms The maximum depth of the western part of the Gulf of Maine is 180 fathoms, found 46 miles east of Cape Ann; and of its eastern part, at a distance of a hundred miles east-southeast from the last, 199 fathoms, this being close north of George's Bank, in latitude

* "Physical hydrography of the Gulf of Maine." Report of the U. S. Coast and Geodetic Survey, for the year ending June, 1879, pp. 175–190. "A plea for a light on St. George's Bank." Appendix No. 11, ibid., for year ending June, 1885, pp. 483–485. The contour of the Fishing Banks, as here described, is shown by Eldridge's Chart from Cape Cod to Belle Isle, 1887 (published by S. Thaxter & Son, 125 State St., Boston).

42° 20′ and longitude 67° 20′. At the mouth of this gulf, between the northeastern border of George's Bank and Brown's Bank, of comparatively small area, which lies halfway thence to Cape Sable, N. S., the soundings are from 150 to 170 fathoms.

Brown's Bank is covered by water from 26 to 50 fathoms deep, and on its north side water of 60 to 80 fathoms divides it from Nova Scotia. Three other small plateaus lie within the next hundred and fifty miles eastward.

Continuing in this direction, the large Western Bank and Banquereau stretch two hundred and fifty miles east-northeast, varying from 50 to 75 miles in width, and separated by a breadth of 25 to a hundred miles of deep water from the eastern part of Nova Scotia and from Cape Breton Island. On the east half of the Western Bank its highest portion is the wave-built broad sand beach of Sable Island, about 25 miles long from west to east, heaped in dunes by the winds. Between Banquereau and Cape Breton Island are some half a dozen small banks, of which the Misaine, about sixty miles long, is the largest and extends farthest northeast.

Next eastward the now deeply submerged preglacial valley of the River St. Lawrence lies at a depth of 260 to 300 fathoms, showing, as Prof. J. W. Spencer has well pointed out, that before the Ice age this part of North America was elevated at least from 1500 to 2000 feet above its present height.*

Beyond this great submarine valley the St. Pierre Bank, covered by only from 22 to 50 fathoms of water, reaches about a hundred and twenty-five miles from northwest to southeast, with a width of 30 to 60 miles. On the north this bank is divided from the Miquelon Islands by water from 61 to 63 fathoms deep.

Soundings of from 80 to 96 fathoms separate the St. Pierre from Green Bank, of which the latter has a length of about 60 miles from north to south with half as great width, being in its turn separated from the Grand Bank by water of 64 fathoms. Farther east the deep water between Cape Race, Newfoundland, and the Grand Bank is mostly from 80 to 100 fathoms, and in one place 115 fathoms. On the northwest, however, Placentia Bay of Newfoundland has maximum soundings of from 125 to 147 fathoms, being thus probably 67 fathoms deeper than any outlet from it to the depths of the North Atlantic.

The Grand Bank has approximately the outline of an equilateral triangle measuring from 275 to 300 miles on each side,

* "The high continental elevation preceding the Pleistocene period." Bulletin G. S. A., vol. i, 1890, pp. 65–70, with map of the preglacial Laurentian river. Also in the Geol. Mag., III, vol. vii, 1890, pp. 208–212.

or very nearly the same as the far more irregular area of Newfoundland. Its depth of water ranges mainly from 25 to 50 fathoms, and its shallowest places are found along the northern edge, on which are the Virgin Rocks, with only from 4 to 10 fathoms; the rocky eastern shoals, stated to be 30 in number, with from 5 to 25 fathoms, but having channels of from 40 to 50 fathoms between them; and, farther east, Ryder's Bank, with only 3½ fathoms, though surrounded by from 38 to 40 fathoms of water. The western part of the Grand Bank contains an apparently enclosed basin, about fifty miles long, called Whale Deep, which has maximum soundings of from 60 to 67 fathoms, with a muddy bottom. Northward from this basin a distance of twelve miles, with soundings from 48 to 53 fathoms, divides it from the deep water outside the bank; and on the south 30 miles, with mostly about 50 fathoms of water, lie between the Whale Deep and the steep descent into the abyssal ocean.

If this portion of the continental border from Cape Cod to the Grand Bank southeast of Newfoundland could be again uplifted as when the St. Lawrence in preglacial times flowed out to sea between the highlands which now form the Misaine, Banquereau, and St. Pierre Banks, we should behold nearly as much diversity of valleys, ridges, hills, plateaus, and all the forms of subaërial land erosion, as is exhibited by any portions of the adjacent New England states and eastern provinces of Canada. During a long time of high elevation closing the Tertiary era and initiating the Quaternary, this region was eroded by rains, rills, brooks, and rivers, cutting such profound chasms as the sublime Saguenay fjord, reaching 800 feet below the sea level and enclosed by precipitous rock walls, 1500 feet high, until the cold climate induced by the increasing altitude covered the land with an ice-sheet which gradually became thousands of feet thick and at last by its weight appears to have brought about the Champlain depression, the return of a temperate climate, and the final melting of the ice. The submerged channels of outlet from the Gulf of Maine and the Gulf of St. Lawrence, and the less profound valleys that divide the Fishing Banks from each other and from Nova Scotia and Newfoundland, with the distinct stream courses revealed by soundings on all the larger banks, as St. George's, Western, Banquereau, St. Pierre, and the Grand Bank, prove that this region during a comparatively late period of geologic time was a land area, its maximum elevation being at least 2,000 feet higher than now.

That the period of uplift was the late Tertiary and early Quaternary is shown by the age of the strata which, beneath a thin envelope of glacial drift, form these submarine banks. In

1877 Prof. C. H. Hitchcock suggested that the Fishing Banks are of Tertiary age;* and much earlier Agassiz had taught his classes that they must consist superficially of drift, the eastern continuation of the drift sheet of the northern United States and of Canada. Both these theories were fully justified in 1878, when in the service of the U. S. Commission at Gloucester, Mass., I gathered from the fishermen of that port many specimens of rocks that had been brought up from the bottom of the Fishing Banks by their lines becoming entangled in the coralline growths attached to these rock masses. A large proportion of the stones so drawn up are rounded and subangular fragments of granitic, gneissic, and schistose rocks, evidently transported to their present position through the agency of ice, either by an ice-sheet during the Glacial period, as was doubtless true for a large part of this drift, or by icebergs and floes, which still are contributing yearly to the drift of the Grand Bank. Apparently a smaller proportion, but more likely to be brought ashore by the fishermen, consists of fossiliferous sandstone and limestone, often well filled with shells or with their empty casts. Many of these fossiliferous rock fragments, varying from one pound to a hundred pounds or more in weight, were collected and submitted to Prof. A. E. Verrill for determination of their species, concerning which he wrote as follows in this Journal for October, 1878 (III, vol. xvi, pp. 323–324).

Among the most important results of the investigations made by the party connected with the U. S. Fish Commission, stationed at Gloucester, Mass., during the present season, is the discovery of fragments of a hitherto unknown geological formation, apparently of great extent, belonging probably to the Miocene or later Tertiary. The evidence consists of numerous large fragments of eroded, but hard, compact, calcareous sandstone and arenaceous limestone, usually perforated by the burrows of *Saxicava rugosa*, and containing in more or less abundance fossil shells, fragments of lignite, and in one case a spatangoid sea-urchin. Probably nearly one-half of the species are northern forms, still living on the New England coast, while many others are unknown upon our coasts and are apparently, for the most part, extinct. From George's Bank about a dozen fossiliferous fragments have been obtained, containing more than twenty-five distinct species of shells. Among these one of the most abundant is a large thick bivalve (*Isocardia*) much resembling *Cyprina Islandica* in form, but differing in the structure of the hinge. This is not known living. *Mya truncata*, *Ensatella Americana*, and the genuine *Cyprina* are also common, together with a large *Natica*, a *Cyclocardia* (or *Venericardia*) allied to *C. borealis* (Con.), but with

* Geology of New Hampshire, vol. ii, p. 21.

smaller ribs, *Cardium Islandicum*, and also various other less common forms. These fragments came from various parts of the bank, including the central part, in depths varying from 35 to 70 fathoms, or more.

From Banquereau, N. S., we received one specimen of similar rock, containing abundant fragments of a large bivalve, and about a dozen other species, among which are *Fusus* (*Chrysodomus*) *decemcostatus*, *Latirus albus* Jeff. (?), unknown species of *Turritella*, etc. From the Grand Bank two similar specimens were received. One of these, from thirty-five fathoms, lat. 44° 30′, long. 50° 15′, contained numerous specimens of *Cyprina Islandica* in good preservation.

. . . .

At present it appears probable that these fragments have been detached from a very extensive submerged Tertiary formation, at least several hundreds of miles in length, extending along the outer banks, from off Newfoundland nearly to Cape Cod, and perhaps constituting, in large part, the solid foundations of these remarkable submarine elevations.

The collections here described, belonging to the U. S. Fish Commission, are under Professor Verrill's care in the Yale University museum; but no further investigation of them has been made. It has been my hope to secure another similarly large collection and to give it attentive study, but other duties have prevented this. Though the fishermen doubtless now draw up on their lines as many of these specimens of the bed-rocks of the banks as they did fifteen years ago, most of them are immediately thrown away and fewer are brought ashore than at that time when the work of the Fish Commission in Gloucester stimulated a worthy rivalry among the captains and fishermen to bring in everything zoological or geological which might possibly be of scientific interest for the Fish Commission. Visiting Gloucester during a few days in the summer of 1890, my only opportunity for this collecting within recent years, I was able to obtain only a few specimens of these fossiliferous rocks, chiefly through donation by Dr. Thomas Conant and Mr. Everett P. Wonson of that city, half of which I have transmitted for these donors to the museum of this Society and the other half to that of Dartmouth College. These specimens were brought from St. George's Bank, and were mostly from depths of about 40 fathoms.

By date of September 29, 1890, Professor Verrill wrote as follows, in reply to my inquiries concerning the Fish Commission collection of the fossiliferous bed-rocks of the Fishing Banks: "I have found it useless to try to work up the fossils till the recent shells from the same region are better known. We have already added more than 200 species to the list of the shells of the banks and their vicinity, and have many others on hand not yet described. Probably many of the fossils may be identical with these newly recorded or unrecorded species, but a very long and laborious study can alone determine how many are recent, owing to their imperfect condition." In the light of this lately added knowledge of the fauna of our submarine continental border,* it seems very probable that these rocks will prove of Pliocene rather than Miocene age. Their uplift and subaërial erosion took place, therefore, as already indicated in the preceding part of this paper, at the close of the Tertiary era and immediately before the Glacial period.

The Fishing Banks are thus to be accounted, like the fjords of all our northern coasts, the submerged continuation of the Hudson River channel, and the similar very deep submarine valleys off the shore of California near Cape Mendocino, to which I have previously called attention,† as evidence of a great epeirogenic uplift of the northern part of this continent preceding and producing the Ice age.

NOTE.—Referring to Mr. J. B. Woodworth's suggestion in this Journal for Jan., 1894, p. 71, that pebbles carved by wind-blown sand should be looked for among the stones dredged from the Fishing Banks, it should be borne in mind that the high uplift exposing these areas to subaërial erosion was preglacial, and that when the ice-sheet disappeared the coast from Boston to Nova Scotia was depressed somewhat below its present height. Although this depression of the land probably carried the Fishing Banks and the border of the ice-sheet there below the sea level, a small postglacial uplift of the seaboard, which is known to have raised the land at the head of the Bay of Fundy at least 80 feet higher than now, may have laid bare considerable parts of the Fishing Banks so that their present surface stones could be worn by drifting sand dunes. (See former articles in this Journal, III, vol. xxxvii, pp. 359–372, May, 1889, and vol. xliii, pp. 201–209, March, 1892.)

* Previous to 1870 the known molluscan fauna of the seas of northeastern America comprised about 290 species; but now, according to Prof. Verrill, it numbers 500 or more. In comparison with this we may note that the British Isles have about 600 species of marine mullusks, and the whole of Europe about 800. (Prestwich's Geology, vol. i, pp. 120–121).

† "Probable Causes of Glaciation." Appendix of Wright's Ice Age in North America, 1889, pp. 573–595. Bulletin G. S. A., vol. i, 1890, pp. 563–567. Amer. Geologist, vol. vi, Dec., 1890, pp. 327–339.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Fusing points of Inorganic Salts.*—The first results of an investigation made by V. Meyer and Riddle to determine the fusing points of certain of the more refractory inorganic salts, and thereby to ascertain what relation if any exists between these points in the case of allied salts, have been recently published. The salts thus far investigated are the chlorides, bromides, iodides and sulphates of sodium and potassium. In order to measure accurately the high temperatures in question, the authors made use of the following method: The salt under examination was placed in a large crucible of platinum and by means of a Perrot furnace, was heated to a point considerably above that of fusion. The crucible was then removed from the furnace and an air thermometer, made of platinum and constructed on the compensation principle, was inserted into the still melted salt. As soon as solidification commenced, the temperature remained constant for a considerable time during which the air in the thermometer was displaced by hydrogen chloride gas. By measuring the volume of this gas by absorption in water, the temperature could be calculated. In this way it was found that the chloride, bromide and iodide of sodium fuse at 851°, 727° and 650°, respectively; the corresponding salts of potassium melting at 766°, 715° and 623°. So that it appears that a lowering of the fusing point is a consequence of an increase in the atomic mass, either of the metal itself or of the halogen elements. Potassium oxide moreover, fuses at 1045° and sodium oxide at 1098°. But in the case of the sulphates, while the sodium salt melts at 843°, the potassium salt melts at 1073°; a result which differs from the law based on the behavior of the halogen compounds, although it agrees with certain other differences already noticed between the behavior of the oxy-salts of sodium and potassium and the haloid salts of these metals.—*Ber. Berl. Chem. Ges.*, xxvi, 2443, November, 1893. G. F. B.

2. *On the Manocryometer.*—A new instrument has been devised by De Visser for the purpose of determining the melting point of a substance under pressure, which he calls a "manocryometer." It consists of a stout glass vessel somewhat resembling Ostwald's modification of the Sprengel density tube; only the shorter capillary tube is sealed off and the longer one is provided with two small bulbs on the ascending portion, the horizontal part, which is sealed at the end, being very long. The principal bulb is filled with the substance to be experimented on, the lower part of the capillary tube and the lower bulb are filled with mercury and the rest of the capillary tube is filled with air which acts as a manometer. The substance is heated to a temperature a little above its melting point for half an hour and the pressure is then

read off. By this means the value dT/dp is obtained, in Professor James Thomson's equation for the variation of the fusing point with pressure

$$\frac{dT}{dp} = 10333 \cdot \frac{T}{E} \cdot \frac{\sigma - \tau}{r}$$

in which T is the fusing point, p the pressure, σ the specific volume of the liquid, τ that of the solid, both at the melting point, and r the heat of fusion at the melting point. The author determined the values of dT/dp, T, σ, $\sigma-\tau$ and r for acetic acid and also the value $(\sigma-\tau)/r$ directly by means of an acetic acid calorimeter. For the melting point of this acid T at 760^{mm} he finds 16·6713° by the mercury thermometer and 16·5965° by the hydrogen thermometer. For the density of the liquid at the melting point, he obtains 1·05315 compared with water at 4°; and hence the specific volume σ is 0·94953. Since the change of volume on fusion of one kilogram in cubic meters $\sigma-\tau$ is 0·00015955, the specific volume of the solid at its melting point is 0·78998 or its specific gravity is 1·26585. The heat of fusion at the melting point r was found to be 46·416 calories. The calculated value of $(\sigma-\tau)/r$ was 0·0000034374; that found directly being 0·0000034425. The value of dT/dp as calculated was 0·02421° as compared with 0·02435° found with the manocryometer.

The author has also described an interesting lecture experiment with the manocryometer. A tube of 2^{mm} interior diameter having walls 6^{mm} thick, is sealed off at one end and drawn out to a capillary size at the other, the whole being about 15^{cm} long. This tube is immersed in pure acetic acid and filled by alternately exhausting it and plunging its open end into the acid. It is then inverted and the capillary end being plunged into acetic acid, the wider end is cooled by surrounding it with cotton wool on which ether is dropped. The acid in the tube solidifies with considerable diminution of volume, fresh acid being drawn into the tube in consequence. When the greater portion of the acid is solidified the capillary end is withdrawn from the acid and the cooling is continued until some air has entered. The end is then sealed and the tube is ready for use. It is now suspended in a beaker of water the temperature of which is gradually increased. At the ordinary pressure acetic acid melts at 16·6°; but when it is thus confined in a closed space, it creates a greatly increased pressure as it melts, and thereby raises the melting point of the remaining solid. In this way the author has succeeded in raising the fusing point as high as 40° corresponding to a pressure of about 100 atmospheres. When these tubes break they do not explode but crack lengthwise.—*Rec. Trav. Chim.*, xii, 201, 154; *J. Chem. Soc.*, lxiv, ii, 563, 566, Dec., 1893. G. F. B.

3. *On the Fusion and Volatilization of Metals and Oxides in the Electric Arc.*—In continuing his researches on chemical reactions at high temperatures, Moissan has exposed various metals, salts and oxides to the heat of his electric arc furnace. To con-

dense and collect the substances that sublime, a copper U-tube through which a rapid current of cold water flows, is placed in the furnace immediately over the crucible, and is surrounded with asbestos card-board. Magnesium pyrophosphate exposed for five minutes to the arc produced by a current of 300 amperes and 65 volts gives a sublimate of magnesium oxide and ordinary phosphorus. Asbestos with 300 amperes and 75 volts almost completely volatilizes in a few minutes leaving only a small residue of fused silicate and a globule of magnesium silicide. Copper with 300 amperes and 70 volts volatilizes rapidly and condenses in globules. In contact with air its vapor forms cupric oxide. Silver enters into ebullition and distills readily, condensing in fused globules, gray amorphous powder and arborescent fragments. Platinum melts almost immediately and very soon begins to volatilize, condensing in brilliant globules and as a powder. Aluminum with 250 amperes and 70 volts also volatilizes and condenses in small spherules. Tin with 380 amperes and 80 volts volatilizes readily and condenses in small globules and in fibrous masses. Gold with 360 amperes and 70 volts volatilizes in six minutes to a considerable extent, condensing in small spheres. Manganese, with 380 amperes and 80 volts volatilizes very readily; only a small residue of carbide being left from 400 grams of the metal, after ten minutes. Iron with 350 amperes and 70 volts volatilizes and condenses as a gray powder mixed with brilliant malleable scales. Uranium with 350 amperes and 75 volts readily volatilizes and condenses in small non-magnetic spheres free from carbon. Silicon volatilizes with 380 amperes and 80 volts and condenses in small spheres mixed with a gray powder and a small quantity of silica. Carbon with 370 amperes and 80 volts rapidly changes into graphite and then volatilizes, condensing in very light thin translucent maroon-colored plates, similar to or identical with the maroon-colored variety of carbon noticed by Berthelot, and burning in oxygen readily. Calcium oxide with 350 amperes and 70 volts volatilizes after 8 or 10 minutes and with 400 amperes and 80 volts it volatilizes in five minutes. The oxide condenses entirely as an amorphous powder. With 1000 amperes and 80 volts, 100 grams of the volatilized oxide can be obtained in 5 minutes. Magnesium oxide volatilizes with more difficulty than calcium oxide and its boiling point is near its melting point. With 360 amperes and 80 volts it gives off a quantity of vapor; distillation becoming very rapid with 1000 amperes and ten volts.

Moissan has also submitted zirconia and silica to the electric arc. When zirconia is heated in an electric arc with a current of 360 amperes and 70 volts it rapidly melts and in about ten minutes is in complete ebullition giving off thick white vapors which condense to a white powder consisting of opaque microscopic granules which scratch glass and possess all the properties of zirconia, having a specific gravity of 5·10. The residue in the crucible has a crystalline fracture. In the cooler parts of the furnace dendritic crystals of zirconia are deposited. If the zirconia be fused in a carbon crucible under these conditions, a button of zirconium mixed with some zirconia but free from carbon and nitrogen is found beneath the non-volatilized oxide. When the zirconia is mixed with an excess of carbon a zirconium carbide is obtained containing from 4·22 to 5·10 per cent of carbon. It has a metallic appearance and a brilliant fracture, and when fused with an excess of zirconia yields pure zirconium of specific gravity 4·25 which scratches glass and rubies easily and resembles closely the zirconium described by Troost. If the carbide contains more than 5 per cent of carbon, it inflames somewhat rapidly when exposed to the air. Silica in an arc of the same intensity melts almost immediately and is in complete ebullition after six or seven minutes. The vapors condense to a slightly bluish white powder consisting of a mixture of amorphous silica with small opalescent spheres which scratch glass easily and have a specific gravity of 2·4. About 20 grams of silica can be volatilized in from 10 to 15 minutes, the condensed product being very easily attacked by hydrogen fluoride and by alkalies. Under these conditions, silica is also reduced by carbon, yielding a crystalline silicon carbide.

Troost has suggested the utilization of the volatility of silica for the purpose of separating it from zirconia or thoria. If finely pulverized zircon be mixed with an excess of carbon, compressed into small cylinders, placed in a carbon disk and subjected to the action of an electric arc in a closed vessel through which a current of carbon dioxide is passed, the silica volatilizes very rapidly, giving a thick black smoke due probably to silicon. The residue contains only 1·5 per cent of silica. Similar results were obtained with thorite and orangite, the separation of the silica in this way greatly facilitating the preparation of the thoria.—*C. R.*, cxvi, 1222, 1428, 1429, 1893; *Ber. Berl. Chem. Ges.*, xxvi (Ref.), 482, 669, July, Oct., 1893. G. F. B.

4. *Modification of Thomson's quadrant electrometer.*—F. Himstedt describes a multicellular electrometer with one or two simple modifications. The needle is suspended by a quartz or glass fiber which is slightly silvered in order to conduct. For the purpose of damping the movements of the needle, an astatic system consisting of two magnets is suspended from a wire, which forms the continuation of the axis of the needle system. These magnets are placed vertical, and are surrounded by a copper cylinder. The earth's directive force is annulled and the movements of the needle system is damped by the presence of the copper cylinder.

The multicellular electrometer was first used in the Jefferson Physical Laboratory in 1885, and the original instrument is now in the Signal Service Bureau at Washington.—*Ann. der Physik und Chemie*, No. 12, 1893, pp. 752–755. J. T.

5. *Coating aluminium with other metals.*—At a meeting of the Physical Society, Berlin, Dec. 1, 1893, Professor Neesen de-

scribed a method of coating aluminium with other metals. The aluminium is first dipped in a solution of caustic potash or soda or hydrochloric acid until bubbles of gas make their appearance on the surface. Then it is dipped in a solution of corrosive sublimate in order to amalgamate the surface. Afterward it is dipped again in caustic potash till gas is evolved. Then the metal is placed in a solution of the salt of the desired metal. A film of the latter is soon formed and is so strongly adherent, that in the case of gold, silver and copper, the plate can be rolled or polished. The coated aluminium can be soldered with ordinary zinc solder. When a coating of gold or copper is desired, it is best to coat first with silver. J. T.

6. *Modifications of Silver.*—H. LÜDKE discusses the various methods of depositing silver, and investigates the properties of the films. He concludes: that Lehmann's hypothesis that a thin layer of silicate of soda on glass is concerned electrolytically in the process of silvering on glass—is not true, for mirror silver is separated on mica porcelain quartz, fluorspar-platinum, etc. The electrical resistance of many kinds of mirror silver decreases. Mirror silver produced however by reduction with sugar of milk, according to Liebig's method, or according to Martin's process, show no decrease of resistance. Heat, light and chemical action can easily change allotropic mirror-silver into other good conducting modifications. Mirror-silver gives with ordinary silver, scarcely any difference of electromotive force. Mirror-silver in its original unchanged condition, is similar to colloidal silver.—*Ann. der Physik und Chemie*, No. 12, 1893, pp. 678–695. J. T.

7. *Vorlesungen über Maxwell's Theorie der Elektricität und des Lichtes*, von DR. LUDWIG BOLTZMANN. II Theil, 166 pp. 8vo. Leipzig, 1893 (Johann Ambrosius Barth—Arthur Meiner).—The appearance of the first part of this important work was noticed in this Journal about a year and half ago and the scope of the author's plan was then remarked upon. The present part contains the discussion, from the standpoint of Maxwell's theory, of action at a distance with the special cases of electrostatic distribution and induction.

ERRATA, in Prof. Mayer's article of "Researches in Acoustics, Paper No. 9," this Journal Jan., 1864.

Page 2, line 9 from bottom for *the* read a.

Page 3, 10 lines from bottom, for *duration or the after-sensation* read duration *of* the after sensation.

Page 4, line 20 from bottom *dele* (;).

Page 7, line 8 from bottom for *center*, read centers.

Page 12, line 2 from top for *tube*, read tubes.

Page 14, line 4 from top *dele end of the*.

Page 21, line 17 from top for *dessons*, read dessous.

Page 21, line 11 from bottom for *dessau*. read dessous.

Page 24, line 7 from top for *vibrate*, read vitiate.

II. Geology and Mineralogy.

1. *The Geological Society of America.*—The sixth annual meeting of the Geological Society was held at Boston, Mass., on December 27th and 29th, and at Cambridge on the 28th, 1893. The opening meeting was held in the hall of the Boston Society of Natural History, Sir J. William Dawson, the president of the Society, in the chair. The annual address of the President, on Some Recent discussions in Geology, was delivered Friday evening, Dec. 29th. A lecture by Alexander Agassiz, giving an account of an expedition to the Bahamas, was read before the society on Wednesday evening.

The following officers for the year 1894 were elected, viz: president, T. C. Chamberlin, Chicago; first vice-president, N. S. Shaler, Cambridge; second vice-president, G. H. Williams, Baltimore; secretary, H. L. Fairchild, Rochester, N. Y.; treasurer, I. C. White, Morgantown, Va., and editor, J. Stanley Brown, Washington, D. C.

There were fifty-one fellows in attendance and fifty-eight papers were presented for reading.

The following notes indicate briefly the contents of some of the papers read.

Sir J. William Dawson, in his presidential address, on *Some Recent Discussions in Geology:* defined the attitudes of geological opinion regarding some of the live questions of to-day, speaking of them as the goals of to-day which are to be the starting points of the researches of to-morrow. In regard to the age of the crystalline rocks he spoke of the lower Laurentian gneisses as probably of igneo-aqueous origin and as the oldest known rocks. In regard to the theories of mountain making he was disposed to think that the action of all the forces emphasised in LeConte's contraction theory, in Hall's deposition theory, in the expansion theory of Reade, and in Dutton's isostatic theory must be considered in reaching the truth.

In the catastrophe—uniformitarian controversy harmony was to be looked for by recognizing the fact that what appears as a catastrophe may be but the culmination of uniformly working laws.

He referred to the fact that organic matter, as in the case of coal, is of slow and gradual accumulation, and is not peculiar to any particular age though a prominent feature in the Carboniferous era. He showed that fossil plants by their distribution are evidence that the vicinitudes of climate in the geological ages were mainly due to the differences in the distribution of land and water. In explanation of the phenomena of the glacial age, he maintained that "local glaciers of great magnitude on elevated ground and depression of lower lands beneath the sea were mainly responsible for this icy episode." He believed that there was an open Polar Sea throughout the glacial age, and that sea-borne ice as well as glaciers must be looked to, to account for the known evidences of glaciation.

In a paper on *New discoveries of Carboniferous Batrachians*, the same author gave an account of the mode of preservation and gradual accumulation of the remains of land animals and insects in the hollow trunks of trees buried in aqueous deposits, as illustrated by the buried Carboniferous trees of the South Joggins section, several new specimens of which have been recently developed.

The paper by G. W. Dawson was read in his absence by the president of the Society. It consisted of *Geological notes on some of the coasts and islands of Behring Sea and its vicinity*, made during his visit to the regions as one of the members of the British Commission investigating the fur-seal problem in 1891.

The localities visited were the Aleutian Islands, Komandorski Islands, Kamtschatka, Pribyloff Islands, Nunivak Island, St. Matthew Island, Plover Bay. Many of the islands are of volcanic origin, and the whole line of islands were found to be on the outer border of the continental plateau, which, elevated above its present level, once connected Asia and Alaska. The author concluded, from his study of the soundings and of the Tertiary formations on the edges of some of the islands, that the submarine plateau and the western part of Alaska were under a shallow sea during the later Miocene epoch, since which time the region was elevated, forming land connection between the two continents by which the mammoth may have reached the Pribyloff Islands. This was followed by depression, and in comparatively recent times there was an elevation of 10 to 30 feet.

The observations of Dr. Dall and others as to the absence of any evidence of general glaciation in the Behring Sea region are confirmed by the author's observations.

The eastern boundary of the Connecticut Triassic.—Profs. W. M. Davis and L. S. Griswold, in their paper, illustrating the general structural features of the Triassic belt by a series of lantern slides, maintained that the eastern boundary of the formation is defined by a system of faults, whose existence is proved, according to the authors' interpretation of the facts, as follows: First, different members of the formation successively terminate along the eastern border; in passing northeastward from the Sound near East Haven, to the Connecticut River near Middletown, the lower sandstones, the anterior trap sheet, the anterior shales, the main trap sheet, the posterior shales and sandstones, the posterior trap sheet and the upper sandstones and conglomerates, gently undulating as a whole, are terminated in alternating succession along the border. This cannot be explained as a result of variable overlap of the Triassic series unconformably upon the crystallines, for the former dip towards the latter; they must be cut off abruptly along the margin of their present area. The border is marked by a depression, wider open when the adjacent rocks are weak, narrow when they are hard. Close to the border, departures from the prevailing dip of the formation are frequent. The crystalline rocks near the border manifest the effects of shearing; and this seems to be subsequent to the formation of the marginal conglomerates, for they do not contain fragments of the sheared crystallines.

The eastern boundary follows an alternating north and northeast course. Hence two systems of faults may be recognized; one having a northerly course, the other trending northeast. Two members of the latter system have been traced for many miles obliquely across the Triassic belt, as well as along the oblique portions of the border. In consequence of the combined movements of both systems of faults, the formation broadens to the north; and in the Manchester district, it is believed that the under sandstones, ordinarily seen along the western border of the monoclinal belt, are repeated along the eastern border. (Author's abstract.)

In his paper on *The fossil flora of Alaska*, F. H. Knowlton reported the total number of species listed as 114, of which the 54 species more recent than Neocomian occur also outside of Alaska. The author gave the following conclusions:

"An examination of the table yields the following numerical results: The Laramie has 3 species of which 1 is doubtful; post-Laramie beds of Colorado 10 species; the Livingston beds of Montana 6 species; the Ft. Union beds 16 species of which 1 is doubtful; the Green River group 9 species of which 3 are in doubt; the Mackenzie River 11 species; British Columbia has 6 species in the Miocene and 4 in the Laramie with 2 common to both; California, represented by the Auriferous gravels and allied formation has 17 species of which 3 are in doubt; the Eocene (Alum Bay, etc.) 6 species; the Greenland Miocene, as represented at Disco Island, Atane Rerdluk, etc., has 29 species; the Miocene of Spitzbergen 20 species; the island of Sachalin (Siberia) 23 species; Senizalia (Italy) 12 species; the so-called Baltic Miocene 13 species; Oeningen 20 species; Oligocene 4 species; Miocene 33 species; Pliocene 15 species.

"By combining a number of the above localities which may be legitimately taken together we have still more impressive results. Thus by the combining of the post-Laramie beds of Colorado with the Livingston beds of Montana we have 13 species common to Alaska. The union of the Mackenzie River and Ft. Union deposits gives 21 species common to Alaska, while Greenland, Spitzbergen and Sachalin have no less than 39 species out of the 54 from Alaska.

"This last result shows, if we are to place any dependence in fossil plants, that the flora of Alaska, Greenland, Spitzbergen and the island of Sachalin are so closely related as to lead to the unavoidable conclusion that they grew under similar conditions and were synchronously deposited. The localities enumerated show that the circumpolar flora at that time was practically similar and continuous."

N. S. Shaler presented three papers, of which the following abstracts give the substance.

1. *Notes on the Pleistocene dislocations of the Atlantic Coast of the United States.*

The dislocations of the Cretaceous, Tertiary and Pleistocene strata of northeastern Massachusetts described by the writer in the Seventh Annual Report of the director of the U. S. Geol. Survey, p. 297, et seq., and in the Bulletin of the Geol. Soc. of Am., vol. i, p. 443 et seq., appear to be a part of a mountain-building process which, in relatively recent times since the beginning of the Pleistocene, has affected the Atlantic coast from North Carolina to Massachusetts Bay. South of New York the type of the dislocations have the fault type, north and east of the Hudson they take on the character of foldings. These movements, though extensive and intense in southern New England, appear to have satisfied the stresses which caused them, for since the development of the topography of the district, so far as it was formed on these dislocated rocks, no considerable movements have taken place.

The foldings of the rocks in the Cretaceous, Tertiary and Pleistocene strata of Martha's Vineyard and neighboring districts, seem to have been due to the formation of a broad, rather compressed synclinal in the crystalline rocks upon which they rest; in this respect resembling the down-fold which encloses the Richmond, Va., coal field.

The disturbed strata of the New England shore district are now at about the level in which they were formed. There thus appears to have been no considerable permanent change of level of this part of the continent due to their orogenic action. (Author's abstract.)

2. *Relation of Mountains and Continents.*

Modern investigations show that mountains do not develop on the deep sea floors in the manner in which they are formed on the continental folds. This shows that there is some causal relation between these two types of relief.

An inquiry into the sub-aerial reliefs of the great coasts shows that they are in the main, made up of the broad pedestals which have been formed in the districts where mountain building has occurred. The mass of these pedestals, or regional uplifts is generally very great. They indicate the movement of inner earth matter toward the seats of dislocation : a large part of the material going to form the uplifted section of the earth's crust on either side of the mountain-built area. A part of this pedestal is in many cases formed of debris worn from the central axes.

Deep-sea soundings show that there are folds of the crust formed in the thalassal areas. Although the number and precise shape of these folds is unknown, it seems not improbable that they are the original type of surface deformations. When one of these ridges attained a supra-marine level, local erosion, with the consequent transfer of weight, brought about the mountain-building disturbances and thus served to determine the form and in part the elevation of the fold.

The history of the peninsula of Florida, the promontory of Yucatan and the Cincinnati axis appear to give support to this view as to the relation of mountains and continents. (Author's abstract.)

3. *Phenomena of beach and dune sands.*

The remarkable endurance of beach sands to the blows which are inflicted by the waves is to be explained by the fact that when mineral matter attains a certain state of division being thoroughly wet, a film of water is usually held between the adjacent grains which serves to keep the surfaces apart and thus, in a great degree, prevents abrasive action. Thus, while pebbles wear rapidly in the mill of the surf, sand is very little worn.

The effect of sea-weeds in bringing pebbles and sand into the beaches is very great: this is accomplished by the floating action of these plants on the objects to which they become attached in the shallow water near the shore.

The effect of floating pumice which becomes stranded along the Atlantic coast is, at certain points, noticeable; but the enquiries as to the value of the contribution have been retarded by the difficulty which has been found in determining in a ready way the difference between certain forms of furnace slag from steamship boilers and true volcanic materials.

The movement of dune sands is to a great extent made possible by the fact that these accumulations of sand rarely become wet through, except it may be during the winter season. A rain-fall of an half an inch will in general moisten the sands to the depth of not over three-fourths of an inch. The water flows laterally to the center of the depressions and there only finds a passage to the deeper parts of the dune. The result being that in a short time the materials are dry enough to be set in motion by the wind.

The large amount of fine dust developed in dune sands, which have been some time stable, shows the rapidity with which the processes of decomposition of their materials advance. (Author's abstract.)

Wm. B. Scott discussed the *Lacustrine Tertiary formations of the West* and gave the paleontological reasons for separating the Paloduro beds from the Loup Fork proper.

The classification of the Neocene formations (fresh water) of the United States, proposed as the result of his latest studies, is given in the following table (first published in Princeton College Bulletin, vol. v, Nov., 1893, p. 84):

Pliocene	Peace Creek (Florida).	
	Blanco.	
	Paloduro (and Archer of Florida).	
Miocene	Loup Fork	Loup Fork proper.
		Deep River.
	John Day	Mesoreodon Beds (Montana).
		Eporeodon Beds (Oregon).
Oligocene.	White River	Protoceras Beds.
		Oreodon Beds.
		Titanotherium Beds.

George H. Williams, in his paper entitled, *Volcanic Rocks in the ancient crystalline belt of Eastern North America*, called attention to the widespread occurrence of truly volcanic rocks in the paleozoic and pre-paleozoic formations of eastern North America. He was led to a search for such rocks by the discovery of their extensive development in the Blue Ridge between Harrisburg, Pa., and the Potomac River, as described in this Journal, Dec., 1892. Since that time personal observation has disclosed great masses of similar rocks on the coast of Maine and in the Carolinas, while the published literature renders probable their abundant occurrence as far north as Newfoundland.

After a review of the opinions prevailing in Europe as to the nature of the differences between ancient and modern volcanic rocks, the author enumerated the criteria necessary for the certain identification of ancient volcanic rocks. While regarding the differences between the products of ancient and modern volcanoes as secondary and therefore non-essential, he considered the proofs that any rocks called *volcanic* (in contrast to plutonic) solidified at or very near the atmospheric surface as very important. A tendency on the part of some geologists to use the word *volcanic*, as synonymous with *igneous* is greatly to be deprecated as introducing only confusion. The former term should be employed, at least in the case of ancient rocks where the external form of the volcano has been destroyed, only for igneous masses whose surface origin is beyond doubt. The most reliable proofs are in the case of acid rocks glassy structures, which in spite of complete devitrification will be preserved, and in the case of basic rock an amygdaloidal or scoriaceous texture. Such structures, while they may rarely occur in narrow dykes which have very rapidly cooled, are essentially characteristic of lava flows, especially if the rocks which exhibit them are of great extent. But even better than these structures as proof of volcanic origin are accumulations of fragmental (pyroclastic) material, tuffs, breccias, agglomerates, etc., stratified either by gravity or water, which accompany such massive effusive rocks. All of these proofs are abundant in the rocks to which the author applies the designation volcanic.

The distribution of ancient volcanic products was traced, either by published accounts or by personal examination of material sent by friends or collected in the field, from Newfoundland through Cape Breton, Nova Scotia, New Brunswick, and along the coast of Maine as far as the Boston basin. Another more westerly belt may be followed from Gaspé, through the Eastern Townships to Vermont; it appears again near Harrisburg and extends at intervals along the whole extent of the Blue Ridge. The eastern belt appears again in North Carolina, not far from Raleigh and is nearly continuous across the State. (Author's abstract).

In the paper on *The Shasta-Chico series of the Pacific Coast*, J. S. Diller described several measured sections of the Cretaceous in different parts of middle and northern California. He demonstrated the stratigraphic and faunal continuity of the Shasta-Chico series composed in California of the Knoxville, Horsetown and Chico beds which attain a maximum thickness of 30,000 feet (see this Journal, vol. xl, 1890, pp. 476–8). The differences in the composition of the several sections was explained as due to transgression of the Cretaceous seas during the deposition of the series.

The geology of southern Indian Territory and northern Texas adjacent to the Red River, was described by Robert T. Hill, showing the remarkable development of Cretaceous and later formations in that region where the typical geographic features of the southern gulf coastal plain, the Texas prairie region, and the Appalachian structure of the Ouachita mountains meet, and where their relations are seen.

Mr. Hill showed the differentiation of the various formations south and westward from this area, and gave a minute description of the Washita division of the Comanche series from the Rio Grande to Red River, its faunal and sedimentary changes, with the zones and hemera of its fossils. The Shoal Creek limestone, capping the Comanche series south of the Brazos, was described as having an entirely distinct fauna from that of the contiguous beds—a fauna entirely new to the North American Cretaceous, consisting of Foraminifera, Coelenterata and Mollusks.

The speaker remarked upon the strong homotaxial resemblance between the great divisions of the Texas Cretaceous formations and those of western Europe, especially the Neocomian, Gault, Turonian and Senonian, although presenting absolutely no similarity to the beds of the pacific region.

The author observed that the Duck Creek chalk and the Kiamitia beds contain the fauna described as Neocomian by Marcou, who was the first to recognize the early Cretaceous age of what are now known as the Comanche series. (From notes by the author).

G. H. Williams called attention to a work written by *Johann David Schoepff*, an almost forgotten contributor to the geology of this country in the last century. His book, dated 1787, "Beiträge zur Mineralogischen Kenntniss des östlichen Theils von Nord Amerika," is full of very good observations made between Rhode Island and Florida, especially in the Appalachians of Pennsylvania, Maryland and Virginia.

WHITMAN CROSS (*Intrusive sandstone dikes in granite*) mentioned the occurrence, in the area of the Pike's Peak granite mass, in Colorado, of sandstone bodies whose *formal* relations to the granite are perfectly analogous to those of dikes of igneous rock, while the *substance* of the masses in question is purely a clastic mixture, almost wholly of quartz, of fine and even grain, very similar to sandstones of sedimentary origin. (Author's abstract).

A paper by T. C. CHAMBERLIN and FRANK LEVERETT on *Certain features of the past drainage systems of the upper Ohio basin*, will be presented in full in this Journal.

The subject discussed and illustrated by specimens under title of a paper on *Facetted pebbles on Cape Cod*, by W. M. DAVIS has already been referred to in this Journal (vol. xlvii, p. 63) by J. B. Woodworth.

ALPHEUS HYATT made a communication upon "*The Fossils of the Trias and Jura of the Western States*," and exhibited specimens of the fossils; his remarks may be summed up as follows: The discovery of Monotis beds above the Carboniferous in American Cañon, south of Cisco, California, showed the probable existence of the Trias there, but just above these in Sailor's Cañon occurred beds of Daonella which were more doubtful. The Daonellæ, although hitherto considered exclusively Triassic, occurred in part near the upper limits of their distribution in curious association with Ammonitinæ of very doubtful aspect.

These Ammonitinæ are not as a whole like any fauna heretofore described as Triassic. They have a distinctly Liassic facies and with them Dr. Curtice found two specimens of Aptychi of the rugose type, which in Europe have not yet made their appearance below the Upper Lias. For these reasons the speaker considered the age of Daonella beds and Ammonites beds to be doubtful, and stated that until specimens showing the sutures of the Ammonitinae were found this could not be determined with certainty.

The Triassic fossils of Gabb's locality in New Pass Desatoya Mts., and near Walker's Lake in Nevada have been found recently in a collection donated by Prof. Whitney to the Museum of Comparative Zoology, and these prove the identity of the faunas at these two localities with that of the Muschelkalk of the Star Peak Range also in Nevada but farther west.

Lias.

The same collection contained Gabb's type of *Arnioceras* (*Amm.*) *Nevadanus* and a *Corniceras*, n. sp. showing the existence of the Lower Lias near Walker's Lake in southwestern Nevada.

A small collection of fossils from Professor Condon, coming from the Blue Mts. of eastern Oregon, showed species identical with those of the Hardgrave Sandstone of Taylorville and with some of the species described by Gabb from near Walker's Lake, thus demonstrating the presence of the Upper Lias at these three localities, two of them separated by the crests of the Sierra Nevada.

Upper Jura.

The Gold Belt fossils were next taken up and discussed. The discovery of Gabb's type of *Ammonites Colfaxi* showed that it was a true Perisphinctes and with other forms of the same genus recently found near Colfax demonstrated the Upper Jurassic age of the rocks on the western slope of the Sierras. The Aucellæ, and the Ammonitinæ of the genera Cardioceras and Perisphinctes, from Mariposa, Calaveras and Tuolumne Counties were represented in collections acquired in the last few years by the U. S. Geological Survey and proved, in his opinion, the Upper Jurassic age of the gold belt series of slates. The species of Cardioceras and Perisphinctes had the common characteristics of the similar forms found in the Upper Jura of the Russian fauna and these occurred in association with similar forms of Aucellæ.

The species of Aucellæ differed as a whole from those of the Knoxville slates in being almost invariably ornamented with radiating striæ. Only one species, the *A. Errington* var. *arcuata*, approximated in outline to the well-known, narrow form of *Aucella Piochi*. This is invariably smooth and as lately demonstrated by Diller and Stanton occurs only in the lower part of the Knoxville slates. The conclusion was thus reached that the fauna of the gold belt series of rocks was Upper Jurassic and younger than that of the Knoxville series. (Author's abstract).

Henry S. Williams read a paper on *Dual nomenclature in Geological classifications*, setting forth the importance of differentiating between the lists of geological formations and the divisions of the time scale. He showed that the former are defined and determined by physical, structural and mineral conditions which are always local and never uniform for any considerable geographical extent; and that the latter, however indefinitely, are always known and defined by particular species or genera of organisms which had a definite life period and hence record an actual determinable point in time.

The imperfection of the present method was illustrated by the case of the Catskill formation, whose place in the scale, and the use of the name has recently been discussed by Hall, Darton, Stevenson, Prosser and the author. The author emphasized the fact that in our common usage there are two entirely distinct sets of facts confused in the nomenclature and classification, called the geological scale; that the confusion and evils arising therefrom are not corrected by merely providing two sets of nomenclature, as the international congress of geologists has done in proposing *group*, *system*, *series*, *stage* with their corresponding chronological terms, *era*, *period*, *epoch*, *age*, so long as there is only a single set of divisions classified. The fact is that the stratigraphical division planes used in defining the formation-scale, while they do indicate relative superposition locally have only relative time value.

Like the lines in the solar spectrum their position must be known before they can be used as chronological marks. The fossils on the other hand have an intrinsic time value, their characters intimately connect them with what has preceded and what follows them. Like the angle of refraction of the rays of light of each color, each fossil has a normal time value.

Fossils thus become the true criteria of the time scale; but the elements of the formation scale are local accumulations of various kinds of sediments whose place in a geological time scale is determinable only by fossils. The formations of one section will overlap, and differ in composition and limits from those of another section,—the time-scale should be a universal standard, with no overlapping, with divisions, arbitrary it may be, but never duplicated; the marks of which are fossils, changing constantly but in a definite order of sequence.

In the case of the Catskill it was shown that within the limits of the New York system, what is called the Catskill formation, group or period is a geological formation, but is not either an epoch or a period, and that Catskill is not an appropriate name to apply to any division of the time-scale. Thus we may say of the Catskill formation, that in the Genesee section in western New York, the whole of Devonian time is recorded without any trace of the Catskill formation, it is neither above, below or within the Chemung. The whole of Devonian time transpires and includes no such division as a Catskill epoch or period. One hundred miles eastward, the section running through Cayuga Lake, shows at the close of the Devonian, after the cessation of the Chemung fauna, a Catskill formation of several hundred feet thickness. Another hundred miles eastward, across Otsego Co., the section contains (1) rocks of the Catskill formation for the upper third of the upper Devonian, below them (2) a sparsely fossiliferous zone of Chemung—probably its lower part, (3) a modified Ithaca fauna, then (4) the Oneonta formation, which is but a detached zone of the Catskill, next (5) a fauna intermediate between that of the Ithaca and the typical Hamilton, underlain by (6) the Hamilton formation of the middle Devonian. Still further east, along the Hudson River valley, the Catskill formation occupies the whole of upper Devonian interval—and if we go still farther east, in Maine we find rocks which are but the extension of the same formation as the Catskill filling the whole interval from the Oriskany to the Carboniferous; i. e. the upper, middle and most of the lower Devonian system.

In elaborating this dual nomenclature, it was proposed to continue the use, for the formation-scale of the present nomenclature in the manner in which the newer work of the United States Geological Survey is being defined, using geographical names in combination with lithological terms for the nomenclature. For the time-scale, the degree of precision increases in the opposite direction—from the general to the particular. A single fossil in most cases is sufficient to determine the time (Paleozoic, Mesozoic or Cenozoic) to which the formation belongs. The times may be divided into Eras, the Cambrian, Silurian, Carboniferous, etc. Refinement in general usage has proceeded far enough to permit the recognition of two-fold or three-fold divisions of the eras, and these may be designated by prefexing *eo*, *meso* and *neo* to the name of the era, and may be called Periods; thus *Eocambrian* is the name of the period of the Olenellus fauna, *Mesocambrian*, is the period of the Paradoxides fauna, *Neocambrian* the period of Dicellocephalus fauna—and so on for each of the other eras.

Thus we would say of the Chemung, the Famennian, the Ilfracombe formations, each belongs to the Neodevonian period. The particular time value of each of these formations in a general time-scale we do not yet know with precision. Although the perfecting of knowledge will undoubtedly enable future geologists to define *epochs* and even *hemeræ*, in the general geological time-scale, our present knowledge of the succession of varieties and species is not sufficiently accurate to make their definition practicable for any extended region. While, therefore, we know the order of succession of faunas in local formations we may not be able to correlate our faunas with greater precision than to define periods for the standard time-scale. Common usage signifies that already this can be done so far as to recognize three-fold, or in some cases only two-fold subdivisions of the following eras, Cambrian, Ordovician, Silurian, Devonian, Carboniferous, Triassic, Jurassic, Cretaceous and Tertiary. (Author's abstract.)

H. S. W.

2. *Le Tormaline del Granito Elbano* di GIOVANNI D'ACHIARDI, parte prima 8°, pp. 82, one plate, Pisa, 1893 (T. Nistri).—Prof. D'Achiardi states in his preface that the purpose of making a mineralogical study of the tourmalines of Elba was suggested by the immense richness of the material in the museum at Pisa and in the present part he gives the bibliography relating to the mineral and "treats of the morphology of the Elban tourmalines describing the crystal form in relation to their multiple varieties."

L. V. P.

3. *Anleitung zur Krystallberechnung* von Dr. BENNO HECHT. 8°, pp. 76. Leipzig, 1893 (Johann Barth).—This small volume gives in highly condensed shape the mathematical relations and formulæ necessary for the calculation of crystal forms and elements. The method employed is empirical and given from a purely mathematical standpoint. It will be of interest to those engaged in crystallographic studies. L. V. P.

4. *Cours de Mineralogie professé a la Faculté des Sciences de Paris* par CHARLES FRIEDEL, Mineralogie générale. 416 pp. 8°, Paris, 1893 (G. Massen).—The object of this text book, so we are informed by the author in the preface, is to supply a more general work and one which does not demand so much training

in mathematics as do the treatises of Mallard and de Lapparent, and to show as "simply as possible the methods that the science owes to crystallography, to physics and to chemistry in order to determine and classify minerals." L. V. P.

5. *Recherches Mineralogiques, Edition Posthume* par Prof. M. TOLSTOPIATOW. Moscow, 1893 (Leipsig in commission bei G. Weigand). 8°, pp. 136. 3 col. plates.—This memoir comprises the results, naturally in somewhat incomplete form, of the studies of the author, who was professor of mineralogy at the University of Moscow, in crystallogenesis and the optical and physical properties of crystals and the discussion of certain theories held by him relating to such phenomena. An obituary of the author is also added. L. V. P.

6. *A large unio-like shell from the Coal measures.*—Prof. Whiteaves describes in the Transactions of the Royal Society of Canada (Sect. iv, 1893, pp. 21–24, Pt. I), a large unio-like shell which he names *Asthenodonta Westoni*, discovered in the South Joggins coal field by Mr. T. C. Watson. The dimensions of the largest specimens are 200^{mm} by 90^{mm}.

7. *Cretaceous in Northern Minnesota.*—H. V. Winchell reports the discovery of Cretaceous deposits of probable Colorado group age, in the Mesabi range, Section 20, twn. 58 N., Range 19 W. (American Geologist, vol. xii, p. 220.) W.

8. *On the evidences of a Submergence of Western Europe* and of the Mediterranean Coast, at the close of the Glacial or so-called Post-glacial Period, and immediately preceding the Neolithic, or Recent Period; by JOSEPH PRESTWICH, (Phil. trans. Roy. Soc. London, vol. clxxxiv (1893), A. pp. 903–984.)—The paper is illustrated by a map giving the position of the Rubble-drift and Raised Beaches for Europe and Northern Africa. The author believes that the phenomena discussed indicate a temporary submergence beneath deep waters (at least 200 or 300 feet about the shores of the Mediterranean), followed by re-elevation at the close of the Glacial period and commencement of the Neolithic age. W.

9. *The Canadian Ice Age*, being notes or the Pleistocene Geology of Canada, with special reference to the life of the Period and its climatal conditions, and lists of the specimens in the Museum (Peter Redpath Museum, McGill Unversity, Montreal); by Sir J. WILLIAM DAWSON. Scientific Publishing Co., New York, pp. 301.—The list of Pleistocene Fossils (chapter VI) has been carefully revised up to date and includes 240 species. The whole of the marine species with two or three exceptions, the author states, are living northern or Arctic forms belonging to moderate depths or varying from the littoral zone to 100 fathoms. Nearly all the marine species of the Leda clay and Saxicava sand are still living on the coasts opposite the points where the fossils occur. The shells of the lower bowlder clay and of the more inland and elevated beds, regarded as older than the lower terraces near the coast, are more Arctic in character.

The author further states that no remains of man or his works have yet been found in the Pleistocene of Canada; none of the implements discovered in alluvial deposits go further back than the modern period properly so called. W.

10. *Bulletin of the Dept. of Geology, University of California.* A. C. LAWSON, Editor, Berkeley, Cal.—Prof. Lawson states that it is the intention to issue these bulletins, each embodying a special piece of research, at irregular intervals, the bulletins to compose volumes of from 400–500 pages. The following numbers of Vol. I have thus far appeared. *No. 1, Geology of Carmelo Bay*, by A. C. Lawson, assisted by J. de la C. Posada. The structure, stratigraphy and geological history of the district are carefully, worked out. The petrology of the igneous rocks is considered in detail, accompanied by analyses. *No. 2, The Soda Rhyolite north of Berkeley*, by Chas. Palache. This is a detailed study of a very acid effusive rock in which soda is shown to be present in relatively large amount. *No. 3, The Eruptive Rocks of Point Bonita*, by L. F. Ransome. Another excellent petrological paper in which the mode of occurrence, petrography and chemical relations of a series of basic igneous rocks is carefully worked out. *No. 4, The Post-Pliocene Diastrophism of the Coast of Southern California*, by A. C. Lawson. This memoir contains the observations and reasoning by which two facts of general interest are established: "the uplift or emergence from the sea of the entire coast of California from San Francisco to San Diego in post-Pliocene time to an extent of from 800 to 1,500 feet," and "the local deformation or differential movement of the crust to a remarkable degree, particularly in the vicinity of San Catalina Island and near the city of San Francisco." These memoirs are well printed and accompanied by excellent maps, illustrations, diagrams, etc.
L. V. P.

11. *The Geological Survey of Missouri.*—The new Board of Managers of the Bureau of Geology and Mines met last week and passed a series of resolutions which contemplate a discontinuance of the geological survey of Missouri after June 1st next. The last State Legislature failed to appropriate sufficient money to maintain even a reduced force and to complete, let alone publish, the reports on hand. After careful consideration the best solution of the difficulty appeared to be the devotion of a greater part of the funds on hand and appropriated to the publication of three reports, on paleontology, lead and zinc, and clays respectively, in the order named, to abandon other work on reports on hand, whether nearly completed or not, and to suspend the work of the bureau with June 1st, the services of the State Geologist and his staff to be then dispensed with.—*The Age of Steel*, Jan. 6, 1893.

12. *Geikie's Fragments of Earth Lore.**—This work is a collection of articles some of which have been delivered as addresses

* Fragments of Earth Lore: sketches and addresses, geological and geographical. By JAMES GEIKIE. Edinburgh, 1893.

before various learned societies, while others have been published in various periodicals. Of the fourteen chapters of the book, one discusses the general relations between geography and geology, with special reference to methods of teaching geography; three are descriptions of the geology of Scotland, or of particular facts of that country; four treat of the evolution of the main geographical features of the earth; and six are devoted to the discussion of various phases of the Glacial Period. The dates of delivery or publication of the articles range from 1876 to 1892. As each article was intended to be complete in itself, and they have been republished in the present volume with little revision, there is inevitably considerable repetition. But each article is a valuable contribution to the knowledge of the subject of which it treats. Without attempting to notice the several articles in detail, we propose to call attention to some of the most important conclusions, in relation to the two important subjects to whose discussion the majority of the papers are devoted.

I. Geographical Evolution.

The author maintains the doctrine of the permanence of continents and oceans, giving credit to Professor Dana for the first clear enunciation of that doctrine.* In support of that doctrine, he refers to the contrast between the formations in progress at the bottom of the ocean, as made known by the naturalists of the Challenger and other expeditions for the investigation of the ocean, and the materials of which the surface of our continents and islands consist.† Certain it is that the rocks of existing land surfaces are in general very different from the volcanic clays and organic oozes of the ocean floor.

Assuming the substantial permanence of continent and ocean, in the sense of areas respectively of relative elevation and relative subsidence, the author holds that the progressive relative subsidence of the ocean basins has led to a progressive emergence of the continental areas, and accordingly a progressive increase in the area of dry land. That, in spite of all oscillations, this has been the general course of geological history, there seems little reason to doubt. A very interesting series of maps is given,‡ showing the areas of land and sea in Paleozoic, Mesozoic, and Cenozoic times, respectively. It is needless to say that the indications given by these maps are intended only as approximations; but they present a picture of geographical evolution whose main outlines are doubtless true. These maps are accompanied by a fourth, in which the areas respectively of dominant depression and elevation are distinguished, the contour line of 1000 fathoms being taken as the boundary. This boundary, is, however, recognized as an arbitrary one,§ since it is obvious "that the true boundary of the continental plateau cannot lie parallel to the surface of the ocean."

* Page 326. † Page 327. ‡ Plate V.
§ Page 378.

In Chapters XI and XIV, the law of continental evolution by gradual emergence is illustrated in the geological history of Europe.

In Chapter III the author gives a classification of mountains, dividing them into mountains of accumulation, mountains of elevation, and mountains of circumdenudation.*

The chapter on Mountains presents some very interesting views in regard to the decay of mountains under erosive agencies. The weakness of anticlinals, and their tendency to degradation is shown in a very striking way.† The tendency to the formation of synclinal ridges and anticlinal valleys is, nevertheless, stated, in our judgment, rather too broadly. Davis has shown that the preservation or reversal of the primitive topography of anticlinal ridges and synclinal valleys depends on the particular relation between hard beds and the base level of the streams.‡ An interesting suggestion of our author is that of the frequency of disastrous rock-falls in the Alps and other young mountain ranges, as compared with their rarity in old mountain regions.§ In the latter case there has been time for the removal of all especially weak and unstable structures.

The Evolution of Climate is discussed in Chapter XII. Our author follows Heilprin in doubting the sufficiency of Neumayr's evidence of the differentiation of climatic zones in the Jurassic.‖ Cosmopolitan species are, however, less numerous in the Cretaceous than in earlier formations; and in the Tertiary the distinction of zones is unquestionable.¶ The temperate climate of high northern latitudes even as late as the Tertiary our author attributes to the submergence of a great tract in Asia, of which the Aralo-Caspian depression is a remnant, permitting warm currents from the Indian Ocean to find their way into the Arctic.**

Professor Geikie maintains Croll's theory of the cause of the Glacial Period. Although the small amount of dry land in the early periods, and the free movements of warm waters into Arctic regions, rendered any general glaciation impossible, he yet believes that, in epochs of high eccentricity, the temperature was so far reduced as to develop ice action in some localities. Traces of such action, he believes, are found as early as the Devonian, in the Lammermuir and Cheviot Hills.††

II. The Glacial Period.

It is needless to say that Prof. Geikie adheres to the doctrine that the characteristic phenomena of the Drift are due chiefly to land ice. There is so general agreement among geologists on that conclusion, that argument thereon is well nigh superfluous. We will, however, call attention to the exceedingly interesting discussion in Chapter VII, on The Intercrossing of Erratics in Glacial Deposits. The objection sometimes still offered to the

* Page 44. † Page 52. ‡ Science, xiii, 320.
§ Page 51. ‖ Page 360. ¶ Page 364.
** Page 365. †† Pages 87, 371.

glacier theory, based on the transportation of bowlders in different or opposite directions over the same area, as if they had been borne by icebergs driven about by changing winds, is triumphantly answered. In the case of a number of localities in France, Germany, and Britain, it is shown that the comparatively local glaciers of an incipient or waning glacial epoch would necessarily move in a different—sometimes even in an opposite—direction from that of the portions of the huge confluent glaciers by which the same regions were covered in the culmination of a glacial epoch. The phenomena in question are thus shown to be an inevitable consequence of the glacier theory.

In this, as in his former works, Professor Geikie advocates the doctrine of a plurality of glacial epochs. The following is the series of Glacial Epochs, according to his latest views:*

"1. *Epoch of Earliest Baltic Glacier.*—Lowest bowlder-clay of southern Sweden; lowest bowlder-clay of Baltic provinces of Prussia; horizon of the Weybourn Crag.

2. *Epoch of Greatest Mer de Glace.*—Lower bowlder-clays of middle and southern Germany, central Russia, British Islands; second bowlder-clay of Baltic provinces of Prussia.

3. *Epoch of Lesser Mer de Glace.*—Upper bowlder-clay of western and middle Germany, Poland, and west central Russia; upper bowlder-clay of Britain; third bowlder-clay of Baltic provinces of Prussia.

4. *Epoch of Last Great Baltic Glacier.*—Upper bowlder-clay and terminal moraines of Baltic coast-lands; district and valley moraines of Highlands and Uplands of British Islands.

5. *Epoch of Small Local Glaciers.*—Valley moraines in mountainous regions of Britain, etc."

A fuller presentation of the evidence of the views set forth in the above table is promised in the forthcoming new edition of "The Great Ice Age."

The problem of the Loess is the subject of valuable discussion.† The eolian theory is rejected, largely on the ground that the prevalence of an excessively dry climate is inconceivable, since "the loess is intimately associated with accumulations, the glacial and fluvio-glacial origin of which cannot be doubted."‡ The loess is considered, in the main, "an inundation-mud deposited in temporary lakes and over flooded areas during the summer meltings of the snow- and ice-fields." Darwin's suggestion is approved, that many valleys were choked with snow, whereby the flooded rivers were often compelled to flow in temporary channels at levels far above the bottoms of the valleys§—a suggestion which finds confirmation in some remarkable phenomena observed in Alaska. The loess of north Germany is held to have been formed in a lake enclosed between the front of the ice-sheet and the foot-hills of the mountains of central Germany.‖

* Page 325. † Pages 176, 236. ‡ Page 177.
§ Page 180. ‖ Page 182.

Professor Geikie appeals to the occurrence of boreal and arctic shells in Quaternary marine deposits as proving that glacial conditions have been for some reason associated with submergence rather than with emergence of the land. "Each glacial epoch," he says, "was preceded and accompanied by partial submergence of the land."* We query whether the correlation of the deposits has been worked out with sufficient accuracy to exclude the view of LeConte, that a glacial climate may have been preceded and occasioned by elevation, but may have continued after considerable subsidence had taken place, the various effects lagging behind their causes.† It may be remarked parenthetically that Professor Geikie no longer holds to a deep Quaternary submergence of Britain, regarding the marine shells of Moel Tryfaen as "erratics."‡

The co-existence of northern and southern forms of vegetation in interglacial deposits is appealed to as showing that the climate in such epochs was exactly what the eccentricity theory requires —a climate of mild winters and cool summers.§

Professor Geikie refers to the estimates of Gilbert and Winchell on the recession of Niagara and St. Anthony's Falls, but rejects them as unreliable.‖

The relation of the succession of geological events in the Quaternary to the history man, is briefly treated. It is maintained that paleolithic man and the southern pachyderms with which he had been associated retired from England before the epoch of the Second Mer de Glace [the third of the five glacial epochs in the table which we have quoted], and never returned to Britain or northwestern Europe.¶

In conclusion, we would express our regret that a book of over four hundred octavo pages, containing so much that is interesting and valuable of fact and theory, should not be provided with an index.

13. *Economic Geology of the United States;* by RALPH S. TARR (Cornell University), pp. 509 (Macmillan & Co.), 1894.— This is the latest of the attempts to popularize the facts of geology by presenting them from the point of view of local distribution and commercial value, and from this point of view is well adapted for the American students. Economic geology was introduced as a special feature at Cornell University first with the use of David Page's Economic Geology, or Geology in its relations to the Arts and Manufactures (1874), a year or two later an elaborate synopsis of lectures for the course was prepared by T. B. Comstock. Later (1886) Samuel G. Williams, now Professor of Pedagogy at Cornell, prepared Applied Geology (Appleton's) on the same lines. In 1893 appeared Ore deposits of the United States, by James F. Kemp (now Professor of Geology at Columbia School of Mines), (The Scientific publishing company) 1894, a valuable work for others than elementary students. The

* Page 321. † Bull. Geol. Soc. Am., iii, 329. ‡ Page 173.
§ Page 385. ‖ Page 286. ¶ Page 243.

present work is much on the same plan as Page's book with the statistics and distribution of American products made more complete and prominent; and the author has added several excellent chapters on structural geology and physical geography which removes the book from being an aggregate of statistics regarding valuable geological products. W.

III. Astronomy and Seismology.

1. *The force that acts on the meteoroids after they have left the comets.*—(Communication by H. A. Newton to the American Philosophical Society at its recent sesquicentennial.)

There are in the comets so many questions that we cannot answer, so many curious and wonderful phenomena that are unexplained, that I am sure you will accept any explanation of any of them that seems plausible, as a matter of interest. From a comet there is continually driven off matter forming the tail, a light substance, and astronomers are agreed that the force that acts on the matter which forms the tail is a repulsive force from the sun acting inversely as the square of the distance, the force of the repulsion being greater than that of attraction.

Not only is this true, but different parts of that tail are acted upon by repulsive forces of different powers; otherwise the tail would form across the sky a single line instead of a broad, expanded mass of light such as we see. From the comet, however, there are driven off also, or there are separated other things entirely distinct from the tail, small bodies, which are not thus driven away, which are not visible, but follow along closely in the path of the comet, and whenever the occasion comes, that is when we go through a group of them, those give us our shooting stars.

The Biela comet, in the period about 1840, passed near to Jupiter. At that time it was turned pretty sharply out of its orbit, the inclination of the orbit being turned several degrees, and the node being carried forward also several degrees, represented by several days in the time at which we crossed the path of the comet.

After 1840 the bodies which formed the meteors that were met in 1872 and in 1885 were separated from one or other parts of the Biela comet. I say after 1840, because if they had been separated earlier they would have given us a different radiant in the skies, the one given by the Biela meteors of 1838. The radiant was changed, the node was changed, all to correspond to the new orbit, and these bodies could not have been turned in that way had they been before scattered, because the force that acted on them, the attraction of Jupiter, would have scattered the group instead of giving us that single compact group through which we passed in 1872 and 1885 in the course of four or five hours, and the bulk of them even in two hours.

In 1872, the comet was something like 200,000,000 miles away from the bodies that we met as we passed through them on the 27th of November, giving us a brilliant shower. Thirteen years later we passed through the group again, and then we were something like 300,000,000 miles ahead of the group. So that some of the particles, leaving the comet between 1840 and 1870, had fallen behind and others between 1840 and 1885 had gained.

What should separate those particles? What are the forces which carried off those particles so many miles—200,000,000 miles on the one hand and 300,000,000 miles on the other, in round numbers? The force that acts on them must be a force acting in one plane, that is, the plane of the orbit of the comet. Any force acting in other planes would have scattered the group and we would not have met them as a single definite group at the times named; but if it acts in the plane, only scattering them on the plane, they would be together as we saw them.

In that plane, it must be either an impulsive force acting once or it must be a constant force acting continually. The only bodies in that plane are the comets and the sun, and if the force is a continuous force it must be from the comet or from the sun. It is almost inconceivable to suppose that the comet could have sent them off, either impulsively or continuously, in such a way as to give us the distance of 200,000,000 and 300,000,000 miles in the course of thirty years; it would require far more than any velocity that we can give in our terrestrial experiments, and we have no reason to suppose that there is any such power of impulsion. Moreover, if the impulsion came from the comet, they would go in all directions and their character, as being in a plane, would have been entirely lost.

We are then thrown back on this one hypothesis, that the sun is the source of that force. In other words, we are led to extend the idea that I gave you in the beginning, and which is accepted by astronomers, that the material which goes off from the comet, after it leaves it, is subject to a force like that of attraction but differing in its intensity. In the case of the tail, it is a repulsive force. To satisfy these conditions of separation, part in one direction and part in the other, from the comet, we must have an attraction in the one case exceeding the attraction of gravitation and, in the other, an attraction less than the attraction of gravitation. In other words, these little bodies of hard matter that go off from the comet and follow very nearly in its train are acted on not in proportion to this mass like the force that acts on the planets in their orbits.

I see no escape, myself, from this conclusion. What it means, I must leave to you to decide. Our experiments make it very improbable that the attraction of matter differs in any way from proportion to the mass. It looks to me as though the more natural explanation is that, in some way, the materials which go off from the comet carry with them a load of electricity, or something of that kind, by which they have a permanent repulsion or permanent atttraction sufficient to change the orbit altogether, not in kind, but in a steady change, throwing them into a new orbit with a new period, and thus scattering them.

What that added force must be, we cannot very well tell, because it differs according to the place in the orbit where the disintegration takes place. If that disintegration takes place near the sun, it is one thing; if it takes place near Jupiter, it is another. It looks more to me as though there was a disintegration all along the line of the comet's orbit, giving us small particles with all sorts of loads of electricity and all sorts of differences of central attraction and differences of orbits, and thus they get widely scattered so as to give us the showers a long distance from the comet itself. The maximum amount of this change would have to be something like the tenth part, possibly, or something less than that. I should think that all the phenomena of the meteoroids could be explained by a change amounting to one-tenth of the attraction; that is, if the small particle carries a load of electricity such as to diminish the attraction to say nine-tenths of the original attractive force of the sun, or increase it to eleven-tenths, it will explain the phenomena.

If that is the explanation, we come to this further conclusion of interest, that the space through which these comets move is not such that the electricity which the particle carries can be lost. Another practical point would be that, in the discussion of the separation of these comet masses that through the telescope we see going on as the comets pass the sun, there might fairly be introduced an unknown correction of the force of central attraction.

2. *Photographs of August and December Meteors.*—At the Yale Observatory Dr. Elkin made trial in August last to determine whether, with a reasonable amount of labor, tracks of meteor flights could be secured upon photographic plates. On the evening of Aug. 9th, he exposed three plates. The camera had a six inch lens of thirty-two inches focus. This instrument had been purchased and presented to the Observatory by Mr. Cyprian S. Brainerd of Brooklyn who was interested in the experiments. It was attached to the mounting of the eight-inch equatorial and directed as nearly as convenient to the radiant in Perseus. The total time of exposure was four hours, and during the period careful watch was kept to note the time, etc. of any meteors crossing that part of the heavens which would appear on the plate. Three meteor tracks were secured, one of which was very bright and left on the plate a line nearly six degrees long. This is a true Perseid, as was one of the other two tracks.

On the same evening Mr. John E. Lewis of Ansonia exposed plates in a stationary camera, and the brightest of the three tracks was secured on one of his plates. A provisional computation shows that this meteor first begun to print its path on the Observatory plate at a height from the sea-level of 68·0 miles. It ceased to print when it was 51·65 miles high. The length of track between these points was 29·3 miles. The velocity with which a Perseid enters the air is 37·2 miles per second; hence the duration of the flight was probably less than one second.

On the following evening plates were exposed without success. Everything was in readiness on the 15th and 16th of November, in case the Leonids should appear in sufficient numbers to justify the exposure of plates. The moonlight and clouds interfered on the 23d to 27th of November, when the Bielids might possibly appear in moderate numbers.

On the evening of December 10th, the work was again resumed, and several plates were exposed, two cameras being used. They were directed near to the Geminid radiant, and three tracks of true Geminids were secured. Mr. Lewis at Ansonia joined in the work, but upon his plates only one possible trace was printed. This is too doubtful to be safely used.

The three Observatory tracks meet very nearly in a point. In fact a provisional computation based upon the Bonn charts, and allowing for differences of zenith attraction of the meteors makes the circle inscribed in the small triangle formed by the tracks produced backward less than one minute in diameter. The Bonn Durchmusterung star-places do not justify this degree of accuracy.

The experiment shows that with a reasonable amount of labor we can get photographs of meteor tracks. The accuracy of results obtained from the photographs is unspeakably greater than those gotten by any other known method. H. A. N.

3. *On the Annual and Semi-annual Seismic Periods*; by CHARLES DAVISON, (from the Proceedings of the Royal Society, vol. liv, pp. 82–85.)—(Abstract). *Method of Investigation.*—The method adopted is similar to that employed by Dr. C. G. Knott in his paper on "Earthquake Frequency."

A definition of the unit earthquake having been adopted, the earthquakes of different districts are classified in half-monthly groups, the first half of February containing fourteen days, and of all the other months fifteen days; and the numbers so obtained are reduced to intervals of equal length (fifteen days). The numbers for the two halves of each month are added together. The mean of the numbers for the six months from November to April gives the six-monthly mean corresponding to the end of January. Six-monthly means are calculated in this way for the end of each month; each mean is divided by the average of all twelve, and the difference between each quotient and unity is multiplied by the augmenting factor 1·589, in order to obtain the correct value of the ratio $a_1 : a_0$. The curve obtained by plotting these reduced means thus gives special prominence to the annual period, by eliminating the semi-annual period and all those which are fractions of six months, and by diminishing the amplitudes of all other periods with respect to that of the annual period.

In investigating the semi-annual period, the numbers corresponding to the first halves of January and July are added together, and so on; the rest of the method being the same as for the annual period. The result gives special prominence to the semi-annual period by eliminating the annual period, and by eliminating or diminishing the amplitudes of all periods less than six months.

Seismic Periodicity in relation to Intensity.—This discussion is founded on: (1) lists compiled from Mallet's great catalogue, first, of shocks which were so slight as to be just perceptible, and, secondly, of those which were strong enough to damage buildings; (2) Professor Milne's classification of the Japanese earthquakes of 1885 to 1889 according to the areas disturbed by them; and (3) different catalognes relating to the same district, it being obvious that two such catalogues for the same time can only differ by the omission or inclusion of slight shocks.

The following results are obtained: (1) In both periods, the amplitude is greater for slight than for strong shocks; (2) there appear to be two classes of slight shocks with an annual period, the stronger having their maximum in winter, the weaker in summer; and (3) in the case of the semi-annual period, both strong and slight shocks, as a rule, have nearly the same maximum epochs.

Seismic Periodicity in relation to Geographical Position.—The number of records examined is 62, 45 belonging to the northern hemisphere, 14 to the southern, and 3 to equatorial countries.

Annual Period.—In every district, and in all but five records (which are obviously incomplete), there is a fairly well-marked annual period. As a rule, different records for the same district agree in giving the same, or nearly the same, maximum epoch. Excluding, however, those which disagree in this respect, we have left 34 records for the northern hemisphere, 9 for the southern, and 2 for equatorial countries. In the northern hemisphere, 4 records give the maximum in November, 16 in December, and 6 in January; in the southern hemisphere, 2 in April, 2 in May, 3 in July, and 2 in August; the end of the month being supposed in each case. As a rule, then, the maximum epoch occurs in winter in both hemispheres. The amplitude of the annual period ranges from 0·05 (New Zealand) to 0·67 (Sicily and Algeria) the average of 57 records being 0·33.

Semi-annual Period.—Of the 62 records examined, only 3 fail to show a semi-annual period, the cause of the failure in these cases being no doubt the imperfection of the seismic record. In New Zealand and Southeast Australia, the maximum epoch generally falls either in February or March and August or September; in North America, as a rule, in March or April and September or October. But for other regions it does not seem possible as yet to deduce any law. The amplitude of the semi-annual period ranges from 0·06 (southern hemisphere) to 0·79 (Mexico), the average value being 0·24.

In fifteen cases, the amplitude of the semi-annual period exceeds that of the annual period. Eleven of these records include the following insular districts, which are among the most well-marked seismic regions in the world, namely, the Grecian Archipelago, Japan, the Malay Archipelago, New Zealand, and the West Indies. The average amplitude of the annual period in these eleven cases is 0·16, and that of the semi-annual period 0·24; *i. e.*, the average amplitude of the annual period is just half that for all the districts examined, while in the case of the semi-annual period the average amplitudes are the same.

Origin of the Annual Period.—In this, the concluding, section of the paper, an attempt is made to show that the annual change in barometric pressure may be the cause of the annual change in seismic frequency. It would be difficult to prove that such a connection exists, but reasons are given which seem to render it in some degree probable.

The most probable cause of the origin of the majority of non-volcanic earthquakes is the impulsive friction, due to slipping, of the two rock-surfaces of a fault. Now, whatever be the causes of seismic periodicity, it seems probable that they are merely auxiliary, and determine the epoch when an earthquake shall take place, rather than there shall be an earthquake at all. Professor G. H. Darwin has shown that the vertical displacement of the earth's surface by parallel waves of barometric elevation and depression is not inconsiderable, and that it diminishes at first very slowly as the depth increases. Since the fault-slip which produces even a moderately strong shock must be very small, and since the work to be done in such a case is, not the compression of solid rock, but the slight depression of a fractured mass whose support is nearly, but not quite, withdrawn, the annual range of barometric pressure does not seem incompetent to produce the effects observed.

Comparisons between the dates of the maximum epochs of the seismic and barometric annual periods are made in 31 of the districts treated in this paper. The seismic maximum approximately coincides with the barometric maximum in 10 districts, and follows it by about one month in 9, and by about two months in 4, districts; the other cases generally admitting of some explanation.

In several insular seismic districts, and especially in Japan and New Zealand, the amplitude of the annual period is very small; and, if many of the earthquakes of these districts originate beneath the sea, this should be the case; for, in the course of a year, as the barometric pressure changes, the sea will have time to take up its equilibrium position, and thus the total pressure on the sea-bottom will be unaltered.

IV. Miscellaneous Scientific Intelligence.

1. *On the laws of organic growth. Bioplastology and the related branches of Biologic research*; by Alpheus Hyatt. (Proc. Boston Soc. Nat. Hist., vol. xxvi, pp. 59–125.)—Prof. Hyatt

has contributed greatly to the elucidation of the laws of embryological development and its relation to paleontological succession in his numerous papers on Cephalopods. Stimulated by some criticism of his nomenclature, recently made by Messrs. Buckman and Bather,* he has set forth at considerable length and detail his views regarding the four different lines of research which are usually described by the popular terms growth, heredity, acquired characteristics and the correlations of development of the individual (ontogeny), with the evolution of the group to which it belongs (phylogeny). He proposes to use the technical names *auxology* or *bathmology* for the first, *genesiology*, for heredity; *ctetology* for the origin of acquired characters and *bioplastology* for the correlation of ontogeny and phylogeny, and describes the field of research and the special nomenclature required for each. As an analysis of the precise methods of research of the advanced investigators in biology this is a useful and timely contribution.
W.

2. *A Bibliography of Vertebrate Embryology*, by Chas. S. Minot (Memoirs Boston Society Nat. Hist., vol. iv, No. XI, pp. 487–614).—This is an elaborate, thoroughly classified list of 3555 titles of works treating directly or indirectly upon vertebrate embryology, classified primarily under 64 groups of subjects, then by authors alphabetically arranged.

3. *A theory of Development and Heredity*, by Henry B. Orr, Ph.D., 225 pp. 8vo, (Macmillan & Co.)—This is a theory of evolution from the psycho-physiological point of view. The substance of Prof. Orr's theory is given in the following sentences: "It would be difficult in the face of the facts to imagine that organic development differs in nature from psychic activity, or rather to speak more accurately, from the material accompaniment of psychic activity" (p. 239), and "the intelligent human action and the simplest process of growth are thus alike the necessary result of the stimuli which are momentarily acting, and those which have acted upon the organism through its racial and individual existence" (p. 242). W.

4. *Bulletin from the Laboratories of Natural History of the State University of Iowa.* Vol. II, No. 4, pp. 295–415, Plates I–XII, Nov., 1893. Iowa City, Iowa.—This number contains ten separate papers, the majority of which are micro-anatomical studies of animals and plants. Mr. Shimek in the fifth paper gives an account of a Botanical Expedition to Nicaragua in which the country traversed and its climatic conditions are described. The number and kinds of plants gathered is given but without generic or specific definition. Prof. McBride described (p. 391) a new Cycad, *Bennettites Dacotensis* from supposed Mesozoic rocks, near Minnekahta, S. Dak., the description having originally appeared in Am. Geologist, Oct., 1893. W.

5. *Horns and Hoofs, or Chapters on Hoofed Animals;* by R. Lydekker, pp. 411 (Horace Cox, London, 1893).—The work is a

* Zool. Anz., xv, p. 420 and 429, Nov. 1892.

popular treatment of the Natural History of hoofed big game of all parts of the world, in which is found, of scientific interest, the discussion of their present and past distribution. Numerous illustrations of the horns of the different species are inserted in the text. W.

6. *Our native Birds of song and beauty ;* by HENRY NEHRLING. Vol. I, pp. i–l; and 371 (George Brumder, Milwaukee).—This is a beautifully made book containing eighteen, full page, colored plates illustrating the song birds and flycatchers of North America. Prepared for the general public, it contains information of scientific interest regarding the geographical distributions and habits of the birds under discussion. W.

7. *Les Émules de Darwin*, by A. DE QUATREFAGES. Two vols. 1894 (Félix Alcan, Paris).—A preface by Edmond Perrier, introduces the first volume, followed by a notice of the life and works of M. Quartrefages by E. T. Haamy. The author has attempted to review the conceptions of the chief rivals of Darwin, those who have either advanced new theories or have sought to perfect the Darwinian theory, and the following names have been considered : Alfred R. Wallace, M. Naudin, M. J. Romanes, Carl Vogt, Ernest Haeckel, T. H. Huxley, Richard Owen, St. G. Mivart, A. Gubler and A. Koelliker, M. Trury, D'Omalreius d'Halloy, and Erasmus Darwin.

Upon closing the book the author says (translated) : " From this detailed examination, which we have endeavored to make as impartial as possible, one unpleasant impression is left : that of our inability to solve actually the great problem which so many eminent men have attacked in vain. The beginning of life upon the earth remains for all an impenetrable mystery. We are unable to assign any plausible cause for the transformations which the composition of faunas and floras have suffered. The modifications of which actually living forms are susceptible are capable of forming only *varieties* and *races*, no one has been able to produce a new *species.* The species remains an indelible entity, like that of the simple elements of chemistry.

Perhaps the darkness which envelopes the origin of the organic world will some day clear up. Science has shown too great power to make it prudent to assign limits to it. We will not repeat, in conclusion the *ignorabimus* of Dubois-Raymond, we will say only *ignoramus.* W.

8. *Bibliotheca Zoologica* II. Verzeichniss der scriften über Zoologie welche in den periodischen werken enthalten und von Jahre 1861–1880 selbständig erschienen sind. Bearbeitet von Dr. O. Taschenburg. Elfte Lieferung, pp. 3249–3568. (Wilhelm Engelmann, Leipsig, 1893).—The number of this valuable work just issued contains the continuation of the Bibliography of Fishes and commences that of Amphibia and Reptiles.

9. *The Mechanics of Hoisting Machinery ;* by WIESBACH and HERRMANN. Translated by Karl Dahlstrom, M.E. pp. 329, with 177 diagrams (Macmillan and Co.).—A part of Wiesbach's great

series on Engineering Mechanics, other parts of which have been translated by Coxe, DuBois and Klein. B.

10. *An Elementary Treatise on Fourier's Series* and *Spherical, Cylindrical and Ellipsoidal Harmonies;* by W. E. BYERLY. pp. 287 (Ginn & Co.). Based upon Rumaun's "Partialle Differential-glischungen" and designed to furnish with Pierce's treatise on "The Newtonian Potential Function" a course of study for students at Harvard University preparatory to modern Mathematical Physics. B.

Geological Survey of Texas. Annual Report for 1892, E. T. Dumble, State Geologist. The following parts have appeared since the notice in this Journal, vol. xlvi, p. 307 was written:

Notes on the Geology of Northwestern Texas, by W. F. Cummins, pp. 177–238.

Report on the Cretaceous Area north of the Colorado river, by J. A. Taff, S. Leverett, Assistant, pp. 239–354, with maps and sectional diagrams.

Report on the Colorado Coal field of Texas, by N. F. Drake and R. A. Thompson, pp. 355–481, with maps and diagrams.

Arkansas Geological Survey, Annual Report for 1890. John C. Branner, State Geologist, vol. iv.

Marbles and other Limestones, by T. C. Hopkins. 443 pages and 6 maps separately bound.

Annals of British Geology, 1892. A digest of the books and papers published during the year—with occasional notes, by J. F. Blake. pp. 310, 100 illustrations. (Dulan & Co., London, 1893.)

Memoirs of the American Museum of Natural History, vol. i, Part I. Republication of descriptions of Lower Carboniferous Crinoidea from the Hall Collection now in the American Museum of Natural History, with illustrations of the original type specimens not heretofore figured. By R. P. Whitfield, 4to, pp. 1–37, Plates I–III. 1893.

Economical Geology of the United States, by Ralph S. Tarr. pp. 509. 1894. (Macmillan & Co.)

Helical Gears; A practical treatise by a foreman pattern maker. pp. 127, 1894. (Macmillan & Co.)

Die Vorwelt und ihre Entwickelungsgeschichte, by Ernst Koken. pp. 654, 1893. (T. O. Weigel Nachfolger (Chr. Herm. Tauchnitz).)

OBITUARY.

RUDOLF WOLF, the distinguished Astronomer and for sometime Director of the Zurich Observatory, died in Zurich, Nov. 6, 1893.

PAUL FISCHER, author of Manuel de Conchyliologie et de Paléontologie Conchyliologique and of numerous papers on conchological subjects, died in Paris, Dec. 29, 1893.

D. A. BRAUNNS, Extraordinary Professor of Geology in Halle University died in 1893.

ARTHUR MILNES MARSHALL, the brilliant Professor of Zoology of Owens College, Manchester, died from the effects of an accident on Scawfell, Dec. 31, 1893, in the forty-second year of his age.

PIERRE T. VAN BENEDEN, Professor of Zoology, Paleontology and Anatomy, Lourain, has recently died at the age of ninety-three.

JEAN VILANOVA Y PIERA, the distinguished geologist of Madrid is dead.

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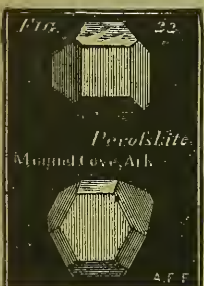

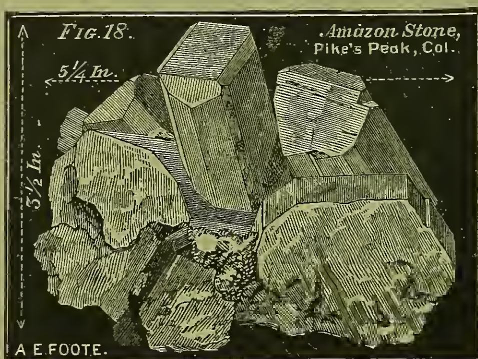

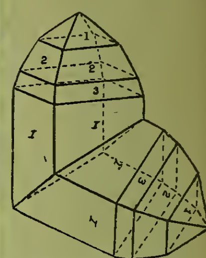

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THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

Art. XVII. — *Continuity of the Glacial Period*; by G. Frederick Wright.

Since the appearance in this Journal, for November, 1892, of my paper upon "The Unity of the Glacial Epoch," many important facts bearing upon the subject have come to light, especially in respect to the extent of preglacial erosion in the Ohio Valley. In my report upon "The Glacial Boundary in Western Pennsylvania, Ohio, Kentucky, Indiana and Illinois," published by the United States Geological Survey in 1891,* it was maintained that the erosion of the rocky gorge of the Ohio River and its tributaries was *pre*glacial. In opposition to this view, Professor Chamberlin, in the Introduction accompanying my report, maintained that the most important part of this rock erosion was *inter*glacial.

To make this point clear it should be stated that the upper portion of the Ohio River and its northern tributaries is characterized by a series of gravel deposits containing Canadian pebbles, resting upon rock shelves from 200 to 300 feet above the present river, and from 250 to 350 feet or more above the rock bottom of the river; while there is a lower series of gravel terraces, rising in places to 130 feet above the river, which is traceable up the streams to the moraine first described by Professor Lewis and myself in 1881.† The relation of

* Bulletin No. 58.

† The accompanying map (Fig. 1) to which frequent references will need to be made, shows the 500-foot and the 1000-foot contours of the Ohio Valley; also the boundary of direct glacial action. The figures give the elevation above the sea. Those along the river refer to the low-water mark. In the lower right hand corner is a typical section of the Allegheny showing the rock channel and the high-level terraces.

this portion of the rock gorge to Glacial movements is one of the principal points in controversy. My contention has been that this part of the rock gorge was preglacial; while in the Introduction referred to, Professor Chamberlin states (p. 35) his position as follows:

"The higher Glacial gravels antedated those of the moraine-forming epoch by the measure of the erosion of the channel through the old drift and the rock, whose mean depth here is about 300 feet, of which perhaps, 250 feet may be said to be rock. The excavation that intervened between the two epochs in other portions of the Alleghany, Monongahela, and Upper Ohio Valleys is closely comparable with this."

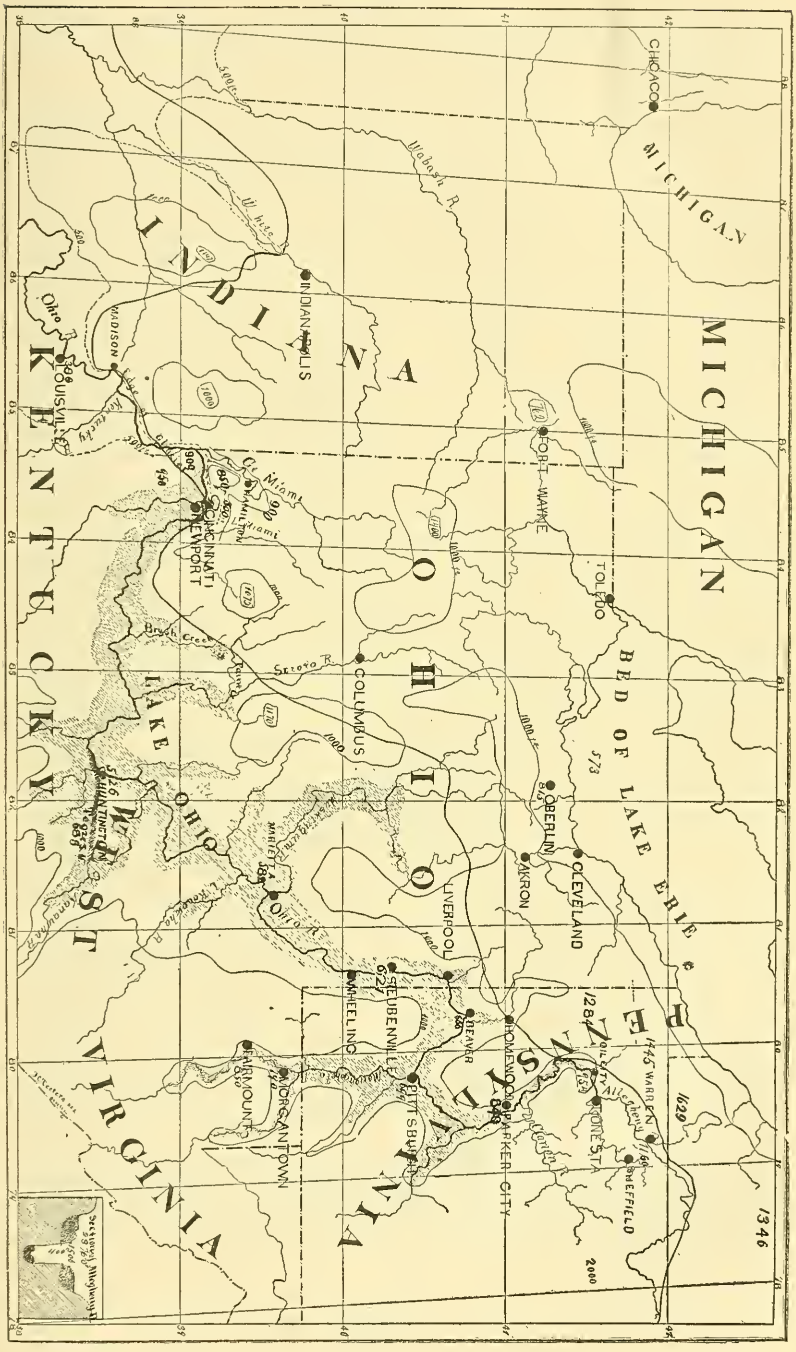
In this Journal, for March, 1893, in a paper replying to mine of the previous November, Professor Chamberlin reiterates in the strongest manner his adherence to his previously expressed views concerning the interglacial date of this rock erosion in the Ohio Valley. Thus he writes:

"These terraces I have maintained* were produced at a time of base level degradation, which in its later stages was contemporaneous with the earlier ice incursion whose water bore gravels down the Allegheny, Upper Ohio and some adjacent streams, and formed the 40 or 50 feet of capping which lies upon the rock benches that constitute the body of the terraces. I have argued that subsequent to this the land was elevated and the lower newer steep-sided gorges of the Allegheny and neighboring streams were cut to a depth that may be roundly stated as 250 feet, and that subsequent to this the later ice incursion formed the outer moraine of the region. From the outer side of this moraine Glacial streams bore their sands and gravels down the Allegheny gorge cut during the interglacial interval. The evidence of this, gathered in a joint study by Mr. Gilbert and myself, may be found in Bulletin 58, U. S. Geol. Surv., pp. 32–36. I therefore argue that between the time when the Glacial gravels were deposited on the high terraces and the incursion of the later ice there was a cutting of the gorge to the depth of 250 feet roundly speaking. I regard this gorge-cutting as a *minimum* measure of the interval between the two ice incursions."

During the past year I have devoted as much time as I could spare from other duties and other fields of investigation to the collection of additional facts bearing upon the solution of this important problem. In December, 1892, under guidance of Mr. Richard R. Hice, of Beaver, Pa., I examined the valley of the Big Beaver between the Ohio and the Glacial boundary, with the result of finding, just below the line of

* Bulletin 58, U. S. Geol. Surv., pp. 20–38.

.FIGURE 1.


CHICAGO
MICHIGAN
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Gt. Miami
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FORT WAYNE
TOLEDO
OHIO
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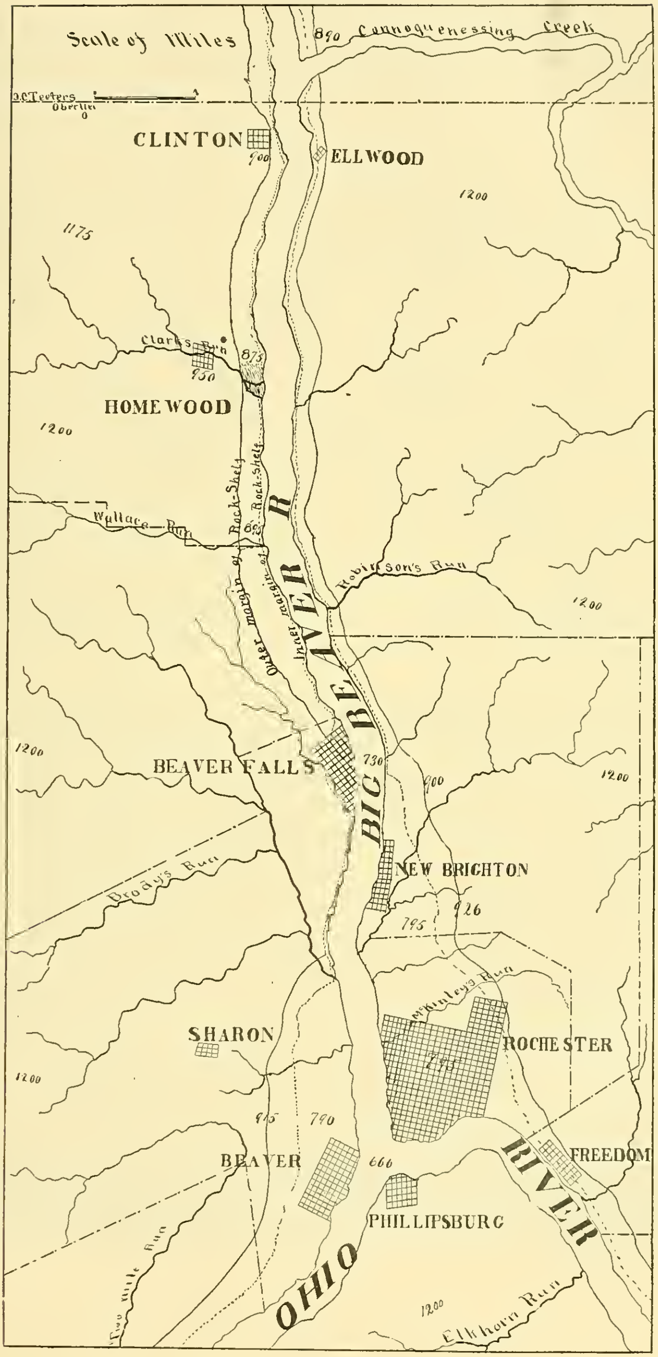
Scioto R.
Brush Creek
LAKE OHIO
BED OF LAKE ERIE
OBERLIN
AKRON
CLEVELAND
HUNTINGTON
MARIETTA
Ohio R.
Kanawha R.
WEST VIRGINIA
LIVERPOOL
STEUBENVILLE
WHEELING
BEAVER
HOMEWOOD
PARKER CITY
PITTSBURGH
FAIRMOUNT
MORGANTOWN
PENNSYLVANIA
OIL CITY
WARREN
TIONESTA
SHEFFIELD
Allegheny R.
Clarion R.
VIRGINIA
1346
2000
1629
1445
1284

direct glaciation, a buried channel which appeared to be preglacial. Of this I wrote a brief account in the March number of the American Geologist for 1893 (pp. 198–199). The accompanying map (Fig. 2) will explain the situation.*

The buried channel occurs at Homewood, on the Big Beaver, about nine miles from its mouth, and where Clark's Run joins it from the west. The Big Beaver is here walled in by thick and extensive deposits of compact Homewood sandstone which is extensively quarried in the vicinity. The river occupies a gorge in the sandstone whose perpendicular descent from the rock shelf to the surface of the water ponded back by the dam at Beaver Falls is, as measured by lock level, 145 feet; but the rock bottom, as determined in building the railroad bridge at Ellwood Junction, two miles above, is, according to data gathered by Mr. Hice, sixty feet below the bottom of the Beaver. Just how deep the water in the pond is I am unable to say, but probably not more than ten or twelve feet. This will make the present depth of the gorge 225 feet. Above Clark's Run this shelf bears a vast amount of sand, gravel, and bowlders derived from the wash of the glaciated region, whose boundary approaches to within two or three miles of the locality. Many sandstone bowlders several feet in diameter occur in this deposit. Clark's Run, which enters the Beaver at right angles, has cut a gorge with a V-shaped mouth through the Homewood sandstone nearly to the level of Beaver Creek. The north side of this wide, deep side channel of Clark's Run is filled in with a water deposit, consisting of stratified sand and gravel, capped by three or four feet of coarser deposits containing large bowlders. This has been resorted to for sand and gravel until great masses have caved down, and obstructed the road which passes along its foot up the run. We were unable to determine just the depth to which this deposit extends; but it is certainly from sixty to eighty feet deep, and the angle between the gravel pits and the Big Beaver is entirely occupied by it. So completely was this filled in at that point, that it is also difficult to tell just how wide the mouth of the V-shaped opening was. On the south side of the gorge of Clark's Run the jagged rocks are exposed from top to bottom, although near the mouth there are some remnants of gravel at the top, showing that it had originally filled the whole space. The shelf south of Clark's Run presents a great contrast to that north of the

* A portion of the valley of Big Beaver Creek above its junction with the Ohio. The broken lines approximately mark the limit of the later Glacial terrace. The space between the broken line and the continuous line outside of it approximately represents the rock shelf bearing the older Glacial gravel. The figures indicate elevations above tide.

FIGURE 2.


Scale of Miles
Connoquenessing Creek
CLINTON
ELLWOOD
HOMEWOOD
Clark's Run
Wallace Run
Outer margin of Rock-Shelf
Inner margin of Rock-Shelf
Robinson's Run
BIG BEAVER R
BEAVER FALLS
NEW BRIGHTON
Brady's Run
McKinley's Run
SHARON
ROCHESTER
FREEDOM
BEAVER
PHILLIPSBURG
OHIO
RIVER
Two mile Run
Elkhorn Run

run, being wholly devoid of drift material. Possibly this is due to its slightly higher elevation.

I see no probable explanation of this deposit in Clark's Run except that which implies the preglacial erosion of the Big Beaver down to nearly its present depth; thus permitting at the same time the erosion of the tributary valley of Clark's Run. Upon the advent of Glacial conditions the wash from the glaciated region brought down the material which is spread over the rock shelf as far as Clark's Run, and partially filled it. Subsequently the stream has had time only to re-erode a part of the loose material, leaving a portion of it still on the north side of the run. That this rock erosion was very ancient is shown by the size of the gorge in comparison with the stream, and by the V-shaped character of its mouth.

Subsequently to my visit, Mr. Leverett looked over the ground, and came to the conclusion that the ice of "the later incursion" had come down into closer proximity to this buried gorge than had been supposed, and hence that the gorge may, after all, have been interglacial.* Still, Professor Chamberlin is compelled to admit that "a portion of the excavation of the rock below the old base-plane may have preceded the incursion of the Glacial wash and even the Glacial period;" and that "If this should prove true the effect will be to extend [?] the importance of the earlier Glacial epoch and to reduce the time necessarily attributed to the interglacial interval of excavation."

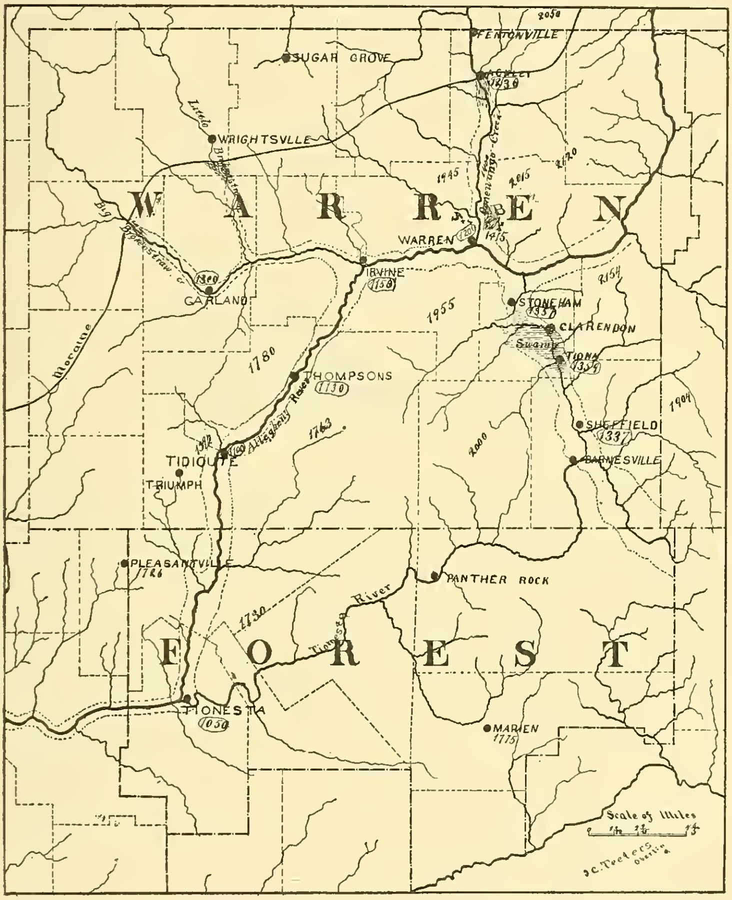
Before the publication, but subsequent to the writing, of this note by Professor Chamberlin, however, Mr. Leverett and I had together gone over a portion of the ground in the Allegheny River Valley most likely to yield definite results, including one of the most important points to which Professor Chamberlin had appealed in support of his theory, and brought to light facts which seem unequivocal in their interpretation. Upon the accompanying map is shown a portion of the Allegheny near Warren, Pa., where the Conewango joins the river to the north, and a short run comes in from the south which heads in a low pass separating it from a branch of the Tionesta River, which reaches the Allegheny fifty or sixty miles below.† The terminal moraine traced by Lewis and myself crosses the C newango at Ackley, about ten miles above Warren. The elevation of the Creek at Ackley is 1236 feet above tide. The

* See Professor Chamberlin's note upon the subject in the Journal of Geology, vol. i, p. 628, Sept.-Oct., 1893.

† Shows details in the Valley of the Allegheny in Warren and Forest counties, Pa. The broken line shows approximately the exterior margin of the rock shelves marking the Tertiary base-level of the stream. The figures along streams give the elevations above tide of the railroad stations which are usually but little above the flood plain.

moraine is about forty feet higher. The overwash terrace plane declines southward, so that at Warren it is but a little over 1200 feet above tide. The trough averages, I should say, about half a mile in width, and is bordered by hills to a height of about 2000 feet above tide, or from 700 to 800 feet above the present valley.

FIGURE 3.

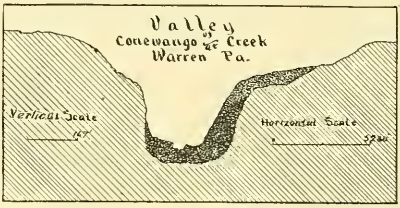


Between the lower terrace referred to and the higher hills there are the remnants of a rock shelf which is about 200 feet above the present level of the Allegheny River, and as the Allegheny and Conewango are both partially filled with gravel, this shelf is about 250 feet above the rock bottom of these streams, and is covered to a depth of from twenty to fifty feet with river gravel containing granitic and other Archæan pebbles from Canada, demonstrating it to be of Glacial age.

It had been supposed that these high level gravels were mere remnants upon the rock shelf, which had endured while the stream had eroded its rock trench to its present level. But evidence is now brought to light which completely excludes this hypothesis.

The new evidence discovered is twofold: First, about three-quarters of a mile northeast of Warren there is a solid bank of stratified gravel extending from the lower terrace of the Conewango up to an elevation of nearly 250 feet above the Allegheny river, or about 1400 feet A. T. and spreading out over a rock shelf to the north. This terrace having been resorted to for gravel at different levels its constitution is plainly shown

FIGURE 4.



almost from top to bottom. The gravel pit at the upper part contains great numbers of Archæan pebbles several inches in diameter, while that in the lower pit which extends back beneath the coarser material is mostly assorted sand and fine gravel of similar composition beautifully stratified. Only one explanation of this is possible, namely, that the rock erosion in this valley had been nearly, if not quite, completed before the deposition of the high level gravels. Upon this special point of the extent of preglacial erosion at Warren Mr. Leverett and I are agreed, except possibly as to the erosion of the lower 50 feet in the rocky gorge immediately beneath the stream. The positive evidence of the gravel bank described covers only the erosion down to the bottom of the first terrace; but the remaining erosion in the rock is relatively too small seriously to affect the discussion.

The second line of evidence is found on the head waters of the Tionesta at and below Clarendon (see Fig. 3). Mr. Leverett had on a previous day visited the place and found evidence that this valley contains a glacial overwash at Clarendon. Some years before Mr. P. F. Carll, of the Pennsylvania Geological Survey, had noted, and I had also had my attention called by Mr. H. H. Cummings, of Tidioute, to the width of the valley at and south of Clarendon, and to the singular course of the Tionesta river in flowing away from the broad valley at Barnesville through a very narrow one at right angles to it. But in a hasty trip to the region no definite results had been attained. Upon returning, however, with Mr. Leverett it was found that the whole appearance indicates that the south branch of the Tionesta formerly flowed along a valley occupied by the north branch, past Clarendon, through a buried channel to the Allegheny. Positive evidence of this fact also was furnished by Mr. D. E. Waugeman, a dealer in materials for well drilling, who was cognizant of the history of nearly all the wells sunk for oil in that vicinity. According to his testimony (and he furnished the materials for many of them) several of the wells sunk near the station at Clarendon were driven through gravel and sand from 160–171 feet before striking rock. This would carry the depth of the buried channel nearly to the level of the present bottom of the Allegheny, five miles to the north. A well was subsequently reported to Mr. Leverett, which is situated on a terrace two miles south of Clarendon, to have penetrated 263 feet of drift, giving the rock floor there an altitude of but 1167 feet A. T. or but 73 feet above the lowest known point in the rock floor at Warren and only 20 feet above the undisputed limit of preglacial erosion there. It was noted further that in the vicinity of the place of reversal below Barnesville the small side valleys are excavated broadly to such a depth as to show (as Mr. Leverett and myself agreed) that erosion there, like that at Warren, had been carried nearly to its present depth in preglacial times, and that the col may not have been materially lowered by the reversal because of the excessive amount of filling north of it (see Fig. 3). We were much impressed by the great amount of drift on the Clarendon watershed, as well as by the fact that Archæan pebbles are numerous. The level of the watershed, near Clarendon station, is 235 feet above the river at Warren, the river level being about 1160 feet A. T. The gravel terrace rises, as determined by Mr. Leverett's observations, 105 feet higher, or 340 feet above the Allegheny, which makes it about 100 feet higher than the terrace just described on the Conewango east of Warren, and fully 200 feet above the rock floor of the Tionesta, at the place of reversal near Barnesville twelve miles to the south, and more than 300 feet above the rock floor in the boring two miles south of Clarendon. This terrace in the valley of the Tionesta is also exceedingly well developed two miles south of Clarendon just west of Tiona. We did not find any Canadian pebbles south of Tiona but there was much gravel in the valley, especially where the two branches of the Tionesta at Barnesville join to enter the gorge down which the water flows for the rest of its course to the Allegheny, and Mr. Leverett subsequently found that the Tionesta contains Canadian rocks in its gravels at Newtown Mills, only a few miles above the mouth of the stream.

This evidence is of itself conclusive upon the main point in question. The accumulation of the oldest Glacial material took place subsequent to the erosion of the rock valleys of the region. Whether these Glacial deposits in the upper part of Tionesta valley imply that the Glacial ice actually crossed the Allegheny at this point, or whether the deposits can all be accounted for as overwash gravel from the ice border north of the Allegheny is immaterial to our main discussion, though it would seem pretty certain that the gorge of the Tionesta from Barnesville down was of preglacial origin. For, in company with Mr. D. C. Baldwin, I followed it through its whole course, and found it everywhere exhibiting signs of great age. The tributary valleys are well developed and eroded to the general level of the main stream. The stream is, however, characterized by a remarkable absence of extensive gravel deposits which I expected to find upon the theory of its having been so important a line of Glacial drainage; but this is probably due to the short continuance of the time of its occupation by Glacial drainage. The only extensive gravel deposit noticed was a deserted channel at Kellettsville, a little below Panther Rock, near where Salmon Creek enters the main stream. The deserted channel was, on the north side, fifty feet above the present river, and separated from it by a narrow ridge 130 feet above the river. Both the old channel and the ridge were covered to a depth of about twenty feet with river gravel, but I failed to discover any Archæan pebbles.

The significance of the facts here brought to light cannot be evaded by the discussion of minor questions relating to the subject. Mr. Carll has indeed adduced many considerations going to show that the former drainage of the upper Allegheny Valley went northward through the Conewango to Lake Erie. The evidence of this being that the rock bottom of the Conewango at the New York State line is, according to Carll, 136 feet lower than the rock bottom of the Allegheny at Great Bend, a few miles east of Warren. It is not necessary to discuss this theory here further than to say that Mr. Carll's facts do not seem to prove the northward flow of this drainage so clearly as I formerly supposed they did; for Mr. Carll's reasoning has failed to take into account two considerations which may essentially modify the inferences from the facts.

In the first place, no one has been able fully to eliminate from the problem the effects of orographic changes of level upon the present attitude of the rock bottoms, to which Professor

I. C. White has specially called attention.* In the second place, I have been led to reflect much for some years past upon another cause which may produce great irregularities in the depth of the rock bottom of river gorges, namely, the effect of the plunging force of a cataract in hollowing out the gorge at its foot to a depth much below the general level. The extent of this process will depend partly upon the character of the underlying rock, and partly upon the conditions which determine the extent of the plunge of the water over the cataract. It is well known that the plunge of the water over the Niagara escarpment has scooped out a channel to a depth of 200 feet or more below the level of the stream north of the falls. While studying the gorge of Snake River above the Lower Shoshone Falls in Idaho three years ago, I was struck with a similar phenomenon. The water is but a few feet deep over the crest of the falls; but, less than half a mile above the falls, the depth becomes 100 feet or more, and so continues for some distance. The most natural explanation of this would seem to be that during the recession of the upper falls there were conditions which favored deep erosion much more at certain places than at others. These conditions may have been those which should determine that at certain places the fall was mainly over rapids, and at other places in a perpendicular plunge. The varying hardness of the strata underneath may also have combined to produce the result. It has seemed to me that some such combination of causes as this may account for many, if not all, the facts which are appealed to in the upper Ohio Valley in proof of the former northward flow of its drainage.

But the settlement of this point is immaterial to the question in hand. The extent of the preglacial erosion now demonstrated to have taken place in the Allegheny Valley at Warren is so great that it carries with it, by natural inference, a similar extent of preglacial erosion all down the Ohio and in its tributaries. The erosion at Clark's Run, in the valley of the Beaver, which I have already described, is in accord with the facts concerning the Allegheny near Warren. In examining the Allegheny River from Warren down to Pittsburgh, although I did not find any other facts which are so unequivocal in their significance as these are; yet I did find much which confirms the view, and so far as I can see there is nothing which can be adduced as strongly favoring the other view.

The 200-foot rock shelf reappears at frequent intervals all the way down the Allegheny to its junction with the Ohio, and down the Ohio as far as Wheeling certainly. It varies

* This Journal, for 1884, p. 149.

considerably in width, depending upon the ability of the rocks to resist or facilitate erosion; while sometimes the shelf is wholly wanting for a considerable distance where the river passes through areas of more uniform and compact strata. But almost everywhere down to the junction of the Big Beaver with the Ohio this 200-foot rock shelf is covered with glacial gravel to a depth of from twenty to sixty feet and sometimes for a width of a half mile. The extent of the deposits of this high-level terrace has not heretofore been duly understood or appreciated. The portions heretofore described at Bellevue on the Ohio, just below Pittsburgh, and that at Parker's Landing, on the Allegheny, can be duplicated at brief intervals throughout the entire length of the valley from the mouth of the Conewango to the mouth of the Big Beaver. The deposits are found almost continuously upon the east side of the Ohio River, from the mouth of the Big Beaver to Pittsburgh, while in Allegheny City remnants of the gravel remain upon the summit of Monument Hill, which rises in the center of the city to the level of the rock terrace, but is separated from it by a quarter of a mile or more of a partially buried old channel of the river. Under guidance of Professor Jillson, who will soon publish a detailed paper upon the subject, I traced this high gravel terrace for some twenty miles up the Allegheny River. It is developed in specially good degree on both sides of the river above Allegheny City and Pittsburgh, and farther up near Verona, upon the south side of the river, and on the north side opposite Parnassus, and again from Tarentum for several miles upon the same side nearly to Freeport. In all these places the accumulation of gravel upon the rock shelf is from twenty to sixty feet in depth, and frequently is as much as a half a mile wide. The material is much of it fine and often well stratified, but contains numerous water-worn Canadian pebbles and occasionally, enclosed in the fine material, angular fragments of granite, gneiss, or sandstone two or three feet in diameter, indicating ice-laden currents. At East Liberty, in the upper part of Pittsburgh, the deposit from the Allegheny River crowds over upon a limited amount of river pebbles which had been distributed along the deserted bed of the Monongahela which is now followed by the Pennsylvania Railroad in getting out of the city, and which is about the same height as the rock shelf referred to. Farther up the Allegheny River, in company with Mr. D. C. Baldwin, I have examined similar deposits along this rock shelf at Ford City, Kitanning, Red Bank, East Brady, Parker's Landing, Kenerdell (formerly Scrub Grass), and many other places. Of these I will now speak further only concerning Kenerdell and Parker's Landing.

Opposite Parker City there occurs the deserted river bed so fully described by Mr. Chance,* and whose descriptions are reproduced by Professor Chamberlin† to controvert my views concerning the preglacial origin of the rocky gorge of the river at this point. But Mr. Baldwin and I discovered some things not heretofore noticed which in themselves strongly confirm my previous views concerning the preglacial date of the rocky erosion. The details can be clearly and briefly stated in connection with the accompanying map (slightly modified from that of Mr. Chance.‡ The elevation of the Allegheny River at low water is here 840 feet, and the width of the rocky gorge is 1500 feet. The rock bottom is fifty feet lower. The summit of the gravel upon the rock shelf which we have been considering is 250 feet above low water, or 1090 feet above tide. Upon the east side of the river there is a deserted rock channel in the shape of an ox-bow extending out about a mile and a half from the main stream, but at an elevation of about 200 feet above it. This is partially filled, to a depth of thirty or forty feet, with river gravel of Glacial origin. Mr. Chance and Prof. Chamberlin supposed that this deposition took place previous to the lowering of the rock gorge from the level of the ox-bow to the present rock bottom of the river, a perpendicular distance of 250 feet. But the additional facts which I now have to present will, even in themselves I think, disprove this hypothesis, and show that the existing rock erosion of the main channel had taken place, to a large extent at least, before the deposition of Glacial gravel in the ox-bow.

That the ox-bow was at an early period eroded by the river appoximately to its level at the point farthest away from the present stream cannot well be doubted; but there is evidence also that after its desertion by the main stream the small streams occupying the two prongs of the bow had accomplished a good deal of erosion before the deposition of the gravel; for there is a considerable slope of the rock bottoms of these small tributaries in their progress towards the river, and it is evident that their beds had finally assumed the shape which results from the erosion of such small streams rather than from the passage of a great river. This would go to prove that the undercutting of the neck had been fully accomplished long before the partial filling of the ox-bow with gravel. Furthermore, the upper prong of the bow is filled in with gravel around to its farthest extremity at A; while the lower prong of the bow is filled in with gravel only a short distance, namely,

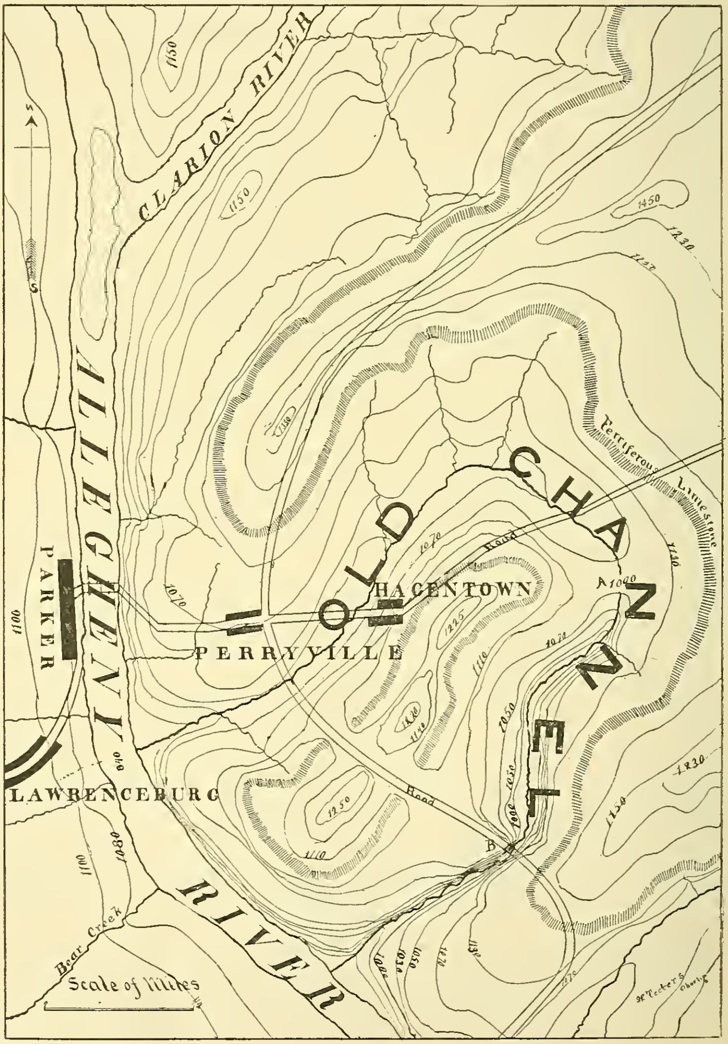
* Second Geol. Surv. Pa., VV, 1880, pp. 17–20.

† Introd. Bull. U. S. Geol. Surv. No. 58, p. 30.

‡ Map of old channel at Parker partially filled with high-level Glacial gravel. See section on lower right hand corner of Fig. 1.

to B. Between A and B the lower prong is entirely free from foreign gravel for a distance of half a mile or more; but the valley of the prong through this distance is broad at the top and V-shaped, and is distinctly constricted near B by the gravel deposits. This portion of the valley could not have been hollowed out of a gravel deposit such as exists upon the northern prong, and nothing of the sort exists on the north side.

FIGURE 5.



Clearly the explanation is that before the deposition of the gravel in the ox-bow the rock erosion had proceeded till it had produced essentially the present topographical conditions. The gorge of the Allegheny was then refilled with Glacial gravel till it reached the summit of the 1100-foot terrace upon the western side, and partially filled in the ox-bow across the outlet of both its prongs. Naturally the work proceeded fastest in the upper prong, and the terrace was gradually built out till it reached the point A. Naturally, also, there would be no such extensive pushing of material up the lower prong; so that we find across it simply a gravel terrace corresponding to other terraces upon that side of the river. The continuance of the Gacial floods at that level was not sufficiently long to permit the deposition which had taken place in the upper prong to extend around the whole circuit of the loop. Evidently the depositing Glacial flood after attaining its maximum height retreated with comparative rapidity,—a rapidity which is not at all consonant with the theory that it was compelled to lower its bed through a rock bottom; nor does the general appearance of the high-level gravel deposit, either here or elsewhere, indicate such an enormous age as Professor Chamberlin's theory would imply. There is everywhere against this theory the relatively small amount of erosion which had taken place in the gravel since the deposition.

The second case upon which I will stop briefly to comment is at Kennerdell, which is situated upon a point of a long ox-bow occupied by the present river. Here the gravel with Glacial pebbles constitutes a continuous blanket up the slope from the river to a height of something over 300 feet. Up both of the roads branching off from the station, and reaching the summit on either side of the ox-bow, this deposit of gravel is continuous, and contains Archæan pebbles nearly up to the height above mentioned. The theory that this blanket of gravel (how thick it is I did not have time to ascertain, for the rock nowhere appeared along the roads) is simply a remnant that has survived the long period during which the whole rock gorge was eroded, and which has gradually slid down from the summit or been re-deposited as the shelf was undercut, I think few people who examine it will entertain. On the other hand, it is not difficult to understand how it might be left in the process of a re-erosion of the trough after it had been filled with loose material.

The conclusion to which all these facts point with convincing force is that, after a long period of base-levelling in the Tertiary era, during which the 200-foot rock shelves formed a portion of the bottom of the stream, there came on a continental elevation which permitted the streams rapidly to cut narrow, gorge-like channels down through the rock to a depth of 250 or 300 feet below their former level. Simultaneously with the culmination of this uplift, and with the conclusion of this long work of erosion, Canadian ice reached the headwaters of the Allegheny, and a work of deposition began which proceeded as long as the ice continued to advance, and probably for some time after it began to retreat. The upper part of the Allegheny River became filled with debris up to the summit of the high-level bowldery terrace extending over the rock shelves, and the sedimentation gradually advanced along the narrow trough until it was entirely filled as far down as the mouth of the Beaver, and perhaps to Wheeling, and possibly still farther. Subsequently the larger part of this material was eroded, and carried down into the Mississippi Valley. If there were two distinct Glacial epochs, the minimum measure of time between them is not that of the rock erosion of the gorge, but the erosion of this loose material.

Now in studying this problem we cannot wholly ignore the Cincinnati ice-dam, even though that hypothesis may have been somewhat overworked in former years. I need not repeat the positive evidence of this dam elsewhere presented* any farther than to say that the arguments adduced by Professor James,† proving that the preglacial course of the Ohio River was around by Hamilton, and thence down the Great Miami,‡ adds immensely to the significance of its obstruction during the Glacial period. The existence of such an obstruction must have greatly facilitated the silting up of the gorges of the upper Ohio Valley, and have had a great influence in modifying the character of the deposits. An immense amount of fine material which otherwise must immediately have been swept onwards to the Mississippi would settle in the slack water depths of this narrow winding lake and serve as the basis to support the coarser deposits that were brought down over them. Some positive evidence upon this point has been furnished me by Mr. R. C. Hice. In digging for the abutments of the bridge across the Big Beaver at Ellwood,§ just above Homewood, the workmen penetrated sixty or more feet below the present bottom of the river, and found it filled uniformly with a very fine deposit such as could settle only in the stillest of water. In the portions of the Ohio Valley nearer Cincinnati the ice dam removes the necessity of supposing so exten-

* See especially Bulletin of U. S. Geol. Sur., No. 58; Ice Age of North America, pp. 326–350.

† See Journal of the Cincinnati Society of Natural History, July–October, 1888, pp. 96–101; also Amercan Geologist, 1893, pp. 199–202.

‡ See map in Fig. 1.

§ See map, Fig. 2.

sive a filling up of the trough as we find above the mouth of the Big Beaver.

The facts brought to light concerning the extensive filling up of the trough of the Allegheny and upper Ohio Rivers must modify to some extent previous theories concerning the still water deposits in the Monongahela River. That the deposits described by Professor White at Morgantown, W. Va., took place in still water, which was produced by some extraordinary obstruction to the drainage after the main part of the rocky erosion had taken place is scarcely capable of being questioned by one who has carefully examined them in detail. This Professor Chamberlin and Mr. Gilbert were not able to do, since their visit to the region was hasty, and they did not have the privilege of the guidance of Professor White, who was absent from home at the time. I have had the privilege of going over much of the ground with Professor White, and need only to reiterate and emphasize the most significant of the facts which he has elsewhere so fully stated. There are at Morgantown both in the immediate vicinity of the Monongahela and at the Flats (a mile or more back from the river, along one of the small tributaries of the main stream) deposits of clay seventy feet deep containing at all levels the impress of the leaves of existing species of trees and fragments of wood in a good state of preservation. I can see no way in which such depths of clay and gravel could accumulate in the ordinary process of the rock erosion of a stream. There must have been some check to the processes of erosion during which this extensive silting took place. Professor White is inclined to believe that orographic changes may have played more of a part in producing slack drainage in the streams on both sides of the Allegheny Mountains than he at one time thought. The slightly higher level (about 100) feet of these deposits in the Upper Monongahela also compels us to suppose some slight orographic changes of level if the Cincinnati ice dam alone is depended upon for the obstruction.

In the light of the present discussion it will be seen that a supplementary cause of great significance may now be taken into consideration. The action of the Allegheny River when swollen with its Glacial floods and burdened with its vast loads of Glacial debris would dam up the mouth of the Monongahela by the same accumulations which filled its own channel. As we have seen, these accumulations rose at Pittsburg to a height of about 300 feet above the present water level, or of 1,000 feet above tide level. As the conditions were so much more favorable for the sedimentation of the Allegheny during the reign of the Glacial period than for filling up the trough of the Monongahela, such an obstruction was inevitable. Thus also the accumulations in the Monongahela attributable to this epoch were chiefly of fine material and near the mouths of tributary streams. It is not necessary to suppose that the Monongahela was filled throughout its entire length, as was the case with the Allegheny. Professor Jillson reports that the 200-foot rock shelf along the Monongahela near Pittsburgh is almost wholly free from gravel, and has but a foot or two of soil for a covering.

A similar damming up of rivers by tributaries has been frequently noted. Mr. G. M. Dawson shows that the deposits of Dead Man's Creek opposite to its mouth have filled up Thompson's River (the principal tributary of Fraser's River in British Columbia) a depth of 450 feet making Kamloop's Lake, a body of water eighteen miles long and nearly two miles wide.* General Warren has detailed similar evidence respecting the Mississippi. Lake Pepin, for example, is made by a delta of Chippewa River which is pushed across the Mississippi just above Waukesha, Minn.†

Thus the investigations of the past year would seem to remove from the problem the most considerable and definite factor used by Professor Chamberlin in estimating interglacial time. What he supposed was *inter*glacial was *pre*glacial, as others had all along contended. We shall therefore be the more ready to accept similar conclusions regarding the date of the extensive rock erosion in the Delaware and Lehigh river valleys, which Professor Chamberlin would also make interglacial.

Preglacial Erosion in the Delaware Valley.

In the summer of 1892 Professor A. A. Wright and myself devoted some time to an attempt to determine the southern limit of the fringe, or "attenuated border" of glacial deposits in the Delaware Valley; for, that there was such a fringe in advance of the moraine was recognized many years ago by Professor Cook and by Professor Lewis and myself; while Professor Salisbury had published in 1891 what seemed to be a much exaggerated view of its extent. The results of our work were summarized in my previous paper upon this subject in this Journal (see pp. 364–367, Nov. 1892). In the time then at our command we only succeeded in determining one fixed point on the southern border, namely, on the summit of the Musconnetcong Mountain, about five miles east of Riegelsville, leaving the rest of the line professedly undetermined.‡

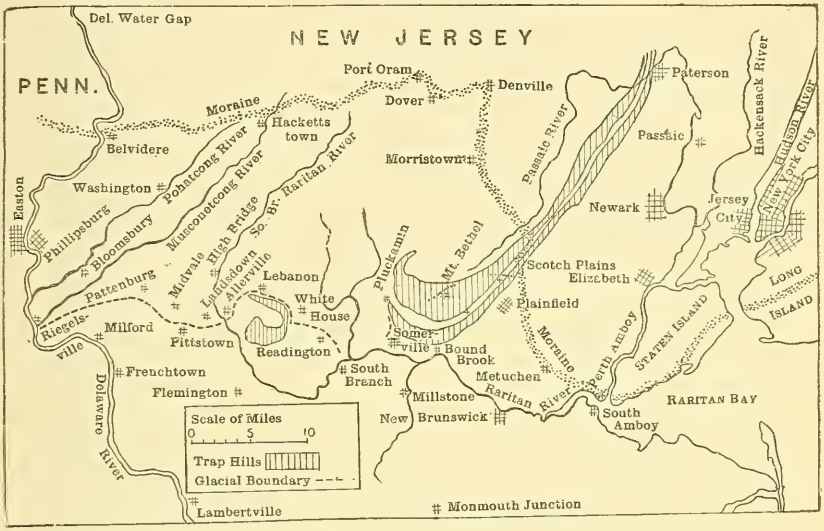
* Geol. Survey of Canada, Report of Progress for 1877–78, p. 17.

† This Journal for 1878, p. 420.

‡ I have presented this evidence more fully in a paper before the Philadelphia Academy of Sciences, published in their Proceedings for 1892, pp. 469–484.

During the summer of 1893 Professor Wright and myself returned to this field, and the results of our work were presented by him to the Geological Society of America at its meeting last August, and are published in their proceedings (vol. v, pp. 7–13). The accompanying map, prepared by Pro-

Fig. 6.



fessor Wright, shows the limits of the Glacial fringe in New Jersey as now determined by us and its general relation to the moraine. It includes the deposits at High Bridge and Pattenburg, concerning whose Glacial character I expressed doubts a year ago. Further search, however revealed outside of these two localities the evidence which we had considered lacking. In the eastern part of the State the level of the land is so little above tide that it is difficult to distinguish between the direct deposits of the glacier and those which have been distributed by water. But from the central part of the State westward I think there will be no occasion materially to modify our line. Meanwhile Professor E. H. Williams, Jr., has been making a careful survey of the southern boundary of the Glacial deposits in the Lehigh Valley, and finds them continuing across the Delaware River at Riegelsville, (where it should be said Mr. C. Laubach, a local observer, has for many years been correctly insisting that direct Glacial deposits existed), and extending over South Mountain, to the Saucon Valley near its head, and thence westward several miles south of Bethlehem, into the limestone valley which runs southward from the Lehigh at Allentown, and joins the Schuylkill above Reading. In this valley the ice extended to Topton, which is the water shed between the two above-mentioned rivers; thus bringing to light an important and hitherto unsuspected temporary line of Glacial drainage into the Schuylkill River.*

One significant observation of Professor Williams has a specially important bearing upon the date of this earlier glaciation. Just south of Bethlehem, at the site of the new reservoir, on the north flank of South Mountain, the gneiss is very deeply decomposed, showing an extremely long exposure to disintegrating agencies. But upon the summit of the mountain, where there are evidences of glaciation, the decomposition of the gneiss extends only to a few inches below the surface. Professor Williams' interpretation of this would unquestionably seem to be correct, namely, that the twenty feet of decomposed gneiss upon the north side represents preglacial work, where the material had, in some way, been protected from erosion during the ice-movement, while the few inches of decomposition upon the summit of the mountain represents the work since the deposition of the fringe; material loosened by preglacial decomposition having been removed by the ice from the summit.

The thinness and irregularity of the deposits over the area which we have denominated "the fringe" in New Jersey and Eastern Pennsylvania are supposed by Professor Salisbury† to be due to the action of the long period of erosion to which it has been subjected. This seems extremely questionable. At any rate, there does not appear to be any definite evidence that this is the true explanation. On the contrary, it is more likely that the original deposition near the margin and for some distance back was slight and irregular, owing to the comparatively brief stay of the ice near the margin of maximum extension and to the small amount of motion which characterized the extreme border.‡ This view is confirmed, also, by the fact that Mr. Leverett in his careful study of the deposits in Southern Ohio is of the opinion that there the attenuation of the border deposits is due "more largely to original deposition, than to subsequent erosion."§

With regard to the age of the Philadelphia brick clays and red gravel in the Delaware Valley, the evidence seems to point more and more clearly to a closer continuity with the Trenton gravels in their deposition than Professor Chamberlin supposes.

* Williams, Proc. of the Geol. Soc. Am., vol. v, pp 13–15. See further convincing facts in the short paper of Professor Williams in this Journal for Jan., 1894, pp. 33–36.

† Annual Report of New Jersey, for 1892, p. 64.

‡ See diagram, Fig. 7, and explanation by Mr. Warren Upham on page 185.

§ See Glacial Succession in Ohio, Journ. of Geol, vol. i, p. 132.

In Professor Salisbury's last Report upon the surface geology of New Jersey, he arrives at nearly the same conclusion with Professor Lewis, namely, that there was during the earlier glaciation a subsidence of the eastern coast in that region to the extent of at least 130 feet. In an examination which I made last summer, in company with Mr. Ernest Volk, of the gravel terraces west of Trenton, N. J., and extending from Fallsington to Yardleyville, Pa., the facts elicited seem to show that the deposition was continuous and comparatively rapid from the gravels at a level of about 170 feet near Yardleyville down to the valley at Fallsington, where the level of the terrace is but slightly above that of Trenton. The gravel rests upon the gentle slope in a nearly continuous blanket, and not in the irregular manner which must have been the case if it had been working down from a higher elevation over a slope that was gradually formed by the lowering of a broad valley through undercutting of the solid rock.

The evidence brought to light during the past year thus seems in the clearest manner to remove many of the arguments which have been adduced to prove an extremely long interglacial episode and the consequent discontinuity of the epochs. Several specially important papers, however, have been presented during the year aiming to show that the lapse of time between the maximum of glaciation and the formation of Professor Chamberlin's "terminal moraine of the Second Glacial epoch" is much longer than the period which extends from the formation of the second moraine to the present. Mr. Leverett (the value of whose extensive observations is becoming more and more apparent), in a paper before the Geological Society of America in August last, adduced much cogent evidence to show that the present valley of Rock River in Illinois is different from the preglacial valley, and that where it now runs through the area of the older drift the erosion is so great that it calls for seven or eight times as long a period as that demanded by the postglacial erosion of the Niagara River or by the postglacial work of the Mississippi below the Falls of St. Anthony. Mr. Oscar H. Hershey,* also, adduces similar evidence from the area of the older drift occupied by several small tributaries of Rock River in Stevenson County, Illinois. The minimum age of those portions of the gorges of these streams which have been formed since the occupation of the region by ice, is estimated by Mr. Hershey to be 50,000 years. Mr. Leverett also adduces the great amount of erosion in the till which covers Sangamon County and the region farther south in Illinois, as compared with that north and east, to prove that the older drift is several times older than the newer.

* Am. Geol., vol. xii, p. 314 seq.

In proof of the same calculation Mr. Leverett also adduces the fact that in Southern Ohio the till is oxidized to a yellow color to a depth of about twenty feet, below which it is unoxidized and blue.*

These moderate conclusions of the date of the period of maximum glaciation are so strikingly in contrast with those which have been adduced from Mr. Croll's astronomical theory, and with those which would be necessary if Professor Chamberlin's theory of the interglacial origin of the rock gorge of the Ohio River had been true, that it is hardly worth while to make any issue with regard to them. At the same time it is proper to note, first, that, in streams which are flowing outward from the glaciated area, there is considerable danger of confounding preglacial with postglacial erosion; and in the second place, that we are bound to keep in mind that when these streams were first pushed out of their original channels by the ice the present channels probably became lines of Glacial drainage, in which the supply of water and other conditions may have favored very rapid work. And, thirdly, apropos of Mr. Leverett's observation upon the oxidation of the till in Southern Ohio, I would say that certain facts which have come under my own observation during the past summer would seem to indicate that local considerations which we do not fully understand may so far control the rate of oxidation as seriously to interfere with calculations from that factor alone.

Oberlin lies in the watershed of Lake Erie in the area of later glaciation north of Mr. Leverett's twelfth moraine. During the past season miles of trenches have been dug in providing sewerage for the town, and the facts have been carefully collected by Mr. Lynde Jones, and have been under constant observation by Professor A. A. Wright and myself. Mr. Jones will soon publish his results. But one fact only is necessary for my present purpose. Everywhere the yellow till extends down to a depth of several feet, ranging from six to fourteen, where it is underlaid by blue till. It would thus appear that in the compact deposit in the northern part of Ohio, in one place at least, the oxidation is from one-third to two-thirds as deep as that which is reported by Mr. Leverett in the oldest drift in the southern part of the State.

Mr. McGee's latest Views.

During the year, also, Mr. W. J. McGee, formerly of the United States Geological Survey, has published a highly illustrated and elaborate report upon "The Pleistocene History of Northeastern Iowa," which brings to light many suggestive

*See the Glacial Succession in Ohio, Journ. Geol., vol. i, p. 132.

facts bearing upon the question in hand. Notwithstanding the general excellence of the report, we are not sure that we have been able altogether to ascertain the personal equation of the writer; for in many places it is evident that slenderly supported inferences are stated with such an unwarranted degree of confidence as is calculated seriously to mislead the uninformed reader. This is specially the case in the part which he has assigned to the Pleistocene water bodies. Repeatedly in his maps he covers the driftless area of Wisconsin with a body of water produced by the damming up of the Mississippi through the junction of the lobes of ice which came down from either side. This he has named Lake Hennepin. I have not much personal familiarity with the region; but, judging from the explicit reports upon it by Professors Chamberlin and Salisbury, they would seem to be correct in discrediting the existence of any such body of water. I am more familiar with the region in Indiana between the forks of the White River, just south of the moraine—a region which I explored somewhat carefully ten years ago. This is the highest land in the State, running up in one place to an elevation of 1147 feet above tide, and the whole country to the south of it was open during the glacial period.* In short it is an impossible position for a Glacial lake. Yet Mr. McGee has it covered with a Pleistocene body of water.

Nevertheless, this tendency to theorizing independent of the facts may not be allowed to discount the great body of Mr. McGee's observations which bring to light several very important things. We note in the first place, that, while the sixteen thousand square miles in Northeastern Iowa upon which he reports lies entirely outside of what Professor Chamberlin had reckoned as "the terminal moraine of the second Glacial epoch," yet Mr. McGee insists that the area is covered by the remains of two Glacial epochs, separated by an interglacial period, which is rather indefinitely reckoned as from 28 to 280 times as long as the period of written history, that is from 200,000 to 2,000,000 years in extent, if by written history he includes the writings upon the monuments in Egypt and Babylonia.

Secondly, the principal basis of this inference is the existence of a forest bed over a portion of the area near the margin, and a marked difference between the character of the upper and lower tills.

But, thirdly, the character of the vegetal deposits does not indicate as warm a climate as that which now characterizes the region; but, like those in Southern Ohio, which Professor Orton and Mr. Leverett have described, the interglacial trees

* See map, Fig. 1.

are mostly coniferous, and such as may well grow upon the very border of an ice-sheet.

Fourthly, though supposed to be separated by such an enormous interval, these two ice-invasions very nearly duplicated each other; the second extending down very near to the margin of the first; so that while the first covered an area of 13,000 square miles, the second covered an area of 12,000 square miles.

Fifthly, Mr. McGee's interpretation of the blue till at the bottom is exactly the reverse of that put forth by Mr. Leverett and most observers. The upper till in this area is yellow, while the lower is blue. Usually it has been thought that the yellow till measured the extent of the oxidation from the surface down. Of course, then, the older till should have been completely oxidized, and yet throughout this part of Iowa it has the blue color of the unoxidized till. Mr. McGee believes—on what basis except purely theoretical it is difficult to see—that it has indeed all been oxidized, but was then deoxidized through the influence of the overlying forest bed.

Altogether this report of Mr. McGee does not seem likely to lend any solid support to the theory of an extremely long interglacial epoch which he has so confidently espoused.

Summary.

In giving a brief summary of the course of events connected with the Glacial period, it will come in the way to state more fully than has heretofore been done how those who question the long interglacial epoch can account for what has been called the moraine of the second Glacial epoch, and for the river terraces which everywhere, east of the Mississippi River, head near the moraine.

So far as known, the following scheme would seem most naturally to comprehend all the facts relating to the Glacial period in America:—

1st. The earlier portions of the Tertiary period were characterized, throughout all the northern hemisphere, by low altitude of land and a warm temperature even in close proximity to the pole.

2d. A period of slow continental elevation of the regions which are now covered by Glacial drift, extending through some hundreds of thousands of years, was in progress late in the Pliocene epoch. During this stage of events the fiords which characterize the northern portions of both Europe and America, and the extensive rock gorges, like those of the upper Ohio River and its tributaries, were eroded.

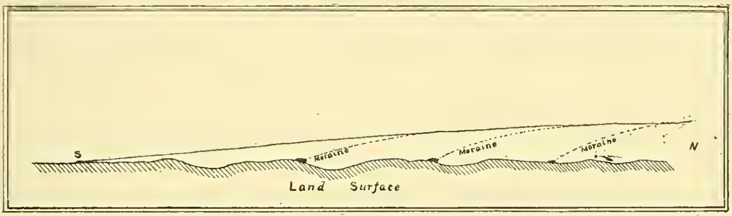
3d. Contemporaneously with this continental elevation at its maximum stage, and chiefly as a consequence of it, Glacial conditions characterized all the higher latitudes of North America and western Europe. In Eastern North America the center of

Glacial radiation was in the vicinity of James Bay. A land elevation of three or four thousand feet would perhaps have been sufficient to produce the Glacial conditions; but the accumulation of Glacial ice would eventually raise the surface several thousand feet higher.

4th. Before the climax of the Glacial period, and perhaps in consequence of its burden of ice, the glaciated area began to sink until the land was, north of the Great Lakes at any rate, several hundred feet, at least, lower than it now is. But for some time after the beginning of the subsidence of the land the rate of accumulation of ice would be greater than that of the subsidence; so that the general level of the glacier continued to rise. Thus the maximum extension of the ice-field was actually reached but a short time before the decline of the period set in.

5th. As suggested to me by Mr. Upham, "The frontal slope of the ice-surface was then less steep than when the warmer climate, bringing the end of the Glacial period, had begun to melt away the southern border. At the maximum of extent the slope may be thus represented:—terminating in a very

Fig. 7.



gentle declivity, allowing some transportation of bowlders to the boundary, but not generally so steep as to produce there any well-defined moraine. In the Glacial recession the warm sunshine and rains were especially efficient, on a belt a few miles or a few tens of miles wide adjoining the boundary, so that when any temporary colder series of years caused a halt or slight re-advance a moraine would be formed."

Lack of personal familiarity with glaciers of the first class has, I am persuaded, led Professor Chamberlin to misinterpret many of the facts connected with what he calls the moraine-headed terraces of the later Glacial epoch. As good an example as any is furnished on the Conewango Creek at Ackley, Pa.,* a region which I had repeatedly visited, both before and after my study of the Muir Glacier. Professor Chamberlin has much to say about the signs of vigorous ice-action in connection with the moraine of the second Glacial epoch, and of the moraine-headed terraces. The indications of this vigorous

* See map, Fig. 3.

action are not only the frequency of Glacial rock scorings to the north, but, among other things, the knobs and depressions in the moraine and in the head of the moraine terraces.

So far as the rock scoring and analogous phenomena are concerned, it is a matter of course that the agencies producing them increased in efficiency as you recede from the border; for all the ice which reached the border moved over the central area of glaciation together with all the ice that reached to any distance beyond the central area. The cup and saucer character of the deposits at the edge of the glacier where a moraine was formed, is probably due in considerable measure to the irregular melting away of ice which originally underlaid the deposit. The present level of the deposits is not by any means always the original level. At Ackley and for a short distance in the valley below, for instance, the ice was very likely originally at one time one or two thousand feet thick, and resting upon the rock bottom of the river trough. In the process of ablation, when the ice at the front had wasted to a thickness of 200 or 300 feet more or less, it was probably covered, as the front of the Malaspina and a portion of that of the Muir glacier are, with a vast amount of pebbles, sand, gravel, and clay which had gradually worked down upon it. In the place where the underlying ice was thickest, its melting away would let the superincumbent mass down to a lower level than that which rested upon a more permanent basis

This seems to be just what we have at Ackley. A terrace upon the east side two miles below Ackley, rises to a height of 150 feet above the flood-plain, and is level topped. On following it up the river, however, it soon ceases to be level topped, and exhibits knolls and saucer-shaped depressions characteristic of true morainic accumulations. At the same time it gradually falls to a lower level, so that at Ackley the moraine is not over forty or fifty feet above the flood plain, and north of Ackley these deposits in the valley give place to a long swampy stretch of country extending for several miles up the stream, and which is absolutely devoid of surface gravel. The explanation of this is that north of the portion of the terrace first mentioned the underlying ice in the valley was assuming greater and greater importance until above Ackley it reigned supreme. When at length it melted away, the gravel gradually and irregularly settled down to lower levels as the ice was thicker and thicker, until back of the moraine there was nothing but space left. If I mistake not, I have seen a similar process going on, on the east side of the Muir inlet, where the front of the ice rests upon the main land. If instead of debouching at its center into the tide water, this glacier was stretching out into a valley above tide with a distinct trough in the center, we might easily have exactly the phenomena repeated which appear at Ackley and at various other places characterized by such moraine-headed terraces as were described by Professor Lewis and myself in 1881. Professor Chamberlin probably needs to revise his interpretation of these facts, in view of a wider knowledge of actual Glacial phenomena.*

6th. From the time the ice first entered the headwaters of the Allegheny, the Susquehanna, and the Delaware River, the silting up of their channels began. This was effected largely by means of the excessive amount of Glacial debris brought within reach of the streams. But during the earlier retreat of the ice-front from its maximum extent, the silting was facilitated by the differential northerly depression which existed. During a part of this time, also, it was facilitated in the Ohio Valley by the Glacial dam at Cincinnati.

7th. After some thousands of feet of ice had melted off, relieving the land from a large part of its burden, the re-elevation of the continent began; (and, as probably the most of the sedimentation of the preglacial river gorges had been effected during the earlier portion of this period of recession), there was then an indefinitely prolonged period of re-excavation by continuous torrents of comparatively clear water, facilitated in the Ohio Valley by the wearing away of the Cincinnati dam, which increased by so much the gradient of the stream.

8th. When equilibrium had been established again, the land was at about its present altitude, but was still covered to a considerable depth with ice north of the most prominent moraines. The great size of these moraines is partly due to the vast amount of englacial material held in the lower strata of the ice.

9th. The deposits of the so-called Champlain epoch near the margin of the glaciated area were considerably earlier in time than those which settled over the Champlain valley itself, since no deposits could take place there until the ice had retreated from the area; but these deposits are properly classed together as Champlain, since they belong to one epoch of general movement.

10th. So great a complication of causes was connected with the production of all the phenomena connected with the period that there were doubtless many oscillations of the ice-front both during the general advance and the general retreat of the ice-sheet. The extent and continuance of these oscillations is to be learned from study of the buried forests and vegetal deposits which lie between the earlier and later sheets of till, and by such instances of erosion as may be clearly proved to be interglacial. But there does not seem to be evidence of any oscillations of the front sufficient to break the proper continuity of the period.

* For an interesting discussion of the points here at issue. see Warren Upham, Bulletin of the Geol. Soc. of America, vol. v, pp. 71–86; 87–100 (Jan., 1894).

ART. XVIII.—*On the Chemical Composition of Chondrodite, Humite and Clinohumite;* by S. L. PENFIELD and W. T. H. HOWE.

Introduction.—These minerals, which are regarded collectively as the humite group, have been the subject of repeated crystallographic and chemical investigation. For our knowledge of their crystallization we are indebted to such careful and accurate observers as Haüy, Phillips, G. Rose, Lévy, Miller, Hausmann, Hessenberg, A. Scacchi, vom Rath, Nordenskiöld, Kokscharow, J. D. and E. S. Dana, C. Klein, Des Cloizeaux and Hj. Sjögren, whose names are familiar to all workers in crystallography and mineralogy. It is not the purpose of this article to take up the details of the crystallization of these minerals or to review the progressive steps by means of which we have derived our present knowledge of their highly modified and complicated crystals, but reference can be made to the excellent historical sketch in a recent number of Dr. Hintze's Mineralogy, page 370. In the description of the crystals that were examined during the course of our investigation we shall use essentially the same system of lettering and of crystal notation adopted by A. Scacchi[*] and E. S. Dana.[†]

In the humite group three distinct species are at present recognized, each characterized by the occurrence of certain forms which are not found on the others and having the following axial relations:

Chondrodite,	Monoclinic,	$a : b : c = 1{\cdot}08630 : 1 : 3{\cdot}14472$	$\beta = 90$[‡]
Humite,	Orthorhombic,	$a : b : c = 1{\cdot}08021 : 1 : 4{\cdot}40334$	$\beta = 90$[§]
Clinohumite,	Monoclinic,	$a : b : c = 1{\cdot}08028 : 1 : 5{\cdot}65883$	$\beta = 90$[‖]

In the above the a axes are practically alike, while, as shown by Scacchi and vom Rath, a simple relation exists between the vertical axes, that of chondrodite being $\frac{5}{9}$ths and that of humite $\frac{7}{9}$ths the length of the clinohumite axis. These relations are shown in the following table, to which the axial ratio of chrysolite, a closely related mineral, has also been added.

Chondrodite	$a : b : \frac{1}{5}c$	$= 1{\cdot}08630 : 1 : 0{\cdot}62894$
Humite	$a : b : \frac{1}{7}c$	$= 1{\cdot}08021 : 1 : 0{\cdot}62905$
Clinohumite	$a : b : \frac{1}{9}c$	$= 1{\cdot}08028 : 1 : 0{\cdot}62876$
Chrysolite	$b : 2a : c$	$= 1{\cdot}0735 : 1 : 0{\cdot}6296$

* Pogg. Ann, Erg. B., iii, p. 161, 1851.
† Mineralogy, Sixth Edition, p. 535. Trans. Conn Acad., iii, p. 67.
‡ E. S. Dana, loc. cit.
§ A. Scacchi, loc. cit.
‖ vom Rath, Pogg. Ann., Erg. B., v, p. 373, 1871.

It is evident from the above that the first three minerals form a crystallographic series and that all of the forms occurring on them could practically be referred to one system of axes, but by so doing the parameter relations on the vertical axis would become exceedingly complicated. Chondrodite and clinohumite, although their inclination β is 90°, are monoclinic both as regards the symmetry in the development of the faces and their optical properties, chondrodite showing an extinction of 26°–30° and clinohumite $7\frac{1}{2}$°–$12\frac{1}{2}$° from the vertical axis, while humite in all of its properties is orthorhombic.

The chemical relations of the minerals have never been satisfactorily determined. This is owing partly to the fact that it has been difficult to obtain pure material in sufficient quantity for analysis, while the analytical difficulties in the accurate determinations of silica and fluorine have not always been overcome. Water in the form of hydroxyl, which is an unfailing constituent of the minerals, has either been overlooked or incorrectly determined. Scacchi* regarded the minerals as representing three types of crystallization of one and the same chemical substance, which he designated as humite type I, type II and type III. Rammelsberg† and vom Rath‡ have suggested for the whole group the formula $Mg_5Si_2O_9$, with part of the oxygen replaced by fluorine, although they recognized that the percentages of silica varied in the different types. Wingard§ also, from the results of his recent analyses, concludes that the three minerals have the same chemical composition, expressed by the formula $Mg_{19}F_4(OH)_2Si_8O_{38}$, while Hj. Sjögren,‖ largely from a recalculation of the older analyses and a consideration that water had been overlooked in them, derived a separate formula for each species, as follows:

Clinohumite	$Mg_6\,[Mg(OH.F)]_2\,[SiO_4]_3$
Humite	$Mg_3\,[Mg(OH.F)]_2\,[SiO_4]_2$
Chondrodite	$Mg_4\,[Mg(OH.F)]_4\,[SiO_4]_3$

Sjögren assumes that hydroxyl is isomorphous with fluorine and calls attention to the fact, already suggested by Rammelsberg and vom Rath, that the three minerals show a variation in their silica percentages.

In the present investigation we have been able to examine the following materials: Chondrodite from Warwick and Brewster's, New York; Kafveltorp, Sweden and Mte. Somma, Italy. Humite and Clinohumite from Mte. Somma.

* Loc. cit.
† Mineralchemie, p. 434, 1875.
‡ Pogg. Ann., cxlvii, p. 254, 1872.
§ Zeitschr Anal. Chem., xxiv, p. 344, 1885.
‖ Zeitschr. Kryst., vii, p. 354, 1883.

After having definitely determined the crystallographic character of the minerals they were pulverized and sifted to a uniform grain and separated from the gangue and other impurities by means of the barium-mercuric-iodide solution. Thanks to this accurate method of separation we have had an advantage over all previous investigators in being able to obtain an abundance of material for the chemical analyses. Each product that was obtained was nearly uniform in specific gravity and almost absolutely pure, as shown by examination with the polarizing microscope.

Method of analysis.—Silica, fluorine and bases were determined in one portion, usually of from one to two grams, which was fused with a mixture of sodium and potassium carbonates and treated according to the Berzelius method of analyzing silicates containing fluorine. On soaking out the fusion with water in a platinum dish it was found that, owing to the basic character of the mineral, only a small quantity of silica had gone into solution, and this was separated directly by means of zinc oxide dissolved in ammonia, thus avoiding the customary precipitation with ammonium carbonate. The solution filtered from the zinc oxide and silica, and containing the alkali carbonate and fluoride, was nearly neutralized with hydrochloric acid, heated to boiling, and calcium fluoride and carbonate precipitated by addition of calcium chloride. After collecting the precipitate it was ignited to low redness in a weighed platinum crucible and the calcium carbonate or oxide removed by means of acetic acid. At this point we have usually proceeded as follows: To the ignited precipitate in the crucible water and 1 or 2^{cc} of acetic acid were added, the whole was then digested for some time on the water bath with the crucible covered, finally the cover was removed and the excess of acid evaporated. The dry salts were then extracted with hot water and the solution filtered through a small filter. After washing, the paper was burned in the same crucible, the residue treated again with water and a small quantity of acetic acid, the operation being repeated until all of the calcium carbonate and oxide had been extracted. Our experience has shown that a large excess of acetic acid used at once gives too low results. This method is not very tedious and is satisfactory, as shown by the following test experiments where determinations were made with known weights of pure fluorite mixed with chrysolite in the proper proportion to give amounts of fluorine and magnesium silicate about equal to those in chondrodite.

Chrysolite.	CaFe taken.	Equivalent of fluorine.	Fluorine found.	Loss.
1·3782	·2942	·1438	·1416	·0022
1·3794	·3012	·1473	·1456	·0017

These results, although low, are within 0·15 and 0·10 per cent of the theory when expressed in terms of the mixture of chrysolite and fluorite. The iron was separated from magnesia by ammonium, the precipitation being repeated at least twice to ensure a complete separation. Water was sometimes weighed directly in a U tube containing sulphuric acid, the mineral being fused with anhydrous sodium carbonate in a Gooch* tubulated crucible, special pains being taken to surround the crucible in which the fusion was made by a larger one containing sodium carbonate. Thus the gas flame never came into direct contact with the inner crucible and the passage of gases through the red hot platinum, which would have rendered the results too high was avoided. This method has been carefully tested by us and gives accurate results. In some analyses, where the percentage of ferrous oxide was small, water was determined as loss on ignition, as follows: About 0·4 gram of lime was ignited to a constant weight in a platinum crucible, into which subsequently the mineral was weighed. The lime was then carefully slaked and mixed with sufficient water to make a thin paste; after drying down on the water bath the crucible was ignited, gently at first, finally over the blast lamp, to a constant weight. The lime keeps fluorine from escaping and the error which would result from the complete oxidation of the iron would amount only to a few hundredths of one per cent. Duplicate determinations made by both methods agreed very well with one another. The water determined in the analyses must have come from hydroxyl as it cannot be completely expelled from chondrodite except by intense ignition. Thus a sample from Warwick, N. Y., which by direct determination yielded 1·43 and 1·48 per cent, gave only 0·48 per cent when ignited in a glass tube over the blast lamp, lime being used to retain the fluorine. The method that has been usually adopted of igniting with lead oxide was also tested and found to be wholly unsuitable, two determinations yielding only 0·77 and 0·56 per cent.

Chondrodite, (Humite Type II of Scacchi.)

Chondrodite from Warwick, Orange Co., N. Y. — The material that was selected for analysis was obtained from a specimen in the Brush collection, Catalogue No. 2054. The chondrodite occurs as rounded grains, of a rich reddish-brown color imbedded in a white crystalline limestone and associated with spinel and graphite. The material was very fresh and showed occasional crystal faces, but not sufficient for the identification of the mineral. It was selected at the beginning of

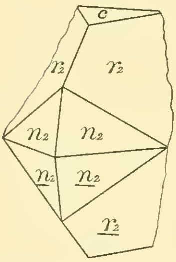
* Am. Chem. Jour., ii, p. 247, 1880.

our investigation as it afforded abundant material for testing the methods of the mechanical separation and the chemical analysis. The powder separated by the heavy solution varied in specific gravity between the limits 3·165 and 3·235. It showed only a trace of impurities when examined with the microscope, probably of partly altered spinel, which accounts for the small amount of Al_2O_3 shown by the analysis. That the mineral is really chondrodite is proved by the chemical analysis, as will be shown later, while from the same locality there is in the Brush collection a small specimen, Catalogue No. 2057, corresponding exactly in color and showing crystals that could be measured and identified as chondrodite. These are associated with an ash-gray amphibole and have evidently weathered out from limestone.

The crystals are attached so that only the following forms could be identified:

c, 001, O	n_2, 111, -1	r_2, 125, $-\frac{2}{5}$-$\grave{2}$

1.



A hemidome, probably $\bar{1}02$ or $\bar{3}05$ was also present but could not be identified with certainty. The crystals are twinned about the base and have the habit shown in figure 1. Only approximate measurements could be made.

	Measured.	Calculated for chondrodite.
$c \wedge n_2$, $001 \wedge 111$	= 76° 30′	76° 50′
$c \wedge r_2$, $001 \wedge 125$	= 54	54 10
$r_2 \wedge r_2$, $125 \wedge 1\bar{2}5$	= 94	94 51½

The analysis will be given later.

Chondrodite from the Tilly-Foster mine Brewster, Putnam Co., N. Y.—The material for analysis was selected wholly from isolated crystals, which were obtained by the authors at the locality. Each crystal was measured and found to possess characteristic chondrodite forms. The habits of different crystals varied considerably but conformed in general to types figured by E. S. Dana. The forms identified by us and some of the measured angles are the following:

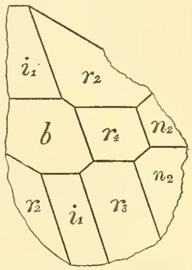
b, 010, i-$\grave{i}$	$-n_2$, $\bar{1}11$, 1	r_1, $\bar{1}27$, $\frac{2}{7}$-$\grave{2}$
c, 001, O	r_2, 125, $-\frac{2}{5}$-$\grave{2}$	r_3, $\bar{1}23$, $\frac{2}{3}$-$\grave{2}$
i_1, 012, $\frac{1}{2}$-$\grave{i}$	r_4, 121, -2-$\grave{2}$	$\mathfrak{m}_2$, $\bar{3}21$, 3-$\frac{3}{2}$

	Measured.	Calculated.		Measured.	Calculated.
$r_2 \wedge r_2$, $125 \wedge 1\bar{2}5$	= 94° 51′	94° 51½′	$r_3 \wedge r_4$, $12\bar{3} \wedge 121$	= 31° 39½′	31° 39′
$r_1 \wedge r_1$, $\bar{1}27 \wedge \bar{1}\bar{2}7$	= 79 15	79 24	$b \wedge r_4$, $010 \wedge 121$	= 26 3	25 58
$r_3 \wedge r_3$, $\bar{1}23 \wedge \bar{2}3$	= 112 43½	112 55	$r_3 \wedge n_2$, $\bar{1}23 \wedge 11$	= 19 42	19 31½
$r_1 \wedge r_3$, $\bar{1}27 \wedge \bar{1}23$	= 21 54	21 53	$\mathfrak{m}_2 \wedge n_2$, $\bar{3}21 \wedge \bar{1}11$	= 13 46	13 42

The crystals were exceptionally fresh and pure, and showed no trace of serpentinization. Some pure transparent pieces were selected for analysis by hand picking, while crystals having gangue attached to them were pulverized and separated by the heavy solution, the powder that was used in the analysis varying in specific gravity from 3·204 to 3·231.

Chondrodite from Kafveltorp, Sweden.—The material for our investigation was obtained from a specimen in the Brush collection, Catalogue No. 2040. The crystals have a yellowish brown color, are imbedded in sulphides, and their habit as well as this unusual association agree exactly with the description given by Hj. Sjögren;* the accompanying minerals being chiefly galena and sphalerite with a little chalcopyrite and amphibole. Only fragmentary crystals could be separated from the gangue, and the forms developed on one of these is shown in fig. 2, which is a projection upon 0$\bar{1}$0. Some of the measured and calculated angles are:

2.

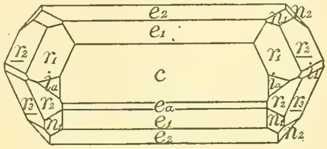


		Measured.	Calculated.
$c \wedge r_2$,	$001 \wedge 125 =$	53° 51′	54° 10′
$r_2 \wedge r_4$,	$125 \wedge 12\bar{1} =$	27 38	27 37
$r_4 \wedge r_3$,	$121 \wedge 12\bar{3} =$	31 45	31 39
$b \wedge r_4$,	$010 \wedge 121 =$	26° 2½′	25° 58′
$c \wedge n_2$,	$001 \wedge 11\bar{1} =$	77 3	76 50
$n_2 \wedge -n_2$,	$111 \wedge 11\bar{1} =$	26 18	26 40

The material for analysis was separated by the heavy solution and varied in specific gravity from 3·252 to 3·265.

Chondrodite from Mte. Somma, Italy.—Our material was selected from a specimen in the Brush collection, Cat. No. 2063, which had been presented to Prof. Brush by Prof. A. Scacchi. The associated minerals constituting the gangue are calcite and biotite (meroxene). The crystals are honey-yellow in color, transparent and present the forms shown in the basal projection, fig. 3, the measured angles being:

3.



		Measured.	Calculated.
$c \wedge e_2$,	$001 \wedge 101 =$	70° 52′	70° 56½′
$c \wedge -e_2$,	$001 \wedge \bar{1}01 =$	70 48	70 56½
$c \wedge e_1$,	$001 \wedge 103 =$	44 1	43 59
$c \wedge -e_1$,	$001 \wedge \bar{1}03 =$	43 52	43 59
$c \wedge e_a$,	$001 \wedge 105 =$	29 55	30 4
$c \wedge i_1$,	$001 \wedge 012 =$	57 24	57 33
$c \wedge i_a$,	$001 \wedge 014 =$	38 4	38 10½
$c \wedge r_2$,	$001 \wedge 125 =$	54° 13′	54° 10′
$c \wedge r_1$,	$001 \wedge \bar{1}27 =$	44 35	44 41
$c \wedge r_3$,	$001 \wedge \bar{1}23 =$	66 24	66 34
$c \wedge n$,	$001 \wedge 113 =$	54 45	54 56
$c \wedge -n$,	$001 \wedge \bar{1}13 =$	54 54	54 56
$c \wedge n_a$,	$001 \wedge 111 =$	76 38	76 50
$c \wedge -n_a$,	$001 \wedge \bar{1}11 =$	76 46	76 50

* Zeitschr. Kryst., vii, p. 113, 1883.

The crystal that was measured was probably twinned about the base, the twinning plane being situated somewhat above the center which accounts for r_2 being situated under r_1 behind, and r_3 under r_2 in front, which is contrary to the usual arrangement of these planes in chondrodite. All of the crystals on the specimen had exactly the same color and general appearance and, although only one was measured it was assumed that they all belonged to the chondrodite type. This is rendered all the more probable by the observations of Scacchi* who states that, on a given block from Mte. Somma, usually only one type of humite occurs. The powder that was separated by the heavy solution varied in specific gravity between 3·194 and 3·215.

The analyses are as follows:

Warwick, N. Y.

Specific gravity = 3·168–3·235.

	I.	II.	III.	IV.	Average.	Ratio.	
SiO_2	33·85	33·67	33·82	33·86	33·80	0·563	0·563
MgO	55·74	55·87	55·78	55·68	55·70	1·396	1·433
FeO	2·59	2·64	2·69		2·64	·037	
Al_2O_3	1·79	1·87			1·83		
F	7·32	7·26	7·32		7·30	·384	0·546
H_2O	1·43	1·48			1·46÷9=	·162	
					102·73		
Oxygen equivalent to F =					3·07		
					99·66		

Brewster, N. Y.

Specific gravity = 3·204–3 231.

	I.	II.	III.	Average.	Ratio.	
SiO_2	33·66	33·48	33·87	33·67	·561	0·561
MgO	54·68	54·92	54·78	54·79	1·370	1·452
FeO	5·89	5·96	5·99	5·94	·082	
F	5·25	5·38	5·31	5·30	·279	0·593
H_2O	2·60	2·44	2·61	2·55÷9 =	·294	
				102·25		
Oxygen equivalent to F =				2·23		
				100·02		

* Pogg. Ann., Erg. B., iii, p. 181, 1851.

Kafveltorp, Sweden.

Specific gravity = 3·252–3·265.

	I.	II.	III.	IV.	Average.	Ratio.	
SiO_2	33·36	33·28	33·18	33·52	33·33	·556	0·556
MgO	54·23	54·37			54·30	1·358	1·450
FeO	6·66	6·58			6·62	·092	
F	6·74	6·58	6·63	6·43	6·60	·347	0·533
H_2O	1·63	1·72			1·67 ÷ 9 =	·186	
					102·52		
Oxygen equivalent to F =					2·76		
					99·76		

Mte. Somma, Italy.

Specific gravity = 3·194–3·215.

	I.	II.	Average.	Ratio.	
SiO_2	33·96	33·78	33·87	·564	0·564
MgO	56·37	56·55	56·46	1·411	1·461
FeO	3·72	3·60	3·66	·050	
F	5·09	5·21	5·15	·271	0·584
H_2O	2·92	2·72	2·82 ÷ 9 =	·313	
			101·96		
Oxygen equivalent to F =			2·16		
			99·80		

In discussing the above analyses it has been assumed that FeO is isomorphous with MgO and hydroxyl with fluorine. The ratios have been collected together in the following table:

	SiO_2	:	(MgO + FeO)	:	(F + OH)					
Warwick,	0·563	:	1·433	:	0·546 = 1·96	:	5	:	1·90
Brewster,	0·561	:	1·452	:	0·593 = 1·93	:	5	:	2·04
Kafveltorp,	0·556	:	1·450	:	0·533 = 1·92	:	5	:	1·84
Mte. Somma,	0·564	:	1·461	:	0·584 = 1·93	:	5	:	1·99

These all approximate to $SiO_2 : RO : (F+OH) = 2 : 5 : 2$ which would give for the formula of chondrodite, $Mg_5(F.OH)_2Si_2O_8$ or an isomorphous mixture of the molecules $Mg_3(MgF)_2(SiO_4)_2$ and $Mg_3(MgOH)_2(SiO_4)_2$. The ratio of fluorine to hydroxyl, or of these two molecules varies considerably. In the Brewster and Mte. Somma minerals it is nearly 1 : 1, in Kafveltorp 2 : 1 and in Warwick $2\frac{1}{3} : 1$. The specific gravities are very close, varying only between 3·165 and 3·265 and, as would be expected, increase with the percentage of iron.

For a better comparison of the analyses with the theory they are given below after recalculating FeO as MgO and bringing the total to one hundred per cent.

	Brewster.	Mte. Somma.	Theory where F : OH = 1 : 1.
SiO_2	34·56	34·52	35·29
MgO	59·69	59·56	58·82
F	5·44	5·25	5·59
H_2O	2·62	2·88	2·65
	102·31	102·21	102·35
O. eq. to F =	2·31	2·21	2·35

	Warwick.	Kafveltorp.	Theory where F : OH = 2 : 1.
SiO_2	34·91	34·42	35·22
MgO	59·23	59·90	58·71
F	7·54	6·81	7·44
H_2O	1·51	1·73	1·76
	103·19	102·86	103·13
O. eq. to F =	3·19	2·86	3·13

These analyses are all slightly high in magnesia and correspondingly low in silica and (F+OH), but on the whole they agree very well with the theory.

Previous analyses of chondrodite.—In discussing the analyses of other investigators it must be borne in mind that water has usually been disregarded or determined incorrectly. We have tabulated below the available analyses that have been made on material of known crystallographic character.

From Mte. Somma.

I. Rammelsberg.* Brownish yellow crystals. Mean of two analyses.
II. G. vom Rath. Light yellow crystals. Mean of two analyses.
III. Wingard. Light wine yellow crystals. Mean of two analyses.

From Kafveltorp, Sweden.

IV. Wingard. Wine yellow crystals. Mean of three analyses.
V. G. vom Rath. Mean of two analyses.
VI. Hj. Sjögren.† Brown crystals.
VII. Hj. Sjögren. Yellow crystals.

From Brewster, N. Y.

VIII. Hawes.‡ Garnet red crystals. Measured and identified by E. S. Dana. Mean of two analyses.

* Pogg. Ann., lxxxvi, p. 413, 1852.
† Zeitschr. Kryst., vii, p. 356, 1883.
‡ Trans. Conn. Acad., iii, p. 86, 1874.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
Sp. gr.	3·190	3·125	-- -	----	----	----	----	3·22
SiO_2	33·26	33·92	33·63	33·60	33·66	33·13	34·01	34·08
MgO	57·92	59·33	58·13	53·05	53·26	54·71	54·97	53·44
FeO	2·30	1·71	3·88	8·67	6·82	4·95	4·62	7·22
F	5·04	2·59	5·20	5·58	4·24	4·99	4·56	4·01
H_2O	----	----	1·37	1·31	---	·55	·61	----
Al_2O_3	1·06	·97	----	----	·67	·68	·71	·44
CaO	·74	----	----	Fe_2O_3 ·12	----	MnO ·75	MnO ·18	----
	100·32	98·52	102·21	102·33	98·65	99·76	100·29	99·19
O = F	2·12	1·09	2·19	2·35	1·78	2·10	1·92	1·69
	98·20	97·43	100·02	99·98	96·87	97·66	98·37	97·50
Cal. H_2O	*2·94*	*4·19*	*1·58*	*1·24*	*3·12*	*2·29*	*2·45*	*3·27*
	101·14	101·62	101·60	101·22	99·99	99·95	100·82	100·77

With two exceptions, analyses III and IV, it will be observed that after deducting the oxygen equivalent to fluorine the analyses add up to only about 96 to 98 per cent, and it is believed that this loss must be due to water which was not determined. Taking the protoxides, MgO and FeO, as a basis of calculation, we have determined the amounts of water which should be added to the analyses in order to yield the ratio RO : (F+OH) = 5 : 2 established by us. These quantities (*Cal. H_2O*) when added give very satisfactory results. In all of the analyses except those of Wingard, III and IV, the summation is nearer 100 per cent than before and this is especially shown in the last four. This method of treating the water is probably fairer than to derive it from the deficiency in the analyses, as by the latter treatment, all of the errors of analysis would be thrown upon this constituent, which, owing to its low molecular weight, needs to be very accurately determined to yield a sharp and correct ratio. The percentages of SiO_2 vary from 33·13 to 34·08 while in our analyses they run from 33·33 to 33·87. In the following table, where the ratios of SiO_2 : RO are given, it may be observed that they approximate closely to 2 : 5 as required by our formula.

	SiO_2 : RO		SiO_2 : RO
I.	·554 : 1·489 = 1·88 : 5	V.	·561 : 1·426 = 1·96 : 5
II.	·565 : 1·507 = 1·88 : 5	VI.	·552 : 1·447 = 1·91 : 5
III.	·561 : 1·507 = 1·86 : 5	VII.	·567 : 1·448 = 1·96 : 5
IV.	·560 : 1·446 = 1·94 : 5	VIII.	·568 : 1·436 = 1·98 : 5

It is very gratifying to be able to show that the formula established by us is thus substantiated by the analyses of previous investigators.

Humite, (Type I of Scacchi.)

In the course of the investigation we have been able to examine only the humite from Mte. Somma, of which two separate samples were analyzed. The material for the first of these was obtained from a specimen purchased from Dr. A. E. Foote of Philadelphia. The humite crystals, which measure from 2–3^{mm} in diameter, are nearly colorless and transparent and are associated with spinel and calcite. Their habit corresponds in general to the figure of vom Rath* copied into the sixth edition of Dana's Mineralogy, page 535. Some of the measured angles are as follows:

		Measured.	Calculated.			Measured.	Calculated.
$c \wedge e_2$,	$001 \wedge 104$	$=45°\ 29'$	$45°\ 32\frac{1}{2}'$	$c \wedge r_2$,	$001 \wedge 128$	$=50°\ 31\frac{1}{2}'$	$50°\ 30'$
$c \wedge e_4$,	$001 \wedge 102$	$=63\ \ 51$	$63\ \ 52$	$c \wedge r_3$,	$001 \wedge 126$	$=58\ \ 16$	$58\ \ 16$
$c \wedge e_5$,	$001 \wedge 101$	$=76\ \ 17$	$76\ \ 13$	$c \wedge i_2$,	$001 \wedge 013$	$=55\ \ 45$	$55\ \ 44$
$c \wedge r_1$,	$001 \wedge 1{\cdot}2{\cdot}10$	$=44\ \ 9\frac{1}{2}$	$44\ \ 8\frac{1}{2}$	$c \wedge i_3$,	$001 \wedge 011$	$=76\ \ 59$	$77\ \ 12$

The material that was separated for analysis varied in specific gravity from 3·194 to 3·201

The material for the second analysis was selected from a specimen in the Yale College cabinet, Catalogue No. 4102. The crystals are associated with calcite and biotite. They are chestnut brown in color, in habit like the ones described above and were identified by the following measurements.

		Measured.	Calculated.
$c \wedge i_2$,	$001 \wedge 013$	$=55°\ 44'$	$55°\ 44'$
$c \wedge i_2$,	$001 \wedge 0\bar{1}3$	$=55\ \ 49$	" "

The specific gravity of the material for analysis varied from 3·183 to 3·225.

First Analysis.

	I.	II.	III.	IV.	Average.	Ratio.	
SiO_2	36·59	36·63	36·63	36·68	36·63	·6105	
MgO	56·34	56·43	56·59	56·45	56·45	1·411	1·444
FeO	2·33	2·43	2·46	2·30	2·35	·033	
F	3·12	3·06	2·96	----	3·08	·162	·423
H_2O	2·42	2·48			2·45 ÷ 9 =	·261	
					100·96		
Oxygen equivalent to F					1·26		
					99·70		

* Pogg. Ann. Erg. B., v, Table VII, fig. 1.

Second Analysis.

	I.	II.	Average.	Ratio.	
SiO_2	36·84	36·63	36·74	·612	
MgO	56·21	56·42	56·31	1·408	1·437
FeO	2·22	2·21	2·22	·029	
F	3·89	4·02	3·96	·208	·444
H_2O	2·18	2·08	2·13÷9	·236	
			101·36		
Oxygen equivalent to F =			1·66		
			99·70		

These analyses differ from those of chondrodite in being about 3 per cent higher in silica and also the ratios are different as shown by the following:

	SiO_2	: (MgO + FeO)	: (F + OH)	
1st Analysis,	0·6105 :	1·444	: 0·423	= 2·97 : 7 : 2·05
2d Analysis,	0·612 :	1·437	: 0·444	= 2·99 : 7 : 2·16

These ratios approximate closely to 3 : 7 : 2, indicating that the formula of humite is $Mg_5[Mg(F.OH)]_2[SiO_4]_3$. The ratio of F : OH in the first analysis is nearly 2 : 3 and in the second about 1 : 1. We give beyond the theoretical composition for both ratios, together with the analyses in which the FeO has been calculated as MgO and the total brought to 100 per cent.

	First analysis.	Theory where F : OH = 2 : 3.	Second analysis.	Theory where F : OH = 1 : 1.
SiO_2	37·15	37·53	37·24	37·50
MgO	58·56	58·38	58·27	58·34
F	3·12	3·17	4·02	3·96
H_2O	2·48	2·25	2·16	1·87
	101·31	101·33	101·69	101·67
O eq. to F	1·31	1·33	1·69	1·67

These analyses show a very satisfactory agreement with the theory and we may regard the formula of humite as well established.

Previous analyses of humite.—The following analyses are available for comparison.

From Mte. Somma.

I. Rammelsberg. Grayish yellow crystals.
II. G. vom Rath. Light brown crystals. Mean of two analyses.
III. Wingard. Light yellow crystals. Mean of two analyses.
IV. Wingard. Dark yellow crystals.

From Ladu Mine, Sweden.

V. Wingard. Material described as not quite pure and showing traces of serpentinization, which accounts for the high percentage of H_2O.

VI. Hj. Sjögren.

	I.	II.	III.	IV.	V.	VI.
Sp. gr.	3·216	3·208	----	----	----	----
SiO_2	34·80	35·49	35·43	35·55	35·26	35·13
MgO	60·08	54·28	56·29	52·86	55·48	55·16
FeO	2·40	5·12	3·70	7·31	3·51	3·26
	----	CaO ·20	----	----	----	MnO ·41
	----	Al_2O_3 ·76	----	----	----	----
F	3·47	2·43	5·63	5·60	4·72	2·45
H_2O	----	----	1·48	1·37	3·07	2·16
	100·75	98·28	102·53	102·69	102·04	98·57
O eq. to F	1·46	1·02	2·37	2·36	1·98	1·03
	99·29	97·26	100·16	100·33	100·06	97·54
Cal. H_2O	*2·29*	*2·52*	----	----	----	*·35*
	101·58	99·78				97·89

It will be observed that these analyses show percentages of SiO_2 varying from 34·80–35·55, agreeing with those made by us in being higher than the corresponding percentages in chondrodite. The *calculated water* represents the amount required to yield the ratio of $RO:(F+OH)=7:2$. When added to analysis II it makes the summation very satisfactory but causes I to overrun. In the analyses of Wingard there are already sufficient quantities of F and H_2O to give the required ratio. Sjögren's analysis is evidently too low. The ratios are as follows:

	SiO_2 : RO : (F+OH)	
I.	0·580 : 1·535 : ----	= 2·65 : 7 : ----
II.	0·592 : 1·428 : ----	= 2·90 : 7 : ----
III.	0·591 : 1·458 : 0·460	= 2·84 : 7 : 2·21
IV.	0·593 : 1·422 : 0·447	= 2·92 : 7 : 2·20
V.	0·588 : 1·436 : 0·589	= 2·87 : 7 : (2·8 ?)
VI.	0·586 : 1·430 : 0·369	= 2·87 : 7 : 1·8

These ratios of $SiO_2:RO$ approximate closely to 3 : 7 as required by our formula and in analyses III, IV and VI the (F+OH) is not far from the correct ratio which should be $RO:(F+OH)=7:2$. Thus our formula for humite is also substantiated by the analyses of other investigators.

Clinohumite, (Humite Type III of Scacchi.)

Of this rare mineral we have been able to examine two specimens from Mte. Somma. For the first analysis the material was derived from a specimen in the Brush collection, catalogue No. 2064, which had been presented by W. Sartorius von Waltershausen. The crystals are light wine yellow, transparent and in habit like the simple crystals figured by vom Rath.* The associated minerals are, forsterite, biotite, spinel, calcite and a little vesuvianite. The measurements that served for the identification of the mineral are as follows :

		Measured.	Calculated.			Measured.	Calculated.
$c \wedge e_4$,	$001 \wedge 101$	= 79° 12′	79° 11½′	$c \wedge r_5$,	$001 \wedge \bar{1}27$	= 60° 42′	60° 42′
$c \wedge e_3$,	$001 \wedge 103$	= 60 13	60 12	$c \wedge r_3$,	$001 \wedge \bar{1}{\cdot}2{\cdot}11$	= 48 35	48 35
$c \wedge e_2$,	$001 \wedge 105$	= 46 24	46 20	$c \wedge r_1$,	$001 \wedge \bar{1}{\cdot}2{\cdot}15$	= 39 46	39 44½
$c \wedge e_1$,	$001 \wedge 107$	= 36 49	36 48½	$c \wedge r_2$,	$001 \wedge 1{\cdot}2{\cdot}13$	= 43 49	43 49
$c \wedge -e_1$,	$001 \wedge \bar{1}07$	= 36 49	36 48½	$c \wedge r_4$,	$001 \wedge 129$	= 54 10	54 11
$c \wedge i_2$,	$001 \wedge 014$	= 54 43	54 45	$c \wedge n_2$,	$001 \wedge 115$	= 57 2	57 2½
$c \wedge i_1$,	$001 \wedge 016$	= 43 19	43 19½				

The specific gravity, when taken with the heavy solution, varied between 3·184 and 3·222 and this being almost identical with that of forsterite the yellow clinohumite crystals had to be separated from the colorless forsterite by hand picking. The specimen only afforded 0·3879 grams of the mineral and the analysis was made on this small portion by fusing the whole with dry sodium carbonate in the Gooch crucible to obtain the water, soaking out the fusion and carrying on the analysis in the usual way. In the course of the analysis a most unusual accident occurred. The platinum crucible in which the fusion was made broke, and it was not discovered till, on soaking out the fusion, it was found to leak. The break was of such a nature that the water determination was not lost and the mechanical loss, caused by the leaking, was slight and, in all probability, evenly distributed on the remaining constituents. It is assumed that the deficiency of the analysis, amounting to about 2 per cent, was caused by this accident, as otherwise the analysis was carried on with more than usual care. The analysis is given beyond under *a* as it stands in the note book and under *b* after distributing the deficiency of 2·28 per cent among all of the constituents except water.

The material for the second analysis was derived from a specimen in the Yale College cabinet, catalogue No. 4143. The crystals are chestnut brown in color and are associated with forsterite, biotite, vesuvianite and a little calcite. Their identity as clinohumite is shown by the following measurements.

		Measured.	Calculated.			Measured.	Calculated.
$c \wedge -e_1$,	$001 \wedge \bar{1}07$	= 36° 45′	36° 48½′	$c \wedge i_2$,	$001 \wedge 014$	= 54° 40′	54° 45′
$c \wedge e_\delta$,	$001 \wedge 109$	= 30 00	30 12	$c \wedge r_3$,	$001 \wedge \bar{1}{\cdot}2{\cdot}11$	= 48 28	48 35
$c \wedge e_2$,	$001 \wedge 105$	= 46 19	46 20	$c \wedge r_5$,	$001 \wedge \bar{1}27$	= 60 41	60 42
$c \wedge e_3$,	$001 \wedge 103$	= 60 12	60 12	$c \wedge -n_2$,	$001 \wedge \bar{1}15$	= 57 2	57 2½
$c \wedge e_4$,	$001 \wedge 101$	= 79 9	79 11½	$c \wedge -n_4$,	$001 \wedge \bar{1}11$	= 82 49	82 37
$c \wedge i_1$,	$001 \wedge 016$	= 43 19	43 19½				

* Pogg. Ann., Erg. B. v, Tables VI, figs. 1 and 7 and VII, fig. 10. Sixth edition of Dana's Mineralogy, page 538.

The material for the analysis had to be selected by hand picking and, when introduced into the heavy solution, showed a specific gravity between the limits 3·219 and 3·258. The analyses are as follows:

First Analysis.

	a.	*b.*			Ratio.
SiO_2	37·15	38·03	·634		4·02
MgO	52·74	54·00	1·350	1·417	9·00
FeO	4·72	4·83	·067		
F	2·01	2·06	·108	·323	2·05
H_2O	1·94	1·94÷9 =	·215		
	98·56	100·86			
O eq. to F =	·84	·86			
	97·72	100·00			

Second Analysis.

				Ratio.
SiO_2	37·78	·629		4·03
MgO	53·05	1·326	1·404	9·00
FeO	5·64	·078		
F	3·58	·188	·336	2·15
H_2O	1·33÷9 =	·148		
	101·38			
O eq. to F =	1·50			
	99·88			

In both of these analyses the ratios of $SiO_2 : RO : (F+OH)$ approximate closely to 4 : 9 : 2 corresponding to the formula $Mg_7[Mg(FOH)]_2(SiO_4)_4$. In the first analysis, the ratio of F : OH = 1 : 2 and in the second it is about 1 : 1. Below we have given the analyses after calculating FeO as MgO and bringing them to 100 per cent and, for comparison, the theoretical composition according to the above formula with F : OH = 1 : 2 and 1 : 1 respectively.

	First analysis.	Theory where F : OH = 1 : 2.	Second analysis.	Theory where F : OH = 1 : 1.
SiO_2	38·87	38·75	38·81	38·77
MgO	57·94	58·12	57·64	58·16
F	2·10	2·05	3·68	3·07
H_2O	1·98	1·94	1·37	1·29
	100·89	100·86	101·50	101·29
O eq. to F	·89	·86	1·50	1·29

The agreement of the above analyses with the theory is very satisfactory.

Previous analyses of Clinohumite.—The following analyses are available for comparison, all made on mineral from Mte. Somma.

I. Rammelsberg. Yellowish white crystals. Mean of three analyses.

II. Rammelsberg. One of the above analyses showing the highest SiO_2 and MgO.

III. G. vom Rath. Orange yellow crystals. Mean of two analyses.

IV. Wingard. Grayish to yellowish brown crystals. Mean of two analyses.

	I.	II.	III.	IV.
SiO_2	36·67	37·23	36·75	33·30
MgO	56·83	57·78	54·88	51·53
FeO	1·67	1·57	5·48	9·71
	----	----	Al_2O_3 ·24	Fe_2O_3 ·89
F	2·62	2·33	2·30	5·67
H_2O	----	----	----	1·41
	97·79	98·91	99·65	102·51
O eq. to F	1·10	·98	·97	2·38
	96·69	97·93	98·68	100·13
Cal. H_2O	*1·64*	*1·83*	*1·81*	*1·03*
	98·33	99·76	100·49	101·16

In the first three analyses the *calculated water* represents the quantity necessary to yield the ratio RO : (F+OH) = 9 : 2, and as in previous instances it makes the analyses add up much nearer 100 per cent than before. The ratios are as follows:

	SiO_2 : RO	
I.	·611 : 1·444	= 3·80 : 9
II.	·621 : 1·466	= 3·81 : 9
III.	·613 : 1·448	= 3·81 : 9

These approximate to 4 : 9 and thus substantiate in a satisfactory manner our formula for clinohumite.

The results of Wingard, analysis IV, differ from those of other investigators. No proof is given that the material which he analyzed is clinohumite except that it was obtained from Prof. Scacchi, and there has undoubtedly been some mistake for his analysis yields a ratio of SiO_2 : RO = 1·95 : 5, which is very close to 2 : 5 as required by our formula for chondrodite. The fluorine and water are low, as in his other chondrodite analyses and the *calculated water* that we have added is that required to complete the ratio SiO_2 : RO : (F+OH) = 2 : 5 : 2.

Conclusions.—In the preceding pages we have shown that the minerals of the humite group are *not* identical with each other in chemical composition and that they can be expressed by the following formulæ, constructed on two, three and four molecules of ortho silicic acid, in which two hydrogen atoms are replaced by the univalent radical [Mg(F . OH)] and the remaining ones by magnesium :

Chondrodite	$Mg_3[Mg(F.OH)]_2[SiO_4]_2$
Humite	$Mg_5[Mg(F.OH)]_2[SiO_4]_3$
Clinohumite	$Mg_7[Mg(F.OH)]_2[SiO_4]_4$

These form a chemical series, varying progressively from chondrodite to clinohumite by an increase of one molecule of Mg_2SiO_4. This variation in chemical composition is intimately connected with the crystallization. Thus on page 188 it was mentioned that the three minerals form a crystallographic series in which the vertical axes increase from chondrodite to clinohumite. It was also shown that by dividing the vertical axes by 5, 7 and 9 respectively the quotients become practically identical and it is a very interesting and remarkable fact that these divisors 5, 7 and 9 correspond to the number of magnesium atoms in the formulæ deduced by us. Groth* has shown that in certain organic compounds the substitution of one hydrogen atom by another atom or radical causes a change in one of the crystallographic axes, the other two and the symmetry remaining essentially unchanged. Such a crystallographic series he calls a "Morphotropische Reihe." In the humite group we evidently have a kind of morphotropic series, but not exactly analogous to that cited by Groth as in the present case we have a change brought about by the *addition* of a molecule of Mg_2SiO_4, instead of the substitution of a radical. This addition of Mg_2SiO_4 causes the vertical axis to increase by about 1·2575, or $\frac{1}{9}$ of the vertical axis of clinohumite, while the other two axes and the inclination β remain the same. The symmetry, however, changes so that the first and last members of the series are monoclinic. In the whole range of chemical crystallography there is no series of compounds known to the authors that can be compared to the humite group. It is reasonable to expect that other members of this series will be found. Thus $Mg[Mg(F.OH)]_2SiO_4$ is a possible and a most likely compound to occur. This should crystallize either orthorhombic or monoclinic with $\beta = 90°$ and should have the axial ratio $a : b : c = 1·086 : 1 : 1·887$. The member next beyond clinohumite would be $Mg_9[Mg(F.OH)]_2[SiO_4]_5$ but, owing to its more complicated composition, it would seem less apt to occur. Chrysolite, Mg_2SiO_4, is closely

* Monatsber. Berlin Akad., 1870, p. 247.

related to the members of this group and, as shown by vom Rath,* a few of its forms are almost identical with those of humite. Their relation is shown on page 188 where the axial ratio $b:2a:c$ of chrysolite is similar to $a:b\frac{1}{9}c$ of clinohumite. As chrysolite contains no fluorine or hydroxyl it deviates considerably in its chemical type from the members of the humite group and its crystalline habit is also different, as the majority of its common forms do not correspond to any of the forms of humite. Of the three species constituting the humite group chondrodite has the simplest composition and is the most common, clinohumite has the most complicated composition and is the rarest, while humite occupies an intermediate position. At Mte. Somma chondrodite, which is the most basic, occurs usually with calcite, while clinohumite, which is the most acid, is usually associated with the silicate forsterite.

Of the formulæ proposed by other investigators that suggested by Rammelsberg and vom Rath, $Mg_5Si_2O_9$, is similar to the one deduced by us for chondrodite. They considered that part of the oxygen was replaced by fluorine, while we have shown that *one atom* of oxygen is replaced by the isomorphous fluorine and hydroxyl. The formula proposed by Wingard, $Mg_{13}[MgF]_4[Mg(OH)]_2[SiO_4]_8$ or $Mg_{19}(F.OH)_6(SiO_4)_8$, is not very different from ours for humite, it being equal to three times the latter, $Mg_{21}(F.OH)_6(SiO_4)_9$, less Mg_2SiO_4. Wingard derived his formula from the analysis of humite given below which, like the accompanying analyses of chondrodite, have been changed from their original shape only by recalculating FeO as MgO and bringing the total to 100 per cent. His humite analysis, naturally, agrees very well with his theory, but it also agrees quite well with the author's, while his chondrodite analyses agree very indifferently with his theory.

	Author's theory for humite F : OH = 2 : 1.	Wingard's theory. F : OH = 2 : 1.	Humite. Anal. IV, p. 200.	Chondrodite. Anal. III, p. 197.	Chondrodite. Anal. IV, p. 197.
SiO_2	37·45	36·87	36·63	34·21	35·01
MgO	58·25	58·38	58·62	61·33	60·29
F	5·27	5·84	5·77	5·29	5·81
H_2O	1·25	1·37	1·41	1·40	1·36
	102·22	102·46	102·43	102·23	102·47
O eq. to F	2·22	2·46	2·43	2·23	2·47

Our formulæ for the different members of the series do not agree in any single instance with those proposed by Sjögren, and yet his formulæ for the two upper members, humite and clinohumite, are identical with ours for chondrodite and humite respectively, as shown by the following:

* Pogg. Ann. Ergänz., Band V, p. 412, 1871.

	Authors.	Sjögren.
Chondrodite	$Mg_3[Mg(F.OH)]_2[SiO_4]_2$	$Mg_4[Mg(F.OH)]_4[SiO_4]_3$
Humite	$Mg_6[Mg(F.OH)]_2[SiO_4]_3$	$Mg_5[Mg(F.OH)]_2[SiO_4]_2$
Clinohumite	$Mg_7[Mg(F.OH)]_2[SiO_4]_4$	$Mg_6[Mg(F.OH)]_2[SiO_4]_3$

Sjögren was correct in assuming that hydroxyl is present in the minerals and that it is isomorphous with fluorine, but he failed to obtain the correct formulæ because he made direct comparisons of the silica percentages calculated from his formulæ, with the actual figures yielded by the older analyses which are somewhat low, while he neglected to take into consideration the fact that magnesia is partly replaced by ferrous oxide, which from its higher molecular weight still further lowers the percentage of silica. Thus it happens that, without making any correction for ferrous iron, the actual determinations of silica in the older analyses of humite and clinohumite agree very well with the formulæ proposed by him. To account for chondrodite, the most basic member of the series, Sjögren adopted a formula containing the Mg(F.OH) group four times. If in this F : OH = 1 : 1 then the calculated silica, 33·33 per cent, agrees very well the average *found* in the older analyses, which is about 33·5, but this should be nearly 35·0 when FeO is calculated to its equivalent of MgO and the analyses are brought to 100. Also the calculated percentages of F(7·04) and H_2O(3·33), taken together, are far in excess of anything observed in chondrodite. In the authors' formula the ratio of RO : (F+OH)=5 : 2 while in Sjögren's it is 5 : 2·5.

That fluorine is isomorphous with hydroxyl, or plays the same part in a molecule, seems too well established to need special comment. The results of our analyses indicate clearly that in the minerals of this group this isomorphism exists and if we abandon the idea a satisfactory explanation of their composition cannot be given. The theory that fluorine can replace oxygen, which formerly was so frequently advanced, is similar to our present idea that fluorine and hydroxyl are isomorphous, and the latter would seem to be the more natural for both fluorine and hydroxyl are univalent, the one having an atomic weight of 19 and the other a molecular weight of 17.

The formulæ thus proposed as the result of this investigation are simple and rational, they agree in a very satisfactory manner with the results of our analyses as well as with those of others and they constitute an extremely interesting chemical series, which is related in a remarkable manner to the crystallization of these minerals.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, December, 1893.

Art. XIX.—*Deformation of the Lundy Beach and Birth of Lake Erie;* by J. W. Spencer.

Contents.—A sequel to the Birth of Lake Ontario and Birth of Lake Huron; Epeirogenic elevation and dismemberment of Warren water: Formation of Lundy Lake and its Beach; Lundy Lake did not receive the waters from the Huron basin; Desertion of the Lundy shore, with the formation of Lake Erie and Niagara River; Deformation of the Lundy shore and the flooding of the head of the Erie basin; Warping northeast of the Huron basin, and its drainage turned into the Erie valley; Estimated rate of terrestrial warping; The future outlet of Lake Erie.

The history of Lake Erie is a natural sequel to the Birth of Lake Ontario* and the Birth of Lake Huron,† which have already appeared in this Journal. Deserted strands about Lake Erie have also been made known,‡ but all of them extended beyond the Erie basin, and formerly embraced the greatest of the inland sheets—the Warren water—which probably covered 200,000 square miles, or more than the entire area of the modern lakes. The last of the deserted shores of that body of water was the Forest beach (see map). The subsequent rise of land or subsidence of the waters has been intermittent with episodes of rest long enough for the waves to carve out broad terraces or build up heavy beaches. Still, the instability of the waters is marked by the greater beaches being composed of a series of beachlets rather than one individual mass. The series is remarkably persistent, although there may be imperfect development of the component parts. Between the different sets of deserted shores, there are often only traces of the receding water-levels.

In the survey of the Forest beach, fragments of old coast lines were observed below that level, and these have recently been found to form part of a great Erie shore, in age synchronous with the Algonquin beach of the higher lakes. This Erie beach, first described here, may appropriately be called the Lundy shore, after the spit near Niagara Falls, which has long been used as a ridge road, and known as Lundy Lane, and where the interpretation of the strand was discovered. The Algonquin and Lundy Lakes were the successors of the Warren water after its dismemberment by the level falling below that of Forest beach.

* "Deformation of the Iroquois Beach and Birth of Lake Ontario." This Journal, vol. xl, p. 443, 1890.

† "Deformation of the Algonquin Beach and Birth of Lake Huron." The same, vol. xli, p. 12, 1891.

‡ "High-level Shores in the Region of the Great Lakes and their Deformation." The same, vol. xli, p. 201—all by J. W. Spencer.

Between Font-hill and Ebenezer (see map) there was an extension of the Erie waters into the Ontario basin through a strait, if such it can be called, as it was over thirty miles across. The country in the Niagara district is a plain from

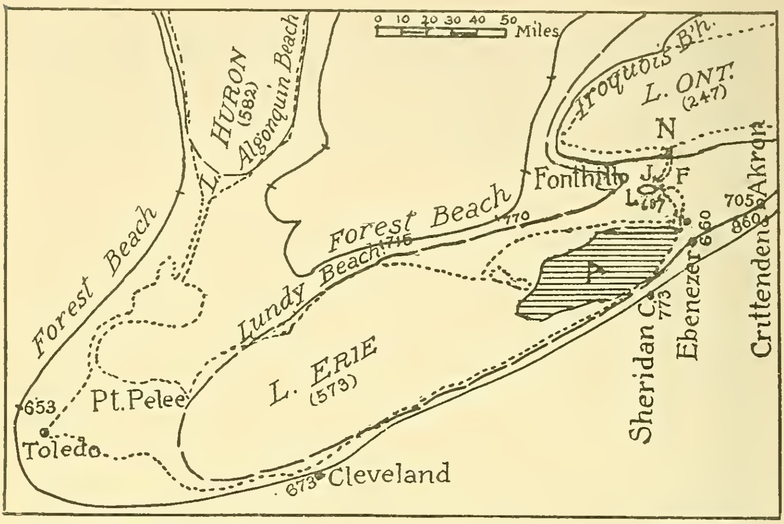


FIG. 1.—Map of Lundy shore, enclosing Lundy Lake. A. infant Lake Erie. N, mouth of Niagara River. F, Niagara Falls. L, Lundy beach near the Falls. J, Johnson's ridge. Elevations refer to sea-level.

10 to 15 feet above Erie Lake. It is rendered somewhat undulating by a few ridges of drift rarely rising 30 feet higher. A rocky ridge of 20 or 30 feet above the lake is parallel with the shores of Erie, a mile or two to the north of its outlet. But the most notable ridge culminated in Drummondville, near the falls, at 144 feet above the lake level. This is a small knob at the end of a long spit which is the historic Lundy Lane. The surface of this strand is 30 feet below the knob just noticed. This ridge formed a spit which was the first barrier that appeared between the Erie and Ontario basins, and here the waters last lingered before they subsided within the lower basin. The knob at Drummondville is not an undulation of the Lundy shore, although it is made up of beach-material, but belonged to a higher level. Whether a fragment of an older strand or not, still equivalent remains of deserted water-lines are found at Font-hill, Akron and elsewhere.

The crest of the Lundy beach is from 100 to 200 feet wide and forms a conspicuous sand and gravel ridge of more than double this width at the base, to which it slopes—20 or 30 feet below, and bounds an extensive plain on both sides, as it constituted a spit between the Erie and Ontario basins, which were connected by a broad sheet of open water. After extending westward from the Niagara River for two or three miles, the Lundy beach is interrupted by a low plain, but again the strand skirts Font-hill (which rises about 300 feet above Lake Erie) and trends southwestward. On the southeastern side of the strait, the beach is equally characteristic, near Ebenezer. It has been traced to Akron or about five miles due north of Crittenden, where the Forest beach was surveyed several years ago by Mr. Gilbert.

At Ebenezer, the Lundy beach has an altitude of 660 feet (bar.) above tide (Lake Erie being 573 feet); at Lundy Lane the elevation is 687 feet (and the older knob 30 feet higher); at Font-hill it is 675 feet (bar.); at Akron, the upper ridgelet is 735 feet (bar.) or equivalent to the lower at 705 feet. Fragments of beaches and terraces have been made known about the head of Lake Ontario and also about the Erie basin, but they have not been previously correlated with the Lundy shore. The Lundy strand is between 140 and 155 feet below the plain of the Forest beach, and it is usually from two to five miles lakeward of it. Between the different strands of Warren water, there is a slight deformation of the deserted shores owing to the unequal terrestrial movement. A somewhat greater amount of warping is recorded between the Forest and the Lundy beeches but the greatest amount of deformation was after the dismemberment of Lundy Lake. West of Cleveland, very little deformation of the old water-lines has occurred. From the relation with the Forest beach, the extension of Lundy Lake towards the west can be approximately delimited. The lake reached to Point Pelée and the islands opposite. The eastern extension beyond Akron has not been surveyed. But enough is known to mark the boundary in the Erie basin; and here we find the counterpart of the Algonquin beach, of the basins of the upper lakes, whose water plain was at substantially the same levels as the Lundy, or about 150 feet below that of the Forest beach. The Lundy water gives us the history of the lake basin between the Warren episode and the nativity of Lake Erie.

After the Lundy rest, the waters were gradually drained to lower levels, until they were held in the Erie basin by a Devonian limestone escarpment, rising 20 or 30 feet above the present outlet of Erie. The remains of another rocky barrier, of 40 feet, now occurs over a mile north of the present site of Niagara Falls. The country between these ridges is low, so that there were pond-like expansions of the Niagara until a recent date, when the falls cut through this William

Johnson* ridge. Below this ridge, for six miles to the brow of the escarpment, the Niagara River drained the Erie waters; and boats might have sailed from lake to lake. The waters in the Ontario basin did not pause long at this high level, but gradually sank to the Iroquois plain 300 feet below the plain of Lundy beach. The Iroquois beach marks a long rest during which the early Niagara cascaded only 200 feet from the upper to the lower lake, and Erie formed only the lakelet as shown on the map.

Upon the dismemberment of Warren water, the Algonquin basin emptied its waters, at first through a strait by way of Lake Nipissing, and later by a river in the same region into the Ottawa valley. There was no connection between the Huron basin and the Erie until after the terrestrial deformation following the Iroquois episode. Then the Huron waters overflowed the southern rim of its basin and emptied into the youthful Lake Erie. The outlet of the Erie basin was also raised so that the plains at the head of its basin were flooded. This tilting has continued until the beach in the vicinity of the falls is now raised about 160 feet above its submerged extension near Point Pelée. Of this amount of tilting, only 46 feet have contributed to the ponding back of the waters so that the lake now extends to Toledo. The deformation of the Lundy beach in the Niagara district amounts to 2·5 feet per mile in direction N. 10°–15° E. More detailed measurements† may possibly show that the warping may reach nearly 3 feet per mile. The deformation of the Iroquois beach, which is newer than the Lundy strand, amounts to somewhat more than 2 feet per mile north of the mouth of the Niagara.

Had the falls receded past the Johnson ridge before the deformation of the region had reached the present amount, the Erie drainage would have been turned into the Mississippi at Chicago, just as the warping has changed the direction of the outlet of Lake Huron from the Ottawa to the St. Clair River. This brings us to the first possible computation of the rate of terrestrial deformation of the old shore of the lake region.

A rise of 7 feet in the level of Lake Michigan would send the waters of that lake over the rocky divide to the Mississippi. A rise of 16 feet in the Erie level would effect the same result; but the silt covering this rocky floor rises 3 or 5 feet higher and the Johnson ridge has been raised so that the deserted banks indicating the old surface of the Niagara river are now

* Named after Sir William Johnson who took possession of the falls about 1760.

† Some of these measurements were barometric from adjacent known levels, and consequently closer calculations were useless.

40 feet above the Erie level. Thus it becomes apparent that the elevation of about the last 20 feet has taken place since the recession of the falls past the Johnson ridge, for otherwise such a large river with a great breadth would have emptied the lakes and the recession of the falls must have ceased. That the water was recently higher about the head of Lake Michigan than now, the swampy flats bear witness, and the low lands continue far southward so that the rocky floor of the country—only 7 feet above the lake level (Ossian Guthrie) is 25 miles distant from the lake. Over this extensive plain, the low country has been a swamp, and drained sluggishly in both directions whilst silting over, to the extent of a few feet, the rocky floor of the country. But the entire drainage of Lake Michigan to the southwest could not have been established. The lowering of the water by a few feet in the Michigan basin as well as in the Erie has been produced by the recession of the falls past the Johnson ridge.

From the modern rate of the recession of the falls, which is about four feet a year, and the distance of 6,000 feet which the falls have receded, since passing the Johnson ridge, we find that the terrestrial warping in the vicinity of Niagara Falls could not have exceeded 24 feet in 1500 years, or 1·5 feet a century. But with the silting up of the Chicago (more correctly Lemont) overflow not more than 20 feet (or possibly 15 feet if the waters were deeper) of the last uplift of the Johnson ridge have been developed since the recession of the falls through that ridge. Thus the rate of terrestrial deformation or uplift in the Niagara district does not exceed 1·25 a century, with a possible reduction to one foot in the same time, if the secular rate were uniform. But there have doubtless been episodes of rest and others of uplift so that the actual rate of movement might have been more rapid, but the above estimate is the average during these times of elevation and intervening repose.

The agents of the deformation in the Erie basin have not been so continuous or so active as in other portions of the lake region; but if a mean rate for long epochs can be taken as here indicated, then nearly 13,000 years* have elapsed since the Lundy beach commenced to be deformed. The Iroquois beach is however more accurately measured. In the vicinity of the outlet of Lake Ontario, the deformation is double that in the Niagara district. At that outlet, the tilting has amounted to 370 feet by the post-Iroquois movement, and at 2·5 feet a century about 14,800 years have elapsed since the close of the episode of the formation of that deserted shore line. The conjectural mean deformation over long epochs

* 160 feet divided by 1 to 1·25 feet a century.

closely accords with our best estimates of the age of the falls, which will make another chapter in the lake history.

The inferred rate of terrestrial deformation in the Niagara district is 1·25 feet a century; 2·5 feet at the outlet of Lake Ontario; and 2 feet northeast of Lake Huron. These figures may be of use in reading the future of Lake Erie.

Applied to the Erie basin, the indicated deformation continuing, it appears that before Niagara Falls can have receded past the Devonian ridge near Buffalo,* the drainage of the upper lakes will have been turned into the Mississippi Valley, just as the Huron waters have been turned from the old Nipissing channel and Ottawa River to cascade over the falls; and thus may require 7,000 or 8,000 years. In this case the future life of the lakes will be very long; as their drainage will only be effected by the excavation of a deep valley backward from the Mississippi River into the lake basins.

ART. XX. — *On the Crystallization of Enargite;* by L. V. PIRSSON.

THE crystal form of enargite, the cuprous sulpharsenate Cu_3AsS_4, was first described by Dauber† from Peruvian specimens in the Krantz collection presented by Breithaupt the discoverer. Dauber gives only a basal projection of the forms noted by him. Also crystals from Brixlegg in Tyrol have been described by Zepharovich;‡ from the Serra Famatina in Argentina by vom Rath§ and from Luzon by Zettler as mentioned by vom Rath.‖ None of these authors give any figures of the crystals observed by them except that vom Rath gives a basal projection of trillings from the Serra Famatina.

It has been thought therefore that a description of some American occurrences accompanied by figures would be useful and not without interest.

Among a suite of eruptive rocks sent to Prof. Dana by Mr. R. C. Hills and collected in the Summit District, Colorado, is a series taken from the Ida Mine which presents in an extremely interesting way, as shown in an accompanying note by Mr. Hills, the method of deposition of enargite at this locality. It occurs in a porphyry containing large phenocrysts of orthoclase often nearly an inch in diameter. By hot solutions these

* These estimates will be more fully explained in a forthcoming paper upon the history of Niagara Falls.

† Pogg. Ann., xcii, p. 237, 1854.

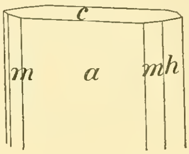
‡ Zeit. Kryst., iii, p. 600, 1879.

§ Zeit. Kryst., iv, 426, 1880.

‖ Jahrb. Min., i, p. 159, ref. 1880.

have been kaolinized and often entirely removed; the enargite, frequently accompanied by free gold, being deposited as a secondary process in the cavities thus formed. The groundmass of the porphyry retains to a considerable extent the form of the feldspar phenocryst and the masses of enargite are thus pseudomorphous in shape.

Fig. 1.



While generally in compact masses or with the crystals so crowded as to be indistinct, at times the cavities are lined by small glittering prisms of a bluish black color, in size up to three mm. in length. They are very tabular from a large extension of the macropinacoid *i-ī* (100) and appear as in fig. 1, being composed of the following simple forms *a*, *i-ī* (100); *c*, *O* (001); *m*, *I* (110) and *h*, *i-2̄* (120). The forms were identified by the following measurements.

	Calc.	Meas.	
$h \wedge m$ $(110 \wedge 1\bar{1}0)$ =	82° 7′	81° 22′	81° 37′
$m \wedge h$ $(120 \wedge \bar{1}20)$ =	59 43	59 55	60 16

In these, as in the following in this article, the calculated angles are derived from the fundamental angles assumed by Dauber in which $(110) \wedge (1\bar{1}0) = 82° \ 7\frac{1}{2}'$ and $(001) \wedge (011) = 39° \ 31'$ the axial ratios derived from these being

$$\breve{a} : \bar{b} : \dot{c} :: 0{\cdot}8712 :: 1 : 0{\cdot}8248$$

The prisms of these enargite crystals are strongly striated in a vertical direction, which accounts for the deviation in the calculated and measured angles. The base is not striated, but is rough and does not reflect light well.

Enargite from various American localities has been analyzed and described by several authors. These may be briefly mentioned as follows:

Brewer's Mine, Chesterfield, South Carolina, analyzed by Genth.* Willis Gulch near Black Hawk, Colorado. Described by Burton.† Morning Star Mine, Monitor District, Alpine Co., California. Analyzed by Root.‡ Tintic District, Utah, described by Silliman,§ where it occurs at several mines, material from the Shoebridge Mine having been analyzed by E. S. Dana.‖

No crystals are mentioned as being suitable for crystallographic work, the various authors describing the material from

* This Journal. II, vol. xxiii, p. 420, 1857.
† This Journal, II, vol. xlv, p. 34, 1868.
‡ This Journal, II, vol. xlvi, p. 201, 1868.
§ This Journal, III, vol. vi, p. 126, 1873.
‖ Op. cit.

these localities as either massive, or in rude columnar structure with cleavage surfaces or those of striated prisms, and this is confirmed by an excellent suite of specimens from the above occurrences in the Brush collection.

More recently enargite in considerable quantities has been discovered in various places in Colorado; and that from the mines at Red Mountain, especially, furnishes material suitable for crystallographic investigation. A very fine suite of specimens from the National Belle Mine was collected by Prof. S. L. Penfield during the summer of 1891, while engaged in work for the U. S. Geological Survey. For the purpose of carrying out the present investigation he has kindly placed these specimens at the disposal of the author, who takes this opportunity of expressing his thanks for the free use of the material.

The mineral, which is here mined for silver and copper, occurs in vertical shafts or "chimneys" in a decomposed volcanic rock. It generally occurs accompanied by pyrite and is in large cleavable masses, rarely in distinct crystals. When crystallized it is usually in thick striated prisms up to two or three mm. in length and of the habit shown in fig. 2, consisting

Fig. 2.

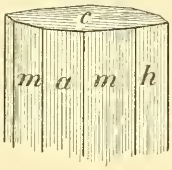


Fig. 3.

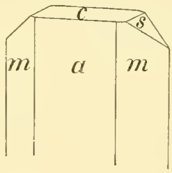
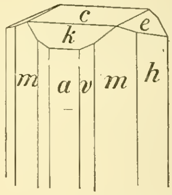


Fig. 4.



of the simple forms *c*, *O* (001); *a*, *i*-ī (100); *m*, *I* (110) and *h*, *i*-2̆ (120). In some specimens the faces are more even and the unit brachydome *s*. 1-ĭ (011) appears as shown in fig. 3. On one specimen crystals were present which showed the unit macrodome *k*, 1-ī (101) and in addition a prominent and well defined brachydome was seen. This was invariably so rough, from small pit-like markings and minute octahedra of pyrite that only an approximate measurement of it could be made. Measured on the base it gave an angle of 25° while 012 ∧ 001 requires 22° 25′. It is therefore regarded as being most probably the ½ brachydome. Besides the planes already mentioned these crystals showed the macroprism *v*, *i*-2̄ (210) and their habit is represented in fig. 4.

Another very common habit, from this locality, is a flat tabular one, both bases being present and the crystal is attached by one end of the macro-axis. This is shown in fig. 5. The most interesting crystals which have been observed among these specimens however are represented in fig. 6. They are

Fig. 5.

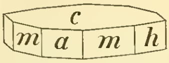
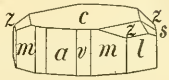


Fig. 6.



rather thick tabular in habit and attached by one end of the macro-axis like those just described. They consist of the planes *c*, *O* (001); *a*, *i*-ī (100); *m*, *I* (110); *l*, *i*-3̆ (130); *s*, 1-ĭ (011) and *z*, $\frac{3}{4}$-3̆ (134). The planes of 130 are dull and do not reflect light well, while the other prisms are extremely brilliant, giving a good reflection of the signal, as do also the dome 1-ĭ (011) and the brachy-pyramids $\frac{3}{4}$-3̆ (134). It was noticed on these crystals, of which several good examples were examined, that the dome and brachy-pyramid always appeared only at one end of the prism, the other being simply cut off by the base (00$\bar{1}$). Moreover the upper base (001) is apt to be dull and not to reflect light well, while the lower one (00$\bar{1}$) is very brilliant and striated by oscillation with the unit macrodome (101). These facts would seem to point toward the species being hemimorphic. Of the forms observed upon these crystals the following are new to the species *e*, $\frac{1}{2}$-ĭ (012); *v*, *i*-2̄ (210) and *z*, $\frac{3}{4}$-3̆ (134). The following table gives the calculated and measured angles by which the forms were identified.

Planes.		Calc.	Meas.
$m \wedge m$,	$110 \wedge 1\bar{1}0$	82° 07½′	82° 3′, 82° 17′, 82° 04′
$a \wedge h$,	$100 \wedge 120$	60 8½	60 3, 60 20, 59 45
$a \wedge v$,	$100 \wedge 210$	23 12	23 13, 23 18
$m \wedge v$,	$110 \wedge 210$	17 31	17 28, 17 42, 17 19
$m \wedge l$,	$110 \wedge 130$	28 0	28 24
$c \wedge k$,	$001 \wedge 101$	43 26¼	43 01
$c \wedge s$,	$001 \wedge 011$	39 31	39 39, 39 10
$s \wedge z$,	$011 \wedge 134$	13 45¼	13 45, 13 49
$z \wedge z$,	$134 \wedge \bar{1}34$	22 45¾	22 46
$c \wedge z$,	$001 \wedge 134$	33 31	33 33, 33 40

The form $\frac{3}{4}$-3̆ (134) was also identified by being in the zones *c* (001) $\wedge$ *l* (130) and *m* ($\bar{1}$10) $\wedge$ *s* (011) which have probably influenced its appearance.

The powder of these crystals tested in the open tube gives abundant reaction for arsenic and none for antimony, from which we may conclude that they are very pure enargite, not more than a trace at most of famatinite, the isomorphous antimony compound Cu_3SbS_4, being present.

Mineralogical-Petrographical Laboratory.
Sheffield Scientific School, New Haven, November, 1893.

ART. XXI.—*Relations of the Lower Menominee and Lower Marquette Series in Michigan (Preliminary)*; by HENRY LLOYD SMYTH.

NEARLY all writers on Michigan geology from Brooks to Wadsworth have maintained the general equivalence of the Marquette and Menominee iron-bearing series.*

This opinion has been founded on the similar unconformable relations of the two series to an undoubtedly older crystalline complex, and on a general lithological similarity between some of the individual members.

It is the object of this paper to review briefly the evidence by which this correlation has been supported, and to present some new facts that appear both to modify and to give it a more definite shape. It should be remembered that the rocks of the two series have never been traced into each other, and that until recently there has been an unbridged gap many miles wide between them.

General Relations.

So long as the iron-bearing rocks of Michigan were thought to constitute an uninterrupted succession, the argument from similar relations to similar older rocks had much force. It was further strengthened by Van Hise's discovery that the Marquette series was divided into two unconformable series, and by his later announcement, that the Menominee series was probably similarly divided by an unconformity. More recent and extended work in the northern extension of the Menominee area has so far confirmed these views that it is now certain that the Menominee rocks are made up of an upper and a lower series, separated by an unconformity.

The general relations in the two districts are given in the table below, which differs from that given by Van Hise in Bull. 86, U. S. G. S., in the substitution of Upper and Lower Menominee for Western Menominee, and Menominee Proper.

* In order not to re-state views that are already so well known, the reader is referred to the following list, which does not pretend to be exhaustive as regards either authors or titles:

Brooks, Geol. Wisconsin, vol. iii, p. 450 table.—Gredner, quoted in Bull. 86, U. S. Geol. Survey, p. 90.—Irving. 7th Ann. Rep. U. S. Geol. Survey, p. 435.—Van Hise, Bull. 86, U. S. Geol. Survey, pp. 197–8.—Wadsworth, Report State Board of Geol. Survey, Lansing, Mich., 1893, pp. 104, 117.

Marquette District.	Menominee District.
Upper Marquette.	Upper Menominee.
Unconformity.	Unconformity.
Lower Marquette.	Lower Menominee.
Unconformity.	Unconformity.
Archæan.	Archæan.

This undoubtedly constitutes a strong chain. The weak point as Van Hise has fully recognized is that neither of the sedimentary series of the one district has been traced into the corresponding series of the other. Consequently to correlate the two series of the one with the two series of the other, involves the assumption that the two time-breaks extend over both districts, and mean the same thing in each.

Lithological Characteristics.

Before considering the lithological similarities of the individual formations, it is first necessary briefly to recall the characteristics of, and the order of succession in, the lower series of the two districts.

Lower Menominee.

Avoiding minute subdivision the lower Menominee consists of

(1) A basal quartzite, rarely conglomeratic. The thickness may reach a maximum of about 1000 feet, and over large areas is at least 700 feet.

(2) A crystalline limestone which averages about 700–1000 feet in thickness. On the Fence River in T's 44 and 45 N. R. 31 W., where it largely if not entirely replaces the lower quartzite, the thickness attained, if there are no subordinate folds, is from 1500–2000 feet.

(3) Red, black and green slates, that are not known to exceed 200–300 feet in thickness. The slates here and there contain the iron formation that affords the rich ores of Iron Mountain and Norway. In the southern part of T. 44 N., R. 31 W., the horizon of the slates is in part occupied by altered eruptives, that rapidly increase in thickness towards the north, the whole attaining a maximum of nearly 2000 feet on the Fence River in T. 45 N., R. 31 W.

(4) The highest member, except volcanics, yet recognized in the Felch Mountain and Fence River divisions of the Lower Menominee is typically developed at Michigamme Mountain, S. 4, T. 43 N., R. 31 W. and S. 33, T. 44 N., R. 31 W., and has been called the Michigamme jasper. This is a greatly altered ferruginous rock usually carrying apparently fragmental quartz grains. Various stages in the alteration permit two or three

types to be recognized. The least modified seems to indicate that the rock was originally in part at least a clastic sediment. The alteration appears to have been effected by the infiltration of iron salts, the formation of cherty silica, and the replacement of the original constituents to varying degrees. The most highly altered type bears the closest possible resemblance in the hand specimen to the banded specular jasper seen on the Republic bluff.

Iron ores occur at three horizons in the lower Menominee. The lowest and least important is found in the upper portion of the quartzite near its junction with the limestone. While lean (usually martite) ores are of wide distribution, only one workable deposit of rich ore has as yet been discovered in this position in the series. The slate member contains the great majority of the rich ore deposits. These occur as local concentrations in a ferruginous rock, composed of banded jasper and iron ore, which perhaps is the modified representative of portions of the slates carrying a large proportion of non-clastic material of original deposition. The banded jasper is not continuous, and it occurs at different horizons in the slates. The third horizon is the Michigamme jasper, which up to the present time has yielded only a few small bodies of rich ore.

Lower Marquette.

The lower Marquette series in the western part of the Marquette area, where it most nearly approaches the Menominee region consists, when exposed, of

(1) A basal conglomerate—quartzite—quartz schist, probably less than 100 feet thick. North of the Michigamme Mine the quartzite passes upward into a slate.

(2) An iron-bearing formation which may be divided further into a lower member, composed of actinolite (or gruenerite),* magnetite, and silica, one or two of which may locally predominate over the rest, and an upper member, usually but not invariably, characterized by bands of red jasper and specular hematite. The iron-bearing member has a maximum thickness of more than 1000 feet, but usually it has been cut down greatly or, with the lower quartzite, entirely, by the Animikie† transgression.

The Marquette iron ores, except those in the Upper Marquette series, occur, as Van Hise has shown,‡ either (*a*) at the

* A. C. Lane and F. F. Sharpless, this Journal. Dec., 1891, p. 505. Report of the State Board of Geol. Survey, Michigan, Lansing, 1893, p. 183.

† Animikie is here used as a general term, covering the time of deposition of the Upper Huronian. Upper Marquette, Upper Menominee, Penokee-Gogebic, and the Animikie of Northern Minnesota and Canada. all of which are regarded as generally equivalent.

‡ This Journal, Feb., 1892.

contact of the lower iron bearing member with the upper quartzite, when the ore may be either a concentration in the lower iron-bearing member, or a detrital member of the upper series, or (*b*) more rarely, entirely within the iron-bearing member of the lower series.

These descriptions are expressed briefly in the following table, in which the members of the two series are shown in parallel columns for lithological comparison.

Menominee.	Marquette.	
Michigamme Jasper.	Jasper banded with ore.	Iron formation.
Slates (Principal iron formation.)	Magnetite-Actinolite Schist.	
Limestone.	Quartzite.	
Quartzite.		
------------------	--------------	
Archæan.	Archæan.	

It will be seen that the lithological resemblances are these:

(1) Each series has a similar quartzite at its base. (2) Each contains iron-bearing formations. Neither is a safe basis for correlation in the absence of direct stratigraphical evidence, for not only has nearly every positive movement throughout geological time been marked by a basal sandstone or quartzite, but the undoubted general resemblance between the iron-bearing formations of the two districts is not closer than that between either and like formations of Animikie age.

On the other hand the lithological differences, and especially the absence from the Marquette column of the Menominee limestones and slates, are very striking. It is on this point that recent work furnishes some positive, though not conclusive evidence.

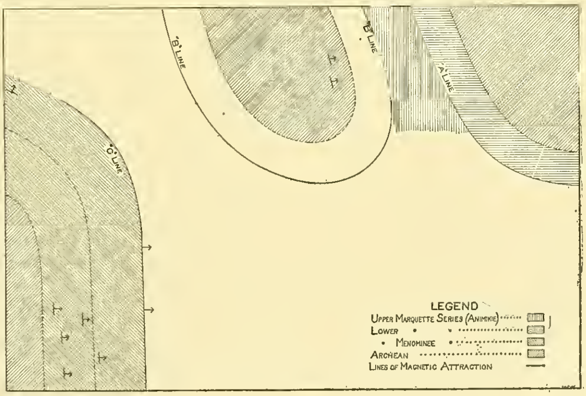
Structure and Distribution.

The Menominee rocks, as will appear in detail in a forthcoming report, have been traced from Michigamme Mountain with a north and south strike, north through T's 44 and 45 N., R. 31 W. In these townships they lie, with an easterly dip, on the eastern side of a structural axis, along which granite-gneisses outcrop in the western part of T's 44 and 45 N., R. 31 W., and in the eastern part of T's 44 and 45 N., R. 32 W. It has been possible to follow the Michigamme jasper carefully and closely by means of its magnetic properties. In the middle of T. 45 N., R. 31 W., where the rock is next found in exposures and explorations, it is seen to have somewhat changed in character. The lower portion has become decidedly quartzitic, containing, however, gashes and films of specular hematite. The upper portion is finely banded, and contains actinolite, magnetite and dark chert. This is the portion of the formation that most disturbs the needle. While thin sections of this rock have not yet been examined, the constituent minerals are evidently not so distinctly segregated as is usual in the Marquette actinolite schists. Otherwise the rocks bear considerable resemblance to each other.

The lower iron-bearing rocks of the western Marquette district have been traced southward from the northwestern end of the Republic tongue, for a long distance. Coinciding with the lower portion of the iron-bearing member, or the magnetite actinolite schist, is a very strong and continuous line of magnetic attraction which was first followed for part of the distance by Major Brooks over 20 years ago. This line of attraction is proved to coincide with the magnetite actinolite schist member by occasional outcrops and by explorations at considerable intervals. East of it is a granite area, and between the two, the lower quartzite outcrops near the northern end of the Republic tongue. Farther south the quartzite is presumably present, but no outcrops have been found in the heavily drift-covered country. This line of attraction may be called the A line. Less than half a mile west of the A line a second line of magnetic attraction runs parallel to it for a considerable distance, which may be called the B line. This B line has been traced completely round an oval area in which granite and gneisses have been discovered in three sections. These gneisses lie east of the axis of the enclosed oval, and strike parallel to the B line and dip towards the east. Throughout the 20 miles or more through which the B line has been followed no outcrops of any kind have been found upon it. That it does, however, represent a belt of magnetic rock entirely enclosing an Archæan area admits of no possible doubt. Explorations along the A line have established the fact that the geological succession in going from east to west across it is from older to younger formations. That is, the dip is towards the west. The gneisses in the oval enclosed by the B line dip toward the east on the east side of the axis of the oval. This, coupled with the fact that both the A and B lines, in the one case partially, in the other completely, encircle domes of Archæan rocks, makes it certain that the rocks which they represent dip towards each other. In other words, in that part of their course in which they run parallel they occur on opposite limbs of a synclinal fold. Moreover the space between them is known by exposures and exploration to contain upper Marquette quartzite and mica-schists.

This occurrence of the A line on one side, and of the B line on the other, of a long and very narrow synclinal fold, together with the entirely similar general relations of each to enclosed Archæan areas, hardly leaves room for doubt that they represent the upturned edges of one and the same formation. Furthermore, no other rock is known in the region that is at once so strongly and so uniformly magnetic. The conclusion therefore is, that the B line like the A represents the lower Marquette actinolite schist.

It has already been shown that the Michigamme jasper, a magnetic rock, can be traced north from Michigamme Mountain, by its magnetic properties, and that when next exposed it has been partly differentiated into a lower quartzite member and an upper member, which alone disturbs the needle, containing magnetite and actinolite. Also, that it overlies conformably an easterly dipping succession, made up below it of nearly 2000 feet of highly altered eruptives and nearly 2000 feet of limestone, the whole resting upon Archæan gneisses, to the west. The magnetic line that marks the upper portion of the Michigamme jasper may be called the C line. For 2½ miles in the northern part of its course the C line runs nearly parallel with, and from 1½ to 2 miles west of the B line, where the latter circles round the southwest quarter of its enclosed Archæan oval. This distance of less than two miles, is the interval that now separates the lower Menominee series from the lower Marquette series. A sketch showing the relations in this interesting region is given below.



The area between the B and C lines is covered and shows no magnetic disturbances. The rock of the C line dips towards the east, that of the B line, in the portion nearest the C line must dip towards the west. They lie then on opposite sides of a trough, and probably are one and the same formation.

If they are not, then the C line has no magnetic representative on the eastern, nor the B line on the western limb of the fold. The probability is moreover strengthened by the lithological affinities of the upper portion of the Michigamme jasper,—the C line rock,—in some phases, to the lower Marquette magnetite actinolite schist, in others, to the specular jasper.

If then these two rocks are regarded as equivalents, the lower Marquette quartzite may, with nearly equal probability, be taken to represent the lower quartzite portion of the C line formation. The whole of the lower Marquette series would thus be represented by the highest member of the lower Menominee. What then becomes in the Marquette district of the great thickness of limestone, quartzite and eruptives which lie below the Michigamme jasper in the Menominee, and how is its absence to be accounted for?

The most probable explanation is that the pre-Algonkian basement sank continuously in both districts, but that the Marquette was initially the more elevated, and as a whole was dry land while the lower quartzite, limestone and slates were going down in the Menominee. The transgressive movement from the south reached it when the lower portion of the Michigamme jasper was being deposited. On this view the lower Marquette quartzite would generally represent the lower quartzite horizon of the Michigamme jasper. But in going from the more distant areas of lower Marquette rocks toward the lower Menominee the base would gradually become the equivalent of older horizons in the latter until it passed finally into the lower Menominee quartzite. The absence of the lower Menominee formations from the Marquette district would thus be explained by overlap of the Michigamme jasper.

The Mt. Mesnard series of quartzite, limestone and slates, as described by Wadsworth,* in the eastern part of the Marquette area, between the Cascade range and Lake Superior has many points of resemblance to that part of the lower Menominee series below the Michigamme jasper. Its age is still in doubt, but if it should prove to underlie the lower Marquette (Wadsworth's Republic Formation), its position would probably indicate the limit of the old Marquette highland on the eastern side.

Conclusion.

The views here presented are based in part on fact, and in part on inference, and it is desirable in conclusion clearly

* Report of the State Board of Geol. Survey, Michigan, Lansing, 1893. Wadsworth is inclined to regard it as of upper Marquette age.

to distinguish the one from the other. The three magnetic lines, A, B and C, and the connection of two of them, the A and the C, with characteristic and similar rocks, are facts not to be doubted. Nor is it any less clear that the rocks of the A and B lines, and of the B and C lines dip toward each other in the respective spaces between them. There is no positive evidence as to the nature of the B line rock, for no one has ever seen it. Therefore the conclusion that the three lines represent the same rock is an inference which underground exploration may prove to be erroneous. All that can now be said is that of the five possible hypotheses of equivalence or non-equivalence between the A, B and C rocks, that of equivalence is by far the most probable.

Assuming equivalence the evidence points then to these conclusions:

(1) The lower Menominee quartzite limestone and slates are all older than any formation in the Marquette area.

(2) The Michigamme jasper was deposited in a continuous sheet over both districts, and in the Marquette constitutes both the iron-bearing formation and, for most of the area, the lower quartzite.

(3) The principal ore horizon of the Menominee has no equivalent in the Marquette district.

Cambridge, Mass., Nov. 21, 1893.

Art. XXII. — *Six and Seven Day Weather Periods;* by H. Helm Clayton.

There is a seven day period in the weather, so noticeable at times in the United States, that it has embodied itself in such popular sayings as, "If it rains on the first Sunday of a month it will rain every Sunday," etc.

In regard to this period, as early as 1858, Prof. Joseph Henry, Director of the Smithsonian Institute, wrote: . . . . "Most persons can remember the occurrence in succession of a series of storms on Sundays. In one case we recollect this to have taken place six times in succession. There is nothing in this particular day to induce the occurrence of a storm, but merely it will be more likely to be remembered when it happens at this time; and although the interval may not be precisely seven days, yet it may differ so little from this that a part of the first and sixth Sundays may be included in the cycles of disturbance." See Patent Office Report, 1858, page 490.

In a work on The Atmospheric System Developed (1870) by Thomas B. Butler is found the following: "It is doubtless within the recollection and experience of every one who has lived long, that at a remembered period some particular day in the week, for several weeks, was stormy ; sometimes with, and at other times without an intervening storm, or showery condition, on some day in the week."

In Vennor's Weather Almanac for 1883, p. 13, it is stated : "We find closely corresponding weather periods have frequently occurred in seven, fourteen, and twenty-one year divisions of time, and most of us are familiar with the every seventh storm day of our winter and summer months. Only as recently as last autumn (1881) the general remark was that every Saturday stormed ; and it will be of further interest to the public to learn that these stormy Saturdays lasted through a period of just about seven weeks."

The fact that this period was independently discovered by the present writer, without any knowledge of its previous observation, may perhaps be taken as additional proof of its existence.

The widespread and tenacious belief in a connection between the changes of the moon and the changes in the weather probably arose from the popular observation of the seven day weather cycle which agrees so approximately in length with the mean interval between the phases of the moon.

In the American Meteorological Journal for August, 1885, p. 162, the writer gave a marked example of this seven day period in which the temperature and weather at several widely separated stations in the United States oscillated with almost perfect regularity for six or seven weeks in succession. Moreover, the oscillations were not simultaneous at all the stations, but due to barometric minima which moved from west to east at the normal rate of American storms. It was stated by the writer that he had followed this seven day period for several years, and found that at intervals it rose to considerable prominence, then decreased in intensity and apparently died out. He also stated that "there seems to be an oscillation of about three days which acts in a similar manner." Later this was called a six day period on account of its similarity to the seven day period, as will be seen from what follows.

In 1887 the trustees of the Elizabeth Thompson fund granted the writer a part of the fund for further research on this subject; but he was unable to undertake it at that time. In January, 1893, however, his attention was again called to this subject by noticing a marked regularity in the oscillations of the temperature at Blue Hill Observatory ; and in the American Meteorological Journal for May, 1893, he showed that all the temperature maxima at the Observatory during 1891 and 1892 could be arranged so as to follow each other at approximate intervals of six or seven days, or half these intervals, and the regularity of the sequences was much greater than could be attributed to chance. It was further shown that intervals of six, or three days, would prevail for awhile and then the sequence would break, and intervals of seven, or three and a half, days would follow. Furthermore, it was found that the changes from intervals of one length to that of another were separated by intervals of twenty-seven days, or some multiple of this number, a period which agrees very closely with the length of a solar rotation.

For a further study of these periodicities, Mr. Fergusson, the assistant observer at Blue Hill Observatory, furnished the writer with the dates and hours of all the barometric minima recorded by the barograph at the Observatory since its establishment in 1885.

In this data were found many instances of six and seven day periodicities lasting several weeks, and sufficiently striking to be easily recognized. A few of these are here given as illustrations:

The Dates and Hours of occurrence of barometric minima at Blue Hill Observatory—lon. 71° W., lat. 42° N.

Showing 7 day intervals.

1886.	Interval. d. hr.
April 6, 6 P. M.	7 −1
" 13, 5 P. M.	7 +33
" 22, 2 A. M.	7 −12
" 28, 2 P. M.	7 +2
May 5, 4 P. M.	7 +22
" 13, 2 P. M.	7 +3
" 20, 5 P. M.	7 +6
" 27, 11 P. M.	7 −10
June 3, 1 P. M.	7 −3
" 10, 4 P. M.	7 +7
" 17, 11 P. M.	7 +40
" 26, 3 P. M.	7 −12
July 3, 3 A. M.	
Means,	7 +6·3
Mean Departure,	±13

1888.	Interval. d. hr.
Oct. 2, 4 A. M.	7 −15
" 8, 1 P. M.	7 +50
" 17, 3 P. M.	7 −4
" 24, 11 A. M.	7 −4
" 31, 7 A. M.	7 −6
Nov. 7, 1 A. M.	7 +43
" 15, 8 P. M.	7 −15
" 22, 5 A. M.	7 +10
" 29, 3 P. M.	7 −10
Dec. 6, 5 A. M.	7 +20
" 14, 1 A. M.	7 +15
" 21, 4 P. M.	
Means,	7 +7·5
Mean Departure,	±18

1891.	Interval. d. hr.
April 12, 4 A. M.	7 +11
" 19, 3 P. M.	7 +46
" 28, 1 P. M.	7 −21
May 4, 4 P. M.	7 +1
" 11, 5 P. M.	7 −1
" 18, 4 P. M.	7 +24
" 26, 4 P. M.	7 +0
June 2, 4 P. M.	7 +1
" 9, 5 P. M.	7 +0
" 16, 5 P. M.	7 −12
" 23, 5 A. M.	7 +17
July ---- ----	7 +17
" 8, 3 P. M.	7 +0
" 15, 3 P. M.	
Means,	7 +6·4
Mean Departure,	±11

Showing 6 day intervals.

1886.	Interval. d. hr.
Oct. 6, 5 P. M.	6 +6
" 12, 11 P. M.	6 −4
" 18, 3 A. M.	6 +1
" 24, 4 A. M.	6 +34
" 31, 2 P. M.	6 +16
Nov. 7, 6 A. M.	6 +10
" 13, 4 P. M.	6 +22
" 18, 2 P. M.	6 −31
" 25, 2 P. M.	6 −20
Dec. 1, 1 A. M.	6 +15
" 7, 4 P. M.	6 +11
" 14, 3 A. M.	
Means,	6 +5·3
Mean Departure,	±14

1887.	Interval. d. hr.
Jan. 6, 7 A. M.	6 +16
" 12, 1 P. M.	6 −16
" 17, 9 P. M.	6 +18
" 24, 3 P. M.	6 +6
" 30, 9 P. M.	6 +21
Feb. 6, 6 P. M.	6 −22
" 11, 8 P. M.	6 +25
" 18, 9 P. M.	6 −7
" 24, 2 P. M.	6 +5
March 2, 7 P. M.	
Means,	6 +3·8
Mean Departure,	±13

1891.	Interval. d. hr.
Jan. 14, 1 P. M.	6 +3
" 20, 4 P. M.	6 −32
" 25, 8 A. M.	6 +21
Feb. 1, 5 A. M.	6 +20
" 8, 1 A. M.	6 −11
" 13, 2 P. M.	6 +36
" 21, 2 A. M.	6 −3
" 26, 11 P. M.	6 −17
March 4, 6 A. M.	6 −5
" 10, 1 A. M.	6 +14
" 16, 3 P. M.	6 −12
" 22, 3 A. M.	6 +25
" 29, 4 A. M.	
Means,	6 +3·3
Mean Departure,	±16

In the preceding are given the longest series of six and seven day periods found; but in all the numerous cases the mean lengths of the periods rarely differed more than one hour from 6 days 4 hours, and 7 days 6 hours, respectively.

The next step in the investigation was to ascertain whether the end of one series was separated from the beginning of the next by even multiples of these mean intervals. This was found to be true if the series in each case were divided into two groups separated from each other about half a period, three days in one case and three and a half in the other. This discovery enabled a more exact determination of the periods to be made, and the mean lengths were found to be 7d. 6·4 hr., and 6d. 4·0 hr.

The next step was to divide the time from Jan. 1, 1885, to Aug. 31, 1893, into intervals of these lengths and ascertain whether the periods would show themselves in the average of all observations. The first investigation in this line was to count the number of times on each day of both periods that barometric minima were observed at Blue Hill Observatory. The results are shown for each interval of three years in the following tables:

Number of Barometric Minima at Blue Hill Observatory—lon. 71° W. and lat. 42° N.

On each day of the Seven day period.

	1	2	3	4	5	6	7
1885–'87,	43	38	47	**48**	40	43	**44**
1888–'90,	44	37	30	**44**	44	25	**50**
1891–'93,	34	19	31	**46**	35	35	**39**
Sum,	121	94	108	**138**	119	103	**133**

On each day of the Six day period.

	1	2	3	4	5	6
1885–'87,	34	**55**	49	40	**53**	53
1888–'90,	43	**52**	45	40	**52**	43
1891–'93,	35	**40**	37	34	**53**	41
Sum,	112	**147**	131	114	**158**	137

In both of these tables are included all the barometric minima recorded at the Observatory. Both tables show two maxima of frequency in each period which persistently remain on the same days of the periods, thus proving that the periods have definite and constant lengths; and that these lengths have been approximately determined. A close examination of the figures, however, leads to the conclusion that the mean lengths as given are not absolutely correct. Thus in the first group of the seven day period, 1885 to 1887, the maxima probably occur between the third and fourth, and the fifth and sixth days; while in the last group, 1891 to 1893, the maxima occur sharply on the fourth and seventh days, thus indicating a forward movement of the maxima of about half a day in six years. In the six day period the figures indicate that the maxima have probably moved backward about half a day in six years. These results show that the mean length of the seven day period as given above should have been increased 0·04 hr. and the mean length of the six day period decreased about 0·03 hr.

The mean height of the barometer at Blue Hill for 8 A. M. and 8 P. M. on each day of the periods was obtained, and the results corrected for the diurnal period by subtracting 0·02 inch from the 8 A. M. means were as follows for the three years 1887, 1891, and 1893. These years were selected merely because they were most convenient for the purpose.

Mean height of the barometer at Blue Hill for each day of the Seven day period.

	1.		2.		3.		4.	
	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1887,	29 34	29·36	29·36	29·33	29·31	29·31	29·31	**29·30**
1891,	**29·32**	29·32	29·33	29·36	29·37	29·33	29·31	**29·30**
1893,	29·31	29·31	29·34	29·33	29·29	29·27	29·26	**29·25**

	5.		6.		7.	
	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1887,	29·34	29·35	29·31	29·28	**29·28**	29·30
1891,	29·33	29·36	29·36	29·36	29·35	29 35
1893,	29·30	29·30	**29·25**	29·26	29·29	29·31

Mean height of the barometer at Blue Hill for each day of the Six day period.

	1.		2.		3.	
	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1887,	29·34	29·32	29·29	**29·25**	29·28	29·31
1891,	29·34	29·33	29·33	**29·31**	29·34	29·35
1893,	29·29	29·30	29 30	**29·27**	29·29	29·31

	4.		5.		6.	
	8 A. M.	8 P. M.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1887,	29·32	29·35	**29·32**	29·35	29·33	29·33
1891,	29·37	29·37	29·32	**29·30**	29·34	29·36
1893,	29·35	29·32	29·27	**29·26**	29·27	29·26

These results show very clearly the occurrence of two barometric minima in each period. The minima occur on the fourth and seventh day of the seven day period, and on the second and fifth day of the sixth day period, corresponding with the times of greatest frequency of minima previously given.

The next step in the investigation was to study the periods from the synoptic weather charts of the United States. There were two methods used, one the statistical, and the other the study of consecutive individual storms.

The average movement of storms in the United States is about 15° of longitude a day toward the east; and if the space between 40° and 50° N. lat. be divided into intervals of this length there are formed approximate squares the sides of which are from 700 to 800 miles in length. The space between 65° and 105° W. lon. was divided up into three of these squares; and Mr. Arthur Sweetland, an assistant, counted the number of storms central in each square on each day of the six and seven day periods during the seven years 1886 to 1892, inclusive. The results are shown in the accompanying table.

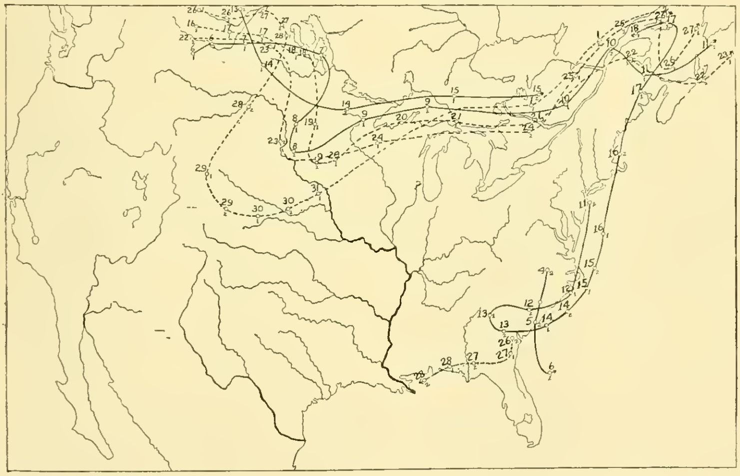
The numbers of storms central between latitudes 40° and 50° N. in sections of 15° of longitude during the seven years 1886–92.

Seven Day Period.				Six Day Period.			
	Long.	Long.	Long.		Long.	Long.	Long.
Day.	90°–105°	75°–90°	60°–75°	Day.	90°–105°	75°–90°	60°–75°
1	**66**	86	76	6	**68**	102	92
2	52	**98**	77	1	58	**121**	93
3	49	97	**92**	2	**69**	97	**102**
4	**58**	73	86	3	59	**103**	93
5	55	**96**	80	4	**74**	101	**105**
6	56	86	**92**	5	62	101	97
7	53	87	77				

It is seen from this table that there were two distinct maxima of frequency in each square, and the maxima occurred successively one day later for each 15° of longitude eastward. This corresponds exactly with the average eastward movements of storms in the United States, and indicates that the periodicities in question arise from a regularity in the origin and eastward drift of ordinary cyclones. When the time is separated into two intervals, namely, from 1886–1888, and 1889–1893, the same double maxima are found, and also the later occurrence of the maxima in the eastern squares. However, in the seven day period the corresponding maxima in each case occur on the average 0·46 day earlier in the interval 1886–1888 than in the interval 1889–93, showing that the length of the period used was about 0·03 hr. shorter than the true length which would be 7d. 6·43 hr. The two intervals in the case of the six day period showed that the most probable length of the period was 6d. 3·94 hrs. When the space between latitudes 30° and 40° is divided into squares corresponding with those between latitudes 40° and 50°, the chief maxima are found on the same days as in the corresponding longitude farther north, showing that the displacement of the maxima is one of longitude and not of latitnde.

To study the question of periodicity in the case of succeeding individual storms, the charts of the U. S. Weather Review showing the position of the storms at 8 A. M. and 8 P. M. and the directions of their tracks were carefully examined. It was found that during intervals of about 27 days, corresponding with a solar rotation, the storm tracks were found in groups, in each of which the cyclones all followed the same general direction, and were separated from each other by intervals of six or seven days, or in some cases by half these intervals.

During each interval of 27 days one of the periods alone was paramount, either the seven day or the six day, as the case might be, and this period ran through all the groups. In many of the groups the storms followed each other along such approximately parallel tracks that even the irregular bends in the tracks were the same in all. One of the 27 day intervals began during the first week in May, 1891, and the chart of storm tracks drawn by the United States Weather Bureau for that month is here reproduced as furnishing a good illustration of the phenomena under discussion. On this chart small circles show the position of the storm centers at 8 A. M. and 8 P. M., and the figures above these circles give the days of the month.



It is seen from this chart that the storms distinctly divided themselves into two groups, one beginning in British America and pursuing the usual course across the great lakes, and the other beginning near the Atlantic seaboard and taking a very unusual course toward the south. It is seen that the succeeding storms in each group followed each other so closely that the irregular bends in their tracks are approximately the same in all. But what is of especial interest here is the approximately regular interval of seven days between the succeeding storms. For example in the northern group of storm tracks, as points which can be easily determined, take first the most southern point reached by the storms in their sudden deflection southward in the Missouri River valley, next the time of their sudden bend northward in the eastern lake region, and thirdly the most northern point reached before turning southward near the mouth of the St. Lawrence River. The observed times the storms were at these points and the times calculated from the assumption of exactly equal intervals of 7d. 6·5 hrs. were as follows:

	Observed.	Calculated.
I.	May 8, 8 P. M.	May 8, 6 P. M.
	" 14, 8 P. M.	" 15, 12 P. M.
	" 19, 8 P. M.	
	" 23, 8 P. M.	" 23, 7 A. M.
	" 30, 8 A. M.	" 30, 1 P. M.
II.	May 10, 8 A. M.	" 10, 8 A. M.
	" 15, 8 P. M.	" 17, 2 P. M.
	" 21, 8 P. M.	
	" 24, 8 P. M.	" 24, 9 P. M.
	June 1, 8 A. M.	June 1, 3 A. M.
III.	May 10, 8 P. M.	May 10, 8 P. M.
	" 17, 8 P. M.	" 17, 12 P. M.
	" 22, 8 A. M.	" 25, 7 A. M.
	" 26, 8 A. M.	
	June 2, 8 A. M.	June 1, 1 P. M.

In the southern group of storms, the times of beginning, and of the most southern positions reached may be taken as points for comparing the times of occurrence of the storms with the times computed on the assumption of exact regularity in the intervals between them. The results are as follows:

Observed.	Calculated.	Observed.	Calculated.
May 4, 8 P. M.	May 4, 2 P. M.	May 6, 8 A. M.	May 6, 8 A. M.
" 11, 8 P. M.	" 11, 8 P. M.	" 13, 8 P. M.	" 13, 2 P. M.
" -- ---	" 19, 3 A. M.	" -- ---	" 20, 9 P. M.
" 26, 8 P. M.	" 26, 10 A. M.	" 28, 8 P. M.	" 28, 3 A. M.

The storm tracks arrange themselves into new groups at the end of intervals averaging slightly less than 27 days, and presumably corresponding with a solar rotation. The preceding chart gives only one of many striking instances which might be given showing the arrangement of the storms in groups, and the approximate regularity of the intervals between the storms.

Surely no one can believe all the data here presented accidental, and no unfavorable data have been suppressed. There is, however, one source of difficulty in investigating and understanding these periods, and that lies in the fact that, besides these frequent divisions of the six and seven day periods into periods of half these lengths, they are clearly associated with others of greater lengths. The shortest of these, however, appear to be multiples of six, or seven days. In the Meteorologische Zeitschrift for February, 1886, p. 49, Magelssen has pointed out a periodicity in the temperature of about 12 days, combined with another of about 50 days. Balfour Stewart claimed the existence of a period of about 24 days (Nature, 1879–81). If these periods are arranged in sequence with the three and six day periods, there is found a geometrical progression as follows, 3, 6, 12, 24, 50.

The present writer has several times found examples in the United States of Periods in the pressure, temperature or rainfall of about 14, 21, and 30 days (American Meteorological Journal, June, 1885, p. 87; and Feb., 1886, p. 429.) Again there appears a geometrical progression as follows, $3\frac{1}{2}$, 7, 14, 21, 29 or 30.

In this way there appears to be an analogy to the phenomena of sound. The six and seven day periods may be considered the primary notes and the periods of 2, 3, 4, 5, 6, etc., times these lengths whose amplitude of oscillation decreases in proportion to their length may be considered as harmonics. The variations in the weather are made up by the variations in intensity of these components.

The causes of these periodicities are not clear; but the fact that they have definite and rigid lengths renders it almost certain that they are connected with some physical or astronomical period, or periods. The breaks in the six and seven day periods, and the redistribution of storm tracks correspond so closely with the accepted length of a solar axial rotation as to make it extremely probable that there is a connection between the two. In this case the sun may perhaps be considered in the light of a tuning fork which sets up the periodic oscillations. The same is probably true of the 11 year sunspot period.

The periodic phase of meteorological phenomena is undoubtedly complex, and much is yet to be cleared up and solved; but even the present knowledge can be used with considerable success in forecasting, as demonstrated by a practical test. See the American Meteorological Journal, February, 1886, p. 429.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On Cryohydric Temperatures.*—The experiments of Guthrie on the cryohydric points of systems of mixed salts, have been repeated and the results discussed by Schreinemakers. He finds that when the two salts do not form a double salt, the cryohydric point of the mixture is lower than the cryohydric point of a solution in equilibrium with either of the salts separately. Moreover when a double salt is formed and this salt decomposes on solution, such for example as PbI_2, KI, $(H_2O)_2$, the cryohydric temperature of a solution in equilibrium with the double salt and one of its components is lower than the cryohydric temperature of a solution in equilibrium with this component alone; and the cryohydric point of a solution in equilibrium with the double salt and the component which is not deposited is lower than that of a solution in equilibrium with the double salt and the component which is deposited. Again if the double salt formed dissolves homogeneously without decomposition, as is the case for example with $CuSO_4(NH_4)_2SO_4.(H_2O)_6$, the cryohydric temperature of a solution in equilibrium with the double salt and one of its components is lower than the cryohydric temperature of a solution of the double salt alone.—*Zeitschr. Physikal. Chem.*, xii, 73, July, 1893. G. F. B.

2. *On the use of Phenanthrene as a Solvent in Cryoscopic determinations.*—In determining cryoscopically the molecular mass of indole in a naphthalene solution Garelli and Ferratini obtained anomalous results which they attributed to the formation of solid solutions of indole in the crystallizing hydrocarbon; this formation being influenced apparently by the similarity in constitution between the two. To test this hypothesis, they examined a liquid solution of carbazole in phenanthrene, and found that the crystals which separate on cooling this solution, contain a large quantity of the dissolved substance, amounting, when the solution contained 7·5 per cent of carbazole, to 11·42 per cent. Other things being equal, however, the authors regard phenanthrene a better solvent than naphthalene for use in determining molecular masses by the cryoscopic method; since its high depression constant, 120, makes it possible to obtain accurate results with very dilute solutions and its lower volatility renders it easier of manipulation.—*Gazetta Chim. Ital.*, xxiii, (1) 442; *J. Chem. Soc.*, lxiv, ii, 512, Nov. 1893. G. F. B.

3. *On the Vapor-pressures of solutions of Sulphur and Phosphorus in Carbon disulphide.*—By enclosing solutions of sulphur and of phosphorus in carbon disulphide, in a space exhausted by a Sprengel pump, and measuring the vapor-pressure by means of a manometer, Guglielmo has determined the molecular masses of these elements. At ordinary temperatures, a glass apparatus was

used, consisting of two bulbs, one to contain pure carbon disulphide, the other to hold the solution; these vessels being provided with mercury traps by which they could be isolated from each other and from the pumps. The vapor pressure of the pure carbon disulphide was first determined, then that of the solution; the ratios of the differences of the two pressures to the vapor-pressure of carbon disulphide at the corresponding temperatures being proportional therefore to the number of dissolved molecules per unit of solution. The experiments with sulphur were conducted between 0° and 13·8° and show that for solutions up to 20 per cent, the molecular depression corresponds to a sulphur molecule containing 8 atoms for the more dilute, and containing 9 atoms for the less dilute, solutions. For phosphorus the vapor-pressures were measured at 0°, several solutions being employed. The molecular depressions observed corresponded approximately to a tetratomic molecule, in the case of a 3 per cent solution; increasing somewhat as the solution was made stronger.—*Real. Accad. Lincei*, ii, 210, 1892; *J. Chem. Soc.*, lxiv, ii, 511, Nov. 1893. G. F. B.

4. *On the Influence of Heat on Chemical Reactions.*—An elaborate investigation has just been made by LEMOINE upon the influence of heat, unaffected by that of light, on the reactions which take place in aqueous solutions containing ferric chloride and oxalic acid. When these substances are present in equivalent proportions, the interaction is irreversible and proceeds according to the equation

$$(FeCl_3)_2 + H_2C_2O_4 = (FeCl)_2 + (HCl)_2 + (CO_2)_2$$

The rate at which decomposition takes place at any temperature is found to follow the well known law of mass action, which states that the amount of substance which is being decomposed at any instant is proportioned to the amount of unchanged substance contained in unit volume of the solution. The concentration remaining the same, the rate of change is found to vary markedly with variation in temperature. For example, while 0·16 of the original amount of substance was decomposed at 100°, in one hour, it was found that at ordinary temperatures only 0·019 equivalent had reacted after six years. Water accelerates the speed of change according to a law which varies slightly with the temperature. A slight excess of oxalic acid also accelerates it, but a large excess either of oxalic acid or of ferric chloride retards it; while an excess of concentrated hydrochloric almost completely arrests it. The author has studied both chemically and thermochemically the effects which these and other foreign substances have upon the course of the simple reaction and finds that they may be explained by the production of secondary reactions.—*Ann. Chim. Phys.*, VI, xxx, 289, Nov. 1893. G. F. B.

5. *Motochemistry or Stereochemistry.*—The term "motochemistry" has been proposed by MOLINARI to indicate the view that the constitution of compounds depends on the intramolecular

movements of the atoms in relation to each other, rather than on the relative positions of the atoms in space, which is the fundamental hypothesis of "stereochemistry." The new view regards the bonds by which the union of atoms is customarily represented, as signifying the nature of the swing of the atoms with relation to each other, i. e., their energy. Thus doubly linked and singly linked carbon atoms are of different value in respect to the energy of their movement with regard to each other, and double or treble bonds signify excess of energy, ready to be exerted in saturating the compound. This hypothesis the author applies to the benzene ring and shows that only one ortho-bi-substitution product is possible. Motoisomerism involves asymmetry but the term must be used in a greatly extended sense, the phenomenon depending on the mass and valence of the atoms or atomic groups as well as on their number and nature. Motoisomerides will exist in those cases in which it is possible for the order of approach of the asymmetrical carbon atom (taken in this sense) to vary toward the neighboring atoms. In the case of benzil-monoxime

$$\mathrm{COPh\,.\,C}\begin{matrix}=\mathrm{N\,.\,OH}\\ \smallsetminus \mathrm{C_6H_5}\end{matrix}$$

for example, it is possible for two motoisomerides to exist; for if the swing between carbon and carbon be designated by a and that between carbon and nitrogen by b, these isomerides will be represented (1) by a, a, b, b, and (2) by a, b, a, b.—*J. prak. Chemie*, II, xlviii, 113; *J. Chem. Soc.*, xliv, ii, 513, Nov. 1893.

G. F. B.

6. *On the Densities of Oxygen, Hydrogen and Nitrogen.*—The densities of oxygen, hydrogen and nitrogen have been determined with great care by Lord Rayleigh. The oxygen was prepared by three different methods: (1) from chlorates, (2) from potassium permanganate and (3) by electrolysis. The air was taken from outside and was passed through potash solution, then through tubes filled with fragments of solid potash and finally over phosphoric oxide. The nitrogen was prepared by passing air through a potash solution, over reduced copper, then through a U-tube to deposit water again over heated copper and finally over heated copper oxide. The values of the densities of oxygen, nitrogen and hydrogen respectively, as compared with those obtained by other experiments, all referred to that of air as unity are given in the following table:

	Oxygen.	Nitrogen.	Hydrogen.
Regnault (corr.)	1·10562	0·97138	0·06949
v. Jolly (corr.)	1·10502	0·97245	------
Leduc	1·1050	0·9720	0·06947
Rayleigh	1·10535	0·97209	0·06960
Mean	1·10525	0·97218	0·06952

The density of hydrogen was calculated from that of oxygen using the ratio 15·882. The mean of the best densities under standard conditions referred to water at 4° as 1000; i. e. the mass of one liter in grams, therefore, is found to be:

Air.	Oxygen.	Nitrogen.	Hydrogen.
1·29347	1·42961	1·25749	0·08991

—*Proc. Roy. Soc.*, liii, 134, 1893. G. F. B.

7. *On Free Hydroxylamine.*—An improved method of preparing free hydroxylamine has been devised by BRÜHL, which is not only safer than those heretofore used, but gives a larger yield. It is based on the reaction of hydroxylamine hydrochloride upon sodium methylate, both being dissolved in methyl alcohol; a reaction first made use of by Lobry de Bruyn. After separating the methyl alcohol solution from the precipitated salt, Brühl transfers it to a modified form of his well known apparatus for fractional distillation in vacuo, consisting of a distillation flask provided with a thermometer and an entrance tube furnished with a tap, a condenser and a multiple receiver by which a rapid change of receptacles may be made during the distillation without impairing the vacuum. The pressure in the flask is reduced to the lowest possible amount and the distillation is effected by immersing the flask in hot water. In this way and under a pressure of 22^{mm} of mercury, the hydroxylamine passes over completely at 56°–57°. The condenser is supplied with ice water and the receiver is surrounded with ice and salt; so that each drop of hydroxylamine solidifies at once as it enters the receiver; the yield being 66 per cent of the theoretical. At the temperature of 23·5° its density is 1·2044. Its refractive index for the red line of lithium is 1·4375 and for the Hγ line 1·4514. The author has proved that the constitution of hydroxylamine is $\begin{matrix}H\\H\end{matrix}\!\!>\!N-O-H$ and has shown that the molecular refraction and dispersion of the nitrogen present in it is the same as that of the nitrogen in ammonia gas and much lower than that of the nitrogen in triethylamine; the probable values of these constants of nitrogen, linked in this manner, for sodium light, being 2·495 and 0·072 respectively.—*Ber. Berl. Chem. Ges.*, xxvi, 2508, Nov. 1893. G. F. B.

8. *On a New Sulphide of Carbon.*—A new compound of sulphur and carbon, having the composition C_3S_2 has been prepared by VON LENGYEL by submitting the vapor of carbon disulphide to the action of the electric arc. The disulphide was contained in a flask and the arc carbons crossed a globe sealed above it, furnished with an upward condenser. The flask was heated on a water bath and the vapor exposed for two hours to the arc. A deep cherry red liquid remained in the flask, which was treated for a week with copper turnings to remove the free sulphur. The disulphide was then evaporated in a current of dry air and left a few cubic centimeters of a deep red liquid, possessing a powerful odor, a mere trace of which produces a copious flow of tears, ac-

companied by violent and persistent catarrh of the eyes and mucous membrane. The specific gravity of this new sulphide is 1·2739. When heated it polymerizes into a hard black substance, having the same composition. It can be partially distilled in vacuo at 60°, but even then a small portion polymerizes. In a few weeks, the liquid spontaneously changes into the black form. This form is soluble in caustic alkalies and is reprecipitated unchanged by acids. On heating it yields an inflammable gas containing sulphur which is not carbon disulphide.—*Ber. Berl. Chem. Ges.*, xxvi, 2960, January, 1894. G. F. B.

9. *Emission of Gases.*—F. PASCHEN shows that previous observers have neglected to take into account a marked absorption effect of CO_2. He finds that a 7^{cm} thick layer of this gas absorbs all the light of the wave-length of the main absorption band. The amount of CO_2 and H_2O in a 83^{cm} thick layer of the air of a room is sufficient to produce sharp absorption bands. This phenomenon is the source of error in Angström's determination of the absorption of CO_2, and apparently also in Rubens and Snow's determination of the dispersion curve of fluor spar, and in their research upon the dependence of the emission of a solid body upon the temperature. A comparison of Paschen's results with those of Angström, shows that the absorption coefficient of the latter must be doubled. CO_2 shows no absorption in the portion of the spectrum in which its absorption bands do not lie. Oxygen and nitrogen in layers a decimeter thick and under atmospheric pressure show no absorption bands. — *Ann. der Physik und Chemie*, pp. 1–39, No. 1, 1894. J. T.

10. *Apparatus for studying and showing electrical resonance.*—A. RIGHI has succeeded in obtaining electrical waves of $7{\cdot}5^{cm}$ in length. His oscillator consists of two straight brass cylinders which are terminated at both ends with spheres 4^{cm} in diameter. The entire length of the exciter with the bulb is 62^{cm}. Upon this two circular copper discs of 34·5 diameter can be adjusted. They are generally placed 43^{cm} distant from each other. Both middle spheres between which spring sparks of from 2 to 5^{mm} length, are placed in a glass vessel filled with a thick mixture of *vaselinöl* and vaseline. Opposite to the two outer spheres stand two other spheres which are connected with the poles of an electrical machine, from which the Leyden jars are removed. The resonator consists of a circle of copper wire of 57^{cm} in diameter closed by a small Geissler tube which was selected out of a large number, and was so sensitive that it lighted at a distance of 6^{m} from the exciter and so brilliantly that the interferences between electrical waves, propagation of these waves along wires, and allied phenomena could be shown to an audience. For very short waves, the exciter consisted of four brass spheres $1{\cdot}36^{cm}$ in diameter which were placed over each other. The upper and under were connected with the electrical machine, the two middle ones, capable of adjustment, were mounted in a vessel filled with a mixture of vaselinöl and vaseline. The resonators consisted of

strips of silvered glass, through the middle of which a scratch of about 0·002^{mm} breadth was made in the silver surface. This scratch served as a spark gap. An investigation was made upon the absorption of electrical waves by different substances. Ebonite, parafine and rock salt showed no absorption. Green glass, quartz-selenite and olive oil showed clearly absorption.—*Rendie, R. Acc. dei Lincei,* (5) 2, 1 Series, pp. 505–518, 1893. J. T.

II. Geology and Mineralogy.

1. *On the Devonian* (*Oriskany*) *in the Southern Appalachians;* by C. Willard Hayes, U. S. Geological Survey. (Communicated.)—In a letter written in January, 1891, concerning the Devonian rocks of the Southern Appalachians I made the following statements: "In the highly faulted region between Weisner and Indian mountains, in Alabama, are some coarse ferruginous sandstones which appear to rest directly on the Rockmart slate (presumably of Trenton or Hudson age), without any intervening rocks corresponding to the Rockwood formation further north. Fossils have been collected in this ferruginous sandstone concerning which Mr. Walcott in a letter to Mr. Russell says: 'The fossils collected by Mr. Cooper Curtice in a sandstone on the side of Frog Mountain, Ala., include *Zaphrentis* sp.?, *Chaetetes complanata?*, *Spirifera arenosa?*, *S. arrecta?*, *Pterinea?* sp.?, *Platyceras* sp.? All of the specific determinations are uncertain, as the material is not in a satisfactory condition, but the horizon of the Oriskany sandstone is strongly suggested by the general facies of the fauna.' The following species which Mr. Russell collected at Frog Mountain were also determined by Mr. Walcott, 'Horizon of the Oriskany sandstone of the New York section; *Zaphrentis* sp.?, *Orthis musculosa?*, *Spirifer arenosa*, Conrad, *Pentamerus* cast like that of *P. oblongus*, *Conocardium*.'

"A few miles south of Cedartown, Ga., the stratigraphic relations are shown better than in the disturbed region about Frog Mountain though no fossils have been collected. Resting on the Rockmart slate is a bed of sandstone not more than twenty feet thick, and upon this is a fossiliferous chert which I assumed to be the Fort Payne (Carboniferous). There may be an unconformity above the sandstone or below it or both."

During the past season this region was re-examined and some further conclusions reached, which may be of interest to you. No fossils in addition to those mentioned above were collected, so that the question of the age of these rocks, in so far as it depends on palæontologic evidence, remains essentially as in 1891. Their relations to underlying formations, however, are better understood. The sandstones in question at present rest unconformably upon all older formations of the region, from the Middle Cambrian up to the top of the Lower Silurian. In studying a region so extensively faulted as that between Weisner and Indian Mountains, the natural tendency is to attribute all unconformities to faulting. And especially is it difficult to discriminate between the broad horizontal thrusts which occur there and deposition overlaps. The work of the past summer has enabled me to make this discrimination in many cases, and has convinced me that the unconformity observed between the sandstone and underlying formations is due generally to deposition overlap and not to faulting. This implies a long period of deformation and erosion between the time represented by the Rockmart slate (probably Hudson River) and the Frog Mountain sandstone, an interval represented elsewhere by the deposition of the Rockwood (Clinton, etc.) which formation to the southward contains heavy beds of conglomerate. This conclusion also strengthens the view, suggested by the fossils mentioned above, that the sandstones of Frog Mountain are of Devonian (Oriskany) age. The uplift which occasioned the unconformity appears to have been along a N.W.–S.E. axis with rather sharp folds transverse to the axis of uplift and in a general way coinciding with folds and faults developed at a much later date.

2. *Marine shell fragments in drumlins near Boston;* by WARREN UPHAM. (Communicated.)—The very interesting paper by Mr. R. E. Dodge in the February number of this Journal (pp. 100–104) draws attention to the greater number of species of Pleistocene fossils found in the section of Winthrop Great Head than in any other drumlin of the Boston Harbor area. This is true, but in a less degree than is supposed by Mr. Dodge, as I am able to state from unpublished observations by Mr. Warren W. Herman of Boston, and from a recently published memoir by Prof. W. O. Crosby (Geology of the Boston Basin, vol. i, Part I, Nantasket and Cohasset, in Occasional Papers of the Boston Society of Natural History, vol. iv, 1893). During the summer of 1891 Mr. Herman spent much time in Winthrop in search for these marine shells, occurring chiefly as glacially broken fragments, in the drumlin sections of Great Head and Grover's Cliff; and he succeeded in finding in each of these hills eight of Dr. Stimpson's original list of fourteen species. Six of this list, namely, the first, second, sixth, and the final three, as given by Mr. Dodge on page 100, were not certainly identified. The most noteworthy difference between these fossils common to the two sections, as shown by Mr. Herman's collections, is the frequency of *Mya arenaria* in Great Head, while it is very rare in Grover's Cliff. In the Great Head section he also found fragments of young specimens of *Scapharca transversa*, several small specimens (about $\frac{1}{3}$ inch long) of a *Lunatia*, one specimen of *Buccinum undatum* (evidently dead and worn, as if cast ashore from outer and deep water, before it was enclosed in the till), one small *Ilyanassa obsoleta*, and one *Crepidula plana* Say, the last being lodged inside a shell of the *Urosalpinx cinerea*. Three of these additional species, and probably also the *Lunatia*, are remarkable in being the same with those of Mr. Dodge.

From three drumlins of Nantasket, namely, Telegraph Hill, Point Allerton Great Hill, and Strawberry Hill, situated five to seven miles southeast of Winthrop, Professor Crosby and Mr. H. D. Card have collected eleven species, the first locality having eight; the second also eight, of which five are found in the first; and the third five, of which four are in each of the two other sections. Only one of these species, *Crucibulum striatum* Say, found only in Telegraph Hill, is an addition beyond the collections of Stimpson, Dodge, and Herman.

The section of the Winthrop Great Head has the highest vertical extent, and therefore affords the most favorable conditions for the preservation of the shell fragments, among all the sections of drumlins in the Boston Harbor district, excepting only the comparatively inaccessible sections of Great Brewster island. To this fact, and to probably more frequent and persistent search than elsewhere, we must ascribe, as I think, the larger list of its discovered species, rather than to greater abundance, either in numbers or in species, of the shells originally supplied to the drift there.

When my previous paper relating to these fossils was contributed to this Journal in May, 1889, I considered them as derived from an interglacial fauna; but it now seems to me more probable that there was no great retreat and re-advance of this portion of the North American ice-sheet, so that these fossils, and the two successive faunas, comprising together about sixty species, at Sankaty Head, Nantucket, would be preglacial. None of these species, however, have become extinct, or undergone important varietal modification, from which it seems certain that no geologically long period has elapsed since their time. In other words, if they are preglacial, the Ice age here, and the epeirogenic uplift which appears to have produced it (this Journal, vol. xlvi, pp. 114–121, Aug., 1893), so far as it affected this part of our coast, were each brief. The uplift, however, farther northeast and north, occupied a much longer time, as is shown by the Fishing Banks and the northern fjords, after which I think that it reached to the latitudes of Boston, New York, Delaware Bay, and beyond, during only a comparatively short stage, when its culmination caused the accumulation of the ice-sheet. That the temperature of the sea at the head of Massachusetts Bay was milder than now, both preceding and following the glaciation, may probably be accounted for, in part or wholly, by the more enclosed and sheltered position of this bay and the whole coast of eastern New England and the eastern provinces of Canada, due to greater height of the Fishing Banks, Newfoundland, and the region of the Strait of Belle Isle.

III. Botany.

1. *Étude sur la constitution de l'appariel fructificateur des Sphenophyllum.* By R. Zeiller. Mém. soc. géol. France, paléont., No. 11, Paris, 1893, pp. 1–39, Pl. I–III.—Although cones of a

number of species of the genus *Sphenophyllum* have since 1804 been figured by various authors, and latterly with partial but not always accurate demonstrations of their structure, the conflict of opinions concerning the systematic position of this most discussed genus has in general been waged on the evidence furnished by the organization, ramification and foliation of the stems and by the superficial features of the cones. Recently, however, largely through the efforts of M. Zeiller, we have been put in possession of so many facts regarding the structure of the true fructification of the genus as to throw great light on its relationship to the rest of the vegetable world.

The additional details of the organization of *Bowmanites* (*Volkmannia*) *Dawsoni* Will., published, not long ago, by Prof. Williamson, (Organization of the Fossil Plants of the Coal Measures, Part XVIII, Philos. Trans. R. Soc., vol. 180, B, pp. 97–101), so impressed M. Zeiller with their striking similarity to those of the cone of *S. cuneifolium* (Stb.) Zeill. (*S. erosum* L. and H.) in which he had in 1888 (Fl. foss. bassin houill. Valenciennes, pp. 415–418, Pl. LXIII, f. 4, 5, 10) detected the union of the bracts in the verticil and the position of the sporangia on the latter, that he reëxamined the Valenciennes material, the result being the announcement in the "Comptes Rendus" for July 11, 1892, of his identification of *Bowmanites Dawsoni* as the cone of *Sphenophyllum cuneifolium.* This correlation of a cone, the structure of which has been so far worked out by Williamson, was promptly admitted by the latter in a short review of the subject in "Nature" of November 3, 1892 (pp. 11–13).

In the present memoir M. Zeiller briefly summarizes the researches of Grand'Eury, Renault, and especially those of Williamson with whose published results he makes a critical and thorough comparison of all the available material. Although confined mostly to opaque specimens he has been able to verify nearly all of Prof. Williamson's discoveries regarding the position and, to some extent, the structure of the parts of the cone, besides contributing much that is new.

Briefly described, the cones of *Sphenophyllum cuneifolium*, the species best known, are 5–10^{cm} or more in length, 8–14^{mm} in width, the diameter of the axis and the internodes each measuring 1·5–2·25^{mm} each. The bracts, which are reflexed for a distance at the base, then curved upward, 6–13^{mm} long, are united for a distance from their origin, forming a funnel. The free ends of the bracts are linear-lanceolate, slender, probably with a median nerve. On the upper surface of these originate the pedicels which curve outward, upward, and then in toward the axis, being adnate for a little distance to the pendant sporangia. The latter, oval, 1–2^{mm} long and ·75–1·25^{mm} wide, are pluriseriate in concentric rings between each pair of verticils, the outer rings being higher than the inner. The sporangium wall is shagreened and slightly spinous. The dorsal surface of the pedicel is, at least near its extremity, formed of thick-walled cells which continue to the surface of the sporangia, appearing to form a disc which presumably assists in the dehiscence of the microspores found within, the arrangement of the parts being apparently analogous to those of the Eusporangiate ferns. The number of concentric rows of sporangia to each internode varies with the species. In one section two pedicels in the row to one bract were observed. It is not known how the vascular bundle, which seems to be slightly developed in the pedicel, reaches the axis of the cone, nor whether the pedicels branch, though it is thought that in one species at least they do so.

After describing in detail the cones of *S. cuneifolium* M. Zeiller reviews what is known of the fructification of *S. emarginatum*, *S. gracile*, and *S. oblongifolium* on all of which he records new observations. A re-examination of the cone described by Renault (Cours de bot. foss., II, pp. 102, 103), which has considerably influenced opinion as to the relations of the genus, brings both Renault and Zeiller to the conclusion that only one kind of sporangia was present, instead of both macrosporangia and microsporangia as was at first supposed.

Also Zeiller and Williamson agree that the leaves of *Sphenophyllum* are sometimes dissected to the base so as to resemble *Asterophyllites*, a circumstance that led the latter to refer *Bowmanites Dawsoni* to *Asterophyllites*, and which, together perhaps in some instances with vertical burial of the leaves in the matrix, caused Director Stur to maintain that *Sphenophyllum* is the heteromorphous, heterosporous branch of *Calamites*, while *Asterophyllites* is the homomorphous branch, a view somewhat modified by Seward ("Sphenophyllum as a branch of Asterophyllites," Mem. Proc. Manchester Lit. Phil. Soc., 1890).

As to the systematic position of the genus, Williamson in his short note in "Nature" agrees with Zeiller that while the organization of the stem allies it to the Lycopodineæ, its highly specialized fructification brings it nearer the Rhizocarpeæ, and that it forms a distinct class among the Vascular Cryptogams. Kidston, in a recent paper "On the Fructification of Sphenophyllum trichomatosum, Stur, from the Yorkshire Coal Field" (Proc. R. Phys. Soc. Edinb., xi, pp. 56–62, Pl. I), reaches the conclusion that there is no recent order in which the genus can be enrolled, since it differs from the Equisetaceæ by its solid axis and the structure of its cone, from the Lycopods by its ribbed, noded stems with verticillate leaves, while "with the Rhizocarps it appears to have little or nothing in common." He therefore makes the Sphenophylla a peculiar and distinct group, the *Sphenophylleæ*, which though close to the Lycopods can not be included with them. Finally, Zeiller, after considering its resemblance in the development of a secondary or centrifugal growth to the Lycopodinæ the stronger analogy of its fruiting cones to the Hydropterideæ and Ophioglossaceæ, its several characters in common with the Equisetineæ, agrees essentially with the others in constituting for it a distinct class in the Vascular Cryptogams, and now places it, not between the Equisetineæ and Lycopodineæ as formerly, but next to the Filicineæ on account of the marked affinities it offers in the structure of its cones with the fructification of the Marsileaceæ and the Ophioglossaceæ. D. W.

IV. Astronomy.

1. *The constant of aberration.*—In Bulletin No. 28 of the U. S. C. and G. Survey Mr. Preston gives a detailed discussion of the observations made at Waikiki, H. I., by which a correction is sought for the commonly accepted values of the constant of aberration (20″·445). Mr. Preston says in closing that the definitive result of the constant of aberration from the latitude observations of 1891–1892, made at Waikiki, Hawaiian Islands, on the part of the United States Coast and Geodetic Survey, is therefore

$$\text{Constant of aberration} = 20''{\cdot}433 \pm 0''{\cdot}034.$$

This value of the aberration constant, combined with the latest determinations of the velocity of light ($V = 186{,}330$ miles) and Clarke's value for the earth's radius ($R = 3963{\cdot}30$ miles), gives the sun's distance and equatorial horizontal parallax as follows:

$$\text{Distance} = 92{,}709{,}000 \text{ miles.}$$
$$\text{Parallax} = 8''{\cdot}82.$$

H. A. N.

V. Miscellaneous Scientific Intelligence.

1. *Sea-water and sea-bottom deposits of the Eastern Mediterranean.*—"The Austro-Hungarian ship *Pola* was again sent out last summer, by the Vienna Academy of Sciences, to the Eastern Mediterranean. Another deep depression has been discovered, this time to the east of the island of Rhodes, in latitude 36° 5′ 30″ N., longitude 28° 36′ E., where the lead gave 3865 mètres (2110 fathoms); and although this depression is apparently shallower than the "Pola-Deep," 4000 mètres (2187 fathoms) in latitude 35° 44′ 20″ N., longitude 21° 44′ 50″ E., to the west of Crete, it is really deeper in relation to the land surrounding it, being fully 7000 mètres (3828 fathoms) below the summit of Ak-Dagh in Anatolia. The new depression is closed to the southeast by a ridge running in a southeasterly direction, which rises to within 1920 mètres (1050 fathoms) of the surface.

As in former years, the chemical character of the sea-water was determined by Dr. K. Natterer, and his investigations appear to him to confirm some previous results, which suggest some remarkable alterations in the accepted theory of the formation of certain geological strata. Dr. Natterer has again been unable to detect the presence of free carbonic acid in any of the samples of sea-water. Since a considerable amount of carbonic acid must be derived from the oxidation of plant and animal remains at the sea-bottom, its absence in the free state can only be explained by supposing that, besides carbonic acid, ammonia is formed, and that in almost equivalent quantities.

These substances, having a tendency to combine, would go to form a corresponding amount of carbonate of ammonium.

Dr. Natterer is inclined to assign the chief part in the formation of not only the partly clayey, partly stony deposits on the sea-bottom, but also of calcareous and siliceous structures in living organisms to precipitates caused by the dissolved carbonate of ammonium. That the mechanical deposition of detritus carried to sea in suspension by surf or by river-waters plays only a subordinate part in comparison with such chemical precipitates (of carbonate of lime, siliceous clay, free silica, etc.), appears especially from the fact that, except near the mouths of rivers, clear water, free from suspended matter, was obtained directly from the water-bottles at all depths in the Eastern Mediterranean; and Dr. Natterer accordingly expresses the view that in the *Porcupine* and *Shearwater* expeditions in 1870–71, it was only because the Sigsbee apparatus was allowed to touch the bottom that fine mud was found in suspension in samples from the lowest layers of water.

The late Dr. W. B. Carpenter, who had scientific charge of those expeditions, ascribes the presence of suspended mineral particles to the fine sand brought down by the Rhone and other rivers (see Proceedings R. S., xix, p. 146, and xx, p. 535). The relatively slight importance of the action of mechanical deposition is further shown by the circumstance that where the chemical conditions necessary for precipitation are absent, mineral particles are dissolved by the sea-water, except when they are present in sufficient quantity to cause the continued reactions observed by Natterer. In fact, the examination of water samples collected at the Tanitic mouth of the Nile, and near the harbor of Port Said, towards which all Nile water is carried by an easterly current, after it reaches the sea showed a surprisingly small amount of suspended matter even in late summer, when the quantity is likely to be large on account of the tropical cloudbursts. Natterer supposes that the fine sand brought down by rivers is only to a small extent deposited directly, but that for the most part it is first dissolved, and remains in solution until a current carries it to a part of the sea where new conditions bring the separating action into play, and precipitation is caused by the action of living or dead organisms. This process assists in the formation of coral reefs and banks, helps the tide and the surf in the building of dunes, and provides materials for the mineral parts of organisms living in the sea.

Where the sinking of decaying organisms is prevented by a strong current, Natterer supposes that a strong crust is formed on the bottom, instead of the muddy deposits which cover by far the greater part of the Mediterranean basin; and this crust is harder the more slowly it is formed. Samples brought to Vienna prove the existence of intermediate transition stages between the two, and it is suggested that the ammonia, formed by the oxidation of the lower layers of deposits containing decaying organisms in the manner already described, rises to the actual sea-bottom by diffusion, and there causes the deposition of the stony crust by its action on the sea-water. The crust, which is chiefly composed of carbonate of lime, siliceous clay, and free silica, varies in thickness from about 1·5 centimètres (0·59 inches) to 8 centimètres (3·15 inches), and tends to obliterate the inequalities of the original sea-bottom. Its upper surface is likely to be smooth and clean, while the lower is in immediate contact with the clayey sand.

Dr. Natterer also draws some interesting conclusions from the application of a special chemical method, based on local variations in the amounts of bromine, of iodine, and of nitrous acid contained in sea-water, to the detection and measurement of currents which move too sluggishly to be amenable to direct observations. He has this year been able to subject his method to a severe test in the currents of the Ægean, where it is possible to make direct measurements for comparison; and although the results are not yet fully worked out, the two methods agree very closely. Finally, with regard to the extraordinary poverty of the pelagic fauna of the Mediterranean as compared with the open ocean, Dr. Natterer expresses the opinion that so far as chemical conditions alone are concerned, these are favorable to animal life, and that as a matter of fact a rich fauna occurs in some regions in the immediate vicinity of quite sterile masses of water. It appears that abundant animal life is present just where the water is in rapid motion; and that, generally, the poverty of the Mediterranean fauna is largely due to the want of circulation in its waters—a result opposed to that of Carpenter, who believed it to be due to the excess of suspended matter."—*The Geographical Journal*, vol. iii, pp. 138–140.

2. *Electric Waves; being Researches on the Propagation of Electric action with finite velocity through Space.* By Dr. HEINRICH HERTZ, Professor of Physics in the University of Bonn. Authorized English Translation by D. E. Jones, B.Sc. With a Preface by Lord Kelvin, LL.D., D.C.L. 8vo, pp. xviii, 280. London and New York, 1893 (Macmillan & Co.).—Probably no greater step in experimental science has been taken in modern times than that which was announced by Dr. Hertz in the spring and summer of 1888 proving the finite velocity of propagation of electromagnetic actions, and showing that these electromagnetic waves in air represent "on a million-fold larger scale the same processes which go on in the neighborhood of a Fresnel mirror or between the glass plates used for exhibiting Newton's rings." The remarkable series of papers in which these discoveries were announced were so much in demand that the publishers of *Wiedemann's Annalen*, in which they appeared, invited him to prepare them for separate publication. This he did under the title: "Untersuchungen über die Ausbreitung der Elektrischen Kraft," adding an introduction and supplementary notes. This admirable book now appears in an English dress; and will be warmly welcomed by English-speaking men of science. Its appearance was almost simultaneous with the death of its brilliant author, Dr. Hertz having died in Bonn on January 1st, 1894, at the early age of 37. G. F. B.

APPENDIX.

ART. XXIII.—*Restoration of Camptosaurus;* by O. C. MARSH. (With Plate VI.)

THE Jurassic deposits of western North America contain the remains of many gigantic Dinosaurs, and various skeletons of these have been obtained by the writer, who has described the more important forms. Restorations of the skeletons of three of the most interesting genera, *Brontosaurus*, *Stegosaurus*, and *Ceratosaurus*, have already been given in this Journal, and another of these huge reptiles is thus represented on Plate VI accompanying the present article. Each of the three forms previously restored was a typical member of a distinct group of the *Dinosauria*, and this is true, although in a less degree, of the present genus, *Camptosaurus*. Restorations of *Anchisaurus* from the Triassic, and *Claosaurus* and *Triceratops* from the Cretaceous, all Dinosaurs of much interest, have likewise been published by the writer in the present Journal.*

The restoration here given is based upon the type specimen of *Camptosaurus dispar*, one of the most characteristic forms of the great group *Ornithopoda*, or bird-footed Dinosaurs. The reptile is represented on Plate VI, one-thirtieth natural size. The position chosen was determined after a careful study not only of the type specimen, but of several others, in excellent preservation, belonging to the same species or to others nearly allied. It is therefore believed to be a position frequently assumed by the animal during life, and thus, in some measure, characteristic of the genus *Camptosaurus*. The present species, when alive, was about twenty feet in length, and ten feet high in the position here represented.

The genus *Camptosaurus* is a near ally of *Iguanodon* of Europe, and may be considered its American representative. *Camptosaurus*, however, is a more generalized type, as might be expected from its lower geological horizon. It resembles more nearly some of the Jurassic forms in England generally referred to *Iguanodon*, but, as these are known only from fragmentary specimens their generic relations with *Camptosaurus* cannot now be determined with certainty.

In comparing *Camptosaurus*, as here restored, with a very perfect skeleton of *Iguanodon* from Belgium, as described and figured, various points of difference as well as of resemblance may be noticed. The skull of *Camptosaurus* had a sharp, pointed beak, evidently encased during life in a horny sheath. This was met below by a similar covering, which enclosed the predentary bone. The entire front of the upper and lower jaws were thus edentulous, as in *Iguanodon*, but of different shape. The teeth of the two genera are of similar

* This Journal, vol. xli, p. 339, April, 1891; vol. xlii, p. 179, August, 1891; vol. xliv, p. 343, October, 1892; and vol. xlv, p. 169, February, 1893.

form, and were implanted in like manner in the maxillary and dentary bones. In *Camptosaurus*, there is over each orbit a single supra-orbital bone, curving outward and backward, with a free extremity, as in the existing Monitor; a feature not before observed in any other Dinosaur except *Laosaurus*, an allied genus, also from the Jurassic of America. Other portions of the skull of *Camptosaurus* as well as the hyoid bones appear to agree in general with those of *Iguanodon*.

The vertebræ of *Camptosaurus* are similar in many respects to those of *Iguanodon*, but differ in some important features. In the posterior dorsal region, the transverse processes support both the head and tubercle of the rib, the head resting on a step, as in existing crocodiles. The five sacral vertebræ, moreover, are not coössified, even in adult forms, and to this character the name *Camptonotus* first given to the genus by the writer in 1879 especially refers.* Another notable feature of the sacral vertebræ of the type specimen should be mentioned. The vertebræ of the sacrum, especially the posterior four, are joined to each other by a peculiar peg and notch articulation. The floor of the neural canal of each vertebra is extended forward into a pointed process (somewhat like an odontoid process), which fits into a corresponding cavity of the centrum in front. This arrangement, while permitting some motion between the individual vertebræ, helps to hold them in place, thus compensating in a measure for absence of ankylosis. A similar method of articulation is seen in the dermal scales of some ganoid fishes, but, so far as the writer is aware, nothing of the kind has been observed before in the union of vertebræ.

In *Camptosaurus*, the sternum was entirely unossified, and no trace of clavicles has been found. The pelvis of *Camptosaurus* differs especially from that of *Iguanodon* in the pubis, the postpubic branch being even longer than the ischium, while, in *Iguanodon*, this element is much shortened.

In the fore foot of *Camptosaurus*, there were five functional digits, the first being flexible, and nearly parallel with the second, thus differing from the divergent, stiff thumb of *Iguanodon*. The hind feet had each three functional digits only, the first being rudimentary, and the fifth entirely wanting, as shown in Plate VI. The entire skeleton of *Camptosaurus* was proportionately more slender and delicately formed than that of *Iguandon*, although the habits and mode of life of these two herbivorous Dinosaurs were doubtless very similar.

The type specimen of *Camptosaurus dispar*, used as the basis of the present restoration, is from the Atlantosaurus beds of the upper Jurassic of Wyoming. This species and other allied forms will be described in full in an illustrated memoir now in preparation by the writer for the United States Geological Survey. The present restoration is reduced from a large drawing made for that volume.

New Haven, Conn., February 23, 1894.

* This name proved to be preoccupied, and *Camptosaurus* was substituted for it. This Journal, vol. xxix, p. 169, February, 1885.

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[THIRD SERIES.]

ART. XXIV.—*Further Studies of the Drainage Features of the Upper Ohio Basin;* by T. C. CHAMBERLIN and FRANK LEVERETT.*

Introduction.

IN the year 1885 the senior writer, in association with Mr. G. K. Gilbert, made a study of the drainage and drift phenomena of the upper Ohio basin. In 1886 work was resumed but was interrupted by other duties. In 1890 the junior writer, working under the direction of the senior writer, gathered data relative to the drainage history of the region while tracing the group of terminal moraines across northwestern Pennsylvania. During the present year he has undertaken a more systematic study of the subject.

We have found the work of Mr. J. F. Carll, of the Pennsylvania Geol. Survey, on the old drainage systems of the region especially valuable and admirable.† We are also indebted to the contributions of Messrs. Chance,‡ White,§ Stevenson,‖

* Presented in abstract to the Geological Society of America, Dec. 31st, 1893.

† Penn. Second Geol. Survey, Rept. III, 1880, pp. 1–10, 330–439; Rept. IIII, 1883, pp. 1–147, 169–175, 219–406.

‡ Penn. Second Geol. Survey, Rept. VV, 1880, pp. 17–20.

§ Penn. Second Geol. Survey, Rept. Q, 1878, pp. 9–17, QQ, 1879, pp. 10–20. This Journal, III, vol. xxxiv, 1887, pp. 374–381. Bull. Geol. Soc. Amer., vol. i, 1880, pp. 477–479. Also discussions of drift and drainage features incorporated in the detailed geology of the several counties covered by reports Q, QQ, QQQ. QQQQ, namely, Beaver, North Allegheny, South Butler, Lawrence, Mercer, Crawford and Erie.

‖ Penn. Second Geol. Survey, Rept. K, 1876. pp. 11–19, KKK, 1878, pp. 251–263. This Journal, III, vol. xv, 1878, pp. 245–250. Proc. Amer. Phil. Soc., vol. xviii, 1880, pp. 289–316.

Lewis,* Wright,† Lesley,‡ Spencer,§ Randall,‖ Foshay,¶ and Hice.**

Probable old Drainage Basins.

We follow Carll in the general view that the present drainage system of the upper Ohio basin has been formed by the union of several pre-glacial systems that formerly flowed into what is now the Lake Erie basin. These were blocked up by the ice of the early part of the glacial period, which invaded their lower courses and forced them to flow over low divides and unite to form a common southwestward flowing system nearly parallel to the border of the ice. In this there is a strong analogy to the upper and middle Missouri system believed to have been formed out of numerous northward, northeastward and eastward flowing streams forced to unite along the edge of the ancient glacier, as determined by the studies of Todd, Salisbury and the senior writer.

If this view be correct, and a part of the purpose of this paper is to add data in support of it, each of the united sections must be considered separately in determining their preglacial and glacial history. Each section may indirectly help to interpret the others but it will be rather by the suggestiveness of analogy than by the direct force of specific evidence. We regard the evidence of the union of separate pre-glacial basins as clear and decisive in at least three cases, as highly probable in another, and as rather weak in another, at the present stage of investigation. These may be treated briefly in succession beginning with the uppermost.

The Upper Allegheny Basin.—Three specific lines of evidence support each other in showing that the uppermost section of the present Allegheny formerly discharged into the Lake Erie basin. (1) There is a notable constriction of the valley near Kinzua, Pennsylvania, from its usual breadth of a

* Penn. Second Geol. Survey, Rept. Z, 1884, pp. 141–202, 279.

† This Journal, July, 1883; Proc. A. A. A. S., 1883, pp. 202–207; The Glacial Boundary, Proc. Western Reserve Hist. Soc., 1884, 86 pages; Bull. U. S. Geol. Survey, No. 58, 1890, pp. 39–110; This Journal, Nov., 1892. Also discussions of the drift and drainage features of this region embraced in the "Ice Age in North America" (1889), and in abbreviated form in "Man and the Glacial Period" (1892).

‡ Penn. Second Geol. Survey, Rept. Q, 1878, pp. XXIV-XLIII; Rept. III, 1880, pp. XIII-XVII: also various footnotes in (III) and (IIII); Rept. Z, 1884, pp. V-XLIX.

§ Penn. Second Geol. Survey, Rept. QQQQ, 1881, pp. 387, 405.

‖ Penn. Second Geol. Survey, Rept. IIII, 1883, pp. 1–30, 309. We are also indebted to Mr. Randall for notes on a detailed study of the distribution of the attenuated drift in the vicinity of Warren, Pennsylvania, in which the distribution of the bowlders together with their altitude has been determined with care.

¶ This Journal, Nov. 1890. Bull. Geol. Soc. Amer., vol. ii, 1891, pp. 457–464.

** Bull. Geol. Soc. Amer., vol. ii, 1891, pp. 457–464: Science, vol. xxii, Sept. 29, 1893, p. 170. We are also indebted to Mr. Hice for favoring us with the esults of careful observation on the distribution of the drift and the depth of hannels in the vicinity of Beaver, Pennsylvania.

mile or more to less than one-fourth of a mile. This constriction appears clearly to be the point at which a former col was located and across which the stream was forced when reversed. (2) From this point the buried rock floor of the valley slopes *northward* to the vicinity of Steamburg, New York, in direct opposition to the present flow of the river. (3) Here it is met by a buried rock floor sloping with the present stream, but from this point there is a broad continuous valley deeply filled with drift leading westward and northward along the line of the upper Conewango (reversed), and the lower Cattaraugus valleys to the Lake Erie basin. The evidence of this is in part shown diagrammatically in the accompanying section

1.

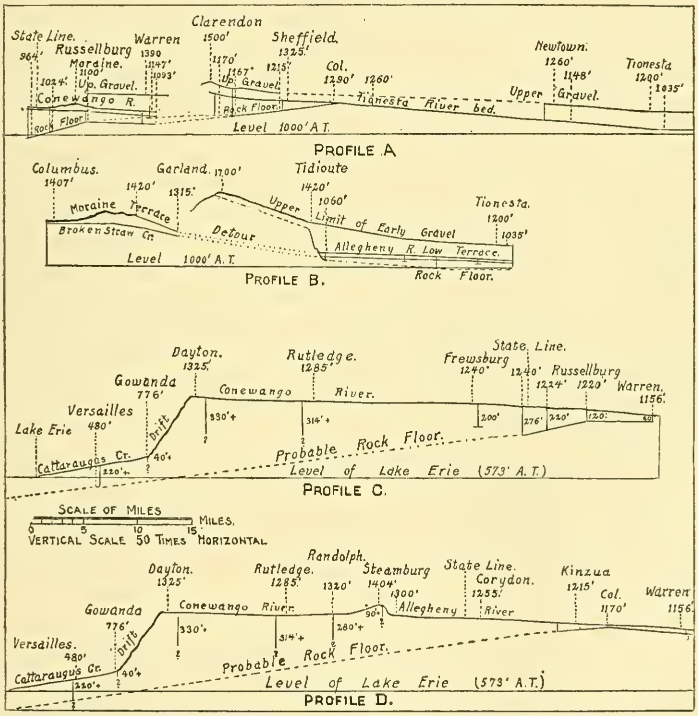


Figure 1. *Profile A* shows the erosion interval between the early glacial gravels and the late glacial or moraine-headed terrace in the Conewango valley and their altitudes compared with the head of the early glacial gravel train on the Tionesta at Clarendon. With the exception of the rook floor the fluvial planes on the Conewango and upper Tionesta belong to different drainage basins; the section is accordingly broken between Clarendon and Warren. The upper of the two broken lines connecting the rock floor at Clarendon with that near Warren was certainly reached by pre-glacial streams, and possibly the lower one. Else-

(Profile D, fig. 1). All but the last of these significant features were noted by Mr. Carll. Having no opportunity to examine the upper Conewango and Cattaraugus valleys he suggested an outlet by the way of the Cassadaga valley. In favor of the route here given we note (1) the greater width of the Conewango valley (two miles or more), (2) its more direct course to the lake basin (see accompanying map), and (3) the presence of a much deeper buried channel. Three wells along it penetrate drift to depths of 284, 314, and 330 feet respectively without reaching rock, while a fourth at Versailles, seven miles from the lake, penetrates to a point 95 feet below the lake level (aneroid) without reaching rock bottom, whereas on the Cassadaga line the rock floor opens out to the Lake Erie basin at an altitude of about 200 feet above the lake.

The general configuration of the drainage features of the region support this view of reversal as may be seen in part by consulting the accompanying map of restored drainage (map 2). The naturalness of this restored system lends support to the more positive evidence.

We note in passing that on this line as well as other pre-glacial drainage lines of this region the northward slope of the rock floor is probably somewhat accentuated by a northward differential depression. We would also note that rock excavation by an interglacial stream may have occurred along this line in the vicinity of the lake basin, it being not improbable that an interglacial stream would have had its source somewhat south of the present divide, which is a moraine of late glacial age. Both factors need to be eliminated in determining the rate of slope of the rock floor of pre-glacial times. The present rate seems too great for the nature of the valley. It may also be necessary to make allowance for excavation by ice or by subglacial water in the portion of the valley within the glacial boundary, but such excavation could not have occurred in the portion of the valley with north-sloping floor that lies outside the glacial boundary, i. e. between Kinzua and Steamburg.

where on this and the three profiles subjoined, broken lines indicate not *alternative* but *probable* positions of the fluvial planes or deposits to which they apply.

Profile B shows the erosion interval between the early glacial gravel and the moraine-headed terrace on the Allegheny near Tidioute, Pennsylvania, together with the head of the early gravel train on Tidioute creek and the later gravel on Brokenstraw creek. The Brokenstraw makes a detour to the east to join the Allegheny. The detour is indicated by dotted lines, and the section is broken at Garland where the stream turns eastward.

Profile C shows evidences of reversal of drainage on the Conewango valley. On this and the succeeding profile the vertical lines beneath the line of the present stream show the depth to which wells have reached. If no rock was encountered the sign (?) is introduced.

Profile D shows the evidence for reversal from the Kinzua col northward along the course of the old outlet.

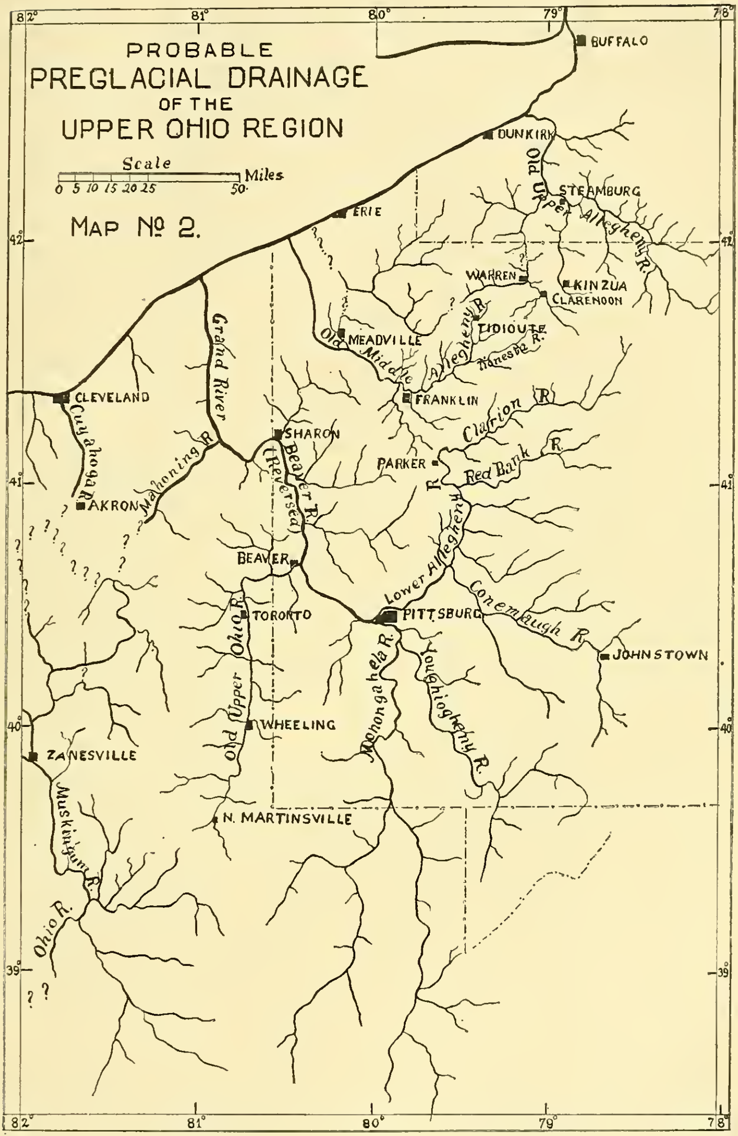
The Upper Tionesta-Conewango Basin. — Mr. Carll also called attention to the evidence of reversal of drainage in the Tionesta and Conewango basins, which are connected with the present Allegheny at Warren below the old col near Kinzua. There is evidence here of the same decisive nature as that cited for the upper section of the Allegheny. The abandoned northward outlet of the upper Tionesta leading to the present Allegheny near Warren is very plainly outlined, and the numerous oil wells of the region show that the rock floor of the abandoned channel slopes northward. The old col where reversal took place is readily located near Old Sheffield (Barnsville P. O.), where the stream enters a narrow gorge scarcely one-fifth the width of the abandoned channel, the latter being 60 to 120 rods wide while the new gorge is but 10 to 15 rods.

That the upper Tionesta-Conewango basin did not discharge southward along the present course of the Allegheny seems evident from a constriction of the valley which sets in near Thompson's station, about twelve miles below Warren, as indicated by Mr. Carll who located the old col at that point. The narrowness of the Allegheny at Thompson's as well as for some miles below, is in striking contrast with the portion of the Allegheny valley between Thompson's and Warren, and also that of the main tributaries (the Brokenstraw and Conewango), the width being scarcely one-third of a mile while the width of the valleys named is nearly a mile. In both situations the bluffs are mainly of soft easily erodible strata, the hard subcarboniferous conglomerate which farther down the Allegheny is an important factor in the valley bluffs being present here only in the highest parts of the bordering upland. Evidence of reversal is also shown by the valleys of small side streams. Below the supposed col these have not been so broadly opened to the level of the Allegheny as they have above and the streams descend near their mouths through narrow trenches fully 100 feet in depth. It would appear, therefore, that the col could not have stood less than 100 feet above the present river bed at Thompson's, or 1220 feet A. T. This view is confirmed by remnants of the old rock floor preserved in an occasional rock shelf beneath early glacial gravels. At Tidioute, some eight miles below the supposed col, the lowest discovered limit of erosion prior to the deposition of these gravels is about seventy feet above the present stream, whereas at Warren, fifteen miles above the col, the erosion seems to have reached a level even lower than that of the present stream.

It is probable that the line of discharge was through the Conewango (reversed), though a deeply filled broad valley connecting Brokenstraw creek with Oil creek along the line of

the Dunkirk, Allegheny Valley and Pittsburg railway between Garland and Titusville, Pennsylvania, raises the question whether the discharge may not have been in that direction.

By reference to profiles A and C, fig. 1, it will be seen that the rock floor is nearly level for a few miles north from Warren, while both to the north and south from this there is a



decided northward descent. This singular feature may perhaps be due to a recession of the Thompson col through valley excavation, as suggested by Mr. Carll (Penn. Second Geol. Survey, Rept. IIII, p. 311), and the formation of a pseudo col north of Warren at a point where excavation and consequent recession were interrupted by a later filling of glacial gravel. An apparent objection to this is found in the fact that there is no appreciable decline in the rock floor from Warren to the Thompson col. This level condition, however, may perhaps find its explanation in northward differential depression of a floor once sloping southward with a low gradient. In profile A, a broken line is introduced which has, at Warren, the altitude of the lowest rock shelf *covered by early gravel* and which perhaps represents the limit of preglacial erosion. This line would give to the rock floor a continuous northward descent.

The course of discharge was probably through the Conewango-Cattaraugus outlet of the upper section of the Allegheny, for there seems to be no direct northward outlet to Lake Erie from either the Chautauqua or Cassadaga valleys so deep as the Conewango-Cattaraugus outlet.

The Oil Creek Basin.—We need refer but briefly to this basin since it does not involve a section of the Allegheny but only a tributary, and since the evidence of reversal has been fully presented by Mr. Carll. The greater part of this basin drained northwestward through Muddy creek to the French creek valley near Cambridge, Pennsylvania. There is some uncertainty as to the course of the outlet from Cambridge, the data being insufficient to show whether it was direct to the Lake Erie basin along the deeply filled Conneautee creek valley or indirect along French creek valley past Meadville to the Conneaut outlet and thence northwest past Conneaut lake and through Conneaut creek valley to the lake basin. Mr. Carll thought it had the latter course because of doubt as to the existence of a deep channel connecting Conneautee and Elk creek valleys. That region is, however, so thickly covered with drift that there is no certainty as yet that a deep channel does not cross it. Furthermore there seem to be objections to the view that the old stream followed down French creek, there being a series of island-like hills in the midst of the valley below Venango, midway between Cambridge and Meadville. These suggest the possibility of an old col there. A decision cannot be reached until each valley is more thoroughly tested by borings.

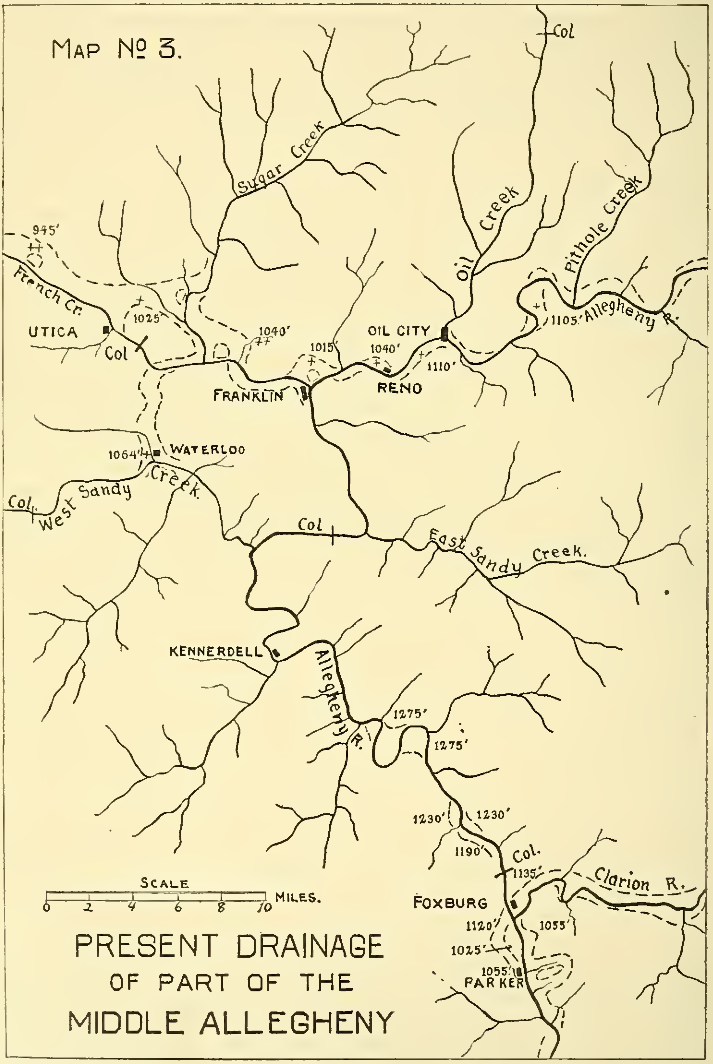
The Middle Allegheny Basin.—This basin includes the lower portion of the Tionesta (below the old col near Barnsville P. O.), the Allegheny from the old col at Thompson's to near the mouth of the Clarion, and the lower part of French creek. Several lines of evidence unite in indicating that this district formerly discharged northwestward past Conneaut lake to the Lake Erie basin. Evidence in favor of the reversal is found in the narrowness of the Allegheny valley above the mouth of the Clarion as compared with the Clarion-Lower Allegheny valley. Evidence is also found in an elevated watershed which crosses the Allegheny immediately above the mouth of the Clarion. Further evidence is found in the rock shelves or old rock floors of the Allegheny and French creek valleys.

Taking up these lines of evidence in the order named, attention may be called to the presence of a broad base-plane or gradation-plane* a mile or more in average width which follows the lower Allegheny, standing about 200 feet above the present stream.† This broad gradation-plane follows up the Clarion but does not extend up the Allegheny above the mouth of the Clarion, the Allegheny having a narrow valley with precipitous bluffs reaching a height of nearly 400 feet above the stream. It seems necessary to suppose either that a disproportionately small gradation-plane with high cliff borders lay in this narrow gorge (having a breadth only one-third to one-half that of the Clarion and Allegheny gradation-plane), or that there has been a reversal of drainage by which a small stream that formerly flowed northwestward through this gorge to join the French creek outlet was reversed and its valley recut to fit the new and larger stream. We naturally look to differences in the hardness of strata for a possible explanation of the difference in the size of the valleys. On the supposition that there has been but little enlargement of the preglacial Allegheny through additions due to glacial agency we must explain the fact that a stream not less than three times as large as the Clarion excavated a valley only one-third to one-half as great. If the ice caused the addition of the two upper sections of the Allegheny, and not of the section under discussion, we must account for the fact that a drainage area about the size of that of the Clarion cut a valley but one-third to one-half as great. The strata along the narrow portions of the Allegheny from Franklin to the mouth of the Clarion, as well as for some distance above Franklin, are on the whole rather more resistant than are those in which the gradation-plane of the lower course of the Clarion was carved, there being in the former a considerable thickness of the subcarbon-

*For use of terms see Physiography in the University, W. M. Davis, Jour. of Geol., vol. ii, No. 1, p. 77. A *degradation* plane or profile (fluvial), results from erosion in excess of deposition, and is the common type. An *aggradation* plane or profile (Salisbury) results from deposition in excess of erosion, the plane being built up. A *graded* or *gradation* plane or profile (Gilbert), results from a balance between erosion and deposition, the work of the stream being expended in widening its valley. This is equivalent to a plane or profile of *equilibrium* (Davis), and to a rather strained application of *base-level* or *base-plane* (Powell). It is advocated by Gilbert and Davis because it avoids this strained use, is measurably convenient, and falls in with the preceding terms to form a symmetrical series.

† Bull. U. S. Geol. Survey, No. 58, 1890, pp. 22–24.

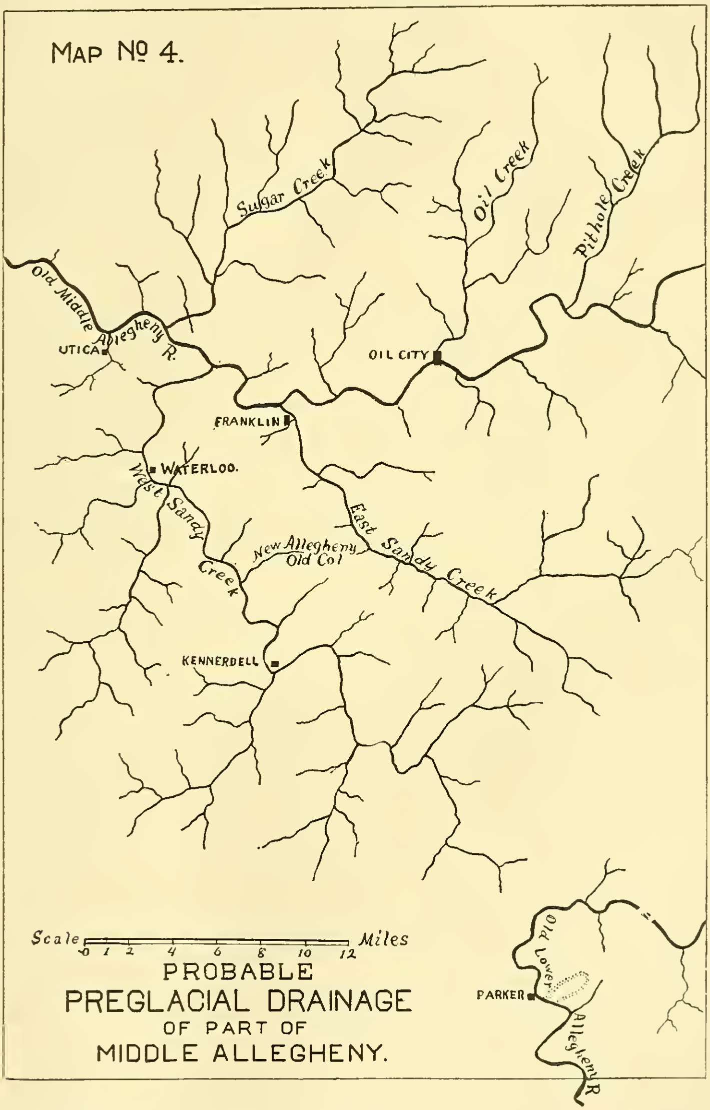
iferous conglomerate (in places reaching as much as 75 feet), while on the latter there are more easily erodible coal-measure sandstones and shales. This greater hardness and resistance to erosion would naturally lessen the size of the valley. It



MAP No 3.

PRESENT DRAINAGE OF PART OF THE MIDDLE ALLEGHENY

should also influence the gradient of the stream if it is an important factor. We turn, therefore, to the latter for light upon this question. In the portion of the Allegheny where the hard subcarboniferous conglomerate appears, that is, from Cobham near the Thompson col to the Brady bend below the mouth of the Clarion, a distance of about 100 miles, the rock floor descends 2·7 feet per mile, fluctuating between 6·85 for a



few miles below Cobham, near where the stream is supposed to have taken its rise, to ·95 in the 18 miles immediately above

Franklin, where the stream is supposed to have been largest. In the portion between Franklin and the mouth of the Clarion the average fall is 2·6 feet, of which the greatest fall appears between Franklin and Kennerdell where a col is supposed to have been crossed (the fall there being 4·3 feet, while between Kennerdell and the mouth of the Clarion it is less than 1·4 feet). Passing now to the portion of the Allegheny between the Brady bend and Pittsburg, where excavation was in the softer strata, there is, in a distance of 70 miles, an average fall of about 2·3 feet per mile, or about ·4 feet less than in the portion where erosion was in the harder strata. The effect of rock resistance would seem, therefore, to be scarcely appreciable when measured by this method and hence inadequate to account for the disparity in the size of the valleys under discussion.

Furthermore, it is significant that the tributaries of the portion of the Allegheny above the mouth of the Clarion had not deepened their channels to levels in harmony with a gradation-plane as low as that of the Clarion. While they have normal gradients on their upper and middle courses, they descend by rapids and cascades to the present Allegheny. This is done from a height of about 400 feet, while the tributaries of the Clarion descend in this way from only about 200 feet. This seems to indicate that they have discharged until recently into a stream which had not reached so low a plane as that of the Clarion.

Turning now to the bordering uplands, we find a second line of evidence favoring reversal. Immediately above the junction with the Clarion, the Allegheny cuts through an elevated tract which to the eastward constitutes the divide between waters flowing north and northwest into the Allegheny and those flowing south into the Clarion, while, to the westward, it constitutes the divide between the northward and eastward flowing tributaries of the Allegheny, and the streams flowing south and west to the Beaver and Shenango (see map 4). The high divide is broken by only a narrow gap scarcely a half mile wide and 500 to 600 feet in depth where crossed by the Allegheny. The altitude and relief of this divide appears to be due to its relation to drainage systems rather than to axes of upheaval for its trend is in large part independent of such axes. That is to say, it constitutes a natural boundary between the middle Allegheny and the Clarion-Lower Allegheny drainage basins.

Before passing to the third line of evidence in support of reversal we should note that the portion of the present Allegheny between the supposed col at the mouth of the Clarion and the French creek outlet appears to have been made from portions of two streams each flowing northwestward but separated by a divide below the mouth of the East Sandy creek. This view is supported, not only by a notable constriction there (to a width of scarcely 60 rods), but also by an abandoned valley leading northward from the bend of West Sandy creek at Waterloo to French creek valley just above the mouth of Sugar creek, which would afford a northward outlet for the western stream. The relationships of the present streams to this abandoned valley and to the supposed col may be seen by a comparison of maps 3 and 4. This comparison will also serve to show how natural the restored system is as compared with the disturbed and unnatural present system.

Turning next to the line of evidence found in the rock shelves and terraces, a general inspection of the French creek valley shows that there has been broader and deeper excavation than on the middle Allegheny. But inasmuch as the French creek valley lies within the glacial boundary, and its lower course nearly coincides with the direction of the ice flow, the question is naturally raised whether its greater size may not be due in the main to glacial excavation. An examination of the valley with this question in mind led to the discovery of old channels and ox-bow curves of pre glacial streams whose preservation is so complete as to furnish decisive evidence that glacial excavation has been of little consequence in determining the size of the valley.

On the stream which, as indicated above, seems to have led northward from the highland tract near the mouth of the Clarion past Waterloo to the present French creek valley, there are remnants of an old valley floor near the supposed divide at an altitude of 375–400 feet above the river, or 1275–1300 A. T., while at Waterloo in the abandoned valley which leads from Sandy creek northward to French creek, the rock floor is shown by several oil wells to have an altitude about 1060 feet A. T. This valley is filled with glacial gravel, apparently of early glacial age, and its rock floor has not suffered excavation since the gravel deposition. Its rock floor is the probable continuation of the elevated rock floor of the head waters and indicates a decline of somewhat more than 200 feet in 18–20 miles. This rate of fall would be natural in such a small stream descending from the elevated tableland and differs but little from the rate of fall in southern tributaries of the upper Allegheny of corresponding size, e. g., the fall on the Tuna, a similar stream, from De Golier, Pennsylvania, to the mouth of the stream, a distance of 14 miles, is 215 feet. (See Carll, Penn. Rept. III, p. 334.) At the north end of the abandoned valley, where it opens into French creek, rock shelves appear at an altitude of about 1040 feet A. T., which seem to mark the continuation of the old valley floor.

Turning now to the main stream of the supposed old middle Allegheny, we find that the col at Thompson's seems to have had a height of at least 1220 feet A. T. At Tidioute, eight miles below, early glacial gravels rest on a rock shelf (that represents the old river bottom), at 1160 feet A. T. At Reno, a similar shelf stands only 1040 feet A. T., while at Franklin, in an ox-bow filled with early glacial gravel, one boring reached rock at 1040 feet A. T., while another penetrated to 1015 feet A. T. without reaching rock. The gravel at these points rises to a level much above that of the terraces connected with the moraine of the later ice invasion and sustains such relations as to show clearly that it has suffered no disturbance since deposition. The shelves, therefore, antedate the gravel, and are remnants of an old river bottom. Following along the supposed outlet to the westward, there is an old meandering valley lying near the present French creek and, in part, coinciding with it. (See map 3.) On a small eastern tributary of this old valley three miles northwest of Franklin, wells, situated a mile or more back from the junction of the tributary with the old valley, strike a rock floor at about 1040 feet A. T., which is about as low as the rock floor found in one of the wells in the Franklin ox-bow, and is within 25 feet of the bottom of the other. These wells penetrate about 100 feet of drift of *early glacial age.* As they are back from the principal valley, the presumption is that the main channel is lower. Continuing northwestward along the valley to a point eight miles from the Allegheny, a well is found which reaches the rock floor at 1025 feet A. T., i. e., at a depth intermediate between the depths of the two wells in the abandoned ox-bow at Franklin. This well is situated near the southern edge of the valley, and can scarcely be supposed to have struck its deepest portion. Farther northwest, in an old ox-bow three miles north of Utica, similar in every way to the ox-bow at Franklin (see map 3), except that it lies within the limits of the later ice invasion, the floor is shown by one well to be 945 feet A. T. and by another 960 feet A. T., i. e., 70 feet and 55 feet, respectively, below the bottom of the lowest well in the Franklin ox-bow. Still farther northwestward on French creek at Cochranton, Buchanan, and Meadville, there are wells showing excavation to still greater depths; the first two not reaching the bottom at 915 and 800 feet A. T., respectively, and the last finding rock at 605 feet A. T. The depth of drift at this last point is not less than 475 feet, and the rock bottom is only 32 feet above Lake Erie. Meadville is only 28 miles from the Allegheny. To reach this depth on the present course of the Allegheny it must be followed 150 miles.

The evidence seems to us very strong that the ox-bow at Franklin, the old channel northeast of Utica, and the ox-bow north of Utica are remnants of the same old meandering stream leading northwesterly. The fact that the rock floor in the ox-bow north of Utica is 70 feet below the deepest determination of the old channel where it left the present Allegheny, renders it highly improbable, if not impossible, that it was formed by a stream discharging toward the Allegheny. It is even lower than the present rock bottom of the Allegheny, notwithstanding all the erosion the latter is believed to have suffered since the deposition of the early glacial gravels. It is highly probable, therefore, that we have, in these abandoned valleys, a continuation of the old middle Allegheny. An inspection of the general configuration of the old channel, as shown on map 3, will lend support to the force of these considerations.

A comparison of the old gradation-planes on the middle Allegheny with the like gradation-plane of the lower Allegheny at the mouth of the Clarion, brings out the significant fact that the rock bottom in the Franklin ox-bow stands about 40 feet *below* the rock bottom of the ox-bow above Parker, just below the mouth of the Clarion. *This is 40 miles distant down stream* (see fig. 4). If we compare the lowest point found on the old gradation-plane near Parker with the bottom of the deepest well in the Franklin ox-bow (which did not reach bottom), it is still 10 feet higher. If we compare their respective heights above the present river, the bottom of the Franklin ox-bow is not more than 35 feet, while that of Parker is 150 feet above the stream. Granting as probable that the old stream had a less fall than the present one, it still seems impracticable to refer the Franklin ox-bow and the gradation-planes and shelves associated with it, to the same stream that made those at and below the mouth of the Clarion at so much higher levels.

An additional point in evidence that the Allegheny has had its upper drainage basin enlarged by additions is found in a comparison of the size of the trench cut in the old fluvial floor of its lower course with that of the corresponding trench of the tributaries. For instance, on the Redbank river, which enters 22 miles below the Clarion, accurate data are obtainable, since the railway follows its valley for 70 miles and has a grade nearly coincident with the stream, and but a few feet (20–40) above it. The profile of this railway (see fig. 2), brings out the significant fact that the stream has a much more rapid fall in the lower 20 miles of its course than above that point, which is the reverse of the normal law of streams. The average fall for this 20 miles is nearly 12 feet per mile, while for the next 20 miles above, or even 50 miles above, the average fall is less than two-thirds of this. In the upper portion, the present floor of the stream nearly corresponds with an old floor. In the lower portion, this old floor continues on to the mouth with a rate of descent a little less than that of the upper portion, following the normal law. The later stream has here, however, cut down 145 feet below the old floor. But this lessens rapidly up stream, and at 20 miles above the mouth, it is reduced to about 60 feet.*

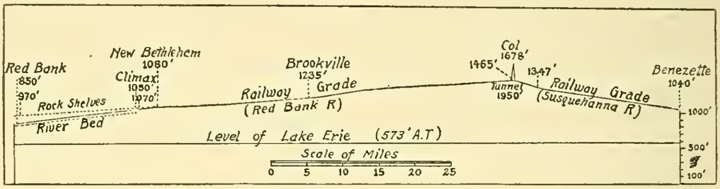


FIG. 2. Profile along a portion of the Low Grade Division of the Allegheny Valley Railway (so named because of the low altitude at which it crosses the Allegheny mountains). It serves to show the increase in the rate of fall of Redbank river in its lower 20 miles, a feature due to the deeper trenching of that portion. The profile also serves to show the extreme narrowness of the col which separates the Redbank and Susquehanna systems, the tunnel beneath the col being but 1950 feet in length.

It appears quite evident from these facts that there has been an abnormal deepening of the Allegheny since the formation of the old floor, and that this has been so recent that it has, as yet, only made itself seriously felt upon the gradient of the Redbank in its lower 20 miles. Such an abnormal deepening is accounted for by the sudden enlargement of the drainage area to several times its previous size in consequence of the diversions of drainage previously discussed. We do not think a simple change in the altitude, or in the general slope of the region, would produce a result of precisely this nature. The main stream, of course, usually leads in rejuvenated excavation, but not in such a disproportionate degree as this nor in precisely this method.

An objection to the northwestward outlet may perhaps seem to be presented by the deposits of gravel which occur along the Allegheny valley between the mouth of French creek and the mouth of the Clarion. In several places, notably at the bends of the river at Brandon, at a point two miles below Brandon, at Kennerdell, at Black's (Winter Hill station), and at Emlenton, there are deposits on the face of the gorge extending from near the river's edge up to heights of 200–300

* Compare statement of Prof. I. C. White respecting the relative altitude of water deposits on the upper and lower courses of the Conemaugh, Youghiogheny and Cheat rivers, this Journal, November, 1887, p. 378.

feet or more above the stream. The occurrence of this gravel at low levels cannot be accounted for by creeping or land slides, since, in some places, notably at Kennerdell and two miles below Brandon, the gravels show clearly by their situation and bedding that they have not been disturbed since the stream deposited them. We are not, however, reduced to the one interpretation that the valley had been opened to its present depth and had southward drainage before the beginning of the glacial period. These gravels are in every observed case situated on sloping points on the inner curves of sharp bends in the river. At such places a stream works outward as well as downward, there being erosion on the outer curve and liability to deposition on the inner curve. It is to be expected, therefore, on the hypothesis that the stream has greatly deepened its channel since the ice invasion, that such deposits should be present, and these deposits do not, we think, necessarily oppose the hypothesis of former northwestward drainage, nor that of great erosion since the beginning of the glacial period.

The Lower Allegheny-Monongahela-Upper Ohio Basin.—Dr. P. Max Foshay, taking up a suggestion of Dr. J. W. Spencer,* has brought out evidence in support of the hypothesis that the Lower Allegheny and Monongahela drainage basins, together with a considerable portion of the upper Ohio, formerly discharged through the Beaver, Mahoning, and Grand river valleys to the Lake Erie basin.† He first called attention to evidence furnished by the elevated base-plane, or gradation-plane (200–300 feet above the present beds). He noted the great breadth of this plane on the Beaver, its apparent northward slope and the occurrence on its rock surface of pot holes which appear to have been formed by a north-flowing stream. This gradation-plane was traced no farther than Wampum, some fifteen miles from the mouth of the Beaver, where glacial deposits become so thick as to make further tracing difficult, but it was thought by him to have followed a direct course along the Mahoning to the Grand river basin.

In the studies of the past season, an attempt was made to trace the old gradation-plane of the Beaver from the point where Dr. Foshay left it to the Grand river basin. It was found that the Mahoning route, which is the most direct one, was not a probable line of discharge since the valley, as indicated more fully below, is very narrow in the vicinity of the Ohio-Pennsylvania state line, and bears evidence of a reversal of drainage. Nothing was found to oppose the view that the

* Penn. Second Geol. Survey, QQQQ, 1881, pp. 385, 409.

† This Journal, Nov., 1890.

old stream may have followed the lower part of the Shenango in reverse as far north as Sharon, Pennsylvania (passing perhaps through an abandoned valley, which leads across from the Mahoning to the Shenango, between Edenburg and Harbor Bridge). From Sharon, it may have turned westward to the Mahoning river at Youngstown, through a lowland tract occupied by the Erie and the L. S. & M. S. railways, since at Hubbard, Ohio, situated in the midst of this lowland, the rock floor is found to be but 790 feet A. T., or about 100 feet lower than the rock surface of the gradation-plane on the Beaver, at Wampum (about 40 miles south). The valley is broader than that occupied by the Mahoning, a feature which lends support to this route in preference to the direct one through the latter valley suggested by Spencer and Foshay.

The slope of the uplands lends some support to the theory of northward discharge, there being a decline of about 200 feet between the mouth of the Beaver and Sharon, and an additional decline of 50 feet to the border of the Grand river basin (see profile B, fig. 3).

3.

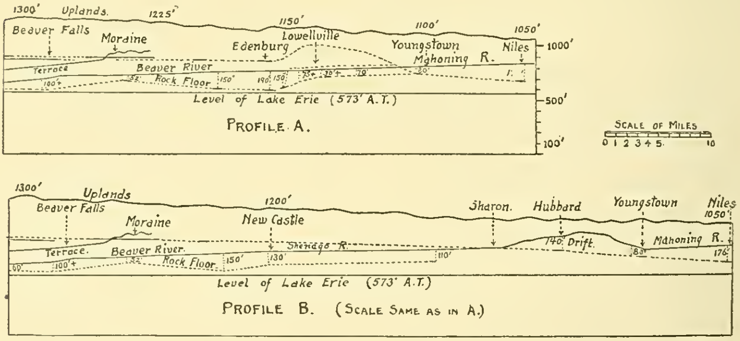


FIG. 3. *Profile A* shows the old gradation-plane, the buried channels, and the present drainage of the Mahoning-Beaver system, between Niles, Ohio, and Beaver, Pennsylvania, together with the old col at Lowellville. In this and in profile B well sections are represented by vertical lines beneath the line of the present stream.

Profile B shows the old gradation-plane, the buried channels, and the present drainage of the supposed old outlet of the upper Ohio between Beaver, Pennsylvania, and Niles, Ohio.

The hypothesis of northward drainage on the upper Ohio derives support from the narrowness of the portion of its present valley along that part of West Virginia known as the "Panhandle." The narrowness of this portion of the valley has been a matter of remark by nearly all glacialists who have traversed the region, the width being scarcely one-half as great as on the portion of the Ohio between Pittsburg and the mouth of the Beaver, or on the supposed outlet along the Beaver and lower Shenango. It is further supported by peculiarities in the drainage of the upper Ohio. Nearly all the tributaries entering the valley above New Martinsville, West Virginia, point northward, i. e. up stream, as the river now flows, while those below point down stream. The suggestion of an old water parting here occurred to the senior writer in a trip up the Ohio some years ago, and we learn that the same thought has occurred to Mr. Carll.

The junior writer gave some attention the past season to the high-level terraces between Wheeling, West Virginia, and the mouth of the Beaver. Many remnants of these terraces occur in recesses of the valley and on the lower courses of tributaries.

At first inspection the shelves do not seem to fall into obvious systems, and as our work on them is not yet complete we shall express no final judgment here. A preliminary study of the data, however, seems to throw the higher shelves into a very interesting and significant two-fold system.

Starting with the well developed high terraces at the mouth of the Beaver where the rock shelf is about 880 feet A. T. and the gravel terrace 935 feet, we find, six miles below, a rock shelf at 940 feet A. T. covered with early glacial gravel; another 12 miles farther down at East Liverpool, Ohio, at 950 feet; another at Wellsville, Ohio at about the same height; another shelf six miles below Wellsville at Tomlinson Run, at about 1000 feet (without glacial gravel); another north of New Cumberland, West Virginia (two miles farther), at about 985 feet covered with scattering pebbles, but no Canadian pebbles found; another at Toronto, Ohio (four miles farther south), has about 10 feet of glacial gravel on a shelf 950 feet A. T. plainly occupying the deepened portion of an old river bend. This is the farthest point to which the high level glacial gravels were traced. Although slightly higher than at the mouth of the Beaver they are 15 feet lower at Toronto than at Pittsburg, a feature which indicates that they have suffered reduction at Beaver. About five miles below Toronto, at Holliday Cove, West Virginia, there is an interesting branch of the deeper channel cutting off an island upland, as it were, which is filled with late glacial gravels. Across this island there passes an old channel of Harmon's creek (an eastern tributary), which stands at 350 feet above the river, or 990 feet A. T. Opposite Steubenville, Ohio (three miles below), a shelf stands at about 1000 feet; another on a western tributary at Mingo Junction, Ohio (two miles farther), at about the same height; another at Wellsburg, West Virginia (four miles below), is slightly higher (1005 feet A. T.). This is well developed along Buffalo creek and also north of its mouth. At Beech Bottom, West Virginia (three miles below Wellsburg), is a broad shelf at 935 feet; at Portland, Ohio (four miles farther), there are two notable shelves, the higher at 1085 feet and the lower at 950 feet; opposite Wheeling, West Virginia (eight miles below Portland), there is a notable terrace at 930 feet and another at 990 feet, while back of Wheeling a plain sweeps about the high hills at about 1100 feet.

Here there seems irregularity and want of system, but if the 930 feet terrace at Wheeling, the 950 feet terrace at Portland, and the 935 feet terrace at Beech Bottom be connected with the 950 feet terrace at Toronto where the glacial gravels cease, and these be interpreted as remnants of the trench cut across the old divide after the supposed reversal and while the gravels above were being accumulated, and if all the rest be interpreted as remnants of the floor of the old system running northward to join the lower Allegheny-Monongahela-Beaver system, the whole seems to fall into tolerable harmony. The terraces referred to the trench below Toronto are generally swept clean of debris and so accord with the hypothesis. The breadth of the corresponding gradation-plane at the mouths of tributaries seems larger than might be expected under this hypothesis unless we make the first glacial epoch long, and this is, perhaps, against the hypothesis. We leave the question open for the present.

Dr. Foshay also called attention to the low altitude of the present *rock floor* of the valley along the supposed outlet (there being oil well records showing lower rock bottom on the Mahoning than at the mouth of the Beaver), and he maintained that northward discharge was continued until the streams had reached this low level. In opposition to this view, it has since been determined by Mr. R. R. Hice that the rock floor does not have a regular descent northward from the mouth of the Beaver, but stands 60 to 70 feet higher in the gorge near the mouth of the Connoquennessing than at the mouth of the Beaver, and about 90 feet higher than at Edenburg, about 15 miles up stream. His data seem complete, as the piers of a railway bridge were built upon the rock floor and so distributed as to test the middle as well as borders of the valley. So far as collected, the data from well sections, both on the Mahoning and Shenango, oppose the view that the low rock floor near Edenburg was occupied by a stream which discharged into the Lake Erie basin (see sections A and B, fig. 3). The Mahoning, just above the very deeply excavated portion, has a narrow valley 80 to 100 rods wide, or scarcely one-half of its width where deeply excavated. From the borders of this narrow portion, tributary streams descend over cascades from levels of 100 to 200 feet above the river. A study of the old and the present rock floors on these tributaries leads us to locate an old col near Lowellville, Ohio, just west of the State line, the altitude of which appears to have been at least 1025 feet A. T. This has been trenched to a depth of about 200 feet, and has a width at bottom of from 80 to 100 rods in the narrowest portions. Within this narrow portion, there is a still narrower trench, in places restricted to the limits of the present river channel, a width of but 15 to 20 rods. (The greater part of the valley is floored with rock at a level 20 feet or so above the present stream, as shown in section A, fig. 3). In this inner trench, no borings have reached the depth of those near the mouth of the Mahoning before entering rock. Two borings, one at Hazleton and the other a mile east of Struthers, Ohio, enter rock at only 80 and 70 feet, respectively, below the present stream. These are 140 to 150 feet *above* the low rock floor, near Edenburg, only nine miles below Struthers. The inner very narrow trench is obviously a minor feature in the history of the valley. The main work, after reversal, was the cutting of a trench across the old divide about 200 feet deep and 80 to 100 rods wide in its narrowest parts. The most interesting feature of the lower part of the valley is the sudden descent it makes just above Edenburg. Here the buried floor falls 165 feet in a half mile, as shown by four wells.* The declivity may even be more precipitous as the wells are not so situated as to limit the space occupied in the descent more closely. A mile further down the stream, a well penetrates 200 feet of drift, about 190 feet being below the present river. Farther down stream, so far as there is evidence, the rock floor rises, and, in the Beaver gorge near the mouth of the Connoquennessing, is within 52 feet of the bottom of the present river, or 90 feet above the deepest portion near Edenburg. Profile A, fig. 3, shows this diagrammatically. This profile strongly suggests a fall or steep cascade at Edenburg with a pool below. And this suggestion falls in very happily with the indicated history of the region, which seems to be as follows:

Before the ice invasion forced the waters of the upper portion of the Grand river basin across the divide at Lowellville thereby forming the Mahoning river, a tributary about three miles long descended to the main valley now occupied by the Shenango-Beaver river (then probably occupied by the northward flowing Monongahela-Beaver system). This small tributary we think joined the main valley at the horizon of the upper terrace level. At any rate, the drainage of the three-mile valley would be quite incompetent to develop a deep pool.

* We are indebted to Mr. W. H. Raub of Edenburg for these data.

But when the waters of the upper Grand river basin were forced over the col in large volume and descended the steep slope of the little valley (from about 1025 feet A. T., to about 850 feet A. T., in three miles), deep scouring at the mouth would naturally result and the formation of cascades or falls would readily follow. These would work up stream as the erosion progressed. They appear to have reached a point just above Edenburg when a later incursion of the ice stopped the process and filled the deep valley with debris. After episodes that need not be noted here, the stream assumed its present horizon.

Passing by several minor features of interest, the phenomena seem to clearly point (1) to very notable erosion (200 to 250 feet), after the drainage was reversed by the ice, and (2) to the filling of the trench so cut 200 feet or more with drift by a later ice incursion, and (3) to only a very moderate erosion since this late filling. This valley which was cut after the early reversal bears on its sides morainic debris, and also at some points in the bottom of the stream. The stream has not here cut into the later drift to exceed 75 feet.

The profile along the Shenango river shows phenomena in harmony with these. Only that portion of the pool which lies below the junction of the two streams appears as a notable phenomenon. It shoals rapidly to the north as though the Shenango merely bevelled the up-stream edge of the Mahoning pool.

The formation of the pool was favored by the softness of the rock in this portion of the valley and the hardness of the Homewood sandstone near the mouth of the Connoquenessing.

This reference of the puzzling phenomena presented by the closed basin in the bottom of the Mahoning and Shenango valleys at their junction to the exceptional scouring action of the Mahoning consequent upon its precipitous descent from the Lowellville col when forced over it by the invading ice seems to fit the phenomena much better than previous hypotheses,* though the other hypotheses may find partial application here and more full application elsewhere in the region.

So far as these observations go, they are in consonance with the hypothesis of northward discharge advocated by Dr. Foshay, differing from it only in suggesting that the probable watershed may be some 50 miles further south on the Ohio, and in restricting the application of the hypothesis to the ele-

* The scouring of streams of ice, I. C. White. Second Penn. Geol. Survey, Q, p. 17, QQ. pp. 16–20, *Q3*, p. 20, *Q4*, pp. 37–38, and elsewhere in these reports. Ice and under-ice currents, J. F. Carll. Second Penn Geol. Survey, III, p. 362 (Footnote), IIII, pp. 234–5 (Footnote). Northward differential uplift, P. Max Foshay. This Journal, Nov., 1890. p. 400. Northward differential depression, ice, and subglacial waters, Frank Leverett. This Journal, Sept., 1891, pp. 208–9.

vated gradation-plane, or to the upper part of the trench within it. They seem to show that it is inapplicable to the lower part.

Other changes of drainage in the Ohio Basin.—Though beyond the field of this paper, we call attention, by way of suggestion, to possible changes of drainage in portions of the Ohio basin further west. The present divide between the Lake Erie and Ohio basins in eastern Ohio is apparently much farther north than the preglacial divide, there being a series of deeply filled valleys crossing the watershed and connecting with the Mahoning and Cuyahoga valleys. A well near this watershed, about six miles southwest of Akron, penetrated 400 feet of drift and struck rock not far from the level of the surface of Lake Erie, though distant 35 miles from the present shore of the lake. Several wells a few miles farther west, in the vicinity of Sterling, penetrate about as great an amount of drift and enter rock at the same low level. How much territory was thus drained to the Lake Erie basin has not been determined. The size of the Cuyahoga valley and of the upper part of the Mahoning warrants the presumption that it was a large territory. The relation of these drainage systems to the present watershed, and the lines of possible connection across the watershed, are shown, in part, on map 2.

We would also add that the small size of the lower Ohio valley is suggestive of great enlargement of drainage area within a recent period.

The suggestion has been entertained by several geologists, notably Professor J. F. James,* that the Ohio river formerly departed from its present course just above Cincinnati and followed Mill Creek valley to Hamilton, and thence the Great Miami valley to its junction with the present Ohio, and that it was forced from this course by the ice invasion, and caused to cut the trench which it now occupies at and below Cincinnati. This hypothesis is to be carefully distinguished from that of the Cincinnati ice dam, with which it is in ill accord since the Cincinnati trench could not have been dammed until it was formed, and, by hypothesis, it was only formed after the ice forced the river out of the Mill Creek channel.

It has long been known that the present channel of the Ohio, at Louisville, Kentucky, is recent. Its present location seems to be the result of valley filling during the later glacial stages.

Summary.—Summing up the preceding, it appears that the evidence is very strong that the two uppermost sections of the Allegheny basin, including also Oil Creek basin, formerly dis-

* Journal Cincinnati Soc. Nat. Hist., 1888, pp. 96–101.

charged northwesterly; that the evidence relative to the middle Allegheny makes it very probable that this also discharged northwesterly; that the evidence relative to the lower Allegheny and the upper section of the Ohio river also favors a northerly discharge, but is, as yet, too incomplete to justify a firm opinion.

Whether this weighing of the evidence is entirely correct or not, it is manifest that the preglacial erosion of these sections must be determined severally and independently if any safe conclusions are to be drawn. If they were separate basins, the depth of erosion of one does not determine that of the others, which were in no way perhaps directly connected with it. There would be a certain harmony, so far as like conditions prevailed, and the argument of analogy would have a proper application. In applying it, however, it is necessary to observe that the united sections were unlike in size, in direction, and in distance from the major basins into which they emptied. More particularly must it be noted that the united parts represent different fractions of their systems. Some are headwater sections, some body sections; and these have each their characteristic differences.

A few of the salient features of the old fluvial floors are all that space will permit here.

Old Fluvial Floors.

The old fluvial floor of the uppermost section finds its lowest point, on the line of the present Allegheny, at Steamburg, where it is about 1050 feet A. T. From this point, the old floor rises both up stream and down stream. Going up stream, the rock floor rises so as to become the bottom of the present stream only far up towards the head-waters, in Potter county, Pennsylvania. Going down stream, it rises so as to come near the surface at Kinzua, where the old col was cut across. The present floor here stands at about 1170 feet A. T. The old floor was considerably higher, but we have little data for an estimate of how much.

In the second of the united sections, we have, in the track of the Allegheny, only a short segment crossing the upper part of the old basin. The old floor appears to drop down from the old col at Kinzua to 1150 feet A. T., and possibly to 1100 feet, and then to rise toward the old col at Thompson's reaching about 1220 feet A. T., as well as we can estimate it,—possibly more. The lowest point of this segment, it will be seen, is 50–100 feet higher than the lowest point in the upper section. It is more than a hundred feet higher than the lowest point in the adjoining section to the south, and about 100 feet above the old floor at the mouth of the Clarion. It is, therefore, the highest of the united segments in the track of the Allegheny and most nearly coincides with the present river bed, which lies above the old floor in the upper section and below it in the lower sections, as we read the phenomena. On the middle Allegheny, or French Creek section, the old floor descends from the col at Thompson's to the ox-bow at Franklin where it stands at less than 1015 feet A. T. From this, the floor of the old east Sandy creek rises rapidly to the col between it and the west Sandy creek, where it descends rapidly to the latter, and then ascends it to the col near the mouth of the Clarion, which has an estimated altitude 1300 feet A. T. From this there was a rapid descent to the old well-developed floor at the mouth of the Clarion, at about 1050 feet A. T. Thence there is a long very gradual descent to Pittsburgh, and thence to the mouth of the Beaver, and probably onward northwesterly to the old Erie basin.

The above represent our interpretations, based upon present data, of the preglacial condition of the track selected by the Allegheny under the compulsion of the ice. It will doubtless require some modifications in detail, at least.

Into the small upper segments of the united basins, the glacial waters, issuing from the edge of the ice that here lay close to the track of the Allegheny, poured great quantities of glacial wash and filled them to irregular heights according to the volume of the feeding and the capacity of the valleys. The present stream, therefore, runs relatively high on these accumulations, and has not reached even the old floors in the axes of the two uppermost sections, if we interpret aright. But in the Lower Allegheny-Monongahela-Ohio section, we understand it to lie far below the old floor as has been urged elsewhere.*

4.

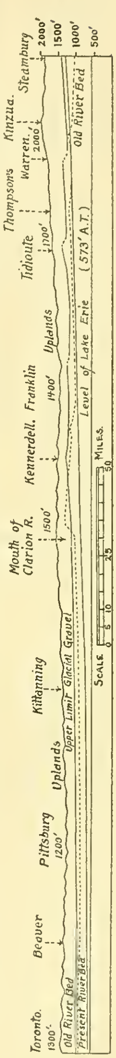


FIG. 4. Profile along the present Allegheny and Ohio rivers from Steamburg, New York, to Toronto, Ohio, representing the upper limit of glacial gravel, the gradation-planes, the cols and the present stream bed, also the general level of the uplands. The gradation-planes and cols are indicated by broken lines, the other planes by continuous lines. Attention is called to the building up of the glacial gravels to great heights at points where contributions were made from the ice sheet, and to the regular slope in the long stretch between the mouth of the Clarion and the mouth of the Beaver where no contributions of glacial gravel were made by tributary streams.

* H. M. Chance, Penn. Sec. Geol. Survey. Rept. VV, 1880, pp. 17–20. T. C. Chamberlin, U. S. Geol. Survey, Bull. 58, 1890, pp. 24–37.

Before pursuing the gravel depositions further, a word needs to be said about the glacial formations.

The Drift.

The general nature of the drift border of this region is so well known as to need but a passing word. It stretches along the northwestern rim of the present Allegheny basin, encroaching considerably upon it. It consists of two important factors, the more obtrusive of which is a group of terminal moraines that, to the southwest and northeast, deploy as separate and independent moraines, but are here so coalescent as to render their individual recognition difficult. It is helpful to bear in mind that we are not dealing with a single terminal moraine, but with a group, and that the more protruding moraine in one part is not necessarily the same as in another. We shall have, however, no occasion to dwell upon this distinction.

Outside of this group of terminal moraines, there is an attenuated drift whose thinness is probably due partly to original deposition and partly to subsequent wastage. To us, it seems demonstrably much older than the terminal moraines and the drift sheets back of them. *Associated with this attenuated drift, and springing from it, there are trains of gravel.* This important fact appears not to have been previously observed. Their connection with it seems to be essentially the same as that of the overwash and outwash drifts that are so common and significant dependencies of the distinct terminal moraines. These trains of gravel have, in several instances, been traced to their heads and found to connect themselves definitely with this attenuated border drift at levels much higher than the junction of the moraine-headed terraces with their drift sheets. For example, at the headwaters of Tidioute creek (some seven or eight miles north from the city of Tidioute), there is found a distinct overwash gravel deposit at the outer edge of the old drift at an altitude of 1700 feet A. T., while just above Tidioute in the Allegheny valley the early gravels attain a height of 1420 feet A. T., or 330 feet above the present level of the river. This great valley filling was probably from a tongue of ice thrust into the Allegheny below Irvineton as well as from contributions from the tributary, Tidioute creek.

On one of the headwaters of Pit Hole creek, at Pleasantville, similar gravels attain a depth of 80 feet and have an altitude of over 1600 feet A. T. Unassorted drift occurs in immediate connection with these up to a height of 1725 feet (see Carll, Penn. Rept. I, 1875). Similar gravels occur on the headwaters of West Hickory creek situated between the above streams. Occasional remnants of gravel deposits on the slopes of the lower courses of these valleys at heights of 200 feet or more above the present creek bottom, together with the fact of an open valley to the Allegheny, at least suggest the view, if they do not demonstrate it, that these gravel trains were connected with the upper terrace gravels of the Allegheny.

At Clarendon, there seems ground for believing that the old ice border sent a tongue into the mouth of the old Tionesta valley, since it left bowlders on the opposite side of the Allegheny at altitudes 300 feet higher, and the glacial waters built up, with an abrupt north border, the unusual thickness of glacial debris which constitutes the head of the gravel train that follows the modern Tionesta valley. The whole aspect of the deposit is that of a glacial gravel train heading on the edge of the ice. It has the extraordinary height (for a valley train), of 1500 feet A. T. We seem to have, therefore, in this, and in the phenomena on Tidioute, Pit Hole and Hickory creeks, four of the points of origin of the high-level gravel terraces about to be considered. They seem to constitute connecting links between the high terrace gravels and the attenuated drift.

Terraces.

From what has already been said respecting the drift border and reversals of drainage, the terrace systems, to which we now turn, would naturally be expected to present much complexity of detail, and yet show general systems corresponding to the leading drainage events and glacial incursions. It will, therefore, be convenient to consider the more pronounced systems of terraces and then give so much attention as time may permit to minor phases.

Whatever more there may be, an uppermost and lowermost series of gravel terraces are well characterized.

The Upper Gravel Terraces.—The upper series of terraces are well developed from the vicinity of Warren, Pennsylvania, to Toronto, Ohio, a distance of 250 miles. They are quite varying in altitude, and in the depth of gravel, on the upper stretches of the Allegheny, where their development was notably influenced by feeders from the adjacent edge of the ice; but in the portion of the valley outside of the immediate influence of the ice edge, the series developed into much regularity. The summit altitudes in the upper irregular portion reach from 1200 to 1500 feet A. T. In the lower and more regular portion, the summit heights reach about 1135 feet near the mouth of the Clarion, thence descending to about 950 feet in a distance of 140 miles. They have been traced down to Toronto, Ohio, where Canadian gravel occurs at the height last named.

The average thickness of the gravel in this more regular portion is found by combining ten excellent sections to be 83 feet; the maximum thickness being 110 feet and the minimum 55 feet. This is about double the thickness heretofore given by the senior writer.

Below this higher system, thin sheets of gravel occur on the slopes of the valley walls, which might be thought, perhaps, to extend the sections, but which we set aside for consideration later, as they do not seem to us to certainly belong to this series.

In the irregular portion, several points of special feeding are recognizable. At Steamburg, New York, the high terraces slope rather rapidly down the stream, the rate being ten feet per mile. They also slope downward in the opposite direction, i. e., up the stream. As this is also in the portion of the valley whose rock floor descends northward, the drift reaches the great depth of 400 feet. It thins out, however, to a few feet down the river near Kinzua.

Besides the great accumulations at Clarendon, already mentioned, there is another special thickening near Reno and Oil City where depths from 100 to 150 feet occur. These are probably referable to the near or immediate presence of the ice edge itself, for the occurrence of foreign drift on the highlands east of Brandon at 1400 feet A. T., suggests the probability that the ice edge crossed the river there and probably lay near it all the way between this point and Clarendon (see map 1).

Lower Terraces.—Passing for the moment over intermediate phenomena, we find low in the valleys a series of terraces which conform in general to the slope of the present stream, and usually do not rise more than 50 feet above it, though exceeding this at points of special feeding, as the mouth of the Beaver, where the unusual height of 130 feet is attained. Traced up stream, these terraces are found to head on the outer slopes of the system of terminal moraines before mentioned, at the points where these cross the respective tributaries. The terrace planes graduate into the overwash planes of the moraines and their material graduates into the morainic material itself in a perfectly clear and characteristic way, which leaves no room for doubt respecting their origin. This connection may be seen near Steamburg in the Cool Spring creek valley, near Russellburg on the Conewango, near Chandler's valley on Jackson Run, near Wrightsville on the Little Brokenstraw, near Horn's Siding on Big Brokenstraw, near

Hydetown on Oil Creek, near Coopertown on Sugar creek, near Utica on French creek, where, however, the connection is not very well displayed, near Raymilton on Sandy creek, above Homewood on Beaver creek, near Gallilee on Little Beaver creek, and near New Lisbon in another valley of the Little Beaver. Besides these twelve localities, at which the relationship of this low system of terraces to the moraines may be seen demonstratively, there are subordinate trains of gravel that make still more certain, if possible, the relationship.

All of these headings of the terraces are much lower than the upper terraces at points nearest to them. In the upper part of the basin, the higher terraces, even in the valleys, head 125 to 200 feet above the heads of the terraces of the lower system. If we compare with these the overwash trains on Tidioute and on Pit Hole creeks, which we interpret as being genetically the same. the difference in altitude is 350–400 feet (see section B, fig. 1). If we compare the head of the high-level gravels of Clarendon with the head of the low-level terrace at Russellburg, which is nearest to it and on the same ice-course, being only thirteen miles distant, the difference in the altitude is 210 feet (see section A, fig. 1). *From this it appears to us perfectly certain that the high-level terraces had no connection with the morainic overwash, but that, after the high-level gravel planes were formed, they were trenched to levels below the horizon of the lower terraces (presumably to the present rock bottom); otherwise, the lower terraces could not have been formed. The two systems are, therefore, separated in time by the interval required for this erosion.*

Thus far we think all careful students of the region must go with us, whatever they may think respecting the time required for the erosion, or regarding the kind of material removed.

Intermediate Phenomena.—The pronounced characters and the wide separation in time of the higher and lower systems of terraces being thus definitely determinate, we may turn to intermediate phenomena that may be less clear in their genesis and import. Between the base of the undisputed high-level gravels and the summit of the low-level systems, gravel is found at numerous points on the sides of the Allegheny trench. This gravel is commonly found on sloping points in the inner bends of the river and in other localities where, in cutting down its valley, the river would be likely to leave remnants of gravels, if they were there before, or would permit their lodgment in the process of sinking its bed, if not there before. Herein lies the radical difficulty of their interpretation. A winding stream, which is cutting down its bed at a moderate rate, tends to extend its meanders as well as deepen its floor, and so it cuts outwards as well as downwards on the convexities of its bed and is disposed to permit the lodgment of material on its concave side where the tendency of the stream is to recede. Now, the Allegheny during the whole progress of its descent from the level of the high terraces to its present position, was undoubtedly a gravel-bearing stream. It was not only engaged in the process of removal of the gravel along its own immediate course, but was receiving very much that was washed in from the drift region adjacent, so that a certain amount of lodgment of transported material may be assumed to have been inevitable. This is dependent upon the same principle of action that would permit the retention of gravels, in such situations, if they had been previously deposited within the trench. As the gravels on the slopes are usually thin sheets or patches, we have not found decisive evidence, in themselves, as to whether they are remnants of earlier gravels, or incidents of degradation. We have searched industriously for evidence that should be decisive on this point. Such evidence should be found in abandoned segments of the old valley, if it had been deeply excavated before the deposit of the gravels and had subsequently been filled by these up to the summit of high gravels. These high gravels fill ox-bows and recessed shelves, and the stream which deposited them had, in many instances, alternative courses. This is notably true in the vicinity of Pittsburg. Here the old high plane of rock was extensively covered by the waters that deposited the gravels, as is shown by the presence of remnants. There are, in the eastern part of the city, four islands surrounded by broad channel-ways, among which the waters distributed glacial gravels in greater or less degree. Now, if the present deep Allegheny and Monongahela trenches had been cut previously to the filling in of the gravels, there is only a small chance that, after the gravel-depositing period, during which they were flowing 50 feet or more above the rock plane, they would have descended the second time on precisely the same lines. Between the several broad channels open to them, the possible combinations are 32 in number, and hence theoretically the chances of a combination repeating itself are one in 32. If it be objected that certain of the courses are more favorably situated than others, our answer is, first, why were these others then ever produced by the streams or occupied by glacial wash, and our second answer is, that, if this be true of certain combinations, it does not seem to us to be at all true of many others.

Besides this, along the Allegheny river above, and also along the Ohio river between Pittsburg and Toronto, to which point the high gravels containing Canadian pebbles have been traced, there are perhaps a score of ox-bows, deep recesses, shelves, or available cols which would afford opportunities for the re-descending river to locate itself on other lines than its old track with all its meanders. When these possibilities are added to the preceding, it becomes exceedingly strange that, below the mouth of the Clarion, no abandoned channel is found which retains any old filling comparable in depth to the present trench. We find numerous old channels containing gravels ranging from 50 to a little over 100 feet that represent such old courses on the higher plane. This demonstrates the truthfulness of the principle here urged and shows its application to this particular field.

If any other proof of the tendency to take new courses in such situations were necessary, we might find it in the Rock River valley in Wisconsin, which was filled up south of the kettle moraine to a depth of from 350 to 400 feet with glacial wash. The stream twice within ten miles of the head of the filling cuts across rock spurs on the side of its old channel, and it makes a third cut within the next ten miles. On the Chippewa river, a similar number of rock cuts within a similar distance show the ready applicability of the principle. In these cases the old valley filling is retained in its integrity, and the fact of such filling is demonstrated.

So also in the middle Allegheny basin, along the line of drainage which we interpret as leading northwesterly to the Lake Erie basin, there are remnants of deeply filled abandoned channels; the present streams occupying, in part, newer rock cuts. At the mouth of the French creek, the old trenches reach within about 65 feet of the present rock floor of the Allegheny adjacent. The ox-bows and recesses retain here and there a full section of the old filling. These seem to us to emphasize the significance of the absence of similar sections reaching the bottom of the present valley below the mouth of the Clarion.

The strength of this negative evidence, in the lower Allegheny and the upper Ohio valley, is such that we are unprepared to accept the existence of thin sheets or patches of gravel on the slopes of the valley as establishing even a presumption that there was a trenching to anything like the present depth previous to the formation of the high terraces.

The improbability of the river re-establishing so completely its old course would not be applicable to a hypothesis which supposed the formation of the upper gravels on a high rock floor and the trenching of the valley afterwards to any depth below and a re-filling to a point *somewhat less* high than the summit of the earlier terrace plane for then it would be kept in its old course. Such an hypothesis would comport with two interglacial epochs, and if these remnants on the slopes are really residues of a re-filled valley, they would seem to point to such an interpretation.

Low Rock Shelves.—Along the lower Allegheny, there stand a number of rock shelves at about 75–100 feet above the present river. These are of some considerable extent, occasionally reaching to a quarter of a mile in breadth. While not all at a common horizon, they are sufficiently near to be fairly correlated. There is but little drift on these. They may mean merely an incident in the cutting down of the valley, or they may signify the termination of an epoch of degradation, followed by a notable halt or possibly a re-filling. We have found little to suggest whether or not they have much significance and so pass them for the present with simple mention.

Interpretations.

The foregoing outline falls far short of properly setting forth the facts, and yet our time is far spent. We nevertheless beg a few words respecting interpretations. There is not time, however, for the discussion of these, and we shall content ourselves with a simple statement of such hypotheses as seem to have any justification in the phenomena now known, and with some comparisons respecting their import.

To us it seems clear that all hypotheses that do not explain the phenomena by simple glacial and fluvial action (with incidental ponding), are excluded by the very characteristics of the deposits themselves. We have reason to believe that this view will be no longer seriously contested.

We are also clear in the conviction that no hypothesis of continuity can explain the phenomena. They seem to demand unequivocally important stages of deposition separated by important stages of excavation.

Of hypotheses which fall within these limits, there are three which postulate a single pair of depositions and of erosions, and a fourth which postulates a triple alternation. The first group fall into accord with the twofold division of the adjacent drift, the attenuated drift, and the moraine-bordered drift. The third conforms to the threefold division of the drift, which is found in western Ohio and beyond. For convenience we shall state these hypotheses as applied to the more regular part of the system below the mouth of the Clarion. The qualifications for the more irregular upper portion may be readily derived from what we have said respecting those portions.

Hypothesis I.—This hypothesis is based upon a minimum expenditure of dynamic action, though this is an after thought and not the parent of the hypothesis. By this we mean that the sum total of work done is the least that will apparently satisfy the phenomena, though more of the work is thrown within the limits of the glacial period than in the following hypotheses.

(1.) This hypothesis supposes that the Allegheny valley was cut down before the glacial period only to the observed base of the high-level sections of gravel, making such allowances for the incompleteness of observations as may be required.

(2.) The first known ice incursion, which reached the approximate limits at which thin drift and scattered bowlders are now found, gave origin to the high terrace gravels through its outflowing waters.

The amount of these gravels, even under this hypothesis, which minimizes them, seems extraordinary, when the thinness of the adjacent old drift is considered. This drift, however, has undoubtedly suffered large wastage as have the gravels themselves.

(3.) After the deposition of the gravels, the ice retired beyond the basin. So far as this problem is concerned, it matters little whether farther or not. Erosion followed, trenching the gravels not only, but the rock beneath to about the present depth.

(4.) Another ice invasion followed forming the adjacent terminal moraines and pouring its overwash gravels down through the trench previously cut, forming the lower gravel system.

(5.) Since the retreat of the ice beyond the limits of the basin, these gravels have been trenched by the present streams.

In this hypothesis, the amount of gravel deposition is minimized. The amount of interglacial erosion is made a maximum.

Hypothesis II.—This hypothesis supposes that (1) the river trenches of the region were cut to essentially their present depths before the glacial period, and (2) that, during the presence of the ice, the valleys were filled to the heights of the uppermost gravels—say 300 feet in round numbers. (3) Subsequently, these were trenched into nearly the present form. (4) Afterwards, the later incursion of the ice formed the adjacent terminal moraines and poured the overwash down the valleys forming the lower terrace planes. (5) These have since suffered trenching as postulated in the previous hypothesis.

This differs from the preceding hypothesis *in very greatly increasing the deposit of the first glacial epoch*, which we observed, even under the preceding hypothesis, was surprisingly large in comparison with the associated drift. It postulates the same volume of interglacial erosion, but this takes place in glacial gravels, instead of part gravels and part rock.

This last statement requires qualification, for, if the joining of the basins by the reversal of streams is true, then we must either suppose that the cols between these basins had been destroyed by the backward working of the stream (which would be likely to be true only in a case of approximate base-levelling), or we must suppose that the cols dividing these basins were trenched to a depth in rock equal to the rock cutting under the first hypothesis. The deep trenches of the Allegheny with their steep sides, show that the region was in the early stages of developing a new valley system, and that, therefore, the cols were presumably intact up to the heights of the old gradation-plane, at least, which, under this hypothesis, is referred to the Tertiary period. While this hypothesis escapes a large part of the rock cutting by referring it to preglacial times, it greatly magnifies the first glacial epoch. When we consider the limited area of the glaciated region between the edge of the drift and the descent to the Lake Erie valley (which limited the amount of inwash after the ice began to retire), we realize the import of this hypothesis. It means that some 300 feet of drift filled the valley for 250 miles at least, while the ice edge occupied the narrow belt between the glacial boundary and the basin of Lake Erie.

Hypothesis III.—This hypothesis postulates a limited amount of trenching of the old Tertiary gradation-plane before the ice reached the basin, the amount of this trenching being inferred from the size of buried trenches found in the bottoms of the upper Allegheny and Conewango basins, which, the theory assumes, were buried by the incoming ice without much modification and have failed to suffer any of moment since. The evidence of such trenches is rather meagre, but a small proportion of the wells in the broad valley of the Allegheny above the Kinzua col and in the Conewango and Brokenstraw valleys sink below the majority of wells to depths amounting to 75 to 100 feet. Wells not far distant from each other sometimes show this difference, from which it is inferred that the sides of the trench are abrupt. The fact that only a minor percentage, perhaps one in ten, of the wells in these basins enter this deeper portion, seems to indicate that it was only the beginning of a process of deeper erosion and had not progressed far. These trenches do not seem to be at all comparable to the trenches on the lower Allegheny below the gradation-plane. The hypothesis recognizes the fact that these northern preglacial streams could reach lower levels by shorter routes than the more southerly ones, even if the latter at length emptied into the Lake Erie basin, and that, therefore, the trenches found here are the greatest that legitimate interpretation could appeal to. Trenches in the lower section would probably be smaller.

Supposing such trenching to have taken place, the first invasion of the ice by its wash filled these lower trenches and covered the gradation-plane to the heights now indicated by the gravel sections previously given. After this, the sequence of events is the same as in the first hypothesis.

This hypothesis reduces the rock cutting, as compared with the first hypothesis, by the amount of this preglacial trench—say by the amount of 100 feet in depth and a part of the breadth of the valley. By so much as it reduces the interglacial rock cutting, it magnifies the work of the first glacial epoch because of the greater amount of filling.

We have had under consideration, in the field investigations, as one of our working hypotheses, a fourth interpretation. This was suggested partly by the phenomena themselves, and partly by the division of the old drift in southwestern Ohio and the region west into two parts, as before indicated.

Hypothesis IV.—This hypothesis presumes (1) a deposition of the high-level gravels in essentially the same way as in the first hypothesis, or possibly the third. (2) After this, there was a retreat of the ice and a period of erosion carrying the trench down to the lower rock shelves, which we have before described. (3) During the chief loess-depositing epoch, this was again filled up to heights as yet undetermined, perhaps to the base of the high level gravels, or possibly a little above, but not to the full height of these gravels, otherwise the river would not presumably have resumed a second time exactly its earlier course. (4) After the close of the loess-depositing epoch, a second stage of erosion carried away almost completely the valley deposits and cut the innermost trench down to essentially the present level. (5) Then followed the ice invasion which produced the adjacent moraines, and the late gravels, and after that, (6) the postglacial erosion, as in the preceding hypotheses.

We do not feel at liberty to make those geologists who have expressed opinions concerning the history of the region, responsible for any of these hypotheses, for they may not be formulated precisely in accord with their views.* We think however, that with minor modifications they embrace essentially all the types of hypotheses which the facts, at present known, warrant. We feel the more at liberty to leave the hypotheses to stand by themselves, without special connection with personal acceptance, since, in the limited space left us, we think it will be more profitable to discuss *their common import* than their differences and relative merits, for they all tell a common story respecting the main features of the history

* The first is the view advanced by the senior writer, in which he follows Mr. Chance in the main. Bul. 58, U. S. Geol. Survey.

of the region and the general acceptance of some one or another of them will, we feel, be very helpful in drawing interpretations of the Pleistocene history of other regions within the limits allowed by evidence.

Ratios of work done.—To better illustrate the import of these hypotheses, we may take, as a unit-measure of deposition, the amount of material poured into the Allegheny trench by the overwash and outwash from the ice while it was forming the adjacent terminal moraines and the drift connected with them, i. e. the last glacial epoch (of this region at least); and, as a unit-measure of erosion, we may take all the excavation which these moraine-headed gravels have suffered since their deposition. This last measures not only the work of postglacial time, but of all that part of the glacial period occupied in the retreat of the ice after it left the rim of the Allegheny basin, when erosion is presumed to have begun by virtue of the withdrawal of the depositing agency. For convenience we will speak of this simply as postglacial erosion.

Now, the amount of glacial filling contemporaneous with the formation of the moraines and the drift connected with them, assuming that the valley bottom was entirely free from other material, amounts to a section averaging 60 feet in depth and 2000 feet in width, as nearly as we can form a judgment from a considerable number of estimates and measurements.*

The amount of postglacial erosion, estimated liberally, may be represented by a section 30 feet deep and 2000 feet wide.*

Taking these as units, we present herewith a diagram (Figure 5) which, in the first column, shows the amount of

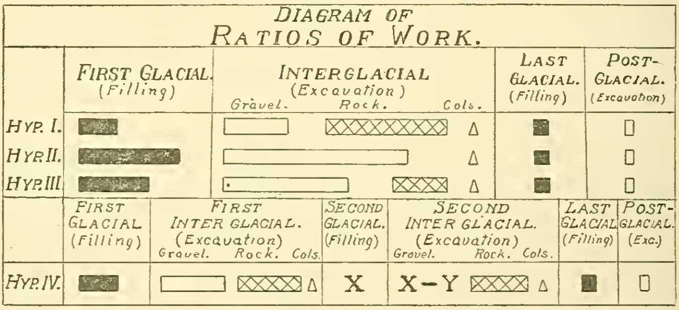


FIG. 5. . Ratios of work under each of the four hypotheses of glacial filling and excavation.

filling during the first ice incursion under each of the four hypotheses. This indicates at once the ratio of the first epoch to the last in terms of valley deposition. These ratios are of

* These are based upon the Allegheny section.

course subject to obvious qualification, yet nevertheless they are very helpful toward tangible ideas. The estimates are probably not very accurate but they are representative.

In the second column, there is shown the amount of excavation that took place between the deposit of the high gravels and of the low gravels, in terms of postglacial excavation. The relative importance of these interglacial excavations is strikingly manifest. They are represented by two symbols, the one indicating excavation in drift, the other, excavation in rock. The excavation of the cols, which is probably to be regarded as somewhat nearly the same in all cases, is merely indicated as a common factor. In the third column is indicated the valley deposition of the last glacial epoch, which is the unit of deposition, and alike in all cases, and in the fourth column, the postglacial excavation, which is the unit of excavation and alike in all cases.

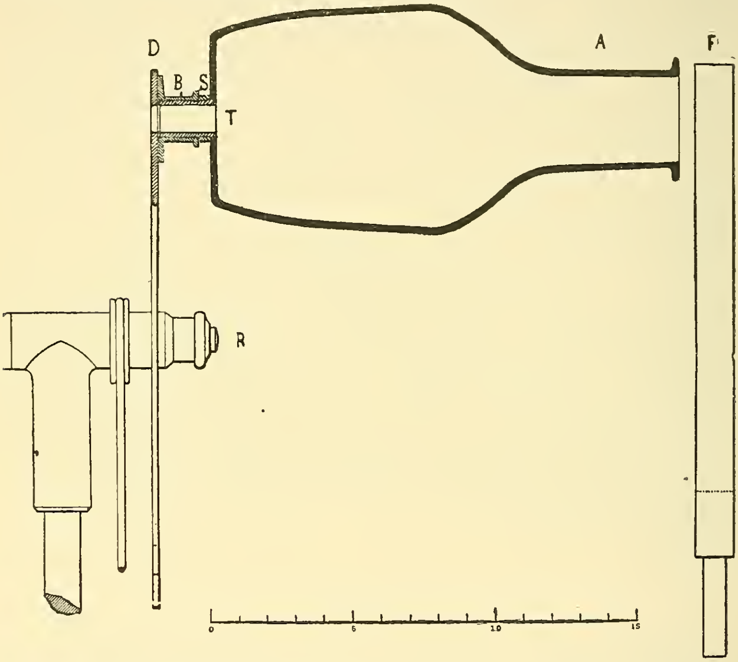
The import of all these hypotheses is alike on most of the vital points. They all greatly emphasize the importance and significance of the first glacial epoch. This is especially true of the second one. They all show very important intervening excavations when compared with the erosion that has taken place since the glacial period. This is especially true of the first and notably true of the third. They all indicate that, while the last glacial invasion was very much more pronounced in its apparent effects and in the expression it took on, it was, after all, much the smaller factor of the total accomplishment of the glacial period.

Art. XXV.—*An apparatus to show, simultaneously to several hearers, the blending of the sensations of interrupted tones;* by Alfred M. Mayer.

In the January number of this Journal, of the current year, I described several forms of apparatus used in my observations on the frequency of the interruptions of simple sounds required to blend these sounds and obtain from them continuous and uniform sonorous sensations. These experiments gave the data of the law connecting the pitch of a sound with the duration of its residual sensation.

The various apparatus described in that paper are, however, unsuited to exhibit the phenomena to more than one hearer at a time. To enable many hearers to observe simultaneously the phenomena I have devised the apparatus shown in the figure.

A brass tube, T, of $1{\cdot}25^{cms}$ interior diameter and $1{\cdot}8^{cms}$ long is cemented in a hole in the bottom of the glass flask, A; which is a common form of flask, used by chemists. When the tube, T, is closed the air in the flask resounds powerfully to the sound of an UT_3 fork, F; but when this tube is open the resonator resounds so feebly as to be just audible at the distance of several feet from the flask.



If the tube be closed and opened several times in a second we shall have short loud sounds with faint interposed sounds. The opening and closing of the tube is effected by a perforated disk, D, revolving on a rotator, R. The tube, T, is placed in the circular path of the 16 holes which perforate the disk, with the mouth of the tube quite close to surface of the disk. A short tube, B, with flanges on it, slides neatly over the tube, T, and the flange of B is pressed against the surface of the disk, D, by the helical spring, S. By this arrangement the tube, T, is fully opened when a hole in the disk coincides with the opening of the tube, T, and is entirely closed when the flange of B is between the holes in the disk and gently pressing against its surface.

On slowly rotating the disk, while the fork is kept in vibration by an electro-magnet, we have the perception of powerful beats which become more and more frequent as the velocity of rotation of the disk is increased till, with a certain velocity, the beats blend into a smooth continuous sound, which is that given by the fork when held near its proper resonator. This sound of UT_3 as given by the blending of its interrupted sound is, however, accompanied by another and graver sound; but the existence of this additional sound does not interfere with the neat perception of the blending of the interrupted sound of UT_3. With this apparatus the blending of interrupted sounds has been shown to the entire satisfaction of a large audience.

To enable one readily to make the apparatus the following dimensions are given. The diameter of opening of mouth of flask is 3^{cms}. Depth of flask $16{\cdot}25^{cms}$. Capacity of flask, including tube, T, is $483^{cub\ cms.}$

In the figure the rotator, R, is shown driven by a cord. It is necessary, if an accurate determination is to be made of the duration of the residual sensation, to drive the disk by gearing as is done in the apparatus I have used. When the disk is driven by a cord one can show the blending of interrupted sounds, but an accurate determination of the duration of the residual sensation is prevented by the friction which exists between the flange of B and the disk, though the surfaces of these are coated with a film of oil.

Art. XXVI.—*The Post-Eocene Formations of the Coastal Plain of Alabama;* by Eugene A. Smith, University of Alabama.

The succession of the Post-Eocene formations of the Coastal Plain of Alabama as brought out by the work of our Geological Survey, is in descending order, as follows:

Quaternary.

Recent and Pleistocene.

1. Soils, and rain wash, River alluvium, and Coast formations (Biloxi).
2. Mobile Bay formation, Second Terraces or Second Bottoms of the rivers, and the mantle of Ozark or Geneva sands.

Of undetermined Classification.

The Third, or Main River Terraces, and the Lafayette mantle of pebbles, sands, and loam. (The Lafayette is by some considered as Pre-glacial Pleistocene, by others as late Pliocene.)

Tertiary.

Miocene.

1. The Pascagoula, upper Miocene.
2. The Grand Gulf, lower Miocene.

Eocene.

The Biloxi.—Concerning the soils, rain wash and recent river alluvium, we need say nothing here, but the character of the coast deposits now in course of formation, has not heretofore been clearly defined. Mr. L. C. Johnson has recently given this subject some study and according to him, these deposits consist of alternations of sand and fine mud or clay to the depth of many feet. The agencies which have contributed to their accumulation are the waves from the Gulf, the minor rivers of Alabama and Mississippi, and the Mississippi River itself.

The washings of sand upon the coast, and the delivering of sediment by the minor streams are constant factors, but the contributions from the Mississippi are occasional, occurring only when in times of flood the river breaks through the levees and spreads over the lowlands on each side of the main channel. Mr. Johnson has shown how this river a few years ago, pouring its waters through the Nita Crevasse into Lake Ponchartrain and Mississippi Sound, covered the Coast sands with a varying thickness of its sediments as far east as the western border of Alabama and almost to the mouth of Mobile Bay, driving out the salt water fish and completely destroying the oysters and other molluscs which were unable to retreat. At Biloxi, borings for artesian water have given a section showing alternations of sand with mud or clay down to the depth of 80 feet or more, and from this locality Mr. Johnson has proposed the name Biloxi for the formation, the lower part of which is probably of Pleistocene age. The upper part of the Biloxi may hence be considered as the marine equivalent of our river alluvium, and the sediments now accumulating in Mobile Bay will form the estuarine connecting link between the two.

Second Terraces and Geneva Sands.—As the Biloxi borings show the gradual passage of these modern coast accumulations into what must be considered as the marine equivalent of the Port Hudson of the Mississippi River, and just as these Port Hudson equivalents are seen along the lowlands bordering the coast, so in Mobile Bay, beneath the sediments now accumulating, and along the western coast, notably on Mon Louis

Island,* we find the marine or estuarine equivalents of our river terraces, in an ancient deposit with imbedded shells, not of extinct species, it is true, but of species not now inhabiting the same localities.† As we come up the bay coast towards Mobile, we find this marine or estuarine deposit giving place to a blue clay with stumps and roots, underlying several feet of sands and yellow loam, thus assuming the characters of the river terraces.

The relations of the Quaternary formations of the Gulf States were first clearly defined by Dr. Hilgard,‡ from their exposures along the Mississippi River. In descending order they are as follows: Yellow loam, Loess, and Port Hudson. The first of these, the Yellow loam, is a fine grained siliceous clay with only a moderate percentage of lime, forming the soils over a large area especially in the northwestern part of Mississippi and the adjacent parts of Tennessee, where it may be seen for at least thirty miles from the river bluff. The Loess is a fine calcareous silt which has often been described, and which in this country seems to be confined to the immediate drainage area of the Mississippi River, and to be composed of materials of Glacial origin. It is strongly calcareous, effervesces with acids, and contains in addition a large amount of carbonate of lime in the form of concretions or "puppets." The loess, unlike the yellow loam, occupies a comparatively narrow belt along the river. The Port Hudson consists of sands with occasional gravel, alternating with greenish or bluish clays, which, especially in the lower parts, hold imbedded drift wood, roots, and stumps in most perfect state of preservation. These clays are like the loess, strongly calcareous and contain similar concretions of carbonate of lime. The present channel of the Mississippi lies in general in this stratum, which, tempered by the later deposits of the river, gives rise to the fertile "buckshot" and other soils of the alluvial plain.

The corresponding deposits along the larger rivers of Alabama constitute what are commonly known as the Second Bottoms or Second Terraces.

These are flat benches, usually not more than a mile in width, and are entirely above overflow except where locally lowered by erosion, and they therefore vary in height from fifty or sixty feet above low water mark along the northern edge of the coastal plain, to not more than ten or fifteen feet in

* On Mon Louis Island at the mouth of Mobile Bay, we find below the white coast sands, a bed containing oyster shells, and below that a blue clay with stumps and other vegetable remains, thus establishing a connection between the Biloxi of the Coast and the Second Terrace formations of the upper part of the Bay and of the rivers.

† D. W. Langdon, Jr., this Journal, vol. xl, p. 237.

‡ This Journal, vol. xlvii, Jan., 1869.

the lower courses of the rivers. In all cases they are only a few feet above the level of the first bottom, or present alluvial plain. The surface material of universal occurrence along these flats is a fine yellow loam several feet in thickness, which is everywhere an excellent "brick clay," and everywhere forms the basis of soils of more than ordinary fertility. For this reason we find most of the great plantations of former days located upon this terrace. The yellow surface loam is underlaid by ten feet or more of grayish sands, into which it gradually shades: near the base of the sands it is common to find pebbles. It is not very often that a fresh clean section can be observed down to the level of low water, because of *talus*, and deposits of recent river muds, but when such sections are exposed, they show below the gray sands a varying thickness of dark gray or blue clay filled with fragments of vegetable remains in the shape of drift wood, roots and stumps, in a state of preservation ranging from what can hardly be distinguished from fresh drift wood, to highly bituminized material. It is probable that this blue clay underlies all the second bottoms of our larger streams, though it is generally hidden by recent deposits. The subjoined sections from localities embracing the entire coastal plain, appear to justify this conclusion :

(*a*) At the site of old Fort Jackson, a few miles below Wetumpka, the Coosa and Tallapoosa Rivers approach within a quarter of a mile of each other, and a "cut-off" has been formed connecting the two channels. Here is shown a perfect section of the entire second bottom formation. Near the low water mark is the blue clay stratum filled with stumps, twigs, and roots, all in a remarkable state of preservation. The blue clay is covered by at least 25 feet of gray sands capped with the usual surface loam of the Second Bottom plain. If we should be disposed to consider the blue clay stratum as a recent river swamp deposit, and *only in appearance* below the sands and loam by reason of re surfacing or overplacement, this section extending entirely across the Second Bottom terrane which makes the plain between the two rivers, would leave no room for doubt as to the relative position of the constituent members above named.

(*b*) At McIntosh Bluff, on the Alabama River, about fifty miles north of Mobile, a similar dark gray or bluish clay filled with vegetable remains, may be seen below the yellow loam and sands; and wells sunk in any part of the second bottom plain there, pass through this blue clay stratum before reaching water in the sands which underlie it, usually less than thirty feet from the surface. From this it would seem that in some places at least, the blne clay forms a layer between sands.

(*c*) Along the western shore of Mobile Bay, just below Frascati, the storms of last October washed away long stretches of the bluff, and exposed the structure of the Mobile terrace in the most perfect way. A section of this shows below the recent surface sands, a yellowish loamy sand about five feet thick ; then a layer of transition material consisting of yellowish sands with lumps of gray clay one foot and a half ; then a layer of lignite from six to twelve inches, and below that down to the level of low tide, and possibly still lower, six feet or more of blue clay containing many stumps and limbs, or roots, bituminized on the outside, but of the nature of yellow rotten wood inside. The same blue clay is reached in wells at many points on the Mobile terrace, at a distance from the actual coast.* This is substantially the succession of strata that may be seen along both the great rivers tributary to Mobile Bay, as well as along the Chattahoochee.

Along the smaller streams emptying into these larger rivers and into the Gulf, the yellow loam and blue clay stratum are rarely, if ever, seen, and the entire second terrace consists of the gray sands mixed with pebbles in the lower parts. In the southern parts of the State generally, and especially in the southeastern, these gray sands form not only the second terraces of the creeks, but are also spread over the divides up to altitudes of 100 feet above tide. Where this is the case the streams rarely have swamps, but the pine-clad second-bottom sandy plain reaches to the very brink of the channel. The sands usually rest unconformably upon the red loam of the Lafayette, though sometimes when this has been removed by erosion, upon the underlying Tertiary formations. Along the Chattahoochee River, and probably along some parts of the Alabama also, these sands occur as a sort of upper second terrace, outside of and a few feet above the usual yellow loam terrace. The growth on the sand terrace is almost exclusively the long leaf pine, while on the true second terrace the growth is much more varied.

We have suggested the name of Ozark or Geneva sands for these beds, which seem to correspond very closely with what have been described by Mr. McGee in other States to the north of Alabama. Here as there they occur along the streams, in the lowlands, and over the divides, corresponding to the fluvial, low level, and interfluvial phases of the Columbia formation. In the lower part of Alabama, these beds lie as if spread upon an undulating surface, and in this respect resemble the Lafayette formation to be described below. They appear to have been deposited upon a gradually emerging sea bottom, the last

* Wherever penetrated in these wells the blue clay stratum is found to be underlaid by white sands.

stage of this emergence and a pause in it being recorded in the yellow surface loam of the Second Bottom of the larger streams.

If we compare these Pleistocene deposits of Alabama with those of the Mississippi River, we shall mark the following:

1st. The Port Hudson clay of the Mississippi finds its parallel in our blue clay stratum with its plant remains. The Port Hudson clay, however, is far richer in lime, effervesces with acids, and contains concretions of lime carbonate, something not yet observed in Alabama. 2d. The sands present no material points of difference in the two states: in both occur masses of pebbles, and both are found as second terraces. 3d. The loess is not found in Alabama. 4th. The yellow loam of Mississippi finds its counterpart in the uppermost layer of our second bottom; the published analyses of these loams, given in volumes V and VI of the Tenth Census Reports, show very closely similar chemical composition. The main difference is in its distribution in the two States, the yellow loam of Mississippi being spread over an area of thirty miles or more from the river bluff, while with us the area rarely exceeds a mile. The explanation of the variations in the character of the materials and the distribution of the Pleistocene of Mississippi and Alabama, is to be found, I think, in the following considerations: (*a*) Dr. Hilgard has shown that the axis of the Mississippi River has been the region of greatest oscillation in this part of the continent during Post-Eocene time, the aggregate of depression and elevation being 1200 feet.* A depression of 450 to 500 feet would allow the waters of the great river to spread beyond its banks as far as we now find the yellow loam. Moreover, the valley of the Mississippi beyond its alluvial plain, is much wider than the corresponding valleys of the Alabama rivers, and the same amount of depression would on this account cause the flooding of very unequal areas in the two cases. (*b*) The Mississippi drains a region which was once covered by glaciers, and its sediments naturally contain much material of Glacial origin. The loess is generally, in this country at least, admitted to be of this character, and the high percentage of carbonate of lime in the clay and its lime concretions, are probably due to the same cause. Our Alabama rivers had no glaciated areas to draw upon for their materials, and they have deposited no loess, no highly calcareous clays. (*c*) In both States, the second bottoms of the minor streams are, as a rule, sandy throughout, and lack the yellow loam capping. This at least seems to be the character of the second terraces of all the rivers of Mississippi that are tributary to the great river, while Pearl and Leaf Rivers that flow into the Gulf

* Hilgard, this Journal, vol. xliii, p. 399.

directly, have the yellow loam similar to that of the Alabama rivers. Perhaps the more rapid slope of these minor streams may have prevented the deposition of anything so light and fine grained as the yellow loam.

Mr. Johnson believes that he has traced the Port Hudson clays with their included roots and stumps, continuously along the Mississippi shores eastward to the Alabama line, where they form the basis of the Pine Meadows of Mississippi and of similar flats along the waters of the Escatawpa in Alabama. But between the waters of the Escatawpa and the Bay of Mobile, intervenes a great deposit of Lafayette extending as a high ridge down to within a few miles of the Gulf. The submarine prolongation of this probably interposes a barrier to the extension of the true Port Hudson beds quite up to the entrance of Mobile Bay. We should be inclined to retain the name Port Hudson for these Pleistocene formations in Alabama, but for the manifest differences in the origin of the materials in the two States, and for the break in their continuity along the Gulf coast; but that the Alabama Second Bottom deposits, from stump layer to yellow loam capping, are the equivalents in time of the Port Hudson, Loess, Yellow loam series of the Mississippi River, can, I think, hardly admit of doubt; nor is there much room for doubt that they are in the main, equivalent to the Columbia formation of Mr. W. J. McGee.

Third Terraces and the Lafayette.—Our larger rivers have a third terrace still more extensive and important than the second. It is upon this terrace, often three or four miles wide, that so many of our river towns are situated, e. g. Tuscaloosa, Coffeeville, Jackson, Claiborne, Selma, Montgomery, Girard (opposite Columbus, Ga.), and Columbia. The third terrace is from 75 to 100 feet above the second, and exhibits in its structure two sets of materials; a substratum of Cretaceous or Tertiary, and a mantle of pebbles, sand, and loam of much later date, which lies upon a deeply eroded surface of the older formations and varies correspondingly in thickness. The average on the terraces may be placed at about 15 feet, but where old hollows have been filled up, the thickness may be as much as sixty feet, as may be seen for instance, within the limits of the city of Tuscaloosa.

The capping mantle of the third terrace is in the quality and arrangement of the material, so far as I have been able to make it out, identical with the beds which under the name of Orange Sand or Lafayette are spread more or less continuously over the entire coastal plain of Alabama, Mississippi, and Georgia and probably of other States beyond, in thickness varying from a few feet near the inland margin of the coastal plain to more than 100 in the counties bordering the Gulf.

Thousands of observations in this and other States, show that the beds of Lafayette materials occur at elevations differing by two or three hundred feet in localities closely contiguous, precisely as if the deposits had been laid down mantle-wise upon a previously eroded surface, the main topographic features of which were at the time of deposition essentially what they now are. It seems almost necessary to consider the third terraces, either as marking the very latest episode in the deposition of the Lafayette, or as a result of its rearrangement and redistribution in times very much more recent than that of the first deposition on the heights, nor do I see how its present position on such different elevations, along slopes, and in general so closely conforming with the existing land relief can be explained except as due in some measure to rearrangement, and yet after many years of close examination of these deposits, I have been unable to discover any material difference between the Lafayette on the hill tops, the Lafayette on the slopes, and in the valleys, and the Lafayette upon the river terraces, whether in the material themselves, or in their relative positions, and for this reason all its phases are considered under one head.

In Mississippi at the typical locality, there are great accumulations of cross-bedded sands of this formation, that have few if any representatives in this State, where the great bulk of the Lafayette consists of rounded water-worn pebbles of quartz, chert, and quartzite, and rounded grains of iron-stained sand mixed with some red clay, and with a few small rounded pebbles of limonite. In the Chattahoochee drainage scales of mica are also abundant. Where all three of the principal constituents above named, pebbles, sands, and loam, occur together, as a rule the upper part of the formation is a very sandy red loam, while the pebbles are mostly to be found in the lower part. Where the pebbles are absent the surface is usually red loam, with the sands below, and in some places the whole formation is sand.

The pebbles sometimes contain markings or fossils which show that they are fragments of the siliceous rocks of the Sub-Carboniferous, Silurian and Cambrian and Crystalline formations, and in their distribution they are more localized than the other main constituents. They are most abundant and of larger size in two locations: 1, along the line of contact of the formations of the coastal plain with the Paleozoic terranes, i. e. along a belt 10 or 15 miles wide stretching from the northwestern corner of the state around in a curve to Columbus in Georgia. If, at the beginning of the Lafayette period, the whole coastal plain were submerged, and the waters of the Mississippi Gulf lapped up on the Paleozoic terrane, the pebbles, sands, etc., washed down into this Gulf would come to rest along this old coast line. 2. The other main pebble streams appear to follow the principal lines of drainage, not being confined, however, to the present narrow channels of the rivers, but occurring beyond the third terraces, on the slopes leading down toward these channels, often at a distance of 25 or 30 miles on each side, and sometimes over the divides. As if, upon the comparatively rapid emergence of the coastal plain from below sea level, the continuing currents from the land either carried new contributions of pebbles and other materials, or took up and redistributed those previously deposited along the coast line mentioned, down the wide shallow drainage valleys, and over the low divides. The third terraces may perhaps mark a pause in this upward movement occurring towards the close.

The two authors who have given this formation most study are Dr. Eugene W. Hilgard and Mr. W. J. McGee. The former refers the origin of his "Orange Sand" of the great Mississippi embayment, to a period of continental elevation, and the deposition of its materials essentially to fresh water in the form of broad shallow floods coming in from the northward and practically devoid of organic life of which the remains would be likely to be preserved.* On the other hand Mr. McGee accounts for the structure and disposition of the Lafayette materials upon the assumption of a submergence of the coastal plain below the waters of the Gulf and the invasion of the sea to the landward limit of this plain, accompanied by a warping of the land and a seaward tilting which stimulated the streams to greater activity both of erosion and transportation. The total absence from the formation of any traces of marine life finds its explanation by Mr. McGee in the comparative rapidity of the submergence and subsequent emergence of the coastal plain. Both authors assume continental elevation, or at least increased seaward slope of the areas beyond the coastal plain, while they differ in their ideas as to the position of the coastal plain during the time of accumulation of the deposits, the one requiring shallow submergence below sea level, the other assuming the flooding of this plain (above sea level) by fresh waters from the land. The wide distribution of these deposits over the whole coastal plain of the United States from the Potomac to the Rio Grande, with essentially the same characters of material and structure, favors the one view; while the peculiar structure of the deposits, the total absence of all sign of marine life, and of beach or coast mark-

* This Journal, vol. xliii, p. 394.

ings favor the other. On any theory yet offered, there are many phenomena difficult of explanation.

That the Lafayette-coated surfaces have suffered a great amount of denudation is everywhere plainly to be seen, and that the amount of this denudation increases with distance from the sea may, I think, also be shown. This would lead us to conclude that the deposition of the Lafayette extended over a long period of time, and that the landward margins of the area covered by it were being denuded while accumulation was still going on further to seaward. Thus, we find upon some of the hills of the Coal Measures in Alabama (Walker County) a good many miles northward from the main mass of the pebbles, etc., covering the junction of the Paleozoic and Cretaceous formations, occasional small remnants of the Lafayette in the form of thin beds of pebbles and sands, capping some of the highest summits, while all trace of this formation has disappeared from the adjacent valleys. Over the Cretaceous terranes there are many spots entirely bare of Lafayette, and the same is true of some of the lower members of the Eocene, but over the newer Eocene and the whole Miocene area the covering of Lafayette seems to be not only continuous, but also of greater thickness than over the older formations. Where it comes down within a mile or two of the coast, as in the divides of Mobile and Baldwin Counties, the thickness cannot be less than 100 feet and it may be more. Over the entire coastal plain the thickness cannot average more than 25 feet, if so much.

Concerning the age of the formation, we know certainly that it lies between the upper Miocene and those beds of undoubted Pleistocene age which we have described under the name of Second Terraces. If the phenomena of glaciation be taken as the criterion of the Pleistocene, then the Lafayette would have to be classed as Pre-Pleistocene, since yellow gravel beds, presumably of this age, have been traced up to and underneath the oldest of the Glacial deposits, and as yet the existence of materials of Glacial origin among the Lafayette beds seems not to be proven beyond question.

And further, the general appearance of the formation and the demonstrably great amount of erosion which it had suffered before the deposition of the undoubted Pleistocene beds, would lead us to conclude that a long period of time and important physical changes occurred between the accumulation of the Lafayette and of the Pleistocene deposits. On the other hand, the phenomena of the distribution of the Lafayette beds and their manner of accumulation, so utterly unlike those of any of the earlier Tertiary formations of the Gulf coast, make it difficult to fit the Layfayette into the Tertiary.

If the great amount of Post-Lafayette erosion should be counted a difficulty in the way of placing the Lafayette deposits in the same category with the Pleistocene, we should have the same difficulty in the equally great if not greater, amount of erosion between the Miocene and Lafayette.

While it must be admitted that the Glacial period stands by itself, sharply distinguished from anything which preceded it, and that Glacial deposits and their derivatives may be clearly distinguished from any other class of deposits, it must also be admitted that the Lafayette beds in their distribution and structure stand out as clearly distinct from anything that preceded them as do the Glacial deposits; they indicate equally great physical changes, and in many respects, especially in their relations to the underlying formations, more nearly resemble some of the Glacial deposits than they do anything else. Besides, the conditions necessary to glaciation could not have been reached instantly, there must have been physical changes that led up to it and made it possible, and it would seem to me not unreasonable to place these precedent deposits along with those due to the Glaciers themselves in the Quaternary.

Pascagoula and Grand Gulf.—Dr. Hilgard, in his Geology and Agriculture of Mississippi, gave the name Grand Gulf, to a great series of sandstones, mudstones, and clays, which in that state overlies the Vicksburg Eocene. These beds were practically destitute of organic remains except some obscure impressions of plants, and perhaps a shell or two, for which reason it has been impossible to fix the age of the formation more definitely than as post-Eocene Tertiary, and probably as Miocene. In 1889 Mr. L. C. Johnson, while examining the Grand Gulf of Mississippi, discovered near Vernal in Greene County, on or near the Pascagoula River, certain beds with marine or estuarine fossils which he at the time considered a part (the upper member) of the Grand Gulf, but so different as to deserve another name. He accordingly suggested the name *Pascagoula.*

In November, 1887, Mr. D. W. Langdon, Jr., under the auspices of the Alabama Geological Survey, made an examination of the banks of the Chattahoochee River from Columbus, Ga., to the Gulf, and discovered nine miles above River Junction (Chattahoochee), overlying the Vicksburg limestone and extending down the river as far as Alum Bluff, a series of marine Miocene beds, consisting of many feet of somewhat siliceous and argillaceous limestones overlaid by highly fossiliferous sands. The excellent state of preservation of the contained shells, renders easy and certain the identification of the geological age of these beds, which is Miocene, the limestone beds and the lowest of the fossil-bearing strata at Alum Bluff being lower Miocene (Chattahoochee and Chipola divisions), while the uppermost of the fossil beds at the bluff are considered as upper Miocene (Chesapeake). These discoveries soon attracted the attention of geologists and collectors, and other localities were speedily found where the lower shell bed of Alum Bluff was more easy of access and more prolific of well preserved specimens than at the Bluff itself. Such localities on Chipola River have furnished the name which is now commonly applied to these beds. Between these fossiliferous sands, which according to Mr. Dall, contain a certain number of Eocene shells, and the undoubted Vicksburg orbitoidal limestone, lie as above intimated, some two to three hundred feet of calcareous rocks, constituting the series to which Mr. Langdon has given the name Chattahoochee. Thus the existence of marine basal Miocene beds was established along or very near to the eastern border of Alabama.

Then in 1892, Mr. L. C. Johnson, working for our Alabama survey, discovered at Healing Springs in Washington County, immediately contiguous to the Vicksburg limestone, the characteristic gray siliceous mudstones splotched with purplish ferruginous stains, of the Grand Gulf formation.

These and other equally characteristic Grand Gulf rocks, dark gray clays, he followed eastward through the lower part of Monroe County and through Escambia to the Conecuh River, on the borders of which they are well exposed in the vicinity of Mason, always immediately adjacent on the south to the Vicksburg limestone. At Roberts on Silas Creek, a tributary of the Conecuh River, Mr. Johnson observed these characteristic and unmistakable Grand Gulf beds, underlying and in direct contact with sands containing shells which Mr. Dall has identified as belonging to the Chipola division of the Chattahoochee River series. And a few miles further south in Florida at Oak Grove, Mr. Johnson found a shell bed with excellently preserved forms which Mr. Dall identifies as of Chesapeake or upper Miocene age. The Pascagoula shells above alluded to, have also been classed with the Chesapeake, and borings from an artesian well at Mobile, have furnished a number of shells characteristic of the same period. We have thus certain evidence from our Alabama work, that the Grand Gulf occupies a place between the Vicksburg limestone and the Chipola division of the lower Miocene, being thus identical in position with the calcareous beds of Langdon's Chattahoochee section. Although the Grand Gulf rocks have not been followed farther eastward than the vicinity of the Conecuh River, being deeply covered by sands, it seems to us reasonably certain that the siliceous and argillaceous rocks that characterize this formation in the west, become calcareous eastward, and find their marine equivalents in the Chattahoochee of Landgon.

Art. XXVII.—*Variscite from Utah*; by R. L. Packard.

In December, 1893, a specimen of a beautiful green mineral was sent to Mr. Merrill, Curator of Geology in the U. S. National Museum, for identification by Mr. F. T. Millis of Lehi, Utah, who stated that it occurred in the form of "nuggets" in a quartz vein near Lewiston, Utah, some twenty miles west of Lehi. Upon a cursory examination the mineral was found to have the blowpipe characteristics of peganite, as given by Dana, but as this species has not heretofore been reported from the United States Mr. Merrill asked me to make an analysis of it. The result showed that the composition is the same as that of variscite, and is as follows:—

H_2O	22·95
P_2O_5	44·40
Al_2O_3 (by difference)	32·65

The other analyses of variscite are given by Dana as follows:—

	Voightland.	Arkansas.
H_2O	22·85	23·80
P_2O_5	44·05	44·35
Al_2O_3	31·25	31·85

while the callainite described by Damour gave

H_2O	23·67
P_2O_5	42·58
Al_2O_3	29·57

The mineral is compact or crypto-crystalline, and dull, not resembling the usual form of variscite in these respects. It flies to pieces before the blowpipe and turns a fine purple or lavender color. This is a characteristic of peganite but Chester remarked it in the case of variscite from Arkansas.* With cobalt it gives a blue color. The flame is tinged green by the phosphoric acid. It is insoluble in acids before heating, but afterwards dissolves readily in hot acids and alkalies. The solution in acid gives no color when a platinum wire is dipped in it and then held in the Bunsen flame. This solution gives no reaction when H_2S gas is allowed to pass through it for half an hour or more and the precipitate with ammonia and sulphide of ammonium is perfectly white. No manganese or chromium was detected by fusing portions of this precipitate with sodium carbonate and with soda *plus* chlorate of potassium respectively. In the large specimen sent to the Museum, the green mineral occurs in nodules separated from each other by

* This Journal, vol. xiii, 1877, p. 295.

banded envelopes of a yellow mineral between which and the green is a powdery white coating, the whole forming a large nodular mass nearly seven inches in its longest diameter. A partial analysis of the yellow mineral and the white powder which separates it from the green, gave for the yellow,

H_2O	16·89
P_2O_5	34·43

and for the white powder

H_2O	19·74
P_2O_5	37·43

showing a progression from yellow through white to the green. Both the white and yellow substances leave an insoluble residue which is larger in the yellow, and as the relation between the water and acid is about the same in all three cases it seemed probable that the three are practically the same mineral, the green being pure, the other two carrying an impurity. A thin section of the green mineral viewed by polarized light shows it to have a finely granular structure with an occasional spherulitic area. The grains do not present well defined crystallographic features but are irregular in outline, and of different sizes.

The banded mineral also shows a granular structure but the section is traversed by streaks of an opaque yellowish substance to which the prevailing yellow color of the bands is doubtless due. The specific gravity of the green mineral is 2·62 and its hardness about 4.

No information was furnished which would throw light on the question of the source or genesis of this mineral, of which the present appears to be the second publicly known occurrence in this country.

Washington, D. C., Jan. 25, 1894.

ART. XXVIII.—*The Appendages of the Pygidium of Triarthrus*; by CHARLES E. BEECHER. (With Plate VII.)

SINCE the previous publications in this Journal, on the antennæ and thoracic legs of *Triarthrus Becki*,* additional features have been worked out from the material in the Yale Museum, and it is now proposed to give the main characters of the appendages attached to the pygidium, or caudal shield. The structure of the under side of the head will next be de-

* Antennæ and other Appendages of Triarthrus Beckii; by W. D. Matthew. This Journal, August, 1893. On the Thoracic Legs of Triarthrus; by C. E. Beecher. This Journal, December, 1893.

scribed, after which it will be possible to review the present knowledge of *Triarthrus*, together with its bearings on the position and affinities of the Trilobita.

Walcott first determined the presence of pygidial legs, and in a restoration of the ventral surface of *Calymene senaria*, one pair is represented to each annulation of the axis.* Matthew (l. c.) figured and described an imperfect and poorly preserved specimen of *Triarthrus*, which obscurely showed two flaps or fin-like extensions, beyond the lower edge of the pygidium. These he considered as possibly anchylosed pygidial limbs.

The specimens here described leave little to be desired in the way of perfect preservation. The lower side of a number of individuals has been exposed, showing the ventral membrane with the appendages attached. The dorsal shield has also been removed from other specimens, and the appendages exposed from that side, so that a very complete idea may be had of the character of the limbs, with many of the finer details of structure. The small size of the pygidium of *Triarthrus*, and the great number of elements in the appendages, however, render it difficult to remove the shaly matrix completely. Moreover, the overlapping and crowded arrangement of the limbs make the structure of the pygidial region seem quite complicated.

In *Calymene*, as worked out by Walcott, these appendages, of which the endopodites alone are shown, are weak and slender, and appear to show important differences from those of *Triarthrus*.

In *Triarthrus*, the thoracic legs near the head are composed of comparatively long joints, the proximal ones only of both endopodite and exopodite being somewhat flattened and expanded (figure 1). The functions of these two branches are clearly indicated, the endopodite being adapted for crawling and the exopodite for swimming. From the anterior region of the thorax, there is a gradual and progressive change in both branches of the legs increasing their functional powers as swimming organs. When the pygidium is reached, the endopodites preserve their slender, jointed distal portion, but the proximal part

1.

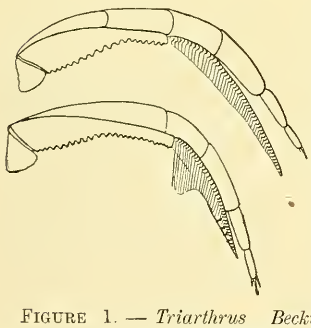


FIGURE 1. — *Triarthrus Becki* Green; dorsal view of right legs of second and third free thoracic segments. × 12.

* The Trilobite: new and old evidence relating to its organization. Bulletin of the Museum of Comparative Zoology, vol. viii, No. 10, 1881.

is composed of segments which are considerably expanded transversely, thus making a paddle-like organ, the anterior edge of which is straight, while the posterior one is serrated by the projecting points of the expanded segments. These points bear small bundles of setæ (Plate VII, figure 2).

The extreme posterior endopodites are made up of endites having a width two or three times greater than the length. A young individual (Plate VII, figure 3) presents pygidial endopodites, having this character while the lower thoracic segments (not represented in the figure) bear endopodites similar in form to a^{VI}, in figure 2. As these phyllopodiform appendages are the youngest and most immature on an adult *Triarthrus*, and are the prevailing form on the pygidium of an adolescent specimen, they probably indicate some primitive feature or simple type of trilobite leg. Their resemblance to the endopodites of *Apus*, figure 4, or to a typical phyllopod limb is very marked.

There is little apparent change in the structure of the exopodites from the anterior thoracic segments to the pygidium, as throughout this length they retain the large basal joint with a slender many jointed end carrying a long fringe of closely arranged setæ. As shown in figure 1, these fimbriæ overlap, and project behind the pygidium, forming with the endopodites a fin-like expansion on each side, especially well adapted to propel and guide the animal in swimming. They may have served also as egg carriers. As far as known, there was but a single pair of biramous limbs to each annulation, or potential segment, of the pygidium.

Yale Museum, New Haven, Conn., March 9th, 1894.

EXPLANATION OF PLATE.

Triarthrus Becki Green.

FIGURE 1.—Dorsal side of pygidium, showing fringes of exopodites (*b*) and ends of endopodites (*a*). The last free thoracic segment is represented in outline. Taken from an entire individual. × 16.

FIGURE 2.—Ventral view of pygidium with appendages well preserved on one side, showing expanded setiferous endites of endopodial limbs (a^{I}, a^{V}, etc) and exopodites (*b*). The last free thoracic segment is represented in outline. Taken from an entire individual. × 16.

FIGURE 3.—The endopodites (somewhat displaced) from right side of pygidium of small specimen. The two end segments of upper limb are restored. The lower limbs are minute and rudimentary. × 60. Utica Slate. Near Rome, N. Y.

FIGURE 4.—Endopodites from right side of fourth larval stage of *Apus*, enlarged. (After Claus)

ART. XXIX.—*On the Geological Position of the Eocene Deposits of Maryland and Virginia;* by GILBERT D. HARRIS.

IN the spring of 1830,* T. A. Conrad made a visit to the western shore of Maryland for the purpose of collecting fossil remains and observing the geological features of the region. He discovered in the vicinity of Ft. Washington beds that he correlated with the London Clay of England since they contained among other extinct species *Venericardia planicosta* of Lamarck. A few years later† he called attention to the resemblance of *Cucullæa gigantea* of this locality to a European species, and noted the similarity of *Ostrea compressirostra* and the European *Ostrea bellovacina.* In the same work he described many new species from Claiborne, Alabama, mentioned others from Vance's Ferry, South Carolina, and classified Maryland, Alabama, and South Carolina deposits alike as "Middle Tertiary or London Clay and Calcaire Grossier."

The Rogers in 1839‡ differentiated this series from the overlying Miocene and underlying Cretaceous in Virginia and correctly referred it to an Eocene horizon and described several of its characteristic species.

Conrad, in the Proceedings of the National Institution, 1841,§ mentioned many Eocene localities in the Gulf and Atlantic slope States and pointed out the resemblance of the Upper Marlboro rocks of Maryland to those of Bangor, England, *Ostrea bellovacina* he affirmed was found at either locality.

Up to this time, no stress had been laid on the stratigraphic position of the various Eocene outcrops in America; to know that they were Eocene was all sufficing. In 1855, however, Conrad‖ established three subdivisions in the Alabama and Mississippi deposits of this series, naming them in descending order, the Vicksburg, Jackson and Claiborne groups. In 1865 he instituted another, the Lignite Formation,¶ wherein he seemingly desired to include beds lying between the "Buhrstone," as described by Tuomey, and the Cretaceous. To this formation he referred the dark colored friable clays of Piscataway Creek and the basal bed of Tuomey's section on Bashia Creek, Clark Co., Alabama; but the "Marlboro rock" to use

* Jour. Ac. Nat. Sci. Phila., 1st Series, vol. vi, 1830, pp. 205 et seq.
† Fossil Shells Tert. Form. N. A., Harris' Reprint, p. [21].
‡ Trans. Am. Phil. Soc., N. Ser., vol. v, 1839, p. 347 et seq.
§ Second Bull, pp. 172–179.
‖ Proc. Acad. Nat. Sci. Philad., vol. vii, p. 257.
¶ Proc. Acad. Nat. Sci. Philad., vol. xvii, 1865.

his own expression, belongs to a higher or "Buhrstone" horizon.

Practically the same conclusions were reiterated by Heilprin* in a "Note on the Approximate Position of the Eocene Deposits of Maryland," published in the Proceedings of the Academy of Natural Sciences of Philadelphia, 1881. Conrad's stratigraphic nomenclature he modernized to some extent and used the term "Eo-lignitic" in place of Conrad's "Lignite Formation."

It was not until 1886 that the typical section of American marine Eocene, namely, that of Alabama was published. This was given in Bulletin No. 43 of the U. S. Geological Survey by Smith and Johnson. In the same year also, appeard Bulletin No. 1 of the State survey of Alabama in which Aldrich listed the known species from the various stages and sub-stages of the series. Herein is found the clue to the special problem in question, i. e., what horizon in the Alabama section does the Eocene of Maryland and Virginia (Pamunkey formation of Darton) represent. Whereas the Buhrstone and the section on Bashia Creek furnish few or no characteristic Maryland and Virginia Eocene species as neither Conrad nor Heilprin were able to show although for some cause they believed all should be relegated to practically the same horizon, the Bell's Landing sub-stage including the Bell's Landing, Gregg's Landing, and Nanafalia deposits do furnish such characteristic fossils. During a recent visit to these localities I observed that the material in which the fossils are imbedded is very similar to that of the Virginia Eocene, while the fossiliferous zones are widely separated by beds of fine dark lignitic clay. The species obtained that are most telling as indices of horizon are as follows:

Dosiniopsis lenticularis Rogers; found at Bell's Landing; also very abundant in the Maryland and Virginia (Pamunkey) Eocene. A slight varietal form from the vicinity of Piscataway Creek and Ft. Washington has been named *D. meeki* by Conrad.

Cucullæa transversa Rogers; common in the Gregg's Landing bed and in Virginia, probably simply a small variety of *C. onochela* Rogers and *C. gigantea* Conrad.

Venericardia planicosta, var. *regia* Con.; common in all members of the Bell's Landing sub-stage as well as in Virginia and Maryland.

Ostrea compressirostra Say; abundant in the Bell's Landing horizon of Alabama and in Maryland and Virginia.

Turritella mortoni, var., *postmortoni*, nov var.; very abundant at Gregg's and Bell's Landing; rare among other *T. mor-*

* Pp. 444–447.

toni from Aquia Creek, Virginia; characterized by its rather smaller size, plainer surface, extremely sharp basal carina. See figs. 1, 2, and 3.

Turritella humerosa Conrad; abundant in several varietal forms in the Bell's Landing sub-stage; common in Maryland and Virginia. This species ranges from the Midway to the Claiborne inclusive, but seems exceptionally well developed at this horizon.

Turritella præcincta Conrad; very common in the Bell's Landing sub-stage of Ala.; rare at Aquia Creek, Va. The Virginia specimens are less strongly carinated than their Alabama representatives.

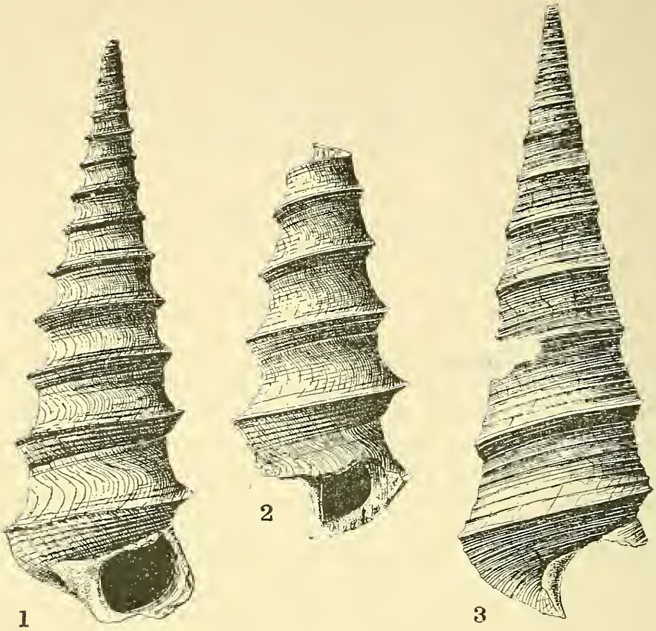
Natica, species probably new, from Bell's Landing and Maryland.

Besides these, other species can be mentioned that are found in common in the Pamunkey and the Alabama Lignitic. Here may be inclnded *Volutilithes petrosa*, var. *tuomeyi*, *Levifusus trabeatus* var., and perhaps *Cytherea ovata* Rogers, which is likely to prove the same as *C. nuttalliopsis* of Heilprin.

The fauna of the Bell's Landing sub-stage is much more varied, i. e., contains a far greater number of species than does that of the Eocene of Maryland and Virginia. As a rule, such species as survive in the later stages of this series are here represented by unusually large varieties. While those that are common to this and the Maryland and Virginia deposits are dwarfed or comparatively smaller than their northern representatives. This however, does not invariably hold true.

As far as is yet known the different horizons of the Maryland and Virginia section contain practically the same fauna, although at some localities and horizons a few forms may appear extremely abundant, while elsewhere, they may be very scarce. It is too early however to speak with much certainty on this point. The fossils, as a rule, are poorly preserved and thus far only the commoner forms have been collected and described. There are traces of many less conspicuous ones that may serve to throw additional light on this subject when their characteristics have been ascertained.

Below will be found a general section of the Eocene series of the Southern States. It is based to a considerable extent on that given by Smith and Johnson (*loc. cit.*) though modified to include and harmonize with the writer's more recent observations. The horizon of the Maryland and Virginia Eocene is moreover, indicated.



EXPLANATION OF FIGURES.

FIGURE 1. *Turritella mortoni* var. *postmortoni* Harris, from Bell's Landing, Ala.
" 2. The same; Aquia Creek, Va.
" 3. *Turritella mortoni* Con., typical, from Glymont, Va.

Series	Stages.	Substages.		Substage.	
Eocene.	Vicksburg.	Coral Limestone.			
		Vicksburg Beds.			
		Red Bluff Beds.			
	Jackson.	Moody's Branch Beds.			
		Marks' Mills Red Beds.			
	Claiborne.	White Bluff Marls (Ark.)			
		Claiborne Sand.			
	Lower Claiborne.	Ostrea sellæformis Beds.			
		Lisbon Beds.			
		Buhrstone.			
	Lignitic.	Hatchetigbee Beds.			
		Wood's Bluff Beds.			
		Bell's Landing.	Bell's L'd'g Bed.	Pamunkey.	Eocene of Maryland and Virginia.
			Gregg's L'd'g Bed.		
			Nanafalia Beds.		
	Midway.	Matthew's Landing Marl.			
		Black Bluff Clays.			
		Midway Clay and Limestone.			

ART. XXX.—*Contributions to the Crystallization of Willemite;* by S. L. PENFIELD.

As far as known willemite is a mineral of rare occurrence. The manganese variety, troostite, is found at Franklin, Sussex Co., New Jersey, in sufficient quantity to make it a valuable ore of zinc. It also occurs sparingly at the Merritt mine, Socorro Co., New Mexico, an analysis and description of it having been given by Prof. F. A. Genth* In the summer of 1891, while collecting for the U. S. Geological Survey, the writer found a well crystallized specimen on the dump of the Sedalia Copper Mine, near Salida, Chaffee Co., Colorado and, as far as known, these three are the only localities for the mineral in the United States.

Our knowledge of the crystallization of willemite is limited to a description by A. Levy† of the simple crystals from Moresnet near Altenberg and to measurements with the contact goniometer of the large troostite crystals from New Jersey by E. S. Dana‡ and Des Cloizeaux.§ From the similarity of the rhombohedral angles of willemite, Zn_2SiO_4 and phenacite Be_2SiO_4 it has been assumed by Groth‖ that willemite probably crystallizes like the latter in the rhombohedral-tetartohedral division of the hexagonal system, but no crystals have ever been described which were sufficiently modified to show the tetartohedrism.

Willemite from the Merritt Mine, New Mexico.

Through the kindness of Mr. Geo. W. Fiss of Philadelphia, Pa., the author has been supplied with a suite of specimens containing crystals suitable for measurement on the reflecting goniometer. The crystals are colorless, transparent and measure on the average about 0·5^{mm} in greatest diameter. Some exhibit a dark center with transparent exterior, or with simply the extremities of the prism clear. The crystals occur as aggregations or as druses lining cavities in the rock. The forms which have been identified are:

c, 0001, O	e, $01\bar{1}2$, $-\frac{1}{2}$
a, $11\bar{2}0$, i-2	u, $2\bar{1}\bar{1}3$, $\frac{2}{3}$-$2l$ or $\frac{\frac{2}{3}P2}{4}\frac{l}{r}$
r, $10\bar{1}1$, 1	v, $\bar{1}3\bar{2}5$, $-\frac{1}{5}{}^{3}r$ or $-\frac{\frac{3}{5}P\frac{3}{2}}{4}\frac{r}{l}$
z, $01\bar{1}1$, -1	

* Proc. Am. Phil. Soc., xxiv, p. 43, 1887.

† Ann Mines, iv, p. 513, 1843.

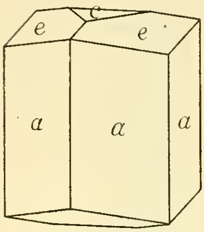
‡ System of Min., Sixth Edition, p. 460.

§ Manuel de Minéralogie 1862, p. 43.

‖ Tabellarische Uebersicht der Mineralien, 1889, p. 111.

Figures 1 and 2 represent the ordinary developments of the faces. The rhombohedron of the second order, *u* was ob-

1.



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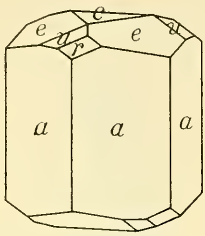

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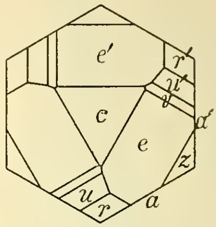


served intersecting both extremities of the vertical axis and always in the position required by rhombohedral tetartohedrism. The rhombohedrons *z* and *v* are of rare occurrence. All of the forms which have been observed are represented in the basal projection, fig. 3. Among a suite of specimens from this locality in the cabinet of the late Prof. F. A. Genth, sent to the writer by Dr. F. A. Genth, Jr., only the simple combination of prism and basal plane was observed.

The crystals are brilliant and give good reflections, but the faces are commonly vicinal, which renders the measurements somewhat uncertain. There was a decided tendency for the basal plane to develop into a flat vicinal rhombohedron, while the prism seemed always to be slightly warped or twisted. Although the measurements of similar angles show a considerable variation, the best of them, judging from the character of the signals, agree closely with the values calculated from the fundamental measurement of Lévy, $p \wedge p$, $30\bar{3}4 \wedge 03\bar{3}4 = 51° 30'$. It was decided, therefore, to retain his axial ratios, $a : c = 1 : 0{\cdot}6696$.

The following is a list of some of the calculated and measured angles.

	Calculated.	Average measurement.	Number of times measured.	Limits.
$c \wedge e$,	$0001 \wedge 01\bar{1}2 =$ 21° 8′	21° 6′	11	20° 40′–21° 28′
$e \wedge e'$,	$01\bar{1}2 \wedge \bar{1}012 =$ 36 23	35 48	11	35 5–36 24
$a \wedge e$,	$11\bar{2}0 \wedge 01\bar{1}2 =$ 71 48	71 39	7	71 14–71 57
$r \wedge e$,	$10\bar{1}1 \wedge 01\bar{1}2 =$ 31 59	32 2	7	31 36–32 38
$r \wedge e'$,	$10\bar{1}1 \wedge \bar{1}012 =$ 58 51	58 45	2	58 25–59 5
$c \wedge r$,	$0001 \wedge 10\bar{1}1 =$ 37 42½	37 56	1	
$c \wedge z$,	$0001 \wedge 01\bar{1}1 =$ 37 42½	37 57	1	
$e \wedge u'$,	$01\bar{1}2 \wedge \bar{1}2\bar{1}3 =$ 11 45½	11 25	3	11 21–11 27
$e \wedge u$,	$01\bar{1}2 \wedge 2\bar{1}\bar{1}3 =$ 31 36	31 51	1	
$c \wedge u$,	$0001 \wedge 2\bar{1}\bar{1}3 =$ 24 3	23 24	1	
$u \wedge u'$,	$2\bar{1}\bar{1}3 \wedge \bar{1}2\bar{1}3 =$ 41 20	40 49	1	
$e \wedge v$,	$01\bar{1}2 \wedge \bar{1}3\bar{2}5 =$ 7 7	7 23	1	

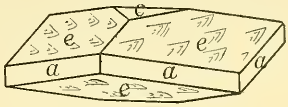
Willemite from the Sedalia Mine, Salida, Colorado.

At this locality it was observed in transparent, colorless crystals up to 3mm in diameter, having the habit shown in fig. 4. The mineral was identified by its blowpipe reactions and the following measurements:

	Measured.	Calculated.
$e \wedge e$, $1\bar{1}02 \wedge 01\bar{1}2$ =	35° 35′	36° 23′
$a \wedge e$, $\bar{1}2\bar{1}0 \wedge 01\bar{1}2$ =	71 42	71 48

The crystal faces are warped and striated and on some of them low, vicinal prominences are developed, which are unsymmetrical with reference to the rhombohedron *e* and indicate clearly that the crystals are tetartohedral. When mounted in Canada balsam these rather flat crystals show with convergent polarized light a normal uniaxial interference figure, and a strong positive double refraction.

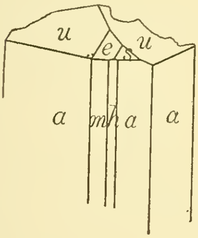
4.



Willemite or Troostite from Franklin, N. J.

The crystals from this locality, which are commonly found imbedded in calcite, are usually rather coarse and show simple combinations of *a*, $11\bar{2}0$; *r*, $10\bar{1}1$; *e*, $01\bar{1}2$ and *c*, 0001. In the private collection of Mr. Frederick A. Canfield of Dover, N. J., there are, however, two specimens which are worthy of special description, as the crystals exhibit combinations which are very unusual for the Franklin mines and are also beautiful illustrations of rhombohedral-tetartohedrism. These specimens were kindly loaned to the writer, who takes this opportunity of expressing his thanks to Mr. Canfield.

5.



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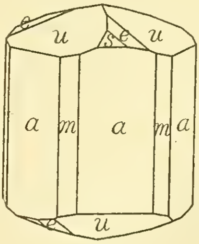

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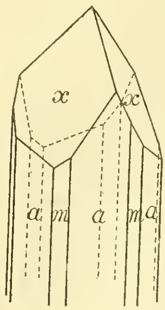

On one specimen there were several nearly transparent, green prisms, attached to a gangue of massive willemite and franklinite. One of these, about 30mm long by 20mm in diameter, was so attached that only a part of its faces were developed, which are represented in about their natural proportion in fig. 5. The prominent rhombohedron u is of the second order, and if it corresponds in position to u in the New Mexico willemite, $2\bar{1}\bar{1}3$, $\frac{2}{3}$–$2l$, then the terminal faces are those of the lower, instead of the upper end of the crystal,* and if symmetrically developed would appear as in fig. 6. The rhombohedron s is $11\bar{2}3$, $\frac{2}{3}$–$2r$ and e is $01\bar{1}2$, $-\frac{1}{2}$. The prisms are of the first order m, of the second order a and of the third order h, $3\bar{1}\bar{2}0$, i-$\frac{3}{2}l$, although the symbol of the latter is uncertain, as satisfactory measurements could not be made.

The second specimen contained long prisms of nearly transparent, pale-green willemite, imbedded in a pink manganiferous calcite. Only one of these, measuring about 6^{mm} in diameter, was well terminated, fig. 7. The rhombohedron x is of the third order and has the symbol $3\bar{1}\bar{2}1$, 1^3l or $\frac{3P\frac{3}{2}}{4}\ \frac{l}{r}$. The prismatic faces are bright but the rhombohedron is dull so that measurements were made only with a contact goniometer, as follows:

	$a \wedge x$, $2\bar{1}\bar{1}0 \wedge 3\bar{1}\bar{2}1$	$a \wedge x$, $11\bar{2}0 \wedge 3\bar{1}\bar{2}1$	$x \wedge x$, $3\bar{1}\bar{2}1 \wedge \bar{2}3\bar{1}1$
Measured ----	28½°	54½°	102°
Calculated --	28 5′	53 59′	102 10′

This interesting and very unusual combination of prisms terminated only by a rhombohedron of the third order is similar to that exhibited by some of the phenacite crystals from Mt. Antero, Colorado.†

On the cleavage of Willemite.

Statements are made by various authors that willemite has a distinct basal cleavage, while the manganese variety, troostite, cleaves parallel to a prism of the second order, and this variation, together with the differences in crystalline habit and chemical composition have been cited as grounds for regarding the two minerals as distinct species.

During the course of this investigation the subject of cleavage has been carefully considered. On the crystals from Moresnet either a basal or a prismatic cleavage may be produced by placing a knife blade in appropriate positions on the crystals and pressing until they break. The cleavages are poor, they can scarcely be called distinct and both are about equally perfect, although, owing to the prismatic shape, the basal is

* Owing to the rhombohedral-tetartohedrism the upper and lower ends of a crystal can not be interchanged without changing the symbols of the faces.

† This Journal, III, xxxvi, p. 320, 1888.

perhaps more easily produced. It was moreover observed that milky, white crystals yielded the basal cleavage more readily than clear, transparent ones. If the crystals are broken without care they usually show only an irregular to conchoidal fracture. The same holds true for the transparent crystals from Franklin, while the ordinary massive specimens usually present only irregular fractures. A good prismatic cleavage, which may occasionally be observed, is perhaps of secondary origin, resulting from pressure. All attempts to produce cleavages on the crystals from Salida and the Merritt mine failed, owing to their shape and small size.

In conclusion, therefore, the author believes that there are no essential differences in cleavage or crystallization between willemite and troostite which warrants their separation into distinct species.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, November, 1893.

ART. XXXI.—*On the Occurrence of Olenellus in the Green Pond Mountain Series of Northern New Jersey, with a Note on the Conglomerates;* by CHARLES D. WALCOTT.

IN company with Dr. John C. Smock, State Geologist of New Jersey, I visited, in October, 1893, several localities of the Green Pond Mountain rocks in northern New Jersey, and also crossed into Orange County, New York, to see the section of the southwestern portion of Skunnemunk Mountain.

The first locality that we examined was at a point four miles northeast of Newfoundland and two miles north of Lake Macopin, where the succession from below upward is, gneiss, bedded quartzite, massive-bedded siliceous limestone, and a belt of shales that pass beneath the conglomerate of Kanouse Mountain. The latter formation extends to the southwest and merges into the Copperas Mountain conglomerate. Fragments of Olenellus were found in the limestone. Subsequently I visited the Gould quarry, one mile north of Macopin Lake, where the section is essentially the same, but more complete.* The quartzites are separated by a slight interval of soil from the gneiss, and pass above into a conglomerate formed of white quartz pebbles in a reddish matrix. Reddish-purple sandstones also occur associated with the conglomerate, the whole forming a mass not over ten feet in thickness. The superjacent limestone has been extensively cut into in quarry-

*Geol. Surv. New Jersey, Ann. Rept. 1884, p. 52.

ing operations and dips beneath a conglomerate formed of white quartz pebbles, essentially the same as those in the conglomerate beneath the limestone. As in the section one mile to the north, an interval of slate occurs between the low ridge formed by the limestone and associated rocks and the massive conglomerate of Kanouse Mountain on the west. The discovery of the Olenellus fauna in the limestone is a positive addition to the data for working out the stratigraphy of the Green Pond Mountain area. Occurring, as it does, in a limestone that merges above and below into beds of conglomerate that are essentially of the Green Pond Mountain type, it proves that the conditions under which this characteristic formation was formed began in *lower* Cambrian time.

In a recent paper Mr. A. F. Foerste* states that "Since the rocks all dip west the conglomerates forming the eastern side of Copperas and Kanouse Mountains must be Oneida, the red sandstone above the same, the Medina, the underlying limestone, the Magnesian limestone, and the basal sandstone, the Cambrian; but instead of the term Potsdam it is necessary now until further developments, to call it Olenellus Cambrian. It is a quartzite sandstone from ten to fifteen feet thick, and so far has not furnished fossils."

The danger of correlation by lithological characteristics is shown by the reference of the limestone in which I found Olenellus to the Magnesian limestone of the Pennsylvania and New York sections. The use of the term "Olenellus Cambrian" for the sandstone or quartzite is objectionable. In the absence of fossils the correlation of the basal sandstone of one basin of sedimentation with the basal sandstone of another basin of sedimentation must necessarily be more or less conjectural.

In the report of 1868 Dr. Geo. H. Cook, the then state geologist, referred the conglomerates of Copperas and Kanouse Mountains to the Potsdam epoch of the New York series on account of their being at the base of the Paleozoic series. Mr. Foerste is now confident that they are of the age of the Oneida conglomerate of the New York section. From the data at present available it may be that the latter is correct; but, from the fact that the sediments of the Green Pond Mountain area were deposited in a basin distinct from that to the west and north, it is evident that any attempt to make exact correlations between the rock series of this basin and that of the more extensive basin of New York, western New Jersey, and Pennsylvania will be more or less theoretical. The sedimentation of the Green Pond Mountain area of New

* This Journal, vol. xlvi, 1893, p. 441.

Jersey and southeastern New York is peculiar to itself; and the use of the term "Oneida conglomerate" for the conglomerate of Kanouse and Copperas Mountains is confusing to one acquainted with the stratigraphy, and much more so to the student who endeavors to class two such unlike formations as one and the same formation. If it is desirable to correlate the conglomerate of Kanouse, Copperas and Green Pond Mountains with the Oneida conglomerate of the New York series, I think less confusion would be caused by calling it the Green Pond conglomerate, and stating that this conglomerate is correlated with the Oneida conglomerate under the belief that it occupies the same stratigraphical position. When I speak of the Green Pond conglomerate, it is understood that the conglomerates of Skunnemunk and Bear Fort Mountains are not included. There appear to be several horizons of conglomerates in the Green Pond Mountain region, viz:

1st. The Macopin Lake, of *lower* Cambrian age;
2d. The Green Pond, Kanouse and Copperas Mountain conglomerate, Ordovician or Silurian;
3d. The white conglomerate west of Greenwood Lake, etc.
4th. The narrow belt of conglomerate beneath the shales carrying the Hamilton fauna, on Greenwood lake, *lower* Devonian.
5th. The massive Devonian conglomerate of Skunnemunk Mountain, which appears to extend to the southwest into Belle-Vale and Bear Fort Mountains.

Of these the 2d and 5th are massive and important formations. The 1st, 3d and 4th are local and appear to be of little stratigraphical importance. With the exception of the 3d, they serve to emphasize the fact shown by the 2d and 5th,—that conglomerates of essentially the same type may be repeated at several horizons within the same basin of sedimentation.

Mr. N. H. Darton informs me that he arrived at essentially the same conclusions from a much more thorough study of the Green Pond Mountain region than I was able to make. He presented his paper at the Boston meeting of the Geological Society of America (Dec., 1893) and I cheerfully yield him priority, as his work was done before I entered the field. These conclusions were not known to me until more than three months after the writing of the preceding notes and after they were in type.

Art. XXXII.—*Notes on Nickeliferous Pyrite from Murray Mine, Sudbury, Ont.*; by T. L. Walker.

The principal nickel ore of the Sudbury district is nickeliferous pyrrhotite. In smaller quantities, nickel occurs in several other forms such as niccolite, gersdorffite, pentlandite, polydymite, and nickeliferous pyrite; these minerals are however often in such quantities as to be of great economic importance. It is intended in the present article to give a few notes on the occurrence of nickeliferous pyrite.

At the Murray mine on the main line of the Canadian Pacific Railway about four miles northwest of Sudbury is found a nickel-iron sulphide containing from four to six per cent of nickel. The writer first had his attention drawn to this mineral in 1891 when assayer at the above mine. Dr. W. L. Goodwin of the Kingston School of Mining published some notes on this mineral in the "Canadian Record of Science" for April, 1893—the specimens then at hand however were massive and somewhat decomposed. The ore occurs in a rock, which on microscopic examination proves to be diorite, which is coarsely crystalline and weathers easily, so that for a few feet below the surface the rock is decomposed and crumbles to pieces when exposed to the air, exposing the kernel-like masses of pyrite. Marcasite (containing no nickel or cobalt), magnetite, galena, chalcopyrite and nickeliferous pyrrhotite are the associated minerals. At first only massive specimens were found, but during the summer of 1893 the mine was again visited and several specimens were obtained showing druses of small bright cubic crystals. These were examined and shown to contain nickel, but as they were very small no quantitative analysis was made of them. The interfacial angles of the crystals were measured under the microscope and found to range from 90° to 90° 40′, which, when it is remembered that the largest crystals measured only ·3^{mm}, is a very close approximation to the cube. The characteristic striæ of pyrite could not be detected. Some of the larger crystals were pressed into a pine splinter and bright surfaces of calcite, fluorite and apatite were in turn scratched. Orthoclase was too hard to be scratched by them—the hardness of the crystals is thus between 5 and 6, which is quite close to that for ordinary pyrite. The mineral strikes fire with the hammer. Specific gravity, color, lustre, and magnetic properties are the same as in ordinary pyrite. The mineral is insoluble in hydrochloric acidbut dissolves readily in nitric acid.

An analysis was made of some of the massive pieces, showing no signs of decomposition, with the following result:

Nickel	4·34%
Iron	39·70
Sulphur	49·31
Moisture	·10
Copper	traces
Insoluble	5·76
Arsenic	none

Seeing that the mineral so closely resembles pyrite, and knowing that iron and nickel are isomorphous in many of their compounds, it is reasonable to regard this mineral as pyrite in which part of the iron is replaced by nickel; its composition will then be represented by the formula $[FeNi]S_2$. When thus considered the above analysis may be represented as follows:

Nickel		4·34%	NiS_2	9·12%
Sulphur	49·31%	4·78		
		44·53	FeS_2	83·49
Iron	39·70	38·96		
		·74	Fe_3O_4	1·02
Oxygen (calculated)		·28		
Water				·10
Insoluble				5·76
Total				99·49%

Doubtless some of the rock-forming minerals, such as chlorite, dissolved in the acids used for solution, but the silica of such would be contained in the insoluble proportion. The small portion of bases belonging to these minerals was not estimated.

A common view with regard to the structure of many of the Sudbury iron-nickel sulphides, is that they are best explained as pyrite or pyrrhotite containing millerite in a finely disseminated form. This would be hard to hold in the present case, for even if we were to consider the whole of the iron as occurring in the form of pyrite (FeS_2), (though we are certain that some of the iron is present as magnetite), the 39·70 per cent of iron would require 45·36 per cent of sulphur, leaving 3·95 per cent sulphur to combine with the 4·34 per cent of nickel. This quantity of nickel in the state of millerite would require only 2·39 per cent sulphur, while in the state of the theoretical di-sulphide (NiS_2) it would require 4·78 per cent sulphur, which is a quantity not very different from that remaining to unite with the nickel, even after *all* the iron has been calculated as pyrite. By allowing ·78 per cent of the iron to be present in the form of magnetite, the agreement between the theory and the analyses is complete.

Professor Penfield in referring to Dr. Emmens' new mineral species blueite, in this Journal for June, 1893, says:

"Although it must be admitted that nickel is a rare constituent of pyrite, yet nickeliferous pyrites are known, and at Sudbury in particular where iron and nickel are so abundant we might expect to find a mutual replacement of these elements."

The notes here submitted show that nickeliferous pyrite *is* found at Sudbury. In a similar way the many other iron-nickel sulphides may be explained as minerals, in which the isomorphous elements iron and nickel replace each other in varying proportions. Doubtless this nickeliferous pyrite is a purer form of the minerals described as whartonite and blueite by Dr. Emmens.

Laboratory of the School of Mining,
Kingston, Ont., February, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Electric Conductivity of Flames.* — Experiments have been made by de Hemptinne to determine the electric conductivity of flames and of gaseous mixtures at the moment of union or of dissociation. The apparatus used consisted of two electrodes of platinum, one connected with a voltaic cell and the other with a capillary electrometer, so arranged that whenever a conducting substance was brought between them, the mercury in the electrometer became of lower potential and moved upward in the capillary tube. When these electrodes were placed in a mixture of nitrogen dioxide and oxygen gases in the act of combining, no effect was perceptible even when the electromotive force employed was 100 volts. The result was equally negative when hydrogen bromide and chlorine, and hydrogen chloride and ammonia, were employed. If the electrodes be placed in the same relative portion of a Bunsen flame however where the combustible gas contains variable quantities of an indifferent gas, the hydrogen flame and the carbon monoxide flame are found to conduct well, the conductivity increasing with the temperature. The experiments on the conductivity of explosive mixtures at the moment of explosion, showed that in the case of oxygen-hydrogen and chlorine-hydrogen mixtures, there is decided conductivity; while in the case of oxygen-carbon monoxide, it exists though in a much less degree. Moreover, although hydrogen chloride and ammonia show no conductivity when uniting, at ordinary temperatures, dissociating ammonium chloride conducts fairly well; as also does ammonium bromide. Vapor of amy-

lene bromide however though dissociated, does not conduct. Nitrogen dioxide is not a conductor.—*Zeitschr. physikal. Chem.*, xii, 244, August, 1893. G. F. B.

2. *On the Electrolysis of Steam.*—The action of electric sparks on steam has been made the subject of investigation by J. J. THOMSON. The steam was passed through the middle limb of a T tube, its closed side limbs being provided with delivery tubes and also with gold or platinum electrodes between which sparks might be passed through the steam. By means of the delivery tubes the gases were conducted into two eudiometers, in which the gaseous mixture which had been formed by the action of the sparks upon the steam, could be exploded. It was noticed that when the sparks were from 1·5 to 4^{mm} long, the volumes of the excess of hydrogen in the one tube and of oxygen in the other, remaining after the explosion of the mixed gases, were, within the limit of error of the experiment, equal respectively to the volumes of the oxygen and hydrogen liberated in a water voltameter placed in series with the steam tube; and further that the excess of hydrogen appeared in the tube which was in connection with the positive electrode, and the excess of oxygen in that which was connected with the negative electrode. If the spark-length be greater than 4^{mm}, the first of the preceding results ceases to hold; and when it reaches 11^{mm} or over, the excess of hydrogen instead of appearing at the positive electrode changes over to the negative; the excess of oxygen at the same time going over to the positive. Reversal again takes place when the length of the sparks is increased to 22^{mm}. The author has further observed that on passing the arc discharge through hydrogen and oxygen respectively, the hydrogen acts as if it had a negative charge and the oxygen as if it had a positive one.—*Proc. Roy. Soc.*, liii, 90; *J. Chem. Soc.*, lxiv, ii, 515, November, 1893. G. F. B.

3. *On the Temperature of Ignition of Gaseous Explosive Mixtures.*—An investigation has been recently made by V. MEYER and MÜNCH to determine the precise point of temperature at which the explosion or silent combination of gaseous mixtures occurs. The mixture to be exploded is contained in a small bulb, placed inside the larger bulb of an air thermometer which was made use of to determine the temperature, this larger bulb being placed in a bath of a fused alloy of lead and tin. The temperature was determined by displacing the air of the thermometer, its volume being known, by hydrogen chloride gas, and measuring this volume over distilled water. As the result of several series of experiments made with four distinct sets of apparatus, the temperature of explosion of electrolytic hydrogen and oxygen was found to vary from 612° to 686°; confirming the theoretical conclusion of Van't Hoff that this mixture does not possess a sharply defined explosion-point. It makes no difference apparently whether the gases are moist or dry; for if dry, silent combination appears to take place to a small extent, thus rendering

them moist before explosion occurs. Sharp solid fragments, such as glass or sea sand were found to be without effect. But fragments of platinum foil or wire made it impossible to bring about an explosion even at 715°, silent union always taking place. Carbon monoxide and oxygen, in suitable proportion to form carbon dioxide united silently in the apparatus, for the most part; the temperatures, when explosion did occur, varying from 636° to 814°. Mixtures of oxygen with gaseous hydrocarbons, excepting perhaps marsh gas, afforded the most trustworthy explosion-temperatures, since there was practically no silent combination. Marsh gas and oxygen explode as a rule, at temperatures varying from 656° to 678°; though sometimes silent and complete combination took place. Ethane and oxygen detonated at 622°, 605° and 622° respectively; ethylene and oxygen at 577°, 590° and 577° in three consecutive experiments. Acetylene with oxygen explodes with remarkable violence, at 510°, 515° and 509°. Propane with five volumes of oxygen, gave 548°, 545° and 548° as the explosion-temperature in three experiments. Propylene, with four and a half volumes of oxygen exploded at 497°, 511° and 499°. Isobutane, with six and a half volumes of oxygen detonated at 549°, 550° and 545°; and isobutylene at 546°, 548° and 537°. Finally coal gas mixed with three volumes of oxygen, was found in three remarkably concordant experiments, to explode at 649°, 647° and 647°. A mixture of coal gas with air could not be exploded however under these conditions of experiment. It will be noticed that the temperature of explosion falls as the content of carbon increases; the mean temperatures, for example, for methane, ethane and propane being 667°, 616° and 547° respectively. Moreover the temperature falls also with the degree of saturation, the less saturated the hydrocarbons, the more readily do they ignite in contact with oxygen; ethane, ethylene and acetylene exploding at 516°, 580° and 511°; propane and propylene at 547° and 504°; and isobutane and isobutylene at 548° and 543°. As might be expected, these differences arising from greater or less saturation diminish as the series is ascended.—*Ber. Berl. Chem. Ges.*, xxvi, 2421, November, 1893.

G. F. B.

4. *On the Composition of Water by Volume.*—By means of improved apparatus, Scott has continued his investigation of the proportion by volume in which hydrogen and oxygen unite. The measurements were all made at constant volume, the pressure only being varied. And as vaselin was found to introduce traces of the oxides of carbon into the gases, syrupy phosphoric acid was used for lubrication. The oxygen was prepared from silver oxide and the hydrogen from sodium and steam. In certain experiments the hydrogen was further purified by absorption in palladium. In five series of 53 experiments the mean ratio of hydrogen to oxygen was found to be $2·002435 \pm 0·00006$, the impurity being supposed in both gases equally; or $2·002431 \pm 0·00006$, the impurity supposed in hydrogen alone. Rejecting six

of the experiments the value obtained would be 2·002466 ± 0·000003, the impurity making no difference whether assumed to be all in the hydrogen or equally distributed between the two gases. The most probable value is 2·00245; which combined with Rayleigh's value 15·882 for the ratio of the densities of the gases, gives 15·862 for the atomic mass of oxygen, hydrogen being 1; or 1·0078 for the atomic mass of hydrogen, oxygen being taken as 16.—*Proc. Roy. Soc.*, liii, 130; *J. Chem. Soc.*, lxiv, ii, 575, November, 1893. G. F. B.

5. *On the Production of Hyponitrous acid.*—The results of the reduction of sodium nitrite in alkaline solution have been studied by Thum. He finds that the first product of this reaction is the sodium derivative of a dihydroxylamine, two molecules of which subsequently condense to form sodium hyponitrite:

$$Na_2 + (H_2O)_2 + NaNO_2 = NaN(OH)_2 + (Na(OH))_2$$

and

$$(NaN(OH)_2)_2 = Na_2N_2O_2 + (H_2O)_2$$

This second reaction seems to be favored by an excess of alkali, for if this be neutralized by a current of carbon dioxide, no hyponitrite is formed. The nitrogen which is set free during the reaction is not due to the reduction of hydroxylamine, as usually supposed, for this substance is scarcely attacked by sodium amalgam; it results probably from a reaction between the dihydroxylamine and hydroxylamine $NH_2OH + NH(OH)_2 = N_2 + (H_2O)_3$. For the preparation of hyponitrites, ferrous hydroxide has no advantage over sodium amalgam. Hyponitrous acid may also be formed by the action of nitrous acid on hydroxylamine. When equivalent solutions of hydroxylamine hydrochloride or sulphate and of sodium nitrite are mixed, allowed to stand until the violent evolution of nitrous oxide has ceased and then treated with silver nitrate, silver hyponitrite is formed in amount equal to about 2 per cent of the theoretical yield. In alkaline solution, however, no hyponitrite is formed. The acid itself may be isolated by acting on the silver salt with the theoretical amount of hydrogen chloride. A colorless and strongly acid solution results which is stable towards dilute acids and alkalies even on boiling. On titration with potassium hydroxide, in presence of phenophthalein or litmus, the solution remains acid until the acid salt is formed and then becomes alkaline. The acid does not affect methyl-orange and does not expel carbon dioxide from the alkali-carbonates. In acid solution it is converted by potassium permanganate quantitatively into nitric acid; while in alkaline solution nitrous acid is formed. Pure solutions of hyponitrous acid do not decolorize solutions of iodine and they prevent the formation of iodide of starch. Moreover, they do not liberate iodine from acid solutions of potassium iodide. The acid, in both acid and alkaline solutions, is very stable towards reducing agents. The acid hyponitrites of the alkalies give precipitates with many metallic salts.—*Monatsb.*, xiv, 294; *J. Chem. Soc.*, lxvi, ii, 13, January, 1894. G. F. B.

6. *Potassium and Sodium Carbonyls.*—For some years Joannis has been investigating the peculiar compounds potassammonium and sodammonium formed by potassium and sodium respectively with ammonia. He has now studied the reaction which takes place between these substances and carbon monoxide. When dry carbon monoxide is caused to bubble through a solution of potassammonium in liquefied ammonia, the containing vessel being cooled to $-50°$, the deep blue color gradually decreases in intensity and is eventually replaced by a pale pink tint, indicating the end of the reaction. On removing the liquid from the cooling mixture, the ammonia gradually evaporates, leaving a rose-colored powder which analysis shows to be pure potassium carbonyl KCO. It darkens when left undisturbed for some time in a sealed tube. It cannot be heated to the temperature of boiling water, explosion taking place below this point. It likewise detonates if the merest trace of air is admitted, and also when touched with a drop of water. If, however, a drop of water be admitted into an exhausted tube so as not to come in direct contact with the potassium carbonyl, the vapor acts upon it and produces a yellow viscous liquid. If sodammonium be similarly treated, sodium carbonyl NaCO is formed. It is a pale lilac colored substance and is also powerfully explosive, even by small quantities of air or water. When exploded by percussion the reaction was found to be $(NaCO)_4 = Na_2CO_3 + Na_2O + C_3$. Ab90° the explosion is so violent that no glass can withstand it.—*C. R.* cxvi, 1518, 1893.

G. F. B.

II. Geology and Mineralogy.

1. *International Congress of Geologists.*—The sessions of the 6th International Congress of Geologists will be held at Zurich, Switzerland, from the 29th of August to the 2nd of September. As many geologists may not have received the descriptive circulars, the following brief summary of the announcement is made for their benefit.

Besides the general meeting there will be meetings of sections, at the same time, for the following general subjects:

Section 1. General and Structural Geology.
" 2. Stratigraphy and Paleontology.
" 3. Mineralogy and Petrography.

Any person may become a member of the Congress by sending, by postal order, a fee of 25 francs = $5.00 to the Treasurer, M. Casp. Escher-Hess, Bahnhofstrasse, Zürich.

A large number of excursions have been planned for the weeks immediately preceding and following the Zürich meetings. The latter are so arranged as to concentrate at Lugano for the closing session of the Congress on the 16th of September. They are of two kinds. *Pedestrian excursions* for geologists alone, and *Round trips* by rail, steamer and carriage, in which ladies may take part and which are in charge of the firm of Ruffieux & Ruchonnet, Lausanne.

There are offered to the choice of members of the Congress 5 pedestrian excursions in the Jura for the week preceding the Congress, costing 50 to 60 francs each, and four after the Zürich meeting, of 8 to 13 days each, costing 150 to 250 francs each.

The round trip excursions under the guidance of M.M. Renevier and Golliez are two in number: 1. In the Jura before the Zürich meeting lasting 13 days and costing 300 francs: 2. After the Zürich meeting, in the Alps, lasting 13 days and costing 400 francs. Some supplementary excursions are also planned. A geological guide book, giving details of all the excursions is in preparation, and will be issued before the meeting of the Congress to those who remit to the Treasurer its cost, viz: 10 francs.

Geologists who wish to attend the Congress can send their names and addresses to S. F. Emmons, Sec'y, 1330 F St., Washington, who will undertake to forward them to Switzerland so that descriptive circulars and accompanying blanks may be sent them, or they can send their fee (including the cost of guide-book if they desire it) to the Treasurer, who will thereupon forward the circulars to them, and they may thus be able to designate what excursions, if any, they desire to take part in.

2. *Geological Survey of the State of New York, Palæontology:* Volume VIII. *An Introduction to the study of the genera of Palæozoic Brachiopoda;* by James Hall, assisted by John M. Clarke. Part II. Fascicle I, July, 1893. Fascicle II, December, 1893.—The delay in the publication of this volume has made it desirable for the authors to issue a limited edition in fascicles, which together with the plates will make the completed volume. The first treats of the genera of palæozoic spire-bearing brachiopods, and the second of the rhynchonelloids, pentameroids, and loop-bearing forms. The limitations of old genera are now clearly defined and many new generic terms are proposed. A review of the entire volume, when complete, will be given.

C. E. B.

3. *Alabama Geological Survey: Report on the Coal Measures of Blount Mountain*, with map, and sections, by A. M. Gibson, Assistant Geologist. 80 pp. Montgomery, 1893.

This is a coal field in North-central Alabama, not now worked, of about one hundred and fifty square miles, lying between the already described and worked Warrior (northwest) and Cahaba (southeast) Coal fields of Alabama, of which the author gives a detailed description.

4. *Geological Survey of Texas, 4th Annual Report for 1892.* E. T. Dumble, *State Geologist.*—The parts 10 and 11 and the Report of the state geologist have appeared, thus completing the fourth volume (see this Journal, vol. xlvi, p. 307, and xlvii, p. 160). Part 10 contains a preliminary list of the land, fresh water and Marine *Mollusca of Texas,* pp. 299–343; and a chapter on *Texas birds*, pp. 345–375 by J. A. Singley. Part 11, is a second

paper on *Carboniferous Cephalopods*, by ALPHEUS HYATT, pp. 377–474, in which a number of new genera and species are figured and described.

5. *Outline of the Geology and Physical Features of Maryland*, with a new geological map of the State and 16 plates; by G. H. WILLIAMS and W. B. CLARK. 4°, 67 pp. Johns Hopkins University Press, Baltimore, 1893; price $1.00—This book is a reprint of the chapters relating to Physical Geography and Geology from the large work on Maryland and its resources, prepared by members of the Johns Hopkins University faculty for the Columbian Exposition. Its first part deals with topography and climate, and is illustrated by many tables and five colored charts which show the distribution of temperature and precipitation in each season and throughout the year. The second part is descriptive of the geology in each of the three great provinces of Maryland—Coastal Plain, Piedmont Plateau and Mountains—and is followed by an historical review of the sequence of events by which the remarkably complete series of geological formations occurring within the State has been deposited and brought into its present position. This part is embellished by ten full-page plates which exhibit the various types of topography, and by a new geological map in colors on a scale of eight miles to the inch. This map also gives the distribution of soils by Prof. Milton Whitney. G. H. W.

6. *Lehrbuch der Petrographie* von Dr. FERDINAND ZIRKEL, Ord. Professor der Mineralogie und Geognosie an der Universität, Leipzig. Zweite, gänzlich neu verfasste auflage. Zweiter Band. 941 pp. 8vo. Leipsic, 1894. (Verlag von Wilhelm Engelmann.)—The first volume of Prof. Zirkel's excellent Lehrbuch was noticed in the last volume of this Journal. This second volume, which extends to 941 pages, treats, under the head of Special Petrography, of part of the massive crystalline rocks, and includes those containing alkali-feldspar and quartz; alkali-feldspar without quartz, nephelite or leucite; alkali-feldspar without quartz, but with nephelite or leucite; and those of lime-soda feldspar without nephelite or leucite. The subject will be continued in the third volume.

7. *Geological Survey of Portugal: Description de la Fauna Jurassique du Portugal. Classe des Céphalopodes*, by PAUL CHOFFAT. 1st series: Ammonites du Lusitanien de la contrée de Torres-Vedras. pp. 82, 20 quarto plates, Lisbonne, 1893.—This memoir contains descriptions of species of Cardioceras, Phylloceras, Lytoceras, Harpoceras, Ochetoceras, Oppelia, Neumayria, Olcostephanus, Perisphinctes, Aspidoceras, Peltoceras, Simoceras, Hoplites.

8. *Untersuchungen über Fossile Hölzer Schwedens;* by H. CONWENTZ. pp. 99, 11 quarto plates. K. Schwedischen Acad. Wissenschaften, Ser. C, No. 120, Stockholm, 1892, contains descriptions of fossil plants from the Halma sandstones, from the drift of Sweden, and comparisons of the latter with the former, the authors

reaching the conclusion that North German, Danish and Swedish fossil drift-wood has not been derived from the Halma-Sandstone (Cretaceous) in S. Sweden but that the great majority of it has had its origin in Tertiary deposits at no great distance;

9. *Swedish lower Paleozoic Hyolithes and Conulariæ. Sveriges Kambrisk-Siluriska Hyolithidæ och Conulariedæ*, af GERHARD HOLM, from the afbandlingar of the Sveriges geologiska undersökuing, Ser. C., No. 112, pp. 1–172 and 6 quarto plates. Stockholm, 1892.—Gerhard Holm has given, in this monograph on the interesting and little known extinct organisms of Sweden an exhaustive list of the known species classified and tabulated according to their range, distribution and supposed genetic affinities. 41 new species of the Hyolithiidæ, 10 new Conulariidæ and one new species of the Torellellidæ are described. An English summary of characters and classification is given at the close of the volume.

III. MISCELLANEOUS SCIENTIFIC INTELLIGENCE.

1. *British Association for the Advancement of Science.*—The sixty-fourth meeting of the British Association will be held in Oxford, under the Presidency of the Marquis of Salisbury, Chancellor of the University, in the week beginning August 8th, 1894.

2. *A History of Mathematics;* by FLORIAN CAJORI.—Macmillan and Co., New York, 1894. 8°, pp. xiv, 422.—The first third of Professor Cajori's book is devoted to the history of methematics among the Babylonians, Egyptians, Greeks (including the Alexandrian schools), Romans, Hindoos, Arabs, and Europe during the Middle Ages. The second third traces the development of the science from the beginning of the sixteenth to the early part of the nineteenth century. The recent develqpments of the science are then treated in several lines, Synthetic Geometry, Analytic Geometry, Algebra, Analysis, Theory of Functions, Theory of Numbers, and Applied Mathematics. The volume has an exceedingly convenient index filling seventeen pages.

No science can be thoroughly comprehended until its history has been learned. Professor Cajori has given the history of Mathematics in an interesting form, and teachers and students of the science have reason to thank him for it. H. A. N.

3. *The Ejected Blocks of Monte Somma,—Part I, Stratified Limestones;* by H. J. JOHNSTON-LAVIS.—The following extract from the article of above title in the Transactions of the Edinburgh Geological Society (vol. vi, 1893, pp. 347–350), contains the interesting conclusions reached by the author from study of a large number of specimens:

"Such are the specimens of stratified limestones which are to serve as clues to the remarkable series of reactions that have converted cretaceous limestones into a series of rocks that, by themselves, one would hardly dare to suppose once to have been nothing more than an impure dolomitic limestone. I do not doubt that it will be argued that changes that occur in such small specimens should not be used as a guide to what occurs in large masses. To this it may be answered that the greater number of chemical phenomena that occur in the mineral world can be studied on the smallest scale in the laboratory. But beyond this these very same metamorphic changes may be traced on a much grander scale amongst the ejected blocks of Monte Somma, and I propose to confirm and extend these few notes in another paper on the massive limestones and their derivatives.

"Further, when we extend our investigations to the contact phenomena of such a region as the Tyrol, which are probably of less importance than what is really going on beneath Vesuvius, and from thence pass to areas of regional metamorphism, we are struck by the great similarity in the changes that have taken place. It must, however, be borne in mind that three important factors enter into the question, namely, the composition of the rock to be acted upon, that of the magma acting, and the time, circulation, and quantity of the latter. And equally imperative is it to remember that such rocks which reach the surface by denudation of the overlying materials have been exposed to so many fresh changes as sometimes to be no longer recognizable.

"The changes that take place in an impure limestone seem to be, in the first place, the carbonization of the bituminous contents with the conversion of them into graphite. Almost coincidentally re-crystallization seems to have taken place, for what was an extremely fine-grained rock begins to approach the saccharoidal structure. This re-arrangement or re-crystallization seems to have occurred without the rock having become fused, or even pasty, since the most delicate stratification, banding, faulting, and contortion structure is preserved. At this stage a few grains of peridote begin to make their appearance, chiefly as inclusions within the calcite crystals. The next process is the destruction of the graphite, and in some cases its apparent replacement by peridote, as in specimen No. 200. In the early stages of carbonization the graphite exists between the grains, but later gets enclosed within them, as if they had undergone fusion. With the disappearance of the graphite, what remains is a more or less coarse-grained, dazzling white marble. This saccharoidal marble, containing more or less white peridote, passes somewhat abruptly into a mass of peridote and white pyroxene, wollastonite, or biotite. Why, sometimes it is one or sometimes another mineral that borders on the white marble, I feel inclined to attribute to the impurities in the original limestone in the absence of alumina, with a supply, though limited, of silica, with much lime and magnesia, so that either fosterite or monticellite may result, and, if much iron, even true olivine may separate out. If only silica and lime are present, then we must look for wollastonite. Likewise, the presence of fluorine may determine the crystallization of humite instead of peridote. In the same way we understand how the other minerals may separate. Now, in a stratified limestone, some bands will be more argillaceous, siliceous, ferriferous, or magnesian, or two or more of these impurities may abound, so that in a stratified rock of this kind, the minerals developed in one band will differ from those in another, as is so strikingly shown in specimen No. 41.

"This metamorphism is selective only in the early stages, for (as in 36, 54, and 40) we have the silicate bands encroaching upon the intervening marble strata; whilst in 44, the well stratified portion, toward the metamorphosing focus, is fused (?) up into a fairly homogeneous mass of coarser grains and larger crystals of the same minerals as in the undisturbed part, together with the addition of others. Yet that the composition of the bands has a strong determining influence on the results is well illustrated in No. 51.

"The order in which the new minerals seem to develop is the following:

(1) Peridote, Periclase, Humite.
(2) Spinel, Mica, Fluorite, Galena, Pyrites, Wollastonite.
(3) Garnet, Idocrase, Nepheline, Sodalite, Feldspar.
(4) Calcite (secondary).

"Although in some cases there is an approach to the order of mineral species found in the druse walls described by Mierisch (*loc. cit.* p. 121), yet these are exceptional, and open up for our investigation a far wider field of facts.

"It is evident that any researches as to the purely chemical changes that take place in the process of metamorphism would be useless in stratified limestones unless it were possible to know the composition of each band. It will therefore be better to consider these questions where treating of the massive limestones and their derivatives.

"Then also, it is necessary to study the changes that have taken place in the minerals originally replacing the limestone. We have distinct evidence of the conversion of periclase into brucite, and of peridote to a whitish fibrous mineral or pilite (?) The biotite, nephelene, feldspar (?) and peridote may be crowded with microliths, which there is good reason to believe consist of pyroxene.

"Another point of interest is that I have not so far noticed the presence of periclase in any rock where graphite could be detected. This might well be explained by the fact that so long as free carbon remained, the magnesia would be maintained as carbonate, and only on its loss of the CO_2 could it take up the SiO_2 to form fosterite, or, with the addition of lime, monticellite; or should silica be absent, to combine with any alumina and to separate as spinel.

"Specimen 51 indicates, at any rate, that the latter result is subsequent to the former. Certainly 200 is curious, as showing an apparent displacement of the carbon grains by peridote, although it may be that that mineral simply occupies the spaces left by the disappearing carbon.

"It is also necessary at the same time to remember the chemical relationship of carbon and silicon. Another point is, that in all probability the first minerals produced by metamorphism are elaborated from materials contained within the rocks themselves; but eventually other constituents are added, or are removed, by the circulation of water, by vapors, or by diffusion from neighboring rock masses or igneous magma. Cossa found that he could reproduce periclase by heating for some hours magnesic sulphate and sodic chloride, and obtained still larger crystals by adding a little ferrous sulphate. This, however, is hardly likely to be the process of formation in the rocks beneath Vesuvius. Deville reproduced periclase by acting on magnesia by hydrochloric acid gas, and Daubrée by the action of magnesic chloride on lime. There is good reason to believe that it was by one or both of the latter processes that resulted in the production of periclase in the magnesian limestone, especially when we take into consideration the great abundance of hydrochloric acid and chlorides contained within the neighboring incandescent lava of Vesuvius. The artificial reproduction of fosterite by Ebelmen probably is a near imitation of what occurred in its natural production.

"In fine, we see a definite order of chemical changes occurring in Jurassic and Cretaceous limestone, which may convert that rock into a granitic mass of crystallized basic silicates and oxides, etc., which may in their turn by decomposition, give rise to a group of rocks in which the original constituents would be represented by serpentine and its varieties, Tremolite, Brucite, etc., an association which prevails amongst metamorphic rocks that are exposed at the surface by that series of precarious events constituting denudation.

"With regard to the removal of the lime in these metamorphosed rocks, Mierisch (*loc. cit.* p. 187) supposes the excess to have been carried off as chloride by fumarolic action, and thinks that the small quantity deposited around fumaroles proof of such being the case. Without laying stress on the latter, we may admit that this is very probable; may it not, however, be that much of the lime is retained in the lava, being utilized in the formation of some or all the lime-bearing crystal components, whilst the HCl would volatilize, as we know it does do, very largely from the volcanic vent.

"As Mierisch has to a great extent exhausted the description of the drusy limestones, it is proposed in the next paper to treat of the massive limestones, their alteration, metamorphism, and their derivatives."

The average elevation of the United States, by HENRY GANNETT, (extract from the 13th Ann. Rept. of the Director of the U. S. Geol. Survey, 1891–92. pp. 282–289 and colored Relief Maps of the United States.

The Mechanics of Appalachian Structure, by BAILEY WILLIS. (Extract from the 13th Annual Report of the Directors. U. S. Geological Survey 1891–92, pp. 211–281 and Plates XLVI–XCVI.) Washington, 1894.

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[THIRD SERIES.]

Art. XXXIII.—*Observations on the Derivation and Homologies of some Articulates;* by James D. Dana.

The term Articulates is used here in preference to Arthropods because the latter group is believed to be not a natural one, Crustaceans and Insects being less closely related to one another, as indicated beyond, than Annelids and Insects.

Derivation of Limuloids and Crustaceans.—As has been suggested by Lankester, it is probable that all the Articulates are successional to the Rotifers. There is reason for believing further that the types of *Annelids*, *Crustaceans*, and probably that of *Limuloids*, had their independent Rotifer origin.

The Nauplius, or larval form of a Crustacean, shows, by its having but 3 pairs of limbs (2 besides an antennary pair) that the type is not successional to a many-jointed Annelid, but rather to some Pedalion-like Rotifer. The discoveries of Prof. C. E. Beecher announced in the preceding and earlier numbers of this Journal leave no doubt that the Trilobites are multiplicate Isopod Crustaceans, precursors of the normal Isopods, as the true Phyllopods, also multiplicate species, were precursors of the Decapods.*

* In the Author's Report on the Crustacea of the Wilkes Exploring Expedition, the Rotifers are made the lowest subdivision of Crustacea (p. 1408); and the Trilobites are placed, with a query, in the subdivision of Tetradecapods as multiplicate forms under the type. In the text above, the expression *true* Phyllopods is used, because most of the so-called Phyllopods of the Paleozoic exhibit, in the specimens, no evidence that they are multiplicate, that is, have an excessive or abnormal number of body-segments or appendages.

The Eurypterids, the early form of the Limuloids, are related to Crustaceans in number of body-segments, it being 19, as in the Tetradecapods; and in the fact that 13 of these 19 segments pertain to the thorax and abdomen. But the wide distinction exists that the Eurypterids have no thoracic or abdominal limbs, and the only true feet which they have are also at base mouth-organs, that is organs that pertain to the head. Moreover, as has been shown, by Packard and others for the Limulus, they do not pass through the Nauplius stage in their development. These diversities and agreements appear to indicate a derivation for the Limuloids nearly like that of the Crustacean type, but probably not *from* Crustaceans. But since Limuloids cannot yet be proved to have existed before the Trenton period in the Lower Silurian, a derivation from some species related to the Ceratiocarids is possible. Since many if not all of the Eurypterids were freshwater or brackish-water species, the transfer to freshwater may have been an incident attending the divergence; and also an explanation of their attaining so great dimensions, freshwater having been their protection. The large Eurypterids, several feet in length, would have been helpless among Sharks and Ganoids.

Derivation of Arachnids.—The line to the lower and earlier Arachnids, that is, to the Scorpions, leads up, according to Van Beneden, Packard and others, from the early Pterygotus-like Limuloids. The early Scorpion, as well as the modern kinds, has the same number of body-segments as a Eurypterus or Pterygotus, namely: 7 thoracic, and 6 abdominal (precisely the normal number in Crustaceans); the same *cephalic* relations of the legs; the same absence of abdominal appendages; a like absence of thoracic appendages from all the segments excepting the first two, and similar functions in the members pertaining to these two segments. Further, according to B. Peach, these early Limuloids sometimes have, like the Scorpions, pairs of "combs" or pectinated organs on the underside of some of the thoracic segments.

But in this change from an aquatic to a terrestrial species the upward progress in structure was great. The 4 posterior pairs of feet in the terrestrial Scorpion have no longer the low-grade feature of serving as jaws as well as feet, but are simply feet; they are the chief organs of locomotion, and only those of the anterior pair are appendages to the mouth. The antennæ are shortened to pincers (falces) that also serve the mouth. The four pairs of feet are thus *cephalic* organs, if comparison be made with the Limuloids and Crustaceans, though in Arachnology they are called *thoracic.* In the later true Spiders, the body had lost its Eurypteroid abdomen, but had still, in Paleozoic species, its distinctly segmented thorax;

and this thorax is the abdomen of Arachnology. It is segmented in some modern species, while in others the subdivisions have become obsolete or are but faintly indicated. The abdomen of the Eurypterid however exists as a slender jointed thread in *Geralinura* of Scudder, of the Carboniferous, which has its Illinois, and also Bohemian, species and has survived till now, in the modern *Telyphonus.*

Derivation of Myriapods and Insects.—Myriapods although inferior to Insects, are as yet known only from the early Devonian. The Devonian species, and also those of the Carboniferous, are of the Millepede or lower doubly-multiplicate section of Myriapods with one exception, that of the remarkable few-jointed, caterpillar-like *Palæocampa* of Meek and Worthen.

The fact of a line of succession from Worms to Myriapods and from Myriapods to Insects has not been proved by geological discovery. The derivation of Myriapods from some type of Annelids is zoologically suggested, as long since recognized, by the apparently transitional form of *Peripatus*, a low-grade Myriapod resembling much the larve of some Insects, and by the like multiplicate structure of Annelids and Myriapods. It might be inferred also from the resemblance of the Palæocampa of the Illinois Carboniferous to the caterpillar of an Insect of the genus Arctia, as remarked by Scudder.

Myriapods are regarded as the precursors of Insects on account of their approximate resemblance to the latter in antennæ and the appendages of the mouth, and because also of the wormlike form of most Insect larves, these larves appearing to be survivals of the Myriapod stage. In the change from an Annelid and Myriapod to an Insect, the *multiplicate* feature disappeared and the number of parts became essentially the fixed normal number of the type, both as regards the body-segments and their jointed appendages.

The rise of grade from the Myriapod to the Insect involved the appropriation of the three body-segments of the Myriapod bearing the three anterior pairs of feet (which correspond normally to half the body segments of the head of an Isopod Crustacean) for forming the isolated middle section of the body called the thorax, and the suppression of all the other pairs of feet. In both Spiders and Insects, the change involved also a general concentration of the structure toward the cephalic nervous center, that is a shortening of the range of cephalic control, and especially the distance to the posterior limit of locomotive action. Compared with a Crab, the highest type in the Crustacean series, its superior, an Ant, is a very little thing.

The fact that in low-grade Insects, there is no proper metamorphosis, while in the higher, as they rise in grade, the larval stage is lower and lower in embryonic level, suggests that the larval stage results from an attendant retrograde embryonic change to a line parallel with the Myriapod, and beyond to the memberless condition of a worm. The principle appears to be a general one among animals, and thence, the higher the species the longer the stage of youth.

The relations in body-segments and limbs between the classes of Crustaceans, Limuloids, Arachnids, Myriapods and Insects are shown in the following table. The segments of the body are numbered along the left margin; the zero opposite signifies that the segment, though present has no appendage.

CRUSTACEANS.		LIMULOIDS.						ARACHNIDS.				MYRIAPODS.		INSECTS.	
Tetradecapods.		Eurypterus.		Pterygotus.		Limulus.		Scorpion.		Phrynus.		Lithobius.			
1. 1st Ant.	Head.	O	Head.	Ant.	Head.	Ant.	Head.	Falces	Head.	Falces	Head.	Ant.	Head.	Ant.	Head.
2. 2d Ant.		M-P.		M-P.		M-P.		M.		M.		M.		M.	
3. M.		M-P.		M-P.		M-P.		P.	Thorax.	P.	Thorax......	Mx.		Mx. & L.	
4. Mx.		M-P.		M-P.		M-P.		P.		P.		P.	Abdomen.	P.	Thorax.
5. Mx.		M-P.		M-P.		M-P.		P.		P.		P.		P.	
6. Mx.		M-P.		M-P.		M-P.		P.		P.		P.		P.	
1. P.	Thorax.	Fol. P.	Thorax.	Fol. P.	Thorax.	Fol. P.	Thorax.	O.		O.	Abdomen.	P.		O.	Abdomen.
2. P.		Fol. P.		Fol. P.		Fol. P.		Comb.		O.		P.		O.	
3. P.		O		O		Fol. P.		O.		O.		P.		O.	
4. P.		O		O		Fol. P.		O.		O.		P.		O.	
5. P.		O		O		Fol. P.		O.		O.		P.		O.	
6. P.		O		O		Fol. P.		O.		O.		P.		O.	
7. P.		O		O		O		O.		O.		P.		O.	
										O.		P.		O.	
1. App.	Abdomen.	O	Abdomen.	O	Abdomen.	O	Abdomen.	O.	Abdomen.	O.		P.		O.	
2. App.		O		O				O.				'P.			
3. App.		O		O				O.				P.			
4. App.		O		O				O.				P.			
5. App.		O		O				O.				15 pairs of feet in Lithobius, 21 in Scolopendra, 200 in some Myriapods.			
6. App.		O		O				O.							

In this table, the following abbreviations are used: Ant., antenna; App., pairs of jointed appendages, either pediform or branchial; M., Mandible; Mx., Maxilla; P., feet; M-P., feet that serve also as jaws; Mx. & L. (under Insects), maxillæ and labium; Fol. P., foliaceous or lamellar feet or appendages.

Under the Limuloids, the genus Eurypterus fails of antennæ; but they are present in Pterygotus, and are chelate; and this chelate (or thumb-and-finger) form characterizes also the modern Limulus, the Scorpions and the common Spiders. In the table the two pairs of maxillæ of Insects are assumed to belong to a single body segment, as held by many zoologists, including (as he himself informs the writer) Prof. S. I. Smith; the table shows that, with this admission, the thorax and head of an Insect are essentially homologous with the head of a Tetradecapod Crustacean.

Art. XXXIV.—*On the Crystallization of Herderite*; by S. L. Penfield.

During the past summer Mr. L. K. Stone of Paris, Maine, sent to Prof. H. L. Wells of the Sheffield Scientific School several specimens of an unknown mineral for identification. The specimens were collected at Paris, Me., but not at the noted Mt. Mica locality. They presented well defined, transparent and almost colorless *monoclinic* crystals, measuring up to 2^{mm} in diameter and 6^{mm} in length. The crystals are implanted mostly upon quartz but some are on feldspar. Their hardness is a little over 5. When tested before the blowpipe they at first sprouted and turned white, but afterwards fused at about 4 to a white, blebby enamel, tinging the flame very pale green, indicating phosphoric acid. In the closed tube at a high temperature the crystals whitened, threw off quite violently a fine scaly powder or dust and gave water which showed only a faint acid reaction. The mineral was slowly but completely soluble in hydrochloric acid. As these characters apparently did not agree with the description of any known species, the mineral was supposed to be new and accordingly the best material available for the chemical analysis was carefully selected and eventually separated from any attached quartz or gangue by means of the heavy solution. The pure mineral, amounting to about one and a half grams, and varying in specific gravity from 2·936 to 2·968, was analyzed by Professor Wells to whom the author's sincere thanks are due. The analysis revealed the interesting fact that the mineral is herderite and that it contains practically no fluorine, agreeing in this latter respect with a variety described by Professor Wells and the author* from Hebron, Me. The analyses of the minerals from both localities are as follows:

	Paris.	Hebron after deducting 5·27 per cent of impurities.	Theory for $Ca[Be(OH)]PO_4$.
Sp. gr.	2·952	2·975	
P_2O_5	44·05	43·08	44·10
BeO	16·13	16·18	15·53
CaO	34·04	[34·35]	34·78
H_2O	5·85	6·15	5·59
F	----	·42	----
Insoluble	0·44	----	----
	100·51	100·18	100·00

The analyses indicate a well defined type of herderite which may well be called hydro-herderite in distinction from the variety containing fluorine. Of the two types the former, $Ca[Be(OH)]PO_4$, occurs quite pure, as shown by the above analyses, and it may readily be told by its peculiar behavior when heated in a closed tube. We have as yet no proof of the existence of a pure fluor-herderite $Ca[BeF]PO_4$. Mackintosh† advanced such a formula for the mineral from Stoneham, Me., but he did not make a test for water or a direct determination of fluorine, the latter being calculated, as he states, from the excess of lime. The anthor in connection with Mr. D. N. Harper‡ proved that the Stoneham herderite contained both hydroxyl and fluorine in the proportion of about 3 : 2 and proposed the formula $Ca[Be(OH.F)]PO_4$, where fluorine and hydroxyl are regarded as isomorphous. This last type, which may be designated as hydro-fluor-herderite, may be readily distinguished by its behavior in a closed tube, as, when heated intensely, acid water is driven off, etching the glass and yielding a deposit of silica. From the quantity of hydrofluoric acid that is liberated it has been assumed that the fluorine and hydroxyl are in combination with beryllium and not with the more basic calcium.

The most interesting feature of the herderite from this new locality is, however, its *monoclinic crystallization*. The discovery of this has lead to the examination of the mineral from other localities and it has been found, as will be shown in the course of this article, that herderite is always monoclinic and not orthorhombic.

* This Journal, III, xliv, p. 114. 1892.
† This Journal, III, xxvii, p. 137, 1884.
‡ This Journal, III, xxxii, p. 107, 1886.

Among the specimens that were examined from the new locality there were only a few small crystals that were well adapted for measurement with the goniometer and these were always so attached that only a part of their faces were developed. Some of the faces are curved and give uncertain reflections but the majority are good and they are very free from vicinal planes, which are prominent on the Stoneham herderite. In the description of the crystals the position adopted by E. S. Dana* has been retained, and as far as possible, his system of lettering.

The habit of the crystals is shown in figures 1, 2 and 3. Number 1 is drawn with $0\bar{1}0$ in front and No. 2 with 001 vertical, these positions being chosen because they are best adapted for showing the monoclinic symmetry. Figure 3 is a basal projection and from this and the spherical projection, fig. 13, the relations of the forms and the prominent zones can readily be made out. The forms which have been identified are as follows :

a,	100,	$i\text{-}\bar{i}$	*e*,	302,	$-\frac{3}{2}\text{-}\bar{i}$	*r*,	112,	$-\frac{1}{2}$	*k*,	122,	$-1\text{-}\grave{2}$
b,	010,	$i\text{-}\grave{i}$	*t*,	032,	$\frac{3}{2}\text{-}\grave{i}$	*q*,	332,	$-\frac{3}{2}$	*w*,	3·12·4,	$-3\text{-}\grave{4}$
c,	001,	0	*v*,	031,	$3\text{-}\grave{i}$	*n*,	331,	-3	*z*,	$\bar{3}94$,	$\frac{9}{4}\text{-}\grave{3}$
m,	110,	*I*	*s*,	061,	$6\text{-}\grave{i}$	n,	$\bar{3}31$,	3			

The axial ratio was calculated from the measurements which are marked by an asterisk in the table of angles. For comparison the ratios derived by Haidinger† from the Ehrenfriedersdorf and by Dana from the Stoneham herderite are also given.

Author	$\grave{a} : \bar{b} : c$	$= 0{\cdot}63075 : 1 : 0{\cdot}42742$	$\beta = 89° 54'$
Haidinger	" "	$= 0{\cdot}6261 : 1 : 0{\cdot}4247$	$\beta = 90$
Dana	" "	$= 0{\cdot}6206 : 1 : 0{\cdot}42345$	$\beta = 90$

The angle β is very close to 90°, but there can be no mistake about the monoclinic character of the crystals as indicated by the development of the faces. As regards the forms, those shown in fig. 1 are almost invariably present. The basal plane *c* always yields good reflections and the edges which it forms with the dome *t* invariably curve and taper to a point as they approach the pyramid *z*, fig. 2. The edges between *t* and *z* were always rounded, and this is especially true in the vicinity where *c*, *t* and *z* approach one another. The pyramid *z* which, owing to the curved nature, did not yield very satisfactory measurements was surely identified by its location in the zones *m*, *e*, *k*, *t* and *m*, *v*. The pyramids *q* and *n* are commonly striated parallel to their intersection edges.

* This Journal, III, xxvii, p. 229, 1884.
† Phil. Mag., iv, p. 1, 1828.

Some of the measured angles are recorded in the following table, where it will be observed that the agreement with the calculated is usually very satisfactory, thus indicating that the axial ratio is nearly correct. Where the variation is considerable the faces were always either rounded or otherwise poorly adapted for measurement.

		Measured.	Calculated.			Measured.	Calculated.
c ∧ *a*,	001 ∧ 100 =	89° 54′*		*m* ∧ n,	$\bar{1}10$ ∧ $\bar{3}31$ =	22° 23′	22° 36′
c ∧ *e*,	001 ∧ 302 =	45 25*		n ∧ n,	$\bar{3}31$ ∧ $\bar{3}\bar{3}1$ =	-----	59 3
b ∧ *v*,	010 ∧ 031 =	37 57*		*c* ∧ *k*,	001 ∧ 122 =	-----	28 35½
c ∧ *m*,	001 ∧ 110 =	-----	89° 55′	*k* ∧ *k*,	122 ∧ $1\bar{2}2$ =	-----	44 3½
m ∧ *m*,	110 ∧ $1\bar{1}0$ =	64 25	64 29	*r* ∧ *k*,	112 ∧ 122 =	11 3	10 35½
b ∧ *m*,	010 ∧ 110 =	57 47	57 45½	*c* ∧ *t*,	001 ∧ 032 =	32 46	32 40
c ∧ *r*,	001 ∧ 112 =	21 52	21 49	*t* ∧ *t*,	032 ∧ $0\bar{3}2$ =	65 36	65 20
r ∧ *r*,	112 ∧ $1\bar{1}2$ =	22 43	22 52½	*b* ∧ *s*,	010 ∧ 061 =	21 17	21 18
c ∧ *q*,	001 ∧ 332 =	50 8	50 11	*a* ∧ *v*,	100 ∧ 031 =	89 55	89 56
q ∧ *q*,	332 ∧ $3\bar{3}2$ =	48 20	48 22	*a* ∧ *w*,	100 ∧ 3·12·4 =	72 34	72 35
c ∧ *n*,	001 ∧ 331 =	67 7	67 20	*c* ∧ *w*,	001 ∧ 3·12·4 =	-----	54 2
n ∧ *n*,	331 ∧ $3\bar{3}1$ =	58 56	58 59	*w* ∧ *w*,	3·12·4 ∧ $3\cdot\bar{12}\cdot4$ =	-----	97 36
b ∧ *n*,	010 ∧ 331 =	60 30½	60 30½	*c* ∧ *z*,	001 ∧ $\bar{3}94$ =	-----	47 26
c ∧ n,	001 ∧ $\bar{3}31$ =	------	67 29	*b* ∧ *z*,	010 ∧ $\bar{3}94$ =	49 --	49 22½

Optical properties.—Sections parallel to the clinopinacoid show inclined extinction. With yellow light, Na flame, the axis of greatest elasticity, which is the acute bisectrix, was found to make an angle of +2½° with the clino axis, hence, as the axial inclination β is approximately 90°, c is inclined 2½° to $\dot{c}$ in the acute angle β. The plane of the optical axes is the clinopinacoid and the double refraction is negative and rather strong. For the determination of the mean index of refraction a prism was prepared with its edge parallel to the ortho axis. Owing to the character of the material the prism was small and its optical orientation only approximately correct. The results of the measurements are given in tabular form below. Two plates were prepared, one at right angles to the acute bisectrix, the other parallel to the base, which is approximately at right angles to the obtuse bisectrix. The first of these was so small that the divergence of the optical axes could not be observed in air but was determined in α–monobromnaphthaline ($ny = 1{\cdot}6572$). The results are as follows, all made with yellow light, Na flame:

From prism: $\alpha = 21° \; 58'$, $\delta = 14° \; 16'$, hence $\beta = 1{\cdot}632$

2Ha =	70° 44′	hence	2Va = 71° 59′
2Ho =	105 1	hence	2Vo = 107 21
			179° 20′
		Theory,	180 00

Also from 2Ha and 2Ho there were calculated for comparison 2Va = 72° 12′ and $\beta = 1{\cdot}628$. The first of these agrees very well with the value given above, the second varies 0·004 from β derived from the prism and the mean of the two determinations 1·630 may be accepted as very nearly correct. The dispersion was $\rho > v$ and was decidedly inclined, the borders of one hyperbola being much more brilliantly colored than the other.

Herderite from Hebron, Maine.

The occurrence of this hydro-herderite has already been referred to and the analysis given. The habit of the crystals is represented in fig. 4. Only a very little of this material was found, and the crystals were not well adapted for accurate measurement. As stated in the original description, one of the best measurements that was made was $n \wedge n$, $331 \wedge \bar{3}31 =$ 102° 22′ which does not agree well with the angle calculated by Dana, 103° 24′, but does, however, compare very favorably with the angle calculated from the hydro-herderite from Paris. If the crystals are twinned about the basal plane, according to a method to be described later, the calculated angle should be 102° 25′ and if they are simple, 102° 41′.

Herderite from Stoneham, Maine.

On the crystals from this locality the following forms have been identified:

b, *c*, *m*, *e*, *s*, *v*, *t*, *q*, *n* and n

corresponding to the herderite from Paris, and in addition:

l, 120, $i\text{-}\grave{2}$	e, $\bar{3}02$, $\frac{3}{2}\text{-}\bar{i}$	*p*, 111, −1	*x*, $\bar{3}62$, $3\text{-}\grave{2}$
d, 101, $-1\text{-}\bar{i}$	*u*, 011, $1\grave{i}$	q, $\bar{3}32$, $\frac{3}{2}$	

Of these all except *d*, which is mentioned by Hidden,* were observed by Dana, while the prism μ, 130 and the pyramid *y*, $3\text{-}\grave{3}$ observed by him have not been found by the writer, and the position of *y* in the monoclinic system cannot therefore be determined. Figures 5 and 6, which, except for the lettering, have been copied from Dana, represent the prevailing combinations. The crystals are penetration twins and imitate orthorhombic symmetry, similar to the crystals of stilbite. The twinning plane can be either the base or the orthopinacoid; β being very near 90°, and the character of the faces such that sufficiently accurate measurements cannot be made to determine this point. Considering the faces in the upper front and lower rear segments as in normal and parallel position, the lettering on the remaining faces has been underlined

*This Journal, III, xxxii, p. 209, 1886.

to signify that they are in twin position. Fig. 7 represents a fragment which was detached from a specimen in the Brush collection. It illustrates monoclinic symmetry in the development of *e*, *q* and *n* larger than e, q and n and also in the occurrence of the positive pyramid *x* between *b* and q and not between *b* and *q*. A thin section was prepared from this crystal parallel to *b* and it showed no indication of twinning. Fig. 8 represents the development of the forms on a crystal in the Bement collection. This was so attached that the majority of its faces could be observed and the monoclinic character is well shown by the occurrence of *d* and *p* in the upper front and lower hind segments only.

Fig. 9 represents a crystal in the Bement collection which is reported as being the largest herderite ever found at Stoneham and has already been described in this Journal by Mr. Hidden.* Its actual dimensions parallel to the crystallographic axes are $\grave{a}$ 23^{mm}, $\bar{b}$ 25^{mm} and $\acute{c}$ 18^{mm}. The crystal was attached at one extremity of the $\grave{a}$ axis and has been drawn with $0\bar{1}0$ in front. It is twinned, and what is undoubtedly the line of twinning may be distinctly traced across the *m* and *x* faces, as indicated by the dotted line in the figure. That portion of *x* above the twinning line is quite perfect, and with reference to the upper half of the crystal, it is situated in its normal position for monoclinic symmetry as a positive hemi-pyramid. The lower portion, however, is very uneven and vicinal and occupies the position of a negative hemi-pyramid, but this has not been included in the list of forms, as this is the only occurrence of it that has been observed and it is not a perfect face but rather an attempt to complete the *x* face in the upper portion of the twin.

As has already been stated the material from Stoneham is a hydro-fluor herderite with OH : F = about 3 : 2 and it presents an excellent opportunity for comparison with the hydro herderite from Paris, and of observing the variations in the physical properties produced by the partial substitution of fluorine for hydroxyl. Unfortunately the crystal faces have such a strong tendency to vicinal development that it is difficult to obtain reliable measurements. Owing to the absence of visible reëntrant angles on twin crystals the inclination β must be very near 90° but it could not be accurately measured. On two crystals which were selected on account of the perfection of their faces the following measurements were made, of which those under I are especially good:

* Loc. cit.

	Measured I.	Measured II.	Calculated, Dana.	Calculated for hydro-herderite.
$m \wedge m$, $110 \wedge 1\bar{1}0$ =	....	63° 57′	63° 39′	64° 29′
$n \wedge n$, $331 \wedge 3\bar{3}1$ =	58° 19′	58 21	58 17½	58 59
$q \wedge q$, $332 \wedge 3\bar{3}2$ =	....	47 58	47 52	48 27
$s \wedge s$, $061 \wedge 0\bar{6}1$ =	137 12	....	137 2	137 23½

It will be observed in the above that the measurements agree very well with the angles calculated by Dana but vary considerably from those found on hydro-herderite. The axial ratio established by Dana is therefore retained, and is repeated below along with the author's ratio for hydro-herderite :

Hydro-fluor-herderite $\grave{a} : \bar{b} : \dot{c}$ = 0·62060 : 1 : 0·42345 β = nearly 90°
Hydro-herderite " " = 0·63075 : 1 : 0·42742 β = 89° 54′

The partial substitution of fluorine for hydroxyl has had, therefore, an appreciable effect upon the axial ratio, shown especially by a perceptible shortening of the a axis. It may also be pointed out that the specific gravity of the Stoneham mineral, 3·006–3·012, is greater than that of the hydro-herderite from Paris and Hebron, 2·952–2·975, which might be expected, as fluorine with an atomic weight of 19 is heavier than hydroxyl with a molecular weight of 17.

Optical properties.—Several clinopinacoid sections that were prepared showed an inclined extinction of about +2° when measured with yellow light. Sections from twin crystals like figs. 5 or 6 revealed the twinning beautifully in polarized light. Fig. 14 represents an ideal section, the opposite portions I and I as also II and II extinguishing simultaneously. Fig. 15 represents the actual disposition of the Parts I and II in a section from a crystal like fig. 6, the arrows indicating the directions of extinction.

The mean index of refraction was determined by means of a prism cut with its edge parallel to the ortho axis and the divergence of the optical axes by a plate cut normal to the acute bisectrix. The results, all determined in yellow light, Na flame, are as follows :

	Hydro-herderite.
From prism α = 22° 55′ δ = 14° 24′ hence β = 1·612	β = 1·630
$2E\alpha$ = 128° 25′ hence $2V\alpha$ = 67 56′	2V = 71° 59′
$2H\alpha$ = 66 0 hence $2V\alpha$ = 68 7	71 59

The double refraction is negative. The dispersion is $\rho > v$ and is distinctly inclined. The indices of refraction have been determined by Bertrand* as follows :

α = 1·621 β = 1·612 γ = 1·592

* Bull. Soc. Min. de France, ix, p. 142, 1886.

The divergence of the optical axes has been measured by Des Cloizeaux.* His optical preparation was undoubtedly cut from a twin crystal, for he states that on both sides of the bisectrix two sets of rings were visible, which may readily be understood by reference to fig. 14, as a section parallel to the ortho-pinacoid would be approximately normal to two bisectrices. He gives 2Ea for the inner hyperbolæ 121° 22′ and for the outer 130° 2′. The true value should be about midway between these. From the study of the optical properties we learn, therefore, that, by the partial substitution of fluorine for hydroxyl, the position of the axes of elasticity has not materially changed but the mean index of refraction β and the divergence of the optical axes have decreased.

Herderite from Auburn, Maine.

The material from this locality as shown by the closed tube reaction is a hydro-fluor-herderite, and as far as known to the author is represented by a single specimen in the Bement collection and two crystals belonging to Mr. T. F. Lamb of Portland, Maine. On the specimen in the Bement collection there is one crystal which is almost colorless and transparent and has the habit shown in fig. 10. It is attached to albite and a large imperfect herderite and measures parallel to the axial directions $\grave{a}$ 8^{mm}, $\bar{b}$ 8^{mm}, and $\dot{c}$ 11^{mm}. It is twinned and shows a reëntrant angle formed by the faces of the dome $\mathfrak{d}$, $\bar{3}01$. This form is strongly vicinal in its development, and was not identified by measurement but by its position in the zones v, m. Some of the large faces are dull and not adapted for measurement but the forms m, n and q, except for a slight striation parallel to their mutual intersections, are remarkably perfect and yielded the following measurements:

		Stoneham herderite.	Hydro-herderite.
$m \wedge m$, upper crystal	63° 53′	63° 39′	64° 29′
$m \wedge m$, lower crystal	63 52	" "	" "
$n \wedge n$, upper crystal	58 31	58 17½	58 59
$n \wedge n$, lower crystal	58 30	" "	" "
$q \wedge q$,	47 54	47 52	48 22
$m \wedge n$,	22 22	22 33	22 35
$m \wedge q$,	39 36½	39 42	39 39

From the values of $m \wedge m$ and $n \wedge n$, which are undoubtedly very accurate, it may be assumed that this variety contains less fluorine than the Stoneham mineral as the values are slightly greater and thus approach the hydro-herderite. The crystals from the collection of Mr. Lamb are in habit similar to the one

* Bull. Soc. Min. de France, vii, p. 132, 1884.

just described, but they are not so perfect and they do not show the reëntrant angle.

Herderite from Greenwood, Maine.

In this township herderite has been found at two localities. At one of these it is a hydro-herderite and, as represented by a small specimen in the Brush collection and by several crystals belonging to Mr. Geo. L. Noyes of Norway, Me., it occurs in crystals measuring 15^{mm} in diameter, but poorly developed and presenting no forms that could be accurately measured on the reflecting goniometer; with the contact goniometer, however, the following were identified: *b*, 010; *c*, 001; *t*, 032 and $\mathfrak{z}$, $\bar{3}64$, $\frac{3}{2}$-2̀. The development of the forms is shown in fig. 11, $\mathfrak{z}$ having been observed only on crystals from this locality.

At the second locality it is a hydro-fluor-herderite and is represented only by a single specimen belonging to Mr. Noyes. This shows several herderites attached to a large quartz crystal. The largest herderite measured parallel to the axial diameters *a*, 9^{mm}; *b*, 5^{mm} and *c*, $3\frac{1}{2}^{mm}$ and had the habit shown in fig. 12. The crystals were not well adapted for measurement with the reflecting goniometer and they were not detached from the quartz, but the forms were identified by approximate measurements made from wax impressions of the faces. The following were observed: *b*, 010; *m*, 110; *l*, 120; *e*, 302; *u*, 011; *n*, 331; $\mathfrak{n}$, $\bar{3}31$; $\mathfrak{q}$, $\bar{3}32$; $\mathfrak{r}$, $\bar{1}21$, 2-2̀ and $\mathfrak{p}$, $\bar{3}91$, 9-3̀. The last two have been observed only on the crystals from this locality. The forms $\mathfrak{q}$, $\mathfrak{r}$ and $\mathfrak{p}$ round into one another and in this respect the crystals resemble those from Paris, where the positive hemi-pyramids are curved and indistinct.

Herderite from Ehrenfriedersdorf, Saxony.

The material from this locality is extremely rare and the author has had no opportunity of examining it. It is undoubtedly monoclinic and the orthorhombic habit described by Haidinger is the result of twinning. In the description given by Des Cloizeaux* of the optical properties it is very evident that he was dealing with a twin crystal as he states that about the acute bisectrix three sets of ring systems were observed. The following values for 2E are given 124° 35′, 123° 10′ and 122° 24′. From the axial ratio given on page 331 it would be expected that the composition of the mineral is intermediate between that of the Stoneham and Paris herderite.

Conclusions.—As has been shown, herderite is a mineral of variable composition and it seems best to designate the dif-

* Loc. cit.

ferent varieties by a suitable prefix. As we speak of fluor-apatite and chlor-apatite, so we can distinguish hydro-herderite, fluor-herderite, if the pure compound is ever found, and for the isomorphous mixture of the two, hydro-fluor-herderite. The axial ratios and other physical properties vary with the composition and the results which have been given in the course of this article will serve as an additional contribution to our knowledge of the isomorphism of fluorine and hydroxyl.

The following is a list of the twenty-nine forms which have been observed on the different varieties of herderite, the accompanying letters signifying the prominent localities: A. Auburn, E. Ehrenfriedersdorf, P. Paris, S. Stoneham and G. Greenwood. The relations of these may be seen by reference to the spherical projection, fig. 13.

Pinacoids.			
a,	100,	*i*-ī	E. P.
b,	010,	*i*-ĭ	A. P. S. G.
c,	001,	*O*	A. E. P. S.
Prisms.			
m,	110,	*I*	A. E. P. S. G.
l,	120,	*i*-2̀	S. G.
μ,	130,	*i*-3̀	S.
Ortho-domes.			
d,	101,	−1-ī	S.
e,	302,	−$\frac{3}{2}$-ī	A. P. S. G.
𝔢,	$\bar{3}$02,	$\frac{3}{2}$-ī	S.
𝔡,	$\bar{3}$01,	3-ī	A.
Clino-domes.			
u,	011,	1-ĭ	S. G.
t,	032,	$\frac{3}{2}$-ĭ	A. E. P. S.
v,	031,	3-ĭ	A. P. S.
s,	061,	6-ĭ	E. P. S.

Pyramids.			
r,	112,	−$\frac{1}{2}$	A. P.
p,	111,	−1	E. S.
q,	332,	−$\frac{3}{2}$	A. P. S.
n,	331,	−3	A. E. P. S. G.
o,	441,	−4	E.
k,	122,	−1-2̀	P.
w,	3·12·4,	−3-4̀	P.
y?	131,	−3-3̀	S.
	$\bar{1}$31,	3-3̀	S.
𝔮,	$\bar{3}$32,	$\frac{3}{2}$	P. S. G.
𝔫,	$\bar{3}$31,	3	A. S. G.
𝔷,	$\bar{3}$64,	$\frac{3}{2}$-2̀	G.
𝔵,	$\bar{1}$21,	2-2̀	G.
x,	$\bar{3}$62,	3-2̀	S.
z,	$\bar{3}$94,	$\frac{9}{4}$-3̀	P.
𝔭,	$\bar{3}$91,	9-3̀	G.

As regards the localities where this rare mineral is found, those in Maine are all within a few miles of one-another, Greenwood, Hebron, Paris and Stoneham being in Oxford County while Auburn is an adjoining township in Androscoggin County. These localities have something in common with the only other known one for herderite, the tin mines of Ehrenfriedersdorf in Saxony, since both are regions of granites and gneisses, and the mineral occurs associated with cassiterite, topaz and beryl in both cases.

As regards the position of herderite in a natural system of classification it seems most closely related to the monoclinic wagnerite-triplite-triploidite group. Although a close relation can be seen between the *a* and *b* axes the relations of the vertical axes and of the inclination *β* are not so clear.

		a : b : c	β
Hydro-herderite,	Ca[BeOH PO_4	0·6307 : 1 : 0·4274	89° 54′
Hydro-fluo herderite,	Ca[Be(OH . F)] PO_4	0·6206 : 1 : 0·4234	very near 90°
		$\frac{1}{2}a$: b : c	
Wagnerite,	Mg[MgF] PO_4	0·6362 : 1 : 1·5059	71° 53′
Triplite,	R[RF] PO_4	? : ? : ?	?
Triploidite,	R[ROH] PO_4	0·6190 : 1 : 1·4925	71 46
Sarkinite,	Mn[MnOH] AsO_4	0·6672 : 1 : 1·5154	62 13½

R = Mn and Fe

In this group fluorine and hydroxyl are isomorphous, and triploidite described by Brush and Dana,* being isomorphous with wagnerite and having undoubtedly the same structural formula as triplite, gave the first instance in which this fact was observed.

In conclusion the author takes pleasure in expressing his sincere thanks to Messrs. C. S. Bement of Philadelphia, Pa., G. L. Noyes of Norway and T. F. Lamb of Portland, Me., for the loan of specimens from their private collections and to Mr. L. K. Stone of Paris, Me., for the supply of material from the new locality.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, January, 1894.

Art. XXXV.—*Additional Note on Leucite in Sussex Co., N. J.*; by J. F. Kemp.

In the Journal for April, 1893, pp. 298–305 the writer described a "Basic Dike near Hamburg, N. J., which has been thought to contain Leucite." The paper dealt with a dike that cut blue, apparently Lower Silurian limestone, was 15–20 feet wide and situated about one and one-half miles northwest of Hamburg, N. J. The dike contained some curious spheroids that strongly suggested leucite, but which were altered in every case to a mass of analcite, calcite, and feldspar. From this it was concluded that fresh material would be necessary to decide the presence of this rare and interesting mineral, although the nearness of the elaeolite-syenite at Beemerville, gave additional reason to suspect it. The past summer, being again in the region, the writer visited the extensive quarries for limestone, that have been opened up at Rudeville, which is over on the opposite side of an Archæan ridge (Hamburg Mountain), from Hamburg and the first mentioned dike. The white crystalline limestone is cut by a dike about 12 feet wide,

* This Journal, III, xvi, p. 42, 1878.

with some smaller offshoots, but with a strike in the large one of N. 45° W. and a dip of 75° N. The dike had been opened up to a depth of 20 feet or more below the surface and appeared quite fresh. Most interesting of all, it was copiously provided with the leucitic spheroids, of which an abundant supply was gathered for investigation. It should be stated that it is the same dike as the one mentioned by F. L. Nason in the Annual Report of the N. J. State Geologist, 1890, p. 35, and determined by Dr. G. H. Williams as mica-diabase in an altered condition, Dr. Williams evidently recognizing its affinities with the one in the mines at Franklin Furnace. In the fresh condition it is, in the specimens with the spheroids, precisely like the earlier mentioned Hamburg dike. Although this is three miles away, and not exactly in the same line of strike, the two dikes are so near it as to give ground for the suspicion that they are the same rock body. Ten sections were prepared in three of which there appeared some apparently unaltered material in the midst of the analcite and other secondary products. One of these was cleaned of balsam, and on one-half the gelatinizing and staining test was tried. The secondary products gelatinized and stained readily; the supposed fresh material was not affected. On the other portion in small, carefully selected grains, the test for fluo-silicates was tried. Abundant cubes of potassium fluo-silicate* were obtained, with but little of the hexagonal sodium salt, much less, in fact of the latter, than the bausch-analysis of the altered spheroids, published in the writer's previous paper (p. 303) would indicate for their general mass. In one of the slides the characteristic twinning of leucite is also developed.

It would seem therefore to be quite certain that there actually is in Sussex Co., N. J., a leucite dike rock, associated with the elaeolite-syenite, and that the determination of a piece of the earlier described dike, by Dr. E. Hussak,† as leucite-tephrite, although based on altered material and thought by the writer at the time to be premature, really is substantiated by the discovery of satisfactorily fresh material. But it is also quite true that similar spheroids formed entirely of feldspar have developed in the mica-diabase dike at Franklin Furnace, showing thus that instability of the leucite molecule, which has been elsewhere met.

* These do not appear at once and are only to be obtained by redissolving the first crop in water or dilute HF, and recrystallizing.

† Neues Jahrbuch, 1892, II, 153. The material was derived from J. F. K. through O. A. Derby.

Art. XXXVI.—*On some Phonolitic Rocks from the Black Hills;* by L. V. Pirsson.

For our knowledge of the geology of the Black Hills and of the occurrence and distribution of the igneous rocks of the region we are chiefly indebted to Newton.* Crosby† has also shown that the greater part of the younger eruptives are to be considered as occurring in the form of laccolites. Our information in regard to the petrographical character of these rocks is due to Caswell,‡ who studied the suite of specimens gathered by Newton. This was one of the earlier contributions to American petrology, and when we consider the amount of knowledge available on the subject at that time, it was an excellent and careful piece of work.

Reading between the lines of Caswell's report however and possessed of the facts which the great advance in petrographical knowledge during the past fifteen years has furnished we can see that many of the rocks studied by Caswell were of great interest, unusual in character and that they possessed relations not then brought out.

This was shown by an examination of several specimens from the region which have come into the writer's hands from various sources to be mentioned later and it was therefore decided to study them more in detail with the results given in the present article.

Phonolite.

This rock is definitely mentioned by Caswell, as occurring at Black Butte and he gives a figure and description of it.§ From the facts stated by him it would seem to be present also in other localities. Thus the rock from Bear Lodge, or as it is now commonly called, the "Devil's Tower," an isolated butte near the Little Missouri Buttes on the northwest border of the region and described by Newton‖ as having a remarkable columnar structure is said to gelatinize readily in acid. It is described as sanidine trachyte.

A specimen of this rock has come into possession of the writer through the kindness of Mr. Geo. Leavenworth of New Haven, who visited the locality in 1889. Both in macroscopic appearance and in thin section it agrees quite well with the description given by Caswell but differs in some important characters. It may also be reasonably inferred that the rock

* Geol. of Black Hills of Dakota, U. S. Geog. and Geol. Surv. Rocky Mts., Washington, 1880.

† Proc. Bost. Soc. Nat. Hist., vol. xxiii, p. 511, 1888.

‡ Geol. Black Hills, as above, Chap. VII, p. 471, Micro. Petrog.

§ Op. cit., p. 503. Plate I, fig. 3.

‖ Op. cit., p. 201.

would vary some in different parts of the mass. For Caswell's description the reader is referred to the original memoir as it would be too long to quote here.

The specimen collected by Mr. Leavenworth shows a dense felsitic looking groundmass of a dark gray color with somewhat greasy luster, very thickly dotted with white or pale gray feldspar phenocrysts which attain a size of 1^{cm} in diameter. Sometimes they are columnar on the $\grave{a}$ axis and sometimes short and stout in their habit. They are so thickly crowded as to form a very considerable proportion of the rock mass. Between them lie occasional small black prisms of augite.

In thin section the microscope discloses the following minerals: *feldspar*, *pyroxene*, *titanite*, *apatite* in the first generation and *feldspar*, *nephelite*, *ægirine* and *sodalite* (?) in the second. The large feldspar phenocrysts sometimes show a zonal structure which is indeed plainly visible on the hand specimen where any process of alteration has taken place, as on a weathered rock surface—the center and certain zones being more affected than the outer mantle and remaining parts. Generally they are very fresh, showing only an occasional trace of decomposition along a cleavage crack. Between crossed nicols they sometimes reveal the zonal structure but never any appearance of microperthite from intergrown albite lamellæ and never any twinning save that according to the Carlsbad law.

Since the chemical analysis of the rock—given later—had shown such an excess of soda over potash it was inferred that this feldspar might be anorthoclase and an analysis of it was therefore made.

To obtain material clear glassy fragments of the phenocrysts were first picked by hand, crushed fine enough to pass through a 100 mesh (to the inch) sieve and then washed free from dust and separated by the potassium mercuric iodide solution. They floated readily at 2·614 which would separate any albite (none sank however) and fell at 2·557 which would support any zeolites or decomposed matter. A considerable portion fell at 2·59 and the average specific gravity was between 2·58 and 2·59. Seen under the microscope the material consists of clear homogeneous grains. The analysis gave:

		Ratio.		
SiO_2	66·44	1·1073		6
Al_2O_3	19·12	·1854		1·005
Fe_2O_3	0·56	----		
CaO	tr.	----		
Na_2O	7·91	·1274	·1815	·984
K_2O	5·10	·0541		
H_2O (ign.)	0·57	----		
Total	99·70			

Neglecting the small amount of water and ferric oxide—the latter due to minute amounts of limonite infiltrated into cleavage cracks—the ratios are those of a normal feldspar in which Or : Ab : : 1 : $2\frac{1}{3}$.

Attempts made to measure the cleavage angle of $c(001) \wedge b(010)$ were not successful as the cleavages were too imperfect to reflect light well and measurements could not be made within 1° with accuracy. The cleavage parallel to $b(010)$ is much better than that parallel to $c(001)$. Such cleavage plates resting on $c(001)$ between crossed nicols extinguish parallel to the edge of $c(001)$ on $b(010)$ or so nearly that no appreciable deviation could be seen with the Bertrand ocular or in monochromatic light; resting on $b(010)$ they have a positive extinction angle of about 9° and in convergent light show the obtuse bisectrix c about perpendicular to the field. The feldspar is therefore a soda-orthoclase.

From these results it would seem that soda-orthoclase or anorthoclase is probably a more common constituent of phonolitic and trachytic rocks than might be supposed from their petrographic description. The concealment of the triclinic character, produced very probably by sub-microscopic or even intimate molecular twinning according to the albite law, would naturally lead to confusion with sanidine while examination of cleavage plates of such material, giving only a slightly increased angle in the positive sense on $b(010)$ and a somewhat higher specific gravity, would scarcely yield sufficient data for reliable conclusions and it is evident that only chemical analysis combined with these can safely establish the precise nature of the mineral.*

Pyroxene.—This is ægirine-augite with characteristic color, pleochroism and extinction. Dispersion of the optic axes is marked. It is zonally built, the ægirine molecule increasing toward the periphery which is finally surrounded by a deep green ægirine mantle. This was evidently growing during the final stage of consolidation as the minerals of the groundmass are idiomorphic against it or else actually imbedded in it. *Titanite* occurs in characteristic lozenge shaped cuts which are almost invariably twinned. The *groundmass* is made up mostly of small lath-like feldspars with Carlsbad twinning arranged in trachytic structure and scattered amidst them are shreds and rods of ægirine and very small idiomorphic nephelites. These latter are very clear and colorless and often bounded by the ægirine shreds as is common in phonolites. They are easily told by their hexagonal basal cuts, dark between crossed nicols and short rectangular prismatic ones with

* Conf. also, article by Wolff and Tarr, Bull. Mus. Comp. Zool. Cambridge, vol. xvi, 1893, pp. 230–231).

parallel extinction and by their very low single and double refraction. There appear also small hexagonal sections of a mineral which is full of dusty inclusions and always isotropic. It is supposed to be of the sodalite group which is also indicated by the chlorine shown in the analysis. Patches of a zeolite in radial structure sometimes occur.

The powdered rock gelatinized readily with hydrochloric acid and no effervescence of CO_2 could be seen. A chemical analysis of it yielded the following results.

Sp. G. 2·582.	SiO_2	61·08
	TiO_2	0·18
	Al_2O_3	18·71
	Fe_2O_3	1·91
	FeO	0·63
	MnO	trace
	CaO	1·58
	BaO	0·05
	MgO	0·08
	Na_2O	8·68
	K_2O	4·63
	H_2O (ign.)	2·21
	Cl	0·12
	SO_3	trace
	Total	99·86
	O = Cl	0·03
		99·83

To be noted is the very small amount of bivalent metallic oxides present and the great excess of soda over potash.

A phonolite occurring in El Paso County, Colorado, has been described by Cross.* It is the only one thus far in North America which has been investigated.† The analysis of it is almost identical with that just given and shows the same excess of soda over potash. So also do the acmite trachytes from the Crazy Mts. described by Wolff and Tarr.‡ In this respect these rocks are noteworthy among American occurrences and

* Proc. Colorado Sci. Soc., 1887, p. 167.

† Recently A. Osann (Geol Surv. Texas, Ann. Rep. 1892, p. 130) has briefly mentioned phonolites as occurring in the Trans Pecos district, Texas. This makes the third American locality. E. Goldsmith has described so-called phonolites from several localities in eastern Pennsylvania, but since he states that these rocks contain plagioclase, hypersthene and quartz and does not mention nephelite it is not likely that the majority of petrographers will agree with his determinations. His chief reason for calling them phonolites seems to be due to the fact that the rocks split into thin plates and ring when struck with the hammer. He calls them *gabbro phonolites!* and seems to have been unaware of the previous work of Cross and Caswell. (Proc. Acad. Nat. Sci. Philadelphia, 1893, p. 176.)

‡ Op. cit, p. 232.

to be paralleled with those occurring in various parts of Europe and especially in southern Norway. For phonolites they are rather high in silica; thus an analysis of "Nordmarkite" or quartz syenite from Aueröd as quoted by Brögger* has a composition very similar but a greater amount of the ferro-magnesian oxides in forming meta-silicates has left a little more silica than was necessary to turn the alkalies and alumina into feldspar and this excess appears as a minute amount of interstitial quartz; while in the present case as the amount of bivalent metals is very small there has not been sufficient silica to turn all the alkalies and alumina into feldspar and nephelite has thus been forced to form.

Another rock very similar to this has been furnished the writer by Prof. C. E. Beecher, who collected it at Deadwood in the summer of 1890. In regard to its occurrence Prof. Beecher says "it occurs as a vertical dike about fifty feet wide cutting through the schists and Paleozoic series in the mountain just south of Deadwood. The specimen was collected in the little ravine above the cemetery near the base of the mountain and where the dike cuts the Potsdam sandstone." The rock has a dense felsitic looking groundmass in which lie reddish *feldspar* phenocrysts, very thin tabular on b(010) and often 1^{cm} across. They are not very numerous. Phenocrysts of a glittering black *hornblende* occur freely sprinkled through the rock. They are generally quite small, and needle-like but are sometimes stouter and attain a length of several m.m.

In thin section are seen in addition *apatite*, *titanite*, *pyroxene*, *nephelite*, *calcite* and zeolitic material. The feldspar is mostly sanidine in Carlsbad twins. A smaller amount of a striated feldspar occurs. The *hornblende* is very idiomorphic, often twinned on a(100) and has the following pleochroism: $\mathfrak{a}$ light brownish yellow, $\mathfrak{b}$ olive brown, $\mathfrak{c}$ olive green, with absorption $\mathfrak{c} = \mathfrak{b} > \mathfrak{a}$. The angle $c \wedge \mathfrak{c}$ is about 12° and the double refraction is weak. A crystal extracted from the rock was found to have the forms m(110), a(100), b(010) and r(011) and to be twinned on a(100). The prism m(110) is largely developed, the pinacoids being very narrow. On the reflecting goniometer $m \wedge m$ $(110 \wedge \bar{1}10)$ was measured and found 55° 45′. Before the blowpipe the mineral fuses easily to a black shining magnetic globule coloring the flame strongly and persistently yellow—thus indicating the soda-iron molecule to be largely present. From these facts it would seem to approach most nearly to *barkevikite*, differing somewhat in pleochroism. There is also a gray green augite present in the rock in much smaller amount, which is generally greatly decomposed—limonite and calcite having formed at its expense.

* Min. der Syen. peg. gänge. Zeit. für Kryst., vol. xvi, p. 57, 1889.

These minerals lie in a *groundmass* of trachytic structure consisting mainly of singly twinned feldspars between which lie patches of a colorless mineral of very low single and double refraction which is assumed to be nephelite. Also shreds and fibers of ægirine and the hornblende just mentioned are present. The rock is considerably altered and for that reason no analysis is given. It effervesces considerably in acid and gelatinizes readily.

A rock from this region has been supplied to European dealers by the specimen dealers in Deadwood. The exact locality is unknown—the labels reading simply "Black Hills," but it is probably from the northern part of the region. It is sold under the name of "Tinguaite." The hand-specimen shows a splintery fracture and is of bright green color with a grayish cast and the rock strongly resembles some of the varieties of the acmite trachyte from the Crazy Mts. already mentioned. The grain is dense and an occasional long columnar augite is the only phenocryst to be seen.

In thin section it is seen to consist chiefly of a singly twinned feldspar arranged in trachytic structure with an occasional patch of nephelite. It is everywhere penetrated by a fine interminable mesh of ægirine rods and needles which sink to trichites in dimensions. While the feldspars are arranged in flow structure these ægirine needles are scattered without orientation, pass through and through the smallest feldspars and penetrate to some distance the larger ones. They particularly abound in the interspaces and with low powers give the section a peculiar mossy appearance. To them is due the green color of the rock. They are evidently a final product of consolidation, forming after the moving mass which had developed some augite phenocrysts and to a considerable extent the microlites of feldspar of its groundmass, had come to rest. The augite phenocrysts are of ægirine-augite with a deep green mantle of ægirine. The rock appears quite fresh. It gelatinizes in acid. As the locality is unknown, no analysis is given.

From Caswell's report and from what has been shown in the foregoing it is evident that in the Black Hills region there is an extremely interesting series of high alkali-rocks, a fuller knowledge of whose mode of occurrence and petrographical and chemical relations would aid materially in solving for the region that most interesting problem in petrology which Judd has so aptly characterized in the term "petrographical provinces."

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, Dec., 1893.

ART. XXXVII.—*The General Structure of the Main Axis of the Green Mountains*; by CHARLES LIVY WHITTLE.

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THE anticlinal nature of the main axis of the Green Mountains was first suggested by Adams in 1846.* In 1847 the elder Hitchcock published a section of Hoosac Mountain in Massachusetts representing the strata overturned to the west and in his opinion the structure of the main axis in Vermont was the same.† Zodack Thompson argued for a synclinal axis‡ and T. Sterry Hunt was of the same opinion.§ Edward Hitchcock in his Geology of Vermont represents the structure of the axis between the Rutland and Plymouth valleys, along the Central Vermont railroad as a simple anticline.‖ At the time this survey was made (1861) the subject of induced schistosity was in its infancy, and it is rather surprising that the stratigraphy worked out so largely on the basis of schistosity alone should so nearly approximate to the real attitude of the very varied terranes that make up the area of the Green Mountains. Hitchcock's section VI, twenty miles north of section V, makes the gneiss dip uniformly east. Although along these lines the gneiss is represented as having a simple structure the text mentions that there are many minor irregularities and curvings in the stratification especially along the southern line near the town of Mt. Holly. The method then prosecuted of making geological maps by crossing the state once in so many miles, making observations on strike and dip where possible, accounts in part for the disagreement in the interpretation of the structure along the two lines mentioned.

My own observations in Vermont made mainly during three field seasons extended north and south along the highest portions of the Green Mountains from Chittenden on the north to Stratton on the south, and defined on the east and west by Windsor and Rutland valleys.

This area comprises part of the stretch of country embraced by sections V and VI above mentioned in Rutland and Windsor Counties.

* Second Annual Report on the Geology of Vermont. Adams. 1846, pp. 167 and 168.

† Elementary Geology. E. Hitchcock. 1847, p. 36 and 37.

‡ Address on the Natural History of Vermont. Preliminary Report on the Natural History of Vermont. Augustus Young. 1856. App. 6, pp. 65–68.

§ On Some Points in the Geology of Vermont. This Journal, vol. xlvi, 1868, p. 229.

‖ See vol. ii, Sec. V, 1861, and text giving description of this section, pp. 624–628.

Lower Cambrian quartzite and limestone occupy the Rutland valley. The quartzite lies at the base and is next above the series of metamorphosed clastics lying between it and the still more metamorphosed core of the range.* Plymouth valley is also occupied by limestone which extends north to North Sherburne, but its age is undetermined. Field evidence points strongly to its equivalence to one of the limestones in the metamorphosed clastics mentioned above occurring on the west side of the range.

The rocks of the range below the Olenellus horizon seem to fall into two groups. 1, a border series consisting alone, so far as I am aware, of metamorphosed sediments; and 2, a core series more metamorphosed, differing lithologically and carrying igneous rocks antedating the border series. When one first visits the eastern or western border of this area he is at once struck by the great variety of rocks and the apparent simplicity of their structure. Throughout the border areas the strike of the most prominent structure is commonly N. 10°–15° E. (magnetic) and the dip is generally steep easterly. This strike, as is now well known corresponds to the trend of the main Appalachian folding in New England. Further study of the rocks shows its secondary nature, traversing as it does rocks of the most varied texture and composition regardless of the real stratification, now usually not decipherable, but in many places still present where it has escaped the destructive dynamic action to which the rocks have been not only once but several times subjected. It is easy to be misled by this lamination and it soon became apparent that where the structure seemed the simplest in reality the obliteration of old bedding planes is the most complete. One of the best examples of this is seen at East Clarendon just north of where the Central Vermont railroad enters Mill River valley after leaving the Rutland valley. Here the rock, a metamorphic conglomerate in places is apparently as evenly-bedded as a Tertiary sandstone, but close inspection locally shows that most of the smaller pebble-like areas of quartz lying along the planes of schistosity are really sheared areas of quartz derived from genuine pebbles. The plane of shearing crosses the pebbles diagonally; by granulation of the several parts of the faulted clastics pseudo-pebbles lying parallel to the schistosity are produced which in cross section strongly resemble ordinary waterworn

*In a paper that will soon appear in the Journal of Geology on "The Occurrence of Algonkian Rocks in Vermont and the Evidence for their Sub-Division" the writer will call these upper metamorphic rocks the Mendon series. The Mendon series is thought to lie discordantly above a still more metamorphosed series in the core of the range that will be designated as the Mount Holly group.

pebbles. As a rule the attitude of the beds can only be determined at contacts between beds of strongly unlike composition, as between flinty quartzite and schist or limestone and some more resistant rock. Such contacts are relatively rare and a day's work in the most metamorphosed areas may not reward one with half a dozen indisputable observations on strike and dip.

The eastern and western borders are belts of near-shore deposits, now regarded as equivalent, of original coarse to fine conglomerates, sandstones and shales, which owing to their zone of deposition must have been persistent as a whole but locally the character would vary greatly. Such a belt, indurated and metamorphosed, has given rise to a series of more or less crystalline rocks which, owing to their extreme diversity of composition have resulted in schists and gneisses whose recognizable continuance of horizon is difficult to follow. Sections made east and west across their strike and one-half mile apart present a great diversity of character. The minor flutings of the more schistose members of this series illustrate on a small scale the larger folds of the main range. Along the western border the schists are bent into minute compressed puckerings commonly overturned to the west. These puckerings in turn compose much larger folds which in the same manner are overturned to the west. In a great many localities the folds and the smaller flutes are seen to accompany the inversion of the entire series; but in many places induced schistosity has so obliterated the stratification that the real attitude of the strata is not apparent, and in others no inversion of the strata as a whole has taken place. Throughout the core of the Green Mountain axis even a greater diversity of structure and rock exists. In the towns of Shrewsbury and Mt. Holly and extending southward the folding and shearing and consequent metamorphism are so great that final and satisfactory decipherment seems hopeless. Days may be spent without obtaining observations that would be of service in unravelling the tangle of gneisses and schists. As suggested to me by Mr. Pumpelly, platting all areas of like lithological character may give us the key to the structure, but this plan is rendered hazardous by the infinite variety of rock phase occurring making necessary grouping of areas of rock now so unlike that, in the present state of our knowledge a correlation of them would be of doubtful value. In the towns of Mt. Holly, Shrewsbury, Wallingford and the western part of Ludlow, there are areas of amphibolite now possessing a thoroughly schistose habit. At Summit station a railroad cut traverses this rock for nearly half a mile. Numerous separate members can still be distinguished in the pass by textual variations.

The amphibolites are cut by dikes of the same rock and also by more modern dikes of camptonite that are younger than the shearing. Such a series of amphibolites probably represents a period of volcanic activity vastly older than the Cambrian and of greater areal distribution than occurs at present. Further south, reconnoissance work has not detected them; they may have been eroded, while to the north, if they exist they are covered, except in two isolated localities by the sedimentary series lying immediately below the lower-Cambrian quartzite. Mr. Wolff has described an amphibolite from a hill situated about one mile south of Mt. Holly station and it is referred with probability to an original diabase by him in his forthcoming monograph on the Geology of Hoosac Mountain.* As mentioned above, dikes of the same rock traverse the amphibolites and possess the same local schistosity. There are many other areas of this rock in the region some of which are undoubtedly dikes, others owing to their extent are considered to be intrusives or surface flows. Their abundance may be cited as evidence of surface flows since it is improbable that any area, reasoning from analogy, would be traversed by so large a number of intrusives. This view is also sustained by the fact that diabases are prevailingly surface flows, such regions as Connecticut, New Jersey, and Keweenaw Point being examples. It may also be mentioned in this connection that in the border series of clastics I have observed no amphibolites. Diabases of any age are rare in Vermont and one would expect that were the amphibolites originally intrusive (assuming that the border series is not separated from the core by an unconformability) that similar areas would occur in rock stratigraphically higher than those under consideration. Below the associated rocks are referred to the Algonkian. As the Keweenawan with its abundance of surface volcanic rocks was presumably laid down near the close of the Algonkian time it is not unlikely that similar associated flows took place in the Algonkian rocks of Vermont.

Following the classification of pre-Cambrian rocks now adopted in this country none of this area studied in Vermont can be referred to the Archæan and must be placed in the Algonkian. The lowest rocks exposed in Shrewsbury and Mt. Holly, although of extreme age and gnarled and crinkled into a hopelessly involved structure still in larger part reveal their sedimentary origin by associated beds of crystalline limestone, now altered in part to serpentine or amphibole, and scattered outcrops of quartzite. With these two rocks or their representatives are biotite, augen gneisses and schists, garnetiferous mica

* Part 3, Geology of the Green Mountains in Massachusetts by R. Pumpelly, J. E. Wolff, T. Nelson Dale and Bayard T. Putnam, submitted in 1889.

schists, etc., etc. The micro-structure of all the core rocks attest the pressure brought to bear upon them by the granulated condition of their quartz and feldspar constituents—a feature which is strongly contrasted with the less-sugared and more modern appearance of the border series. The rocks of this area are less schistose; biotite seems to replace muscovite or sericite of the border metamorphics; gneisses are more dominant and the border regional cleavage of N. 10°–15° E. is not nearly so pronounced. In place of this we find a more coarsely crystalline structure—the structure being due more to an apparent rearrangement of their mineral constituents than to a development of mica along planes of shearing. This banding is lacking in any uniformity of trend and is strongly at variance with the persistence observed in the direction of the schistosity of the border: east and west strikes of lamination are perhaps as frequently met with as those trending north and south, and the dips are equally variable.

The upper part of the Algonkian or border series affords evidence of at least two periods of orographic disturbance; microscopic data for this the writer outlined in a bulletin of the Geological Society of America.* This evidence is based on the development of ottrelite and albites in the metamorphic conglomerate. These minerals as they grew include the crushed quartz and feldspar mosaic resulting from an earlier period of environment produced in part by folding. In turn the ottrelite and albite are occasionally bent and fractured evidencing a second period of disturbance less violent than the first. Structurally we have stronger evidence furnished by a conglomerate gneiss at North Sherburne where an anticlinal axis trending about 25° west of north represents the first period of disturbance; a later one induced in the rock the regional schistosity of the range striking, as mentioned above N. 10°–15° E. Other periods of folding in this series have probably taken place but the data for their detection are not at hand. The lower rocks of the Mt. Holly-Shrewsbury area must have experienced even greater mutations. The greater granulation and lithological differences observed and character of the folding may be cited as evidence in support of such a belief.

Mr. Wolff describes a northerly pitch in the crystallines of the New Jersey Highlands† and I have observed with him the same pitch of the rocks of Hoosac Mountain. In general the minor folds of the Green Mountains in the area described above have the same gentle, northerly pitch. In a large way

* Some Dynamic and Metasomatic Phenomena in a Metamorphic Conglomerate in the Green Mountains, vol. iv, pp. 147–166.

† "The Hibernian Fold," read before the Geological Society of America at the winter meeting held in Boston, Mass., in December, 1893.

the V-shaped area of pre-Cambrian rocks mapped by Hitchcock, occurring along the trend of the range indicates a falling away of the axis to the north.

Section VI of Hitchcock passes through Mendon and Sherburne where the border rocks are exposed capping the summits of the highest peaks, furnishing a key to the structure along this line where most of the detailed work has been done. As a working hypothesis the following sequence of metamorphosed clastics, exposed in continuous section on the west slope of Blue Ridge Mountain making the border series, has afforded positive results in deciphering Green Mountain structure: descending geologically from the base of the Olenellus quartzite the next rock is a bed of chloritic mica schist* very much crumpled, hence its thickness is difficult to obtain. It seems always to be present in this part of the State, although on Clarksburg Mountain in Massachusetts, lower Cambrian quartzite lies directly upon granitoid gneiss without any clastic series intervening. The question of the relationship between the mica schist and the Olenellus horizon will not be discussed at this time. In Vermont the mica schist at a minimum has a thickness of not more than fifty feet and in places it is certainly five hundred feet in thickness and may reach a thousand feet. Below the schist comes in several hundred feet of micaceous quartzite locally assuming a schistose phase, or on the other hand becoming massive and compact. All phases carry numerous pebbles of orthoclase, microcline and quartz, feldspar being most abundant. The quartzite horizon also varies greatly in thickness and may thin out entirely. Due east of Rutland a micaceous phase probably attains a thickness of four hundred feet. Next below is a white crystalline limestone, carrying the same varieties of pebbles, some phlogopite secondarily developed, and graphite. It locally thins out first passing through micaceous phases. In places areas have escaped recrystallization and are still blue in color, promising with careful search to yield fossils. Two hundred feet may be postulated as its maximum observed thickness in the heart of the range. Another thin bed of micaceous quartzite occurs below this containing one or more beds of interstratified limestones ten or fifteen feet in thickness. These lie upon the lowest member of the border series, the metamorphic conglomerate horizon which is separated from the

* Dana has used the name hydro-mica schist for similar rocks occurring in Massachusetts. Although it seems for many reasons the best name that has yet been proposed it does not seem generally to have been adopted. Microscopically the schist is composed mainly of chlorite and muscovite with varying proportions of sericite and biotite; quartz is nearly always present, but in extremely fissile phases it is practically absent. On the other hand varieties occur in which the micaceous constituent is much less in quantity.

lower rocks by no line of demarcation whatever—the two formations possessing an induced structural conformity due to dynamic processes. This conglomerate is by no means invariable in character, but is subject to great differences of habit. Normally it may be described as a conglomerate-gneiss in which more or less detrital material can still be seen. Its clastic character may be entirely lost when it passes into a chlorite, muscovite schist or when it is represented by a vitreous quartzite or quartzite breccia. I have previously described an ottrelite-bearing phase of this horizon.* It forms with the mica schist the most persistent horizon in the pre-Cambrian rocks known to me.

This border series has been extended eastward nearly continuously across the range to the Plymouth valley. A schistose phase of the metamorphic conglomerate forms the summit of Mendon and Killington, two of the highest peaks in the State. Blue Ridge is capped by the same rock and the beautiful mountain known as Pico is also surmounted by the same horizon overturned to the west upon the pebbly limestones. The limestones having been eaten out on the west and southwest undermining of the schist has taken place resulting in steep escarpments near the summit. In a general way this is true of many of the mountains in the heart of the range that have been examined by me north of Mt. Stratton. The eastern slopes are commonly much less steep than the western as would be the case were the strata really dipping towards the east and no doubt the topography is directly dependant on the eastward-dipping schistosity. But it is noticable that it is not the general schistosity that determines the positions of mountain crests but a somewhat local one of more pronounced character developed in the backs (east side) of overturned folds where, owing to greater shearing and stretching the maximum schistosity is developed, resulting in a belt of greatest resistance to erosion. The schistosity planes on the backs of the folds have a gentle dip easterly and consequently these slopes are comparatively gentle; the western slopes are often structurally infolded synclinal troughs in which by the reversal of the geological series the limestone belts occur with lower members above them. Whatever member of the metamorphic series now occupies the eastern or gentle slope of the mountains it is uniformly schistose. Ascending any of the high peaks in Mendon or Sherburne from the west one encounters steep slopes and usually a duplication of the infolded members of the series. In such environment crinkling and crushing are most pronounced,—the strata making the eastern slopes being much less crinkled

* An Ottrelite-Bearing Phase of a Metamorphic Conglomerate in the Green Mountains. This Journal, vol. xliv, 1892.

and more laminated,—and duplication of beds is very evident. One often meets the same infolded limestone bed three times on the steep western slopes of the mountains. The topography is seen to be genetically dependant upon the enforced schistosity while the stratigraphy exercises but little controlling influence. Steep westerly slopes, however, are in part due to the less resistant limestones in the troughs which, as on Pico undermine the more resistent rocks and give rise to pronounced escarpments. On a large scale Green Mountain folding is a parallel of the minute plications so often observed in the crenulated schists; a vertical line would often penetrate the same bed several times. As a result of sharp over-turning, thrusts probably occur but where metamorphism is so great it is doubtful if they can be detected in many cases.

A measure of the stretching and consequent thinning of the strata on the backs of folds is frequently found in the effect produced on pebbles in the quartzite or upon secondarily-developed tourmalines. Pebbles of feldspar having an original diameter of a quarter of an inch are now found drawn out to four inches; crystals of tourmaline which one may fairly assume were not more than one inch in diameter are now seen as linear films over a foot in length. Stretching of so pronounced a character as this takes place commonly along zones; belts of slipping in quartzite are frequently met where the surfaces for several hundred feet are ridged in parallel lines as though the quartzite were pulled out in the same manner that the confectioner stretches some varieties of confectionery when partly chilled. Compensation is not always made in this way; in some localities minute faulting takes its place. It is noticed that in the lower rocks the strain is often relieved in this manner. Lower coarse gneisses, for example, have not infrequently hundreds of minute faults to the square foot; along each of these fault planes, films of sericite are developed giving the weathered rock a reticulated appearance. Such faulting might suggest normal brecciation, but there is only slight displacement not attended by crushing and consequent destruction of the angularity of the faulted areas. Zones of this character were probably too far below the surface to be caught in the more superficial belt of crinkling and stretching, but underwent great pressure under enormous load giving rise to the observed faults, or the rocks suffered the faulting before the border rocks were deposited. The last explanation is regarded as much the most probable.

The structure of the main axis of the Green Mountains is thus seen to be a series of sharp, compressed folds striking approximately north and south and overturned to the west in most localities so that induced schistosity and stratification dip eastward. Localities on the western border have a steep westerly dip in many instances; in others the border series as a whole is nearly in a vertical position. Many areas occur along this belt where the series is overturned to the west, but the exact angle at which the strata lie is difficult of determination. The orographic thrust producing the folding was directed nearly from the east and west. Normal faults and overthrusts are indicated but data for their detection is not now at hand except in one instance.

Cambridge, Mass., January 10, 1894.

Art. XXXVIII.—*Notes on Apparatus for the Geological Laboratory*; by J. E. Wolff.

The utility of the following methods and apparatus having been established by laboratory practice a brief description of them may be of benefit to others, a familiarity with the usual methods being assumed.

Diamond Saws.

These are made in the laboratory as follows: Disks of ordinary sheet tin are procured from a tinsmith, 6 inches in diameter, with a central hole $\frac{5}{8}$ inch in diameter to fit the arbor of the lathe. Two round wooden blocks are turned out from board, about $5\frac{1}{2}$ inches in diameter, and a central hole of the same size as that of the disk bored in one, while a corresponding round wooden stick is set into the center of the other. The tin disk is then placed between the two blocks, the round stick holding it central, and the whole fastened in a vise. The edge of the disk projecting beyond the wood is then notched by a shoemaker's knife which is held against it and struck a sharp blow with a light stick, but the plane of the knife is held slanting or oblique to the plane of the disk and not transverse, and moreover is inclined on opposite sides in adjacent quadrants. The notches are made as close together as possible without breaking the tin and about $\frac{1}{10}$ inch deep. The bort (preferably the so-called scrap carbon left as waste from diamond drills) is pulverized in a diamond mortar to a fine sand, corresponding nearly to grade 100 in corundum or emery powder, mixed with a little oil to form a stiff paste and inserted between the teeth of the saw by a pointed match. The edge is then gently hammered back to a plane, using a light hammer on an anvil, and the saw then turned over and hammered smooth on the other side. It requires one carat of bort to charge a saw properly. By this method, which has been perfected in the laboratory by Mr. C. L. Whittle, the bort is forced into the tin and held fast by the teeth, which owing to the oblique cutting of the notches press tightly together when hammered back to place. The teeth are cut obliquely on opposite sides in adjoining quadrants in order to distribute the bort equally on both sides of the saw. A refinement on the notching process described above consists in the use of a brass disk with guide notches cut into its edge, by which the knife can be guided and the notches made evenly.

Saws thus made will do a surprising amount of work before wearing out. In two cases, where a record was kept, the saws cut respectively 300 and 400 square inches of rock, mainly of crystalline varieties.

Method of sawing sections thin.—Power is furnished for the laboratory from a 5 H. P. electric motor which is run from a street current (500 volts) but only 2 H. P. of current is used and paid for as this suffices for the lathes and electric light. For grinding rock surfaces the usual revolving zinc and iron plates are used with three machines, for coarse, medium and fine emery or corundum (Nos. 60, 80, and F.F.F.). The diamond saw, placed in an ordinary lathe, revolves at a speed of 600 to 700 revolutions per minute in the narrow slit of a brass platform on which an adjustable gauge slides in a groove at right angles to the saw, with a pivot and clamp so as to allow the adjustment to exact parallelism between its face and the plane of the saw. The piece of rock, sawed and polished on one side, is cemented to a square piece of thick glass but little larger than the specimen. The cementing substance used is a mixture of Venetian turpentine and shellac boiled down to the proper consistency. White shellac is preferable to brown on account of the increased transparency but the white stick shellac is often impure and refuses to melt, hence it is best to use liquid white shellac. The tenacity of this mixture is greater than that of Canada balsam and when white shellac is used may often be left under the section when finally mounted. The glass, with the specimen attached, is put against the gauge which is then moved close to the saw so that it almost touches the glass at the base of the specimen and is also adjusted to parallelism. The saw is then started and gently pressed against the glass while the longest side of the specimen is presented to the cutting edge; as the saw cuts in, the glass is slowly turned around while pressed against the gauge, until a cut is made completely around the specimen, when the central part is cut through and the slide removed. Where many persons use the same machine, it is impossible to keep saw and gauge in permanent adjustment, but after adjusting them to parallelism by eye, the precaution of turning the slide will generally keep the saw from cutting through the specimen into the glass. The saw must be kept wet by dropping water or by a sponge. When it is stated that slices have been sawed in the laboratory from $\frac{1}{60}$ to $\frac{1}{150}$ of an inch thick it will be plain how easily this accident may happen without precautions, but that when successful this method saves much time and labor in attaining the ultimate thickness (about $\frac{1}{800}$ inch).

The Arc Light for Projection.

In microscopic projection, especially with high powers and polarized light, the lime-light is insufficient for a projection of any size, while with the arc light, objectives of 4^{mm} focus and less can be used. The following arrangements are made in the laboratory for this purpose.

A 1 Kilowatt dynamo, requiring about 1½ H. P., is run by a belt from the motor in the basement and the current carried to two lecture rooms above. At full load the dynamo gives 18 to 21 amperes current at 55 volts, while by varying the load and regulating the current to the fields, from 80 to 0 volts can be obtained. For microscopic projection a large Zeiss micro-photographic apparatus was available, but any petrographical microscope with condenser and water chamber can be used with a suitable arc lamp. Special projecting microscopes such as those made by Newton & Co., London, are said to give excellent results. We use the Schuckert projection lamp which belongs with the Zeiss apparatus, in which the carbons are inclined so that the crater of the positive carbon radiates the light to the condenser. The lamp is adjusted for 45 volts 16 amperes but runs perfectly with 50 volts and 19 or 20 amperes giving from 2500 to 3000 c. p. It is perfectly steady and self-regulating, so that when once started it burns without attention. It can be run with least trouble from a storage battery of 25 to 30 cells, thus avoiding inequalities of current due to the running of the dynamo. The imported carbons cost about 5¢ a pair and burn two or three hours. A variable German silver wire resistance with sliding contact is introduced into the circuit near the lamp, so as to give some control over the current in case of variation in speed of the dynamo. A switch throws the same current into 20 incandescent lights for lighting the room when the arc is not in use. With this arrangement projections of rock slides in polarized light are shown to the class in illustration of the lectures. The screen, which consists of a plaster surface cast on plate-glass and mounted in a frame, stands at 12 feet from the microscope and the projections are then about 2 ft. 6 in. in diameter, corresponding to the diaphragm in the eye-piece, while with the objectives alone they are of course much larger. Objectives are used ranging from 3 inches to 4^{mm} focus; with the latter it is barely possible to make microfelsitic structure visible. The rings and brushes of crystals in converging polarized light and other facts of optical mineralogy are well shown. For the projection of ordinary lantern-slides the microscope is replaced by a projecting lens and slide holder and at this short distance the light is so powerful that the projections are visible by ordinary daylight, a great convenience in a continuous lecture. The arc-lamp is also used for this purpose in a large lecture-room with a great gain in amount of light and convenience over the oxyhydrogen light.

The lamp is also used for microphotography and is occasionally useful in other ways. The dynamo current, properly regulated can be used in place of the usual battery for exciting the electro magnet in the magnetic separation of the iron-bearing minerals of rocks, with the advantage of easy variation in the strength of the pull exerted.

Harvard University, Petrographical Laboratory, Feb., 1894.

Art. XXXIX.—*Diversity of the Glacial Drift along its Boundary;* by Warren Upham.*

Recency and probable Brevity of the Glacial period.—The recession of the ice-sheet at the end of the Glacial period in the northern United States and Canada and in Great Britain seems to have been separated from the present day by a Post-glacial or Recent epoch of only about 6,000 to 10,000 years, as made known by the observations and reasoning of N. H. Winchell, Gilbert, Andrews, Wright, Mackintosh, Prestwich, and others. This conclusion, and the uniqueness of the Ice age, standing quite alone as a strange episode of geologic history, unexampled besides in all the very long Cenozoic and Mesozoic eras, forbid our longer reliance upon the once generally accepted astronomic theory of Croll, Geikie, and Ball, that the accumulation of the ice sheets was due to terrestrial conditions springing from the earth's relations to the sun during a period of increased eccentricity of the earth's orbit from about 240,000 years to 80,000 years ago. Dr. Croll's theory supposed glacial epochs to recur alternately in the northern and southern hemispheres each 21,000 years during the astro-

* A paper presented before the Geological Society of America at the Boston meeting, Dec. 29, 1893.

nomic period mentioned, giving seven or eight epochs of glaciation and as many interglacial epochs when the ice-sheets were melted away; but continuous temperate conditions similar to those of the present would have prevailed during the past 50,000 years or more. The recency of the date marking the close of the Ice age is inconsistent with the astronomic theory. But under the fruitful incentive of that theory many glacialists in Europe and America have interpreted their observations as establishing the recurrence of glacial and interglacial epochs which it suggested; and some who distrust or reject astronomic causes for the Ice age continue to hold this interpretation of the records of the glacial drift.

Looking through the long past ages previous to the Pleistocene, we come to no time affording evidences of widely extended glaciation, probably affecting continental areas, till we pass back at least many million years. Only one earlier stage of the earth's changes was attended, so far as geology can tell us, with the envelopment of large land areas beneath ice-sheets, and this was in the Permian period, closing the Paleozoic era. It was a time of great orogenic and epeirogenic changes; and I think that then, as in the Pleistocene Ice age, the accumulation of thick sheets of land ice was due to great epeirogenic uplifts of those areas so high as to give them a cool climate and chiefly snowfall instead of rainfall throughout the year. If extensive glaciation has been so rare, shall we readily believe that during the geologically very short Quaternary or Psychozoic era there have been two or three or several Glacial epochs? More probably, as I think, we shall find all the diverse phases of our glacial drift referable to a single and continuous Ice age; and the very slight changes of marine molluscan faunas during this age implies its exceptional brevity in comparison with any of the preceding periods recognized by geologists.

Earlier and Later Drift near its boundaries in the Mississippi basin.—The admirable work of Profs. Chamberlin and Salisbury on the Wisconsin driftless area and farther south in the Mississippi basin discriminates earlier, mostly thin, and later, thick and morainic, varieties of the drift border. These differ widely in their volume of drift, in its constituent material, and in the times of its deposition. Along the greater part of the boundaries of the drift on those areas, it terminates in an attenuated border, slowly thinning out and presenting considerable difficulty for the recognition and mapping of its limits. Indeed, it is apt to occur on its outermost tracts in low and thin, smooth patches, more or less isolated, and these are thought to represent in large degree the original method of deposition, not being a result of subsequent erosion. These drift deposits belong to the time of maximum ice advance, and are much earlier than the marginal moraines of thick and irregularly knolly and hilly drift which were accumulated when the ice-sheet terminated farther north. There was, however, in some districts, as Mr. Frank Leverett has found in Illinois, a special massing of the early drift upon a belt near its boundary. In general the drift border is attenuated, but occasionally its thickness in the outermost five miles attains a maximum of 50 feet; and several times as much drift is found on that belt as in the adjacent drift-bearing belt 5 to 20 miles farther back within the glaciated area.

In this great region of smoothly spread early till, comprising large expanses on both sides of the Mississippi River, there was very scanty glacial erosion of the bed rocks. An area of 16,500 square miles in northeastern Iowa, according to McGee, has nearly everywhere a small thickness of the preglacial residuary clay and decaying rock still remaining beneath the universal mantle of the drift, which is principally till, the product of an overriding ice-sheet. McGee further notes that nearly all of the bowlders and smaller rock fragments of that till in both its lower and upper deposits, and by inference also its finer sandy and clayey matrix, were derived from formations lying north of the limits of Iowa. Bringing much drift, the ice-sheet twice advanced upon this area. Its first advance did not erode even so much as the thin preglacial residuary products of secular rock decay and denudation, which are found to average about seven feet in depth on the adjacent Wisconsin driftless area. Between the two ice incursions a forest grew on the land, and its fallen trees and peaty swamps were left upon many townships almost intact, as is known by the forest beds found in digging wells, while the later ice advance covered them with a second sheet of till, which is mostly from 3 or 5 to 10 or 20 feet thick and in some places is probably as much as 80 feet thick.

The feeble eroding action of the ice-sheets depositing the smooth expanses of the outer and earlier drift is remarkably contrasted with the vigor of erosion displayed by the planed and striated rock surface of the areas enclosed by the later marginal moraines. When the ice-sheets heaped these morainic hills it wore into its adjacent rock bed and accomplished much rock erosion upon all the region of the later and uneven drift, which encloses lakes and lakelets, reaching northward from the outermost large and continuous moraine and covering the far greater part of our drift-bearing area.

Portions of the Drift Border formed by Marginal Moraines of the Later Drift adjoining the Wisconsin Driftless Area and in the eastern United States.—Along a distance of about 80 miles on the east side of the driftless area in Wisconsin the magnificently developed Kettle moraine, belonging to a late part of the Ice age, forms the extreme border of the drift. Its correlation or continuation in Minnesota, Iowa, and South and North Dakota, is probably the Altamont moraine, the outermost of the series of twelve approximately parallel successive retreatal moraines which I have explored and mapped, under the direction of Prof. N. H. Winchell, for the Minnesota Geological Survey. Near Des Moines in central Iowa this Altamont or first moraine of the Minnesota series, there forming the southern extremity of an area of the later drift deposited by the Minnesota and Iowa lobe of the ice-sheet, lies 175 miles north of the southern boundary of the drift in its course through Missouri and northeastern Kansas. Within the Mississippi basin the ice sheet forming the Kettle and Altamont moraines occupied less area by 125,000 square miles than was enveloped by the ice forming the earlier drift. But while there had been in general this great decrease in the extent of the ice previous to the accumulation of the outer large moraine, it even advanced at that time farther than ever before upon the east side of the Wisconsin driftless area.

In the eastern United States, the outer moraine along an extent of about 700 miles, from the Scioto basin in Ohio to Martha's Vineyard and Nantucket, stands upon the boundary of the drift or very near it. At its time of maximum extension the ice-sheet in this region generally reached a short distance, from a few miles up to twenty miles or more, beyond the position of the moraine. Besides this remarkable difference from the drift of the Mississippi basin, it must be confessed that we cannot yet be sure that this outer moraine, at least eastward from the angle of the drift boundary in southwestern New York, is to be correlated with the Kettle and Altamont belt. Following a suggestion or query of Mr. Leverett, I incline to believe that quite as likely it may belong somewhere within the time of the very large Fergus Falls, Leaf Hills, and Itasca moraines, which are the eighth, ninth and tenth of the series in Minnesota.

Oscillations of the Boundary and Changes in the Thickness and Currents of the Ice-sheet during its general Recession.—The great contrast between the glacial retreat from northeastern Kansas to Des Moines and the contemporaneous encroachment of the ice upon the eastern side of the Wisconsin driftless area seems to be accounted for, in part or wholly, by interdependence of snowfall at the east with rains and ice melting at the west. While the ice was being melted away by rains and sunshine over its 125,000 square miles that had been uncovered south and west of central Wisconsin, the eastwardly moving air currents, abundantly laden with moisture from that region, were chilled in their farther progress over the ice-sheet north and east of the driftless area, and there gave exceptionally heavy snowfalls, permitting that part of the ice-sheet to grow thick and high, with only slight recession. At last, when there came a temporary general reversal of the warm climate under which the ice-sheet had been mainly retreating, its halt or re-advance producing the first of the prominent moraines carried the ice-front in Wisconsin forward upon a part of the area which previously had no drift.

During the great recession of the ice in the Mississippi basin, it probably withdrew much less, perhaps mostly from ten to thirty or forty miles, in Ohio, Pennsylvania, northern New Jersey, and Long Island, and south of Rhode Island and eastern Massachusetts. Meanwhile, as in eastern Wisconsin, it had grown thicker than during its time of maximum area, and the sudden and short climatic changes leading to the formation of the moraines allowed the ice in the eastern states to flow out again almost to its earlier limit, and in some places even beyond it. Considering how nearly coincident the earlier and later drift boundaries are for this long distance from the Scioto River in Ohio eastward, we naturally feel much reluctance against referring them to distinct epochs of glaciation separated by a long interglacial time, as some have supposed, when the ice-sheet made a long retreat to the north or was wholly melted as now from this continent. It seems to me more reasonable to appeal, as Prof. James D. Dana has recently done,* to meteorological differences between the Mississippi basin and the eastern states, whereby comparatively long glacial retreats and re-advances could take place at the west while in the east the ice-border more steadily remained near the drift boundary.

What shall be said, consistent with this view, concerning the extra-morainic drift in New Jersey, some of which occurs more markedly in isolated patches than any of the early drift before noted in the Mississippi basin? Prof. Salisbury estimates that a very long time of ordinary subaërial erosion intervened between the times of deposition of the earlier and later drift in New Jersey, so that the denudation of the land had removed the greater part of the earlier drift, leaving only its present patches on the extreme boundary, before the late moraine-producing ice advance. If this is a needful explanation, it goes far toward establishing a longer and probably more complex history of the Ice age than the view taken in this essay. It seems to me, however, that the manner of transportation and deposition of that early drift may explain its

* This Journal, III, vol. xlvi, pp. 327–330, Nov., 1893.

uneven distribution. The early accumulation and advance of the ice to its extreme limits gave a comparatively thin ice-sheet with feeble erosive action on all the outer part of the drift-bearing area. Its drift there was nearly all brought from considerable distances at the north and was deposited in obedience to the glacial currents of the marginal portions of the ice-sheet. Now we have upon many districts of the thick later drift the remarkable aggregations of the till called drumlins, which appear to have been amassed by convergent currents of the ice-sheet during its retreat.* Similar selective action of the outflowing early ice advance close to its farthest limits I think to have amassed that outermost early till in the patches where it is now found, having received little change by later erosion.

The well oxidized and leached condition of the early outer drift everywhere is easily referred to its derivation chiefly from the preglacial residuary clays, decaying rocks, weathered rock cliffs and tors, and bowlders of secular disintegration. Again, its smoothed surface, without the inequalities of accumulation which provide basins for the myriad lakes and lakelets of the later drift, seems attributable to the gentle currents of the early thin ice-sheet, in contrast with which the late thick ice powerfully eroded its rock bed, even close to the boundary, and tumultuously heaped or very irregularly spread its drift with many lake-enclosing hollows.

Forest beds between deposits of till in northeastern Iowa, and in portions of other states of the Mississippi basin, testify of glacial recessions and re-advances, the ice-sheet probably recovering at some times marginal belts from 50 to 100 or 200 miles wide of its previously lost ground. These great oscillations, however, need not have required a very long time, certainly no more than a few thousand years for them all, as we may well learn from Prof. I. C. Russell's observations of the drift-enveloped and forest-clad borders of the Malaspina ice-sheet between Mt. St. Elias and the ocean.

Amid the waverings of the retreating ice, often large channels were cut in the early drift and became covered and partially filled by the later drift. In southern Minnesota these old water-courses are recognized as far northward as the Minnesota river valley, considerably to the north of all our recorded observations of forest and peat beds enclosed in the till sheet. They seem to have been probably rapidly eroded when the altitude of the country and its slopes of descent from north to south were greater than now. The few thousand years which are here regarded as the time of the fluctua-

* "Conditions of Accumulation of Drumlins," Am. Geologist, vol. x, pp. 339–362, Dec., 1892.

tions of the ice-front recorded by the forest beds appear to be ample for the attendant stream channelling.

Farther northward, along the 700 miles of length of the glacial lake Agassiz the retreat of the ice-sheet, with the formation of numerous large moraines, was demonstrably very rapid, occupying apparently no more than one thousand years.* In all, I believe that a duration of five thousand years is sufficient to account for the records of the waning and closing stages of the Ice age, from the time of the maximum area of the ice-sheet depositing the early drift to the time when Lake Agassiz was drawn off into Hudson Bay and the northern United States and Canada were freed from their glacial mantle and occupied by hunting and fishing tribes of the red race, who have abode here with many intertribal wars and migrations during the 5,000 years or more since the departure of the ice. A very large part of my belief that these oscillations and important changes of the currents of the ice-sheet during its recession were comprised within a time geologically so short, comes from my studies of the shore erosion and beach accumulations of Lake Agassiz, and of great changes in the relations of the northeastern and northwestern convergent ice-currents in Minnesota during the deposition of the later drift.† These, I am convinced, took place fast, in a geological sense, and I am persuaded also that the ice oscillations and varying conditions causing the diversity of the drift near its boundaries were not of great duration and are referable to a continuous and brief Ice age, not divided by interglacial epochs.

Loess deposition mainly continuous from the time of maximum ice extension to the time of formation of the Moraines of the Later Drift.—On the drift border in southern Illinois and Indiana, Prof. R. D. Salisbury finds that the deposition of the loess ensued immediately after that of the early till and was in part contemporaneous with the till. As soon as the ice-sheet retired from its farthest limit the glacial drift was covered by this fine silt of the modified drift supplied by streams that flowed from the melting and retreating ice.‡

In the northeastern part of Iowa Mr. W J McGee similarly finds the loess to have been deposited while the ice-sheet that spread the upper portion of the early till was melting away. The very remarkable paha of that district, which are eskers of loess, were accumulated while the waning ice-sheet walled them in on each side.§

* Geol. and Nat. Hist. Survey of Canada, An. Rep., new series, vol. iv, for 1888–'89, pp. 50, 51E.

† Proc. A. A. A. S., vol. xxxii, for 1883, pp. 231–234.

‡ Geol. Survey of Arkansas, Ann. Rep. for 1889, vol. ii, "The Geology of Crowley's Ridge" (1891), pp. 228, 229.

§ U. S. Geol. Survey, Eleventh An. Rep., for 1889–'90, pp. 435–471.

That the later part of the loess deposition was contemporaneous with the formation of the prominent Altamont moraine of the later drift, I ascertained in northwestern Iowa, where this moraine along a distance of 75 miles, from Guthrie County northwestward to Storm Lake, is bordered on its west side by an expanse of loess as high as the crests of the morainic hills, while its elevation above the expanse of till eastward is from 50 to 75 feet. During the time of deposition of this part of the loess the ice-sheet reached to the Altamont moraine and was a barrier preventing the waters by which the loess was brought from flowing over the lower area of till that reaches thence east to the Des Moines river.*

These observations in three widely separated regions prove that the loess, like the coarser portions of the modified drift forming sand and gravel plains, was in progress of deposition upon successive areas as fast as the ice-sheet supplying these stratified drift beds receded. Immediately after the land was bared by the retreat of the ice, and even while the ice itself occupied the adjoining land, the loess was being laid down, contemporaneous successively with the earliest till on the southern limit of the drift, with the till of intermediate age in northeastern Iowa, and with the later till enclosed by the Altamont moraine.

Such being the well demonstrated origin of the loess and its relations with the earlier and later glacial drift, it seems impossible that the rock gorges described by Mr. Oscar H. Hershey upon the area of the early drift in northwestern Illinois can have been eroded, as he supposes, between the times of deposition of the drift and of the loess.† Instead, I think that the early drift there and its closely ensuing loess so filled the valleys and raised the streams above the beds of the deep preglacial channels that in the places noted by Mr. Hershey the streams were turned aside into preglacial courses of small tributaries or across cols of plateau tracts which had become isolated alongside the valleys by the processes of ordinary land erosion and general weathering with rain, rill, and stream sculpture. This view brings harmony with Prof. Salisbury's assignment of the loess upon the early drift region to a time contemporaneous with the retirement of the ice-sheet from its farthest boundaries.

* Geol. and Nat. Hist. Survey of Minnesota, Ninth An. Rep. for 1880, pp. 307–314, 338.

† Am. Geologist, vol. xii, pp. 314–323, Nov., 1893.

Art. XL.—*An Elementary Expression in Thermo-electrics*; by Carl Barus.

1. The thermo-electric equation due respectively to Avenarius* and to Tait,† does not reproduce the observations satisfactorily when long temperature ranges (>1000° C.) are dealt with.‡ Within an interval of a few hundred degrees, however, the equation is usually in good accord with the experimental results. It is desirable, therefore, to endeavor to find a more general relation, from which the Tait equation may be derived as an approximation. This is my object in the present paper. I have tried to throw some light on the subject without explicit reference either to the Peltier or to the Thomson effect, and in a deductively experimental way, as follows:

2. In an investigation of the relation between the thermoelectric power and the specific resistance of steel varying with hardness, Dr. Strouhal and I found a linear relation§ to obtain. Some 90 states of hardness were examined, all tempered with scrupulous care. I have since endeavored to test this relation further, by making as many different platinum alloys as I could (54 in all), but found‖ that marked changes of specific resistance (10–65 microhms) were as common, as marked changes of thermoelectric power were rare, and no law was apparent. Nevertheless I am unwilling to concede that the results for steel in their bearing on the subject in hand are devoid of suggestion; at least I believe that the relation which holds for temper will also hold for temperature because in the latter case the structure of the metal is to a less extent interfered with.

3. When long ranges of temperature are considered the relation of metallic resistance¶ to temperature is not such that its nature can be closely enough inferred, experimentally. Electrolytic resistance, however, presents a promising case. The thermal variation of the resistance of an electrolyte, as I found both in the case of aqueous solutions (zinc sulphate)

*Avenarius: Pogg. Ann., cxix, p. 406, 1863.

†Tait: Trans. R. S. Edinbgh., xxvii, p. 125, 1872–73.

‡Prof. Tait does not claim that the formula will do so.

§Wied. Ann., xi, p. 969 et seq., 1880. It will be remembered that the resistance of hard steel is 3 to 4 times as large as that of soft steel. Cf. Phil. Mag., (5), viii, p. 341, 1879.

‖Barus: this Journal, xxxvi, p. 427, 1888; Bull. U. S. G. S., No. 54, pp. 143, 146, 1889.

¶The striking results of Dewar and Fleming (Phil. Mag., xxxvi, p. 271, 1893), from which an absence of metallic resistance at the absolute zero of temperature may be inferred, are rather of the nature of an initial tangent to the curve above in question.

under pressure,* and in connection with the examination of rock magmas† made by Prof. J. P. Iddings and myself, can be reproduced by an elementary equation, $dr/d\theta = a - br$, where r denotes the resistance, θ the temperature, a and b are constants, and where a is probably introduced by observational errors.

4. Following out the suggestions of §§2, 3, I tested the elementary expression

$$de/d\theta = -Ae \quad . \; . \; . \; . \; . \; . \; . \quad (1)$$

where e may be called the thermoelectric *condition* of an element of length of either wire of the couple, at the temperature θ. A is a specific constant for the metal, and may be either positive or negative.

Let θ, θ_0 be the temperatures of the hot and the cold junction, and θ_n the neutral temperature of the two given wires. Let e_n be the thermoelectric condition of one of the wires at the neutral temperature θ_n. Then (1) leads to the integral

$$\frac{e}{e_n} = \varepsilon^{A(\theta_n - \theta)} \quad . \; . \; . \; . \; . \; . \; . \quad (2)$$

where ε is the base of Napier's logarithms. Hence if the two wires of the couple be distinguished by accents, the parts which the hot junction contributes to the total electromotive force E, will be

$$\frac{e}{e_n} = \varepsilon^{A(\theta_n - \theta)}, \text{ and } \frac{e'}{e'_n} = \varepsilon^{A'(\theta_n - \theta)};$$

and the cold function contributes,

$$\frac{e_0}{e_n} = \varepsilon^{A(\theta_n - \theta_0)}, \text{ and } \frac{e'_0}{e'_n} = \varepsilon^{A'(\theta_n - \theta_0)}.$$

Hence since the observed or total electromotive force is $E = e \pm e' - (e_0 \pm e'_0)$ in the most general case; and since $e_n = e'_n$ by definition, therefore

$$(3) \quad E = e_n \left\{ \varepsilon^{A(\theta_n - \theta)} \pm \varepsilon^{A'(\theta_n - \theta)} - \left(\varepsilon^{A(\theta_n - \theta_0)} \pm \varepsilon^{A'(\theta_n - \theta_0)} \right) \right\},$$

which is the equation required. With reference to (3) it is to be noted that A, A', θ_n, may be either positive or negative; hence the exponents may represent either a sum or a difference. Again if θ_m be the temperature at which E is a maximum or minimum, then

$$A\varepsilon^{A(\theta_n - \theta_m)} \pm A'\varepsilon^{A'(\theta_n - \theta_m)} = 0, \quad . \; . \; . \; . \quad (4)$$

whence

$$\theta_m = \theta_n + \frac{\log A \pm \log A'}{A \pm A'}.$$

* This Journal, xlii, p. 134, 1891. † This Journal, xliv, pp. 242, 255, 1892.

5. Now to show that equation (3) contains Tait's equation as one of its approximate forms, suppose that in an expansion of the exponentials in (3), terms involving higher powers than the second can be rejected. Then (3) leads to

$$(5) \quad E = (\theta - \theta_0)(A^2 \pm A'^2)e_n \left\{ -\left(\frac{A \pm A'}{A^2 \pm A'^2} + \theta_n \right) + \frac{\theta + \theta_0}{2} \right\}$$

But for $dE/d\theta = 0$, $\theta = \theta_m$, and θ_m may therefore be found either by differentiating (5) or by expanding (4). Its value is

$$\theta_m = \theta_n + \frac{A \pm A'}{A^2 \pm A'^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

Substituting (6) in (5),

$$(7) \quad . \quad . \quad . \quad . \quad E = (\theta - \theta_0)(A^2 \pm A'^2)e_n \left\{ -\theta_m + \frac{\theta + \theta_0}{2} \right\}.$$

Since $(A^2 \pm A'^2)e_n$ is constant for the given couple, and since θ_m for reasons already given, § 4, may be either positive or negative, equation (7) is identical with Tait's equation.

6. Now it is desirable to look somewhat more in detail at the physical meaning of the elementary equation (1). In my work* on the thermal variation of the viscosity, η, of a very viscous body like marine glue I found that the elementary equation $d\eta/d\theta = -B\eta$, where θ denotes temperature, very fully reproduced the results. But since by Maxwell's theory of viscosity, η is immediately dependent on the configurational stability of a body, the same is true of the rate $d\eta/d\theta$ at which viscosity varies with temperature. Again the result, mentioned in §3, put in the form $dr/d\theta = -br$ shows that like the resistance r, so also the rate $dr/d\theta$ at which resistance decreases with temperature is immediately dependent on the molecular stability of the electrolyte. An interesting research of Auerbach's† on the resistance and bulk density of a given metallic powder (silver) is particularly suggestive here. He finds $dr/d\delta = -nr$, where δ is the bulk density and n constant. Comparing this with the preceding equation, it is clear at once that the internal contacts are similarly increased in the two cases. I therefore infer finally that equation (1) is open to an analogous interpretation, viz: that the thermoelectric condition e of an element of length of the thermocouple is directly related to the molecular stability of the element. In other words two metals are thermoelectrically identical, when the sign and the number of *available* molecular paths which the current (or better the elementary charge) is free to take, is the

* Proceedings Am. Acad., xxvii, p. 13, 1892; this Journal, xlv, p. 87, 1893.
† Auerbach: Wied. Ann., xxviii, p. 609, 1886.

same in both metals; and they differ thermoelectrically when this is not the case. If the transfer of charges is brought about in essentially similar ways both in metals and in electrolytes,* it follows that the available paths of a charge must be in its immediate neighborhood.

Long ago Wild† pointed out that bad metallic conductors were apt to occupy extreme positions in the thermoelectric scale, relative to good conductors. An analogous but much more definite result was brought out strikingly in the investigations on tempered steel‡ already cited, §2. Indeed we found it expedient to refer all our thermoelectric data to an imaginary steel rod whose specific resistance is zero, and an independent consideration§ then showed that this rod would be nearly given by steel (better perhaps by iron) cooled down to the absolute zero of temperature.

7. A somewhat pictorial yet nevertheless interesting development of the preceding paragraphs is obtained as follows: From its mode of derivation, the thermoelectric condition, e, depends on the state of electric dissociation at the given point of the couple, for the given temperature. Hence it is conceivable that a current in the wire, and e, will at all points be reciprocally related. Indeed a serviceable mechanism for Peltier and the Thomson effects is apparently near at hand. To begin with the former: if the two wires of the couple are thermoelectrically active, then they cannot be at the same state of dissociation. If therefore a current crosses the junction, it passes suddenly from a wire in a lower state of dissociation (say) to one in a higher state; or in other words from a metal having relatively fewer available paths to one having relatively more available paths. The case is thus closely analogous to that of a fluid passing from a state of compression suddenly into a state of dilatation, whereby heat is absorbed because internal work is done. Conversely if the current pass from a metal in a more advanced state of dissociation to one in a lower state, the case is that of a liquid passing from greater to smaller bulk and heat is evolved. Here therefore is a tangible mechanism for the Peltier effect: for if it be admitted that electricity travels in definite charges, its condition in a given space must be quite as atomic‖ as the matter which transports it, and heat is therefore absorbed or given off in marked degree at the thermoelectric junction for much the same reasons that

* Cf. J. J. Thomson: Application of dynamics, etc., p. 296, and others.

† Wild: cf. Mousson Physik, III, 2d ed., p. 387.

‡ Barus and Strouhal: l. c., p. 62 et seq.

§ l. c., pp. 65, 92.

‖ v. Helmholtz commenting on Faraday's law: ". . . gerade so, als wäre die Elektricität selbst in Atome getheilt." Berliner Sitzungsberichte, 1883, p. 651.

may be brought forward in accounting for the thermal effects of the expansion of the metals themselves.

Again since in virtue of the character of e the same state of things must supervene at any section between parts of the same wire at different temperatures, a mechanism for the Thomson effect is also apparent and differs from that of the Peltier effect only in degree.

If the current passing through a thermoelectric junction be spoken of as having a certain sectional density or intensity in each of the wires, it is clear that this quantity need not vary from the first wire to the second. What has varied is the number and the internal or molecular distribution of the component paths. The postulated expansion is a configurational change within the fixed bulk of the wires. An example might be given of charges traveling bivalently in one metal and univalently in the other, though I do not wish to limit myself to such a case.

8. In the further pursuit of the subject it is advisable to proceed from a different point of view, by taking advantage of vant'Hoff's* conception of a solid solution. Seeing moreover that in a large and important class of thermo-couples (iridio-platinum and other platinum alloys, iron and steel, etc.) the metals consist of what may be regarded as two different states of concentration of the same alloy, Helmholtz's† results for "Concentrationsströme" are available, particularly in the form given in a remarkable paper by Nernst.‡ Eliminating the osmotic pressures in the usual way, an equation results in which the electromotive force of the couple is expressed in terms of the concentrations and of the velocities of the ions at the temperatures of the junctions together with those temperatures. The problem then consists in finding the conditions or approximations under which the equation reduces to Tait's form. I have carried this out obtaining results of a certain degree of interest but not enough so to make it worth while to reproduce the long computation here.

9. In closing the present paper I had hoped to make a test of equation (3) above, by the aid of data obtained in a direct comparison§ of the platinum-iridioplatinum couple with the air thermometer. Moreover as the corresponding electromotive forces of this couple and of platinum-rhodioplatinum, in

* vant'Hoff: Zeits. Phys. Chem., v, p. 322, 1890. Ideas of this kind seem to have originated with Matthiessen, cf. Rep. Br. Assoc. 1866, p. 15, and Bulletin U. S. G. S., No. 14, 1885.

† Helmholtz: Zur Thermodynamik chem. Vorgänge, Verh. d. Berliner Ak., July, 1882, p. 489.

‡ Nernst: Zeits. Phys. Chem., iv, p. 129, 1889.

§ Barus: Bull. U. S. Geolog. Survey, No. 54, p. 216 et seq., 1889; cf. Phil. Mag., July, 1892, p. 1.

their variations with temperature throughout an interval of nearly 2000° centigrade remain strictly linear functions* of each other, both may be reasonably looked upon as evidencing a clearly pronounced thermoelectric law. However, in the absence of a set of tables similar to Kulik's† for the catenary, the labor of computation becomes so great as to be almost prohibitory. In the mean time I have therefore contented myself by suitably stretching a chain across the chart of observed results (electromotive force in terms of temperature) for iridio-platinum, and noting the essential similarity of the two curves in question.

The Smithsonian Institution, Washington, D. C.

Art. XLI.—*Gases in Kilauea;* by William Libbey, Jr., Professor of Physical Geography, Princeton, N. J.

In 1865 Mr. W. T. Brigham called attention to the existence of certain bluish-green flames which broke from the crust of Halemaumau during a disturbance of its slag-like surface.

In 1887 Mr. Emerson of the Geological Survey of the Islands and several others identified these same flames. They are referred to in Prof. Dana's book upon "The characteristics of Volcanoes" (p. 119) as being pale in color and of a slightly greenish color rather than bluish. This corresponds with my own observations. In order to test this matter I took with me upon my recent visit to the volcano (Sept. 14th to 25th, 1893) a pocket spectroscope. I did not imagine that I should have such a splendid opportunity or I should have taken a better instrument; however the little spectroscope did good service and the observations may possibly lead to something better later on.

I spent the greater part of three evenings down on the edge of the boiling cauldron in Halemaumau and the observations I made were repeated many times so that I have every confidence in them. As to the conditions I may say that they were exceptionally favorable. The surface of the molten lava was so high during the whole of our visit that it could be reached with an ordinary walking stick. The volcano seemed to be in a very active state as several overflows occurred, and the ebullition from what appeared to be three centers of weakness or disturbance were very remarkable. The lava was thrown into the air for a distance of 40 to 50 feet and as we could approach

* Barus: Phil. Mag., xxxiv, p. 376, 1892.
† Kulik: Theorie und Tafeln der Kettenlinie, Prag, 1832.

these fountains quite closely in two instances, we could form very good estimates of their size and the amount of lava involved in such an outbreak. The surface for a considerable area near one of these centers (for they seemed very constant in position) would sway up and down, at first gently and then more violently, particularly in the neighborhood of the intersection of the fissures which were constantly forming in the crust of slag, then there would be two or three small explosions accompanied by a bumping sound, as though gas had escaped from the mouth of an uncorked bottle; after this there would be a great rush of lava into the air, to be repeated several times; when the surface would become quiet once more.

At the edge of this cauldron, 1000 feet in diameter, I placed myself after dark and for a couple of hours in each instance had opportunities nearly every five minutes to observe the flames which almost invariably accompanied these explosions. At times they would make their appearance along the fissures, in the crust when they would be very short lived; and I failed to get much information concerning them, aside from the fact that they seemed the exact counterpart of the hydrogen flame from a Bunsen burner.

It was the study of the flames which accompanied the larger outbreaks which appeared to promise most return. Getting as near as possible to one of the giant fountains (probably 50 yards distant) I watched for the premonitory symptoms of an outbreak and got all ready for it, and seldom failed to catch indications of the presence of gases.

For a good part of the time there was a continuous spectrum while the spectroscope was directed across the lava. The first thing that impressed me was the sudden appearance and disappearance of broad *bands* of bright light, showing conclusively the presence of gas burning under high pressure. The location of these bands became the next problem and then I longed for a better instrument with a micrometer eyepiece. The first which appeared with constancy was a band in the green, indicating the presence of carbonic oxide in all probability. Then I found on other occasions bands of lighter intensity in the red and blue, and the red and purple portions of the spectrum, thus apparently marking the presence of the hydro-carbons. There were also occasionally noticed upon a full spectrum a large series of dark lines in the yellow and orange, sometimes completely blotting these colors out of the spectrum altogether. These need more careful study before assigning them definitely to any substance or substances.

It is hoped that the above may serve to indicate a point upon which valuable work can be done and that some one will take advantage of it and follow the subject up.

Art. XLII.—*A Simple Method of Determining the Eccentricity of a Graduated Circle with one Vernier;* by F. L. O. Wadsworth.

In certain forms of instruments intended for angular measurements only one vernier is provided, either because the graduated arc is less than 360°, as in the case of the sextant, position circle and other instruments of that class, or because, as in certain forms of spectrometers, in which the vernier is attached to the arm which carries the view telescope, it is of advantage, from the point of view of mechanical simplicity or convenience, to use but one. Except for the trouble involved in determining and applying the necessary corrections to the reading there is no serious objection to the use of a single vernier, for if the mechanical work is reasonably well done little change may be expected in the instrument even after very considerable use.

In this case however it becomes necessary to determine accurately the errors of graduation—particularly those due to eccentricity, and the method usually resorted to, is to remeasure with the instrument whose circle it is desired to test, a series of angles whose value has been first carefully determined with another instrument whose constants are all known. This method involves a very considerable amount of work even if rendered possible by the possession of a suitable instrument.

Recently the writer had occasion to test the error of eccentricity of the graduated circle of a spectrometer, of the class alluded to above, and as no other instrument was just then available for checking its angular readings, the following simple method was devised for this purpose.

A piece of plane parallel glass (an ordinary sextant mirror) is silvered on the face, *a*, fig. 1, and mounted on the prism

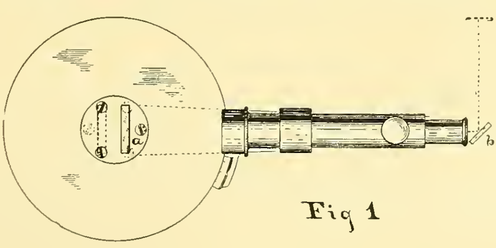


Fig 1

stand, or on a bit of board provided with three leveling screws, as shown, with a little soft wax or cement. The whole is then placed on the spectrometer table and the mirror face set perpendicular to the plane of the circle in any convenient way, say by adjusting it until the image of any distant object as seen by reflection from the silvered surface occupies the same position in the field of the observing telescope when the mirror is either in the position shown, or is turned through 180° as shown by the dotted lines.

The telescope is then set with its axis perpendicular to the mirror by making the image of the cross wires coincide with the wires themselves, the wires being illuminated for this purpose by placing a small piece of unsilvered glass, *b*, in front of the eyepiece at an angle of about 45° so as to throw the light from a gas flame or window into the field of the telescope. There is no difficulty in seeing the image by placing the eye behind and close to *b*.*

The single vernier attached to the telescope is then read, and either the circle, carrying with it the mirror, or the telescope is turned through 180° or until the image of the vertical cross wire as seen by reflection from the other side of the silver coat (this time through the glass), is again in exact coincidence with the wire itself and a second reading of the vernier taken. If the unsilvered face of the mirror is parallel to the silvered face the angle through which the telescope or circle is turned between these two settings will be just 180°, if they are not parallel it will be $180 \pm \frac{1}{2}\varphi$, where $\frac{1}{2}\varphi$ is the deviation due to the prismatic form; equal approximately to $\frac{1}{2}$ the angle φ between the faces .... Usually however the error of parallelism in a good sextant glass is not more than 5″ and the resulting error in angle consequently only 2″ to 3″, a quantity smaller than the venier will ordinarily indicate. If larger however the effect may be readily eliminated by reversing the glass on the spectrometer table, repeating the settings and taking the mean of the readings. Then if ε be the eccentricity of the circle and θ the angle between the 0 of graduation and the line of centers of rotation and graduation, α the circle reading for the first setting, β that for the second setting . . . then evidently

m = true angular reading for 1st setting $= \alpha + \varepsilon \sin(\alpha+\theta)$
n = " " " " 2d " $= \beta + \varepsilon \sin(180+\alpha+\theta)$

$$m - n = 180° = \alpha - \beta + 2\varepsilon \sin(\alpha+\theta)$$

$$\Delta_1 = 180° - (\alpha-\beta) = 2\varepsilon \sin(\alpha+\theta) \qquad (1)$$

If now we take a second set in which the first reading is γ and the second δ we have

* The setting of the mirror perpendicular to the plane of the circle and of the telescope at right angles to the mirror is readily accomplishad at one and the same operation, for the telescope can first be set perpendicular to the mirror face, the latter then turned through 180° and the vertical difference between image and cross wires, corrected, half by adjustment of the mirror, half by the adjustment of the telescope.

$$\varDelta_2 = 180-(\gamma-\delta) = 2\varepsilon \sin(\gamma+\theta) \qquad (2)$$

If the second set is made with the faces of the glass at right angles to the position they occupied in the first set and if farther the first setting is made when the circle reads 0; we have simply

$$\text{tang } \theta = \frac{\varDelta}{\varDelta_2} \qquad (3)$$

$$\varepsilon = \tfrac{1}{2}\sqrt{\varDelta_1^2+\varDelta_2^2} \qquad (4)$$

In case the graduated arc is less than 180° the eccentricity can still be determined by the same method by the use of two mirrors mounted together on a single block as shown in fig. 2.

The first mirror *a* is as before a sextant glass silvered on one side and the second mirror *b* is placed behind it and inclined to it at a small angle, sufficient to allow the surface of *a* to be seen normally by reflection from *b* as shown by the dotted lines. The mirror *a* is first set perpendicular to the plane of the divided circle and the observing telescope perpendicular to it as before. The second mirror is then brought to perpendicularity to the axis of the telescope and to the divided circle. The telescope is set to perpendicularity with the first surface, and the reading of the circle taken, then to perpendicularity with the opposite side of the same surface as seen by reflection from *b* and a second reading taken.

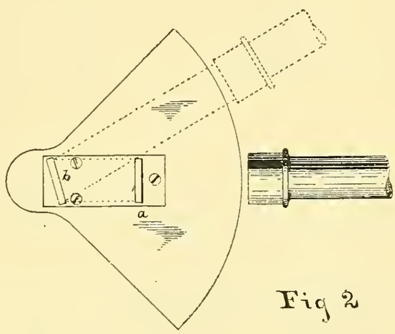


Fig 2

Using the same notation as before,

$$m = \alpha+\varepsilon \sin(\alpha+\theta)$$
$$n = \beta+\varepsilon \sin(\beta+\theta)$$

Let ω denote the angle between the two glasses;

$$\text{Then } m-n = 2\omega^* = \alpha-\beta+\varepsilon \sin(\alpha+\theta)-\sin(\alpha+2\omega+\theta)$$
$$2\omega-\varDelta'_1 = \varepsilon \sin(\alpha+\theta)-\sin(\alpha+2\omega+\theta) \qquad (5)$$

A second and third set of readings taken at different points on the same circle gives the two additional equations necessary for the determination of the three unknown quantities ω, ε, and θ.

*If the glass *a* is wedge-shaped the angle $m-n$ will not be exactly 2ω, but $2(\omega \pm \tfrac{1}{2}\phi)$. The effect however is the same as if the angle ω had been changed to $\omega' = \omega \pm \tfrac{1}{2}\phi$.

$$2\omega - \Delta'_2 = \varepsilon \sin(\gamma+\theta) - \varepsilon \sin(\gamma+2\omega+\theta) \quad (6)$$
$$2\omega - \Delta'_3 = \varepsilon \sin(\psi+\theta) - \varepsilon \sin(\psi+2\omega+\theta) \quad (7)$$

If the settings are taken by repetition so that $\gamma = \alpha+2\omega$ and $\psi = \gamma+2\omega = \alpha+4\omega$, and the first setting is made when the circle reads 0, we have

$$2\omega - \Delta'_1 = \varepsilon \sin\theta - \varepsilon \sin(\theta+2\omega)$$
$$2\omega - \Delta'_2 = \varepsilon \sin(0+2\omega) - \varepsilon \sin(\theta+4\omega)$$
$$2\omega - \Delta'_3 = \varepsilon \sin(\theta+4\omega) - \varepsilon \sin(\theta+6\omega)$$

If many arcs are to be tested it would be convenient to have a prism cut to a convenient angle of either of the forms shown in fig. 3.

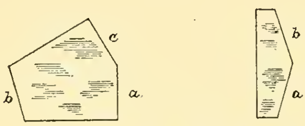


Fig 3

In the first of these forms, the faces a, b, c are polished and a and b are silvered.

In the second form, only the two adjacent faces a, b are polished and silvered.

The angle 2ω may be determined carefully once for all, and the number of sets of readings necessary for the determination of the eccentricity reduced to two, as only the two unknown quantities ε and θ then remain to be determined.

It is obvious also that in the determination of the eccentricity of a complete circle we may use an ordinary 60° prism instead of the plane parallel glass silvered on one side—the only disadvantage being that the reduction of the observations is not quite so readily accomplished.

If we know the angle of the prism ($60° \pm \delta$), two sets of readings only are necessary, and we have

$$\Delta'_1 - 2\omega = \Delta_1 = \tfrac{3}{2}\varepsilon \sin\theta - \frac{\sqrt{3}}{2}\varepsilon\cos\theta$$

and for a second set 90° from the first,

$$\Delta_2 = \tfrac{3}{2}\varepsilon\cos\theta + \frac{\sqrt{3}}{2}\varepsilon\sin\theta$$

whence
$$\operatorname{tang}\theta = \frac{\sqrt{3}\,\Delta_2 + 3\Delta_1}{3\Delta_2 - \sqrt{3}\,\Delta_1}$$

and
$$\varepsilon = \frac{\sqrt{\Delta_1^2 + \Delta_2^2}}{\sqrt{6}}$$

If the angle of the prism is not known three sets are necessary and the resulting equations are the same as those already deduced—(5), (6), (7)—from which the values of the three unknown quantities ω, ε, and θ may be calculated as before.

Astro-Physical Observatory, Smithsonian Institution,
Washington, D. C., January, 1894.

ART. XLIII.—*Transformations of Mechanical into Chemical Energy. Third Paper. Action of Shearing Stress continued;* by M. CAREY LEA.

THAT mechanical energy may be transformed into chemical, has been, I believe I may say, well proved by the reactions described in the previous papers of this series. But the matter is one of sufficient importance to make it desirable to accumulate evidence and to obtain a solid foundation of fact on which to rest the argument.

In the paper which described the effects of shearing stress (this Journal, Dec. 1893), I was able to cite one instance only in which the decomposition product was obtained in easily weighable quantities. More lately others have been obtained, among them one, mercuric oxide, in which it can be determined how many units (gram-meters) of mechanical energy have been transformed into chemical.

Silver-oxide precipitated and dried in the absence of daylight is soluble without residue in ammonia. After trituration therefore, the unchanged portion is easily removed by that solvent.

1. Half a gram of silver-oxide wholly soluble in ammonia was triturated for 20 minutes in a porcelain mortar the unchanged portion was removed by ammonia, the residue was treated with nitric acid, filtered, and the silver thrown down by hydrochloric.

Silver chloride obtained	·0402
Corresponding to metallic silver	·0303

The use of a porcelain mortar is attended with the disadvantage that during the prolonged and forcible grinding necessary, a very appreciable amount of material is removed from the mortar and pestle, which must be separated from the product subsequently. I have therefore made some comparative experiments with a large agate mortar and an agate pestle provided with a stout wooden handle adapted for the use of as much force as with a porcelain mortar. But even under the most favorable conditions, the efficiency of such a mortar is (as will be seen) only one-fifth to one-tenth that of a porcelain mortar of the same size. This is largely due I think, to the high polish which is very unnecessarily given to the inside of agate mortars.

It is therefore better to make use of a porcelain mortar, taking adequate means afterwards to separate the material abraded.

2. The same quantity of silver oxide was triturated also for 20 minutes, in an agate mortar. As the abrasion is inappreciable it was only necessary to dissolve ont the unchanged oxide with ammonia. There was left

Metallic silver	·0048

showing the much less efficiency of the agate mortar.

Mercuric Oxide.—The specimen taken was examined for its solubility in cold dilute (one-tenth) hydrochloric acid, in which it dissolved slowly but completely.

Half a gram was taken and after trituration the unchanged oxide was dissolved out by repeated digestions with hydrochloric acid. There remained mercurous chloride, a trace of metallic mercury, and as a porcelain mortar was used, abraded porcelain. The reduction products were dissolved out by a few drops of aqua regia, were filtered and precipitated by hydrogen sulphide.

Mercuric sulphide obtained	·0354
Corresponding to Hg.	·0305
And to mercuric oxide	·0329

This therefore (disregarding the traces of metallic mercury), is the amount of mercuric oxide which underwent reduction to mercurous oxide.

The oxidation of mercury to mercurous oxide and that of mercurous to mercnric are both exothermic reactions. As respects the thermic equivalent of the oxidation of mercury to both its oxides, quite different numbers have been found by different chemists. Nevertheless if from these different numbers we calculate the amount of heat disengaged by the combination of Hg_2O with O we get almost exactly the same figures whether we use Thomsen's results as modified by Nernst, or those of the French chemists; it matters little therefore which are taken. Ditte in his work "Les Métaux" (Fascicule II, p. 500) adopts the numbers 21·1 and 15·5 respectively.

On this basis, the amount of energy that must be supplied to convert 2HgO to Hg_2O+O (endothermic) is that which corresponds to 9·9 great calories. Therefore 400 grams of mercury existing in the state of mercuric oxide will require that amount of energy supplied to reduce it to mercurous oxide. One gram therefore will require the equivalent of 24·75 small calories and one milligram, ·02475.

In the experiment described mercurous oxide corresponding to 30·5 mgs. metallic mercury was obtained. The energy required to reduce 30·5 mgs. existing as mercuric oxide to mercurous corresponds to 0·755 water gram degrees and this again to 321·5874 gram meters. This number therefore, 322 gram meters, represents the amount of mechanical energy transformed into chemical energy in the above operation.

Potassium Ferricyanide.—A good method of obtaining this salt absolutely free from ferrocyanide is to dissolve the commercial product in hot water and add a little potassium permanganate by degrees until the solution takes a faint reddish color. Very little is usually required. The solution is then filtered and crystallized, taking the first crystals only.

Ferricyanide purified in this way, was triturated about 20 minutes in an agate mortar. On adding water a deep green solution was obtained which by standing and warming let fall abundance of a blue powder.

Ferric Ammonia Alum.—A specimen of this salt which, when tested with potassium ferricyanide gave a pale wine colored solution without a trace of green, was taken and 3 decigrams were triturated for 25 minutes in a porcelain mortar.

After trituration the ferrous salt formed distinctly reduced gold solution. A few drops of the dissolved substance being added to a solution of ferricyanide changed it to an intense green color. Undoubtedly reduction had taken place. It need scarcely be mentioned that in this case the tests should be applied immediately after the trituration. A few hours interval completely changes the reactions owing to the re-oxidation of the ferrous salt formed.

This experiment was repeated with additional precautions. To a strong solution of ferric ammonia alum, enough potash permanganate was added to distinctly color the liquid which was then made to crystallize quickly by cold. These crystals, certainly free from ferrous salt, were then actively triturated in a porcelain mortar for 25 minutes. The filtered solution produced immediate purple clouds in a cold very dilute solution of gold chloride and an abundant blue precipitate in one of potassium ferricyanide.

It is essential that the ferric alum be thoroughly dried (at a temperature not exceeding 40° C.), otherwise owing to the large quantity of water of crystallization it will become pasty in grinding and then no reduction will take place.

Cupric Chloride.—Even by long trituration this salt showed no indication of reduction.

This reaction taken with the preceding shows how distinct is the action of mechanical energy from that of heat. For cupric chloride is reduced by heat to cuprous chloride, but shearing stress has no such action. On the other hand shearing stress reduces ferric sulphate which heat does not.

Sodium Chloraurate.—In the previous paper, the effect of triturating this salt in a porcelain mortar was given. For comparison it has since been tried in an agate mortar. With

20–25 minutes' trituration, 3 decigrams gave 2·7 milligrams metallic gold, showing as in other cases the much lower efficiency of the agate mortar.

Silver Carbonate.—Half a gram was triturated about 25 minutes in a porcelain mortar. It darkened much. The unaltered carbonate was dissolved out by exhausting repeatedly with ammonia. The residue was treated with nitric acid, filtered and the silver thrown down by hydrochloric acid. It amounted to 11 milligrams corresponding to

Metallic silver .... ·0083

Silver Sulphite was precipitated in a dark room by alkaline sulphite and treated in the same manner as the foregoing. Silver chloride obtained ·0092 corresponding to

Metallic silver .... ·0069

Silver compounds although easily giving weighable results, are not well suited for determining the transformation of energy that takes place. It is probable that the reduction is to argentous salt, but it is not certain. Ammonia decomposes argentous salts into argentic salts that dissolve and metallic silver that remains. So that whether we consider the reduction as being to argentous salt or to metal, in either case we find the same quantity of metallic residue after treatment with ammonia and cannot distinguish with certainty.

It scarcely needs to be said that the object of these various determinations is not to establish any relation between the quantity of substance taken and the amount of decomposition that ensues, for none exists. It often happens that when a larger quantity is taken there results a diminished decomposition product, the particles protect one another. And even when all other things are equal the product will depend on the activity and dexterity with which the grinding is done.

But what is really important is that the amounts obtained enable us in particular cases, to determine the exact amount of mechanical energy which has been transformed.

In concluding this paper, two cases will be mentioned which do not belong to the above category, inasmuch as the reductions are exothermic. As a general rule, to cause substances to part with oxygen, energy must be supplied, but there are exceptions. Auric oxide, for example, disengages heat in parting with oxygen and the same is the case with potassium permanganate.

Auric Oxide.—As just said the reduction of auric oxide is exothermic. Thomsen found the equation for its formation

$$2Au + 3O + 3H_2O = 2Au(OH)_3 - 2 \times 6{\cdot}6C$$

The production therefore of a molecule of auric hydroxide requires that 6·6C be supplied. We should therefore expect to find gold hydroxide more easily and more largely reduced by shearing stress than other oxides.

Experiment confirms this expectation and although this case does not belong to the subject proper of this paper which deals with endothermic reactions, it seems sufficiently interesting to add in this appendix.

Gold trioxide hydrate $Au(OH)_3$ was obtained by Figuier's method (a gold solution is rendered strongly alkaline with potash or soda and barium chloride is added as long as it causes a precipitate. Part of the gold remains in solution. The barium aurate is washed and decomposed with very dilute nitric acid). The brown powder after drying was ascertained to be completely soluble in warm dilute hydrochloric acid (1 to 10) showing that no gold had been reduced.

(1) Of gold oxide ·155 gms. were taken and were triturated 25 minutes in a porcelain mortar. The large reduction was at once evident to the eye, the pestle looked as if plated with bright gold. The unchanged portion of oxide was removed by digesting with dilute hydrochloric acid. The metallic gold was dissolved in aqua regia, filtered, reduced and weighed.

It amounted to .... ·0718

The 155 mgs. of gold oxide taken contained 123·1 of gold. The reduction was therefore as 718 to 1231. Fifty-eight per cent or more than half the gold contained in the material employed was reduced.

(2) 200 mgs. gold oxide were triturated 30 minutes in a porcelain mortar. After removing the unchanged oxide as above the metallic gold was dissolved, filtered and reduced—

Obtained .... ·0538

Potassium Permanganate.—Two molecules of permanganate by reduction to $2MnO_2H_2O$ lose 3 atoms of oxygen and at the same time 28·4 Cal. The reaction is therefore exothermic.

By active trituration a portion of the permanganate taken easily undergoes reduction. Exhausted with water, a brownish black insoluble residue remains which dissolves with effervescence in strong warm sulphuric acid forming a violet solution—the residue is therefore manganic peroxide.

Three estimations were made. A first rough one, after trituration for 25 minutes in a porcelain mortar, gave of washed and dried material which had become insoluble, 43 mgs.

The second was made on a like quantity of permanganate also in a porcelain mortar. The portion rendered insoluble was dissolved in hydrochloric acid and estimated as Mn_3O_4

Quantity obtained .... ·0136

showing that 28·25 mgs. of permanganate had been reduced to MnO_2

The same quantity of permanganate treated in the same way in an agate mortar gave only ·0030 MnO_2 owing to the less efficiency of the mortar.

The reductions in the case of these last two substances are exothermic, they however do not take place spontaneously, but require the aid of an exterior force—this aid is supplied by shearing stress.

In these three papers a large number of reactions have been described in which mechanical energy has been transformed into chemism. The number might be extended, but in practice is necessarily limited to those cases in which a perfect separation can be made between the original substances and the altered product.

Art. XLIV.—*The Detection and Separation of Arsenic associated with Antimony and Tin;* by F. A. Gooch and B. Hodge.

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

Upon the well known fact that hot strong hydrochloric acid is capable of dissolving the sulphides of antimony and tin while exerting solvent action to a very slight degree upon arsenious sulphide is based the simplest and most rapid method in common use for the separation of arsenic from antimony and tin. Unfortunately, however, the forcible treatment necessary to bring about the solution of large amounts of antimony is sufficient* to dissolve small quantities of arsenious sulphide, so that for the purposes of general analysis the method is inadequate. Koehler† has shown that only the arsenic is precipitated, and that very completely, when hydrogen sulphide acts upon the solution of arsenious and antimonious salts in hydrochloric acid of 20 per cent strength, but

* Rose-Finkener, Anal. Chem., ii, 423.
† Zeit. für Anal. Chem., xxix, 192.

the adaptability of Koehler's treatment to the detection of arsenic in the ordinary course of analysis is limited by the necessity of so constituting the solution to be tested that hydrogen sulphide shall occasion no deposit of free sulphur to conceal or be mistaken for a precipitation of arsenious sulphide. In the course of analysis the mixed sulphides of arsenic, antimony, and tin, remaining after the removal of the sulphides insoluble in alkaline sulphides and recovered from solution by the action of hydrochloric acid, require for their complete solution the action of an oxidizing agent which must, of course, interfere with the immediate use of Koehler's method. If simple means can be found for the destruction of the excess of the oxidizing agent and the simultaneous reduction of the arsenic and antimony to the lower condition of oxidation, it is plain that the test for arsenic by passing hydrogen sulphide into the solution of antimony and tin in hot hydrochloric acid of half-strength should be sure and easy. In a former paper from this laboratory* a method was described for the quantitative separation of arsenic from antimony, based upon the reduction and volatilization of salts of arsenic by the action of a current of gaseous hydrochloric acid upon the solution containing potassium iodide. It is this reaction—the reduction of arsenic and antimony and the volatilization of the former by the simultaneous action of potassium iodide and hydrochloric acid—which we have now endeavored to apply in simple form to the rapid detection of small amounts of arsenic associated with antimony and tin. We have studied the effect of repeated distillations of small portions of concentrated hydrochloric acid upon mixtures of the salts with potassium iodide. The apparatus which we employ is essentially the distillation apparatus of Mohr, and consists of a $25cm^3$ flask fitted by means of a rubber stopper to a pipette bent, drawn out at the lower end, and dipped into a test tube which is at the same time supported and cooled in a flask partly filled with water. The pipette tube is wide enough (about $0{\cdot}7^{cm}$ in diameter) to prevent the formation of bubbles within it, and the bulb, holding about $20cm^3$, is sufficiently large to retain any liquid which may be momentarily forced back by the accidental cooling of the flask during the distillation.

In the test experiments recorded below the arsenic was introduced into the flask in the form of arsenic acid dissolved with 3 grm. of potassium iodide in $5cm^3$ of water, an equal volume of the strongest hydrochloric acid (sp. gr. 1·20) was added, the distillation was carried nearly to dryness, and the distillate was

* Gooch and Danner, this Journal, xlii, 308.

condensed in $10cm^3$ of a mixture of strong hydrochloric acid and water in equal parts. The iodine evolved during the distillation was bleached by the addition to the distillate of stannous chloride dissolved in hydrochloric acid of half-strength, and hydrogen sulphide was passed to precipitate the arsenic if present. The residue in the flask was treated with $10cm^3$ of the strongest hydrochloric acid and the process of distillation was repeated, but this time the distillate was condensed in $10cm^3$ of water in order that the final acidity of the liquid should be that of acid of half-strength, and so, after bleaching by stannous chloride, immediately available for the test for arsenic by hydrogen sulphide. Subsequent treatments of the residue were carried out similarly until arsenic ceased to appear in the distillate.

The results of experiments (1) to (5) show that four successive distillations of $10cm^3$ portions of the strongest acid are enough to transfer 0·01 grm. of arsenic completely to the distillate, while a single distillation appears to be sufficient to volatilize anything less than 0·003 grm.

Experiments (6) to (9) made similarly with antimony, taken in the form of purified tartar emetic and oxidized by iodine in alkaline solution previous to treatment, either alone or with arsenic, show that antimony is discoverable in the residues when even so little as 0·0001 grm. of that element is originally introduced, though it was very evident that a portion of the antimony may pass to the distillate when much of it is present in the flask. Indeed when large quantities of antimony are treated the appearance of the brownish-red fumes of antimonious iodide in the distilling tube may serve as a very good indication that the concentration should go no further, since the antimonious iodide may, if it reaches the receiver in quantity, impart to the distillate a color which is not discharged, by the stannous chloride used to bleach the iodine and which makes it necessary to look subsequently for a precipitate of arsenious sulphide in a liquid of its own tint. The amount of antimony volatilized seems to be proportioned to the amount present, and, if the distillation is properly conducted, enough antimony remains in the residue to be found if it was originally present in discoverable quantity.

The results of similar work with tin alone, and with tin and arsenic, are recorded in experiments (10) to (15), and the evidence goes to show that, though like antimony it may pass to the distillate under the conditions, enough tin always remains to be found in the residue, if the amount originally taken was discoverable.

	Arsenic taken as H_3O_3AsO. grm.	Antimony taken as H_3O_3SbO. grm.	Tin taken as $SnCl_4$. grm.	Precipitation by H_2S in successive distillates.	Precipitation by H_2S in the residue dissolved in water.
(1)	0·0001	----	----	I. Found. II. None.	None.
(2)	0·0033	----	----	I. Found. II. None.	None.
(3)	0·0050	----	----	I.–III. Found. IV. None.	None.
(4)	0·0100	----	----	I–IV. Found. V. None.	None.
(5)	0·1000	----	----	I–VII. Found. VIII. None.	None.
(6)	----	0·0001	----	I. None.	Distinct color.
(7)	0·0050	0·0001	----	I–IV. Found. V. None.	Distinct color.
(8)	0·0001	0·4	----	I. Found. II. None.	Large.
(9)	0·0100	0·4	----	I–IV. Found. V. None.	Large.
(10)	----	----	0·0001	I. None.	Distinct color.
(11)	0·0100	----	0·0001	I–IV. Found. V. None.	Distinct color.
(12)	0·0001	----	0·0005	I. Found. II. None.	Distinct.
(13)	0·0100	----	0·0005	I–IV. Found. V. None.	Distinct.
(14)	0·0001	----	0·5	I. Found. II. None.	Large.
(15)	0·0100	----	0·5	I–IV. Found. V. None.	Large.

It is plain that a single distillation, which may easily be completed in five minutes, is sufficient to discover the presence of 0·0001 grm. of arsenic associated with so much as 0·4 grm. or 0·5 grm. of antimony or tin.

It is also evident that amounts of arsenic not exeeeding 0·003 grm. may be completely removed from the residue by a single distillation. When larger amounts of arsenic are to be removed, so that the tin and antimony may be obtained free from that element, the result may be accomplished by repeating the distillation sufficiently; or, inasmuch as only a little iodine remains after the first distillation, the end may be attained by dissolving the residue in hydrochloric acid of half-strength, bleaching the iodine with exactly the necessary amount of sulphurous acid or sodium thiosulphate (since the use of the stannous chloride is here precluded), and passing hydrogen sulphide.

ART. XLV.—*On the Presence of Water in Topaz*; by PAUL JANNASCH and JAMES LOCKE.

WE give in the following article the first results of an investigation of the mineral topaz, which we have undertaken in connection with our recently published work on the formula of the axinite from Bourg d'Oisans.* As the first step in this investigation we subjected the mineral to a careful examination for water, and have found, as the analyses below show, that it contains a very significant quantity of water of constitution.

The method which we employed to detect and estimate the water has been described by us in detail in another article,† but it may be well to explain again its principle and some of the precautions which we took to secure accurate results. The substance was mixed with lead oxide in a bulb-tube and strongly fused over the flame of a Bunsen burner, and the escaping water received in a weighed calcium chloride tube. To retain any traces of hydrofluoric acid or silicon fluoride which might also be evolved, a layer of lead oxide about an inch long was placed in the posterior arm of the bulb-tube. The lead oxide used was in some cases the purest article to be obtained from Merck, in others we prepared it ourselves by precipitating lead acetate with ammonium carbonate, thoroughly washing by decantation, evaporating to dryness and igniting the residue in a platinum dish. The ignited product was placed, while still warm, over potassium oxide under a bell-jar and kept there when not in use. After being introduced into the tube, but before its mixture with the powdered mineral, each portion of lead oxide was freed from the last traces of moisture by gentle ignition in a current of dry air. We watched carefully, in every one of the experiments, for signs of escaping hydrofluoric acid or silicon fluoride, but could detect neither: the glass remained perfectly smooth and unattacked throughout, and the water, which could be plainly seen as it condensed in the cold part of the bulb-tube and in the bulb of the calcium chloride tube, showed no trace of silica.

The specimens of topaz examined were in every case fresh and well formed crystals, and absolutely free from foreign substances. The analyses cover four varieties, one of which contained nearly 3·0 per cent of water, the others approximately 1·0 per cent. The analytical results follow:

* Zeitschrift für Anorgan. Chemie, Bd. vi, Heft 1.
† Ibid., Bd. vi, Heft 2.

Locality and Description.	Substance taken.	Water found.	Per cent.	Average.
I.				
San Luis, Mexico. Small crystals; 1, 2, white; 3, brown.	0·5128 gr.	0·0040 gr.	0·79	= 0·81%
	0·5234	0·0046	0·88	
	0·4890	0·0036	0·74	
II.				
Ilmen Mts. Large white crystals.	0·5422	0·0057	1·05	= 1·02%
	0·5554	0·0055	0·99	
III.				
Schneckenstein Saxony. Small gray-white crystals.	0·5743	0·0073	1·27	= 1·28%
	0·5564	0·0071	1·28	
IV.				
Brazil. Large brown crystal.	0·4954	0·0140	2·82	= 2·69%
	0·6308	0·0164	2·60	
	0·5263	0·0140	2·66	

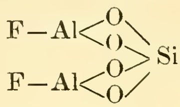
To assure ourselves that the presence of the water was not due to organic substances or other impurities in the lead oxide we made two additional determinations; one, of the water given off by the lead oxide alone, the other conditions of the experiment being observed; the second, of the water in the specimen from the Ilmen Mountains by means of lead oxide which had been previously fused. In the first determination the calcium chloride tube increased in weight by an amount corresponding to less than 0·1 per cent of the quantity of mineral usually taken for analysis, and the second experiment yielded results agreeing with those previously obtained.

Whether the presence of water will necessitate any radical change in the formula of topaz we are not yet in position to state. We are at present engaged, however, in making several complete analyses of different varieties of the mineral, and hope soon to be able to decide this question.

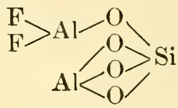
Heidelberg, Feb. 17, 1894.

Art. XLVI.—*On the Chemical Composition and Related Physical Properties of Topaz;* by S. L. Penfield and J. C. Minor, Jr.

The chemical composition of topaz has never been satisfactorily settled. The results of the analyses thus far published show clearly that silicon and aluminium are present in the proportion of 1:2, but the percentage of fluorine as given in them varies from 16·12–18·83. The formula that is usually accepted is that of Groth* [$Al(O.F_2)$] $AlSiO_4$, corresponding to an isomorphous mixture of (AlF_2) $AlSiO_4$ with the andalusite molecule (AlO) $AlSiO_4$ in which the former predominates and in which fluorine is supposed to be replaced by oxygen. Rammelsberg† suggests a mixture of Al_2SiO_5 and Al_2SiF_{10} in the proportion of 5:1. The ratio of SiO_2 : Al_2O_3 : F varies from 1:1:1·50 to 1:1:1·84 and if this could be shown to be 1:1:2 the composition could be expressed by either of the following simple orthosilicate formulæ:



or



Since it has been shown by one of us that hydroxyl so frequently replaces fluorine, and it now seems very doubtful if bivalent oxygen ever plays this rôle, the idea has suggested itself that perhaps the variations in the percentages of fluorine and the failure to yield a simple ratio are due to the partial replacement of fluorine by hydroxyl. Accordingly tests were made for water and it has been found to be always present. This fact seems to have been generally overlooked.‡

In testing by the ordinary closed tube method it is not always evident that hydroxyl is present, since in a mineral like topaz an acid vapor comes off, probably hydrofluosilicic acid, instead of water. By mixing the mineral, however, with lime or some other substance to hold the fluorine, water is evolved. In order to determine to what extent hydroxyl is present and what part it plays in the chemical composition, material from a number of localities has been examined, and it will be shown in the course of this article that the variations which topaz shows both in chemical composition and physical properties result from an isomorphous replacement of fluorine by hydroxyl, while a simple composition has been established which can be expressed by the formula [$Al(F.OH)]_2SiO_4$.

Method of analysis.—The important features of the analysis were of course the accurate determination of fluorine and water. For fluorine the method of Berzelius was adopted. The mineral, mixed with half its weight of quartz, was fused with five times the total weight of mixed sodium and potas-

* Tabellarische Uebersicht der Mineralien, 1889, p. 106.

† Mineralchemie, 1875, p. 580.

‡ As this article was going to press, we have observed in Nos. 2 and 3, vol. vi of the Zeitschrift für anorganische Chemie, p. 168, March, 1894, which has just come to hand, that Jannasch and Locke have also determined the presence of water in topaz with the following results, but they have not discussed the relation of the water to the chemical composition.

San Luis, Mexico.	Ilmen Mountains.	Schneckenstein.	Brazil.
0·80	1·02	1·28	2·69

sium carbonates. The fusion was soaked out, filtered and washed with hot water. To the hot filtrate five to ten grams of ammonium carbonate were added and after cooling, still another addition of the same reagent. After standing in the cold for twelve hours the precipitate was filtered off, the excess of ammonium carbonate expelled from the filtrate by heating in a platinum dish on the water bath, and an ammoniacal solution of zinc oxide added. After evaporating until the odor of ammonia had disappeared the zinc oxide precipitate was removed by filtration, the filtrate heated and dilute nitric acid added until the excess of alkali carbonate was nearly decomposed. To the slightly alkaline, boiling solution an excess of calcium chloride was added and from this point the precipitate was treated as previously described by one of us.* That determinations made by this method are satisfactory was proved by the following: In an experiment with topaz the residue resulting from soaking out the alkali carbonate fusion, and the precipitates formed by the ammonium carbonate and zinc oxide were united, mixed with a fresh portion of alkali carbonates, fused and treated as before. The amount of fluorine that was obtained by this second treatment was only 0·07 per cent, showing that practically all can be extracted by one fusion. Moreover, fluorine determinations were made by the above method in an artificial mixture of cryolite, cyanite and quartz, taken in proportions to correspond with the composition of topaz with the following results.

Cryolite taken.	Fluorine calculated.	Fluorine found.	Loss.
·3325	·1805	·1788	·0017

This result indicates only a slight deficiency, and it is probable that the determinations in the regular topaz analyses are not over 0·20 per cent low, as usually a gram and sometimes a gram and a half of the mineral are taken for a determination. In the above no allowance has been made for what might be recovered by a second fusion of the residues, and probably some of the loss is occasioned by volatilization during the alkali carbonate fusion, but since the crucible was kept covered this must have been very slight. Since water is present, it is evident that attempts that have been made to determine fluorine by loss on ignition, assuming that silicon fluoride is given off, can not have given reliable results. For the determination of water, the mineral has been fused with dry sodium carbonate and the water absorbed in a weighed sulphuric acid tube. The method, which has been carefully tested, gives accurate results. The mineral is completely decomposed and it is impossible for acid

* This Journal, III, xlvii, p. 190, 1894.

vapors to pass off with the water.* There can be no doubt about the water having come from hydroxyl, since it is not driven off except at an intense heat. In an experiment on topaz from Stoneham, Me., where the water was found to be 0·98 per cent, the powder suffered a loss of only 0·12 per cent by heating for a long time in a platinum crucible at the highest heat of a ring burner.

The remainder of the analysis was conducted in the ordinary manner.

Material for analysis.—The specimens which we have examined are from the following localities:

Stoneham, Maine.—The material was colorless and transparent and was taken from the center of a large crystal in the Brush collection, catalogue number 185. Analyses have also been made by Genth† and Whitfield.‡ The former found 18·83 and the latter 17·10 per cent of fluorine, also Na_2O 1·25, K_2O 0·14 and H_2O 0·20 per cent. A careful test that we have made for alkalies has shown that they are absent.

Pike's Peak, Colorado.—A perfectly colorless and transparent cleavage piece from a large crystal.

Nathrop, Colorado.—Wine yellow crystals in rhyolite, described by Cross.§ The habit is similar to fig. 4, page 493 of the sixth edition of Dana's Mineralogy, or fig. 54, page 123 of Hintze's Mineralogy.

Utah.—Perfectly colorless transparent crystals from the rhyolite of the Thomas Range, forty miles north of Sevier Lake. The crystals were selected from a suite of specimens in the Brush collection, and have been described by A. N. Alling.‖

San Luis Potosi, Mexico.—Colorless, transparent crystals like those described by Bücking¶ and similar to the ones from Nathrop.

Zacatecas, Mexico.—Colorless crystals similar to the preceding. The material was generously supplied to us by Prof. A. J. Moses, from the mineralogical collection of the Columbia School of Mines, New York.

Schneckenstein, Saxony.—Wine yellow crystals, selected from a suite of specimens in the Brush collection.

Adun-Chalon, Siberia.—The specimen corresponded to the description given by Kokscharow.** A colorless and transparent crystal in the Brush collection was used for the analysis.

* A full description of this method is in preparation and will appear in a later publication.

† Trans. Am. Phil. Soc., Oct., 1885, p. 43.

‡ This Journal, III, xxix, p. 378, 1885.

§ This Journal, III, xxxi, p. 432, 1886.

‖ This Journal, III, xxxiii, p. 146, 1887.

¶ Zeitschr. Kryst., xii, p. 424, 1886

** Materialien zur Min. Russlands, II, p. 232.

Tenagari, Mino, Japan.—The material was taken from a colorless, transparent crystal, in habit like those from Adun-Chalon.

Minas Geraes, Brazil.—Transparent, yellow crystals selected from a suite of specimens in the Brush collection.

We take pleasure in expressing to Mr. Geo. L. English of New York our thanks for generously supplying us with the specimens from Nathrop, San Luis Potosi and Japan.

The following complete analyses have been made :

Utah.

	I.	II.	Average.		Ratio.		Theory for $(AlF)_2SiO_4$
SiO_2	31·93	----	31·93		·532	0·98	32·61
Al_2O_3	56·26	----	56·26		·551	1·015	55·44
F	20·33	20·41	20·37	1·072	1·093	2·02	20·65
H_2O	·19	---	·19÷9=	·021			----
			108·75				108·70
O. equivalent to F.			8·58				8·70
			100·17				100·00

Nathrop, Colorado.

			Ratio.	
SiO_2	32·23		·537	0·99
Al_2O_3	56·01		·550	1·01
F	20·42	1·075	1·107	2·03
H_2O	·29÷9 =	·032		
	108·95			
O. equivalent to F.	8·60			
	100·35			

Japan.

	I.	II.	Average.		Ratio.	
SiO_2	32·28		32·28		·538	·98
Al_2O_3	56·61		56·61		·555	1·02
F	19·41	19·60	19·50	1·027	1·090	2·00
H_2O	·57		·57÷9=	·063		
			108·96			
O. equivalent to F.			8·21			
			100·75			

Schneckenstein, Saxony.

				Ratio.
SiO_2	32·82		·547	1·00
Al_2O_3	55·41		·543	1·00
F	18·50	·974	1·077	1·97
H_2O	·93÷9=	·103		
	107·66			
O. equivalent to F.	7·80			
	99·86			

Stoneham, Maine.

	I.	II.	Average.		Ratio.		Theory for $[Al(FOH)]_2SiO_4$ F : OH = 9 : 1.
SiO_2	32·28	32·40	32·34		·539	0·99	32·68
Al_2O_3	56·33	56·33	56·33		·552	1·01	55·56
F	18·56	18·30	18·43	·970	1·080	1·98	18·63
H_2O	1·04	·93	·98÷9=	·110			·98
			108·08				107·85
O. equivalent to F.			7·76				7·85
			100·32				100·00

Brazil.

			Ratio.		Theory where F : OH=3 : 1.
Si_2O_2	32·53		·542	1·00	32·79
Al_2O_3	55·67		·546	1·00	55·74
F	15·48	·815	1·087	2·01	15·57
H_2O	2·45÷9=	·272			2·45
	106·13				106·55
O. equivalent to F.	6·52				6·55
	99·61				100·00

From the results of these analyses it is evident that fluorine has been replaced by hydroxyl and the ratios indicate very clearly that $SiO_2 : Al_2O_3 : F+OH = 1 : 1 : 2$ as required by either of the following formulæ $[Al(F.OH)]_2SiO_4$ or $[Al(F.OH)_2]\ AlSiO_4$. The first two analyses show very little hydroxyl, so that the material may be regarded as practically the pure fluorine compound, $(AlF)_2SiO_4$. In addition to the complete analyses, isolated determinations have been made on material from the other localities mentioned on page 390 and these results will be given beyond in tabular form.

Physical properties and their relations to the chemical composition.—The specific gravities were very carefully determined on a chemical balance. pains being taken to boil the crystals for some time in water to expel any air bubbles. The results vary within the limits 3·574 and 3·533, a difference of only 0·041, and as a rule they decrease as the molecularly lighter hydroxyl replaces fluorine.

Also basal plates were prepared and the divergence of the optical axes 2E measured on a large axial angle apparatus. The values for 2E have been found to vary in topaz from different localities and according to the observations of Des Cloizeaux they extend from 129° 30′ on crystals from Durango, Mexico* to 71° 32′ on those from Mugla, in Natolien, Asia Minor,† both measurements being for red. These variations have generally been supposed to be connected with some change in chemical composition, but a satisfactory explanation has never been given. In the following table the measurements that we have made are arranged according to decreasing values of 2E for yellow, and with these the determinations of the specific gravity, fluorine and water are given :

	2E yellow.		Specific gravity.	Fluorine.	Water.
Zacatecas, Mexico,	126°	28′	3·574	....	·18
Thomas Range, Utah,	125	53	3·565	20·37	0·19
Nathrop, Colorado,	125	51	3·567	20·42	0·29
Pike's Peak, Colorado,	122	42	3·567	....	0·48
Tenagari, Japan,	120	59	3·565	19·50	0·57
Adun Chalon, Siberia,	118	46	3·562	19·24	0·58
San Luis, Mexico,	118	17	3·575	19·53	0·80
Schneckenstein, Saxony,	114	28	3·555	18·50	0·93
Stoneham, Maine,	113	50	3·560	18·56	0·98
Minas Geraes, Brazil,	84	28	3·532	15·48	2·45
" " "	......		3·523	.....	2·50

On the last mentioned crystal the value of 2E was not measured owing to the strong optical anomalies which the section presented; it was observed, however, that the angle was small. It is evident from the results given in the table that the value of 2E decreases as the percentage of water increases or as fluorine is replaced by hydroxyl, and this relation is so constant that the percentage of water can be told from the value of 2E. It is evident, therefore, that the topaz from Durango, mentioned by Des Cloizeaux as giving the largest value of 2E = 129° 30′, must be the nearest approach to the fluorine compound, while that from Asia Minor, also cited by him as

* Bull. Soc. Min. de France, ix, p. 135, 1886.
† Nouv. rech., Inst. France, xviii, p. 612.

giving the smallest value of 2E = 71° 32′, must be the richest in water or hydroxyl and poorest in fluorine of any topaz that has thus far been examined.

The indices of refraction also show a progressive change along with the variations of 2E as may be seen by the following determinations, given for yellow light by different investigators.

	2E.	2V.	α.	β.	γ.
Thomas Range, Utah,*	126° 24′	67° 18′	1·6072	1·6104	1·6176
Nerchinsk, Adunchal Mts.,†	121 55	65 30½	1·61327	1·61597	1·62252
Colorless Crystal, Brazil,‡	120 40	65 14	1·6120	1·6150	1·6224
Schneckenstein, Saxony,†	114 17	62 33	1·61549	1·61809	1·62500
" " §	110 12	60 55	1·6156	1·6180	1·6250
Minas Geraes, Brazil,†	86 21	49 37	1·62936	1·63077	1·63747

As hydroxyl replaces fluorine, therefore, the indices of refraction increase and the strength of the double refraction decreases, as shown by the values $\gamma-\alpha$ in the extremes:

Thomas Range, Utah $\gamma-\alpha = 0·0104$
Minas Geraes, Brazil $\gamma-\alpha = 0·00811$

The crystallographic axes are also affected by the isomorphous replacement of fluorine by hydroxyl. The variation however is not very great and only exact determinations can be used for showing it. Mr. C. A. Ingersoll has kindly made for us some careful measurements on a crystal from the Thomas Range, Utah, which, next to the topaz from Zacatecas, contains the least water of any examined by us, and upon which the forms *o*, 221 and *f*, 021 were well developed and gave beautiful reflections. Also on one from Brazil upon which very exact measurements could be obtained from the *f*, 021 faces only, the other forms, the striated prism and the pyramid *u*, 111, not being suitable for measurement.

Utah.

	Measured.		Measured.	Calculated.
$f \wedge f$, $021 \wedge 0\bar{2}1$ =	87° 19′*	$o \wedge o$, $221 \wedge \bar{2}21$ =	105° 10′	105° 10′
$o \wedge o$, $221 \wedge 2\bar{2}1$ =	49 36*	$o \wedge o$, $221 \wedge \bar{2}\bar{2}1$ =	127 47	127 51

Brazil.

Measured.

$f \wedge f$, $021 \wedge 0\bar{2}1$ = 86° 55½′*

The axial ratios are given in the following table and with them a number of others given by investigators who regard them as very exact.

* Alling. This Journal, III, xxxiii, p. 146, 1887.
† Mülheims. Zeitschr. Kryst., xiv, p. 226, 1888.
‡ Des Cloizeaux. Manuel de Minéralogie, p. 475, 1862.
§ Zimányi. Zeitschr. Kryst., xxii, p. 339, 1893.

	$\breve{a}$	:	$\bar{b}$	:	$\dot{c}$
Utah, Ingersoll	0·528110	:	1	:	0·477115
Urals, Koksharov*	0·528542	:	1	:	0·476976
Schneckenstein, Laspeyres,†	0·531548	:	1	:	0·475973
Brazil, Ingersoll	....	:	1	:	0·473862

Optical anomalies.—Of the crystals examined by us the only ones that showed optical anomalies were those from Brazil. A basal section of the crystal that was used for the complete analysis showed an interior rhomb, having the outline of the unit prism, surrounded by four symmetrical trapeziums, and two opposite V-shaped segments, with their angles turned toward and touching the acute angles of the inner rhomb. The disposition of the parts was practically like that described by Mallard‡ and Mack.§ The extinction directions of the outer segments corresponded almost exactly to that of the inner rhomb. On another crystal from Brazil, for which only the specific gravity and water determinations are given, the optical anomalies were much more marked, and the extinction in the different segments undulatory, so that the divergence of the optical axes 2E could not be measured. When the sections were examined by transmitted light it was evident that they were not homogeneous, since the well defined outlines between the inner rhomb and outer segments indicated a variation in the refractive indices. The structure indicates very clearly the existence of an inner core or older crystal, surrounded by a later growth of topaz of different composition. This idea agrees with the observations of Des Cloizeaux, who found that the central and outer segments of a zonal crystal gave different values for 2E. Since it has been shown that the physical properties vary with the composition all the changes to which such a compound crystal is subjected must give rise to mechanical strains and cause the disturbance in the optical orientation of the different zones.

Comparison between topaz and herderite.—The changes that have been brought about by the partial substitution of fluorine by hydroxyl have previously been studied by one of us, page 329, and it will be interesting in closing to make a comparison of the results that have been obtained. In herderite we know the pure hydroxyl compound, hydro-herderite $Ca(BeOH)PO_4$ and the hydrofluor-herderite $Ca[Be(OH.F)]PO_4$ with $OH : F = 3 : 2$. With topaz the nearly pure fluorine extreme is known $(AlF)_2SiO_4$ and the hydrofluor topaz from Brazil $[Al(F.OH)]_2SiO_4$, with $F : OH = 3 : 1$.

* Materialien zur Minn. Russ., ii, p. 198, 1854.
† Zeitschr. Kryst., i, p. 351, 1877.
‡ Ann Mines, x, p. 155, 1876.
§ Wied. Ann., xxviii, p. 153, 1886.

In both herderite and topaz an increase in hydroxyl is accompanied by a decrease in specific gravity and an increase in the indices of refraction. In monoclinic herderite the axes of greatest and least elasticities correspond nearly to the crystallographic axes, and overlooking this slight deviation the optical orientation in both minerals is the same, $\mathfrak{a} = a$, $\mathfrak{b} = b$ and $\mathfrak{c} = c$. Since topaz is positive and herderite negative the acute bisectrices are $\mathfrak{c}$ and $\mathfrak{a}$ respectively, but the angle of the optical axes measured in each mineral over the axis of least elasticity (that is in herderite over the obtuse bisectrix) is smaller for the hydroxyl than for the fluorine compound. In both minerals the substitution of hydroxyl for fluorine causes a change in the lengths of the crystallographic axes but the changes are not of the same character, since in herderite the *a* and *c* axes both increase while with topaz *a* increases and *c* decreases.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, April, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Effect of absorbed Hydrogen on the Electrical Properties of Palladium.*—In a recent paper by Brucchietti, he gives the results of his investigations upon the effect of the absorption of hydrogen upon the thermo-electric power and the electric resistance of palladium. He finds that this absorption increases the resistance, the increase being proportional to the quantity absorbed; a palladium wire saturated with hydrogen having a resistance 1·55 times as great as before it was charged. When the same wire is repeatedly saturated with hydrogen and discharged, its resistance appears to tend toward a constant value (whether hydrogen is present or not); this value being intermediate between its resistance before being charged and that after being charged for the first time. In his experiments on thermo-electric power, the author used a couple consisting of palladium and nickel and found that the power of this couple increases with the amount of hydrogen which the palladium has absorbed; so that when the metal is saturated, the thermo-electric power is 1·66 times that observed before charging. When a thermo-electric couple was made of charged and uncharged palladium, the current at the cooler junction was found to flow from the charged to the uncharged metal.—*Nature*, xlix, 65, November, 1893. G. F. B.

2. *On the Determination of the Molecular Formulas of Liquids by means of their Molecular Surface Energy.*—The

striking and important analogy between the volume-energy equation of a gas and the surface-energy equation of a liquid has recently been investigated by RAMSAY. The former equation has the well-known form $pv = \mathrm{RT}$, in which v is the volume of the gas, p the pressure upon it in atmospheres, T the absolute temperature, and R a constant, which when the unit of volume is the volume in liters occupied by the molecular mass in grams, becomes 0·0819. The equation representing the surface-energy of a liquid is $\gamma s = k(\tau - d)$; in which γ is the surface tension, s the surface, k a constant analogous to R and τ the temperature measured downward from the critical temperature. Since the origin of the line representing the variation of surface energy with temperature is not at the critical temperature but about 6° below it, a constant d is subtracted from τ. By a series of experiments with ethyl oxide, methyl formate, ethyl acetate, benzene, chlorbenzene and carbon tetrachloride, the author has shown that the molecular surface energy of liquids which do not dissociate, varies directly with $(\tau - d)$ within very wide limits of temperature. In comparing different liquids with each other it is necessary to select surfaces on which equal numbers of molecules lie. And since the molecular volume of a liquid is that volume in cubic centimeters which is occupied by the molecular mass taken in grams, it is evident that the cube root of the molecular volume gives the relative number of molecules along a line one centimeter long and that the square of this value represents the relative number of molecules distributed on unit surface; i. e., on one square centimeter. Hence the expression $(\mathrm{M}v)^{\frac{2}{3}}$ may be termed the "molecular surface" of a liquid. This quantity multiplied by γ the surface tension, gives $\gamma(\mathrm{M}v)^{\frac{2}{3}}$, the molecular surface energy; i. e., the energy which must be expended in producing a surface on which a definite number of molecules is distributed, this number being the same for all liquids. Since the rate of change of the surface energy with temperature is a linear function of the temperature, the first differential coefficient $d\mathrm{E}/dt$ or $d[\gamma(\mathrm{M}v)^{\frac{2}{3}}]/dt$ has the constant value 2·121.

In connection with EMILY ASTON, Ramsay has now applied these considerations to the determination of the molecular formulas of liquids. From the equation $(\gamma(\mathrm{M}v)^{\frac{2}{3}} - \gamma'(\mathrm{M}v')^{\frac{2}{3}})/(t' - t) = 2.121$ or K, we have $\mathrm{M} = \mathrm{K}\,(t' - t)/(\gamma v^{\frac{2}{3}} - \gamma' v'^{\frac{2}{3}})$; from which knowing the molecular surface energy at two or more temperatures, the molecular masses can be calculated. The liquids used were such as promised to show a higher molecular mass than that expressed by their ordinary formulas; such as phenol, bromine, nitric and sulphuric acids and phosphorus. The value γ was obtained from the rise of the liquid in a capillary tube, by the ordinary equation $\gamma = \frac{1}{2} rhg\delta$, in which r is the radius of the tube, h the height of the column, g the gravitation constant and δ the density of the liquid. For phenol, at 46° to 78°, the value of E the molecular surface energy, was found to be 736·9 and that of K 1·682; whence M=133·5. At 131° to 184°, these values were 490·6, 1·899 and 110·9 respectively; the value of K being less than 2·121 but approaching it as the temperature rises. There is therefore in this case some condensation on liquefaction; or as the authors call it, "association." In the case of bromine the value of M obtained between 10·6° and 46° was 202·77 and between 46° and 78·1°, 184·59. It may be assumed that even in the liquid state, therefore, most of the molecules have the formula Br_2; though there is apparently some association with fall of temperature. Nitric acid gave 105·9 for the value of M between 11·6° and 46·2°, and 117·4 between 46·2° and 78·2°; showing that the liquid acid is a mixture probably of HNO_3 and $H_2N_2O_6$. Sulphuric acid, H_2SO_4 is unstable and dissociates on warming into SO_3 and an acid of the composition $(H_2SO_4)_{12}H_2O$ approximately. This acid gave a mean value for K of 0·209; indicating a molecular mass corresponding to $(H_2SO_4)_{32}$. Phosphorus between 78·3° and 132·1° gave a value of 2·205 for K, corresponding to a molecular mass of 117; or practically P_4. Hence it appears (1) that phenol like the alcohols forms complex molecules in the liquid state, which dissociate as the temperature rises; (2) that bromine also is somewhat associated but on rise of temperature gives simpler groupings of Br_2; (3) that nitric acid consists largely of molecular groups $(HNO_3)_2$; (4) that sulphuric acid is a very complex substance at ordinary temperature its complexity being probably not lower than $(H_2SO_4)_{32}$, a rapid diminution taking place above 132°; and (5) that phosphorus in the liquid state has a molecular mass the same as that of its gas P_4.—*Jour. Chem. Soc.*, lxiii, 1089, Sept. 1893; lxv, 167, March, 1894.

G. F. B.

3. *On the Manufacture of Oxygen from Calcium Plumbate.*—It had been observed by Le Chatelier, on investigating the dissociation of calcium plumbate, that in order to evolve the oxygen by heat alone, it was necessary to raise the temperature about 200° higher than was required by barium peroxide; but that, on the other hand, the oxygen is more rapidly and completely reabsorbed from the air at lower temperatures by the plumbate than by the peroxide. Kassner has now called attention to the fact that while the oxygen can be obtained from the plumbate by heat alone other methods are more advantageous. He especially recommends the following: Porous calcium plumbate is moistened with steam and subjected to the action of washed furnace gases preferably at a temperature below 100°. The carbon dioxide in these gases is rapidly absorbed, the material then consisting of a mixture of calcium carbonate and lead peroxide. This is transferred to a retort kept constantly at a red heat and in this the oxygen is evolved, the evolution being much helped by the introduction of a current of steam. After the oxygen is evolved, the current of steam is continued, and the temperature

raised; when carbon dioxide is set free and may be collected for use. The calcium plumbate is then regenerated by means of a current of air. Peitz has modified this process by decomposing the plumbate by a current of pure carbon dioxide at a red heat. Kassner claims for his plumbate process as advantages over the Brin barium oxide process 1st, obtaining pure carbon dioxide as a by-product; 2d, the use of low temperatures and consequent saving in fuel and in wear and tear of the retorts.—*Chemische Zeitung*, xvii, 1242; *J. Chem. Soc.*, lxvi, ii, 89, March, 1894.

G. F. B.

4. *On the Base-forming Function of Iodine.*—Thus far iodine has been classed solely as a negative or acid forming element. But V. Meyer and Hartmann have now shown that it is capable of acting to form basic compounds, and so is analogous in this respect to nitrogen. In fact trivalent iodine can form a powerful base resembling ammonia and which forms well defined salts with acids. This base is constituted thus: $I\begin{cases}H\\H\\OH\end{cases}$ being in its structure similar to hydroxylamine $N\begin{cases}H\\H\\OH\end{cases}$. The new substances prepared by the authors are derivatives of this simple form and have the constitution $I\begin{cases}C_6H_5\\C_6H_4I\\OH\end{cases}$ and $I\begin{cases}C_6H_5\\C_6H_5\\OH\end{cases}$. Meyer was led to suspect this property of iodine from the fact that the group IO seems to give basic properties to the compounds in which it occurs, iodosobenzoic acid for example $C_6H_4(IO)(COOH)$ being a much weaker acid than iodo-benzoic acid $C_6H_4I(COOH)$. It would appear therefore that H.I:O, though called hypoiodous acid, will when isolated be found to be a base. The first new iodine base was produced from iodosobenzene C_6H_5IO, which itself forms salts with acids. By dissolving this substance in the calculated quantity of strongly cooled concentrated sulphuric acid, the solution becomes brown and contains only the sulphate of the new base. On diluting by adding ice and treating with potassium or sodium chloride, bromide or iodide, the halogen salt of the new base is precipitated; this base resembling closely in this respect the metals silver, lead and thallium. From the precipitated iodide thus obtained the free base is obtained by treatment with moist silver oxide. Its solution reacts strongly alkaline, and on evaporation yields a gummy mass. The empirical formula of the iodide is C_4H_3I; but as it decomposes on dry distillation completely into mono- and di-iodobenzene, its molecular formula must be $C_{12}H_9I_3$, and the formula of the base $C_{12}H_9I_2.OH$. The chloride is a white curdy precipitate much resembling silver chloride, but crystallizing from warm acetic acid. The bromide is a pale yellow precipitate, similar to silver bromide, fusing at 167°–8°. The nitrate is precipited by nitric acid from the sulphuric acid solution as a white mass, soluble in hot water.

In a subsequent paper the authors describe the diphenyl derivative of the new base which they call *iodonium hydroxide.* On treating iodosobenzene, which has been exposed in a thin layer to sunlight for a few days or better, has been heated for some hours to 60°, with moist silver oxide, the diphenyl derivative of the new base is produced. It appears that the iodosobenzene C_6H_5IO is oxidized to $C_6H_5IO_2$; and the reaction is $C_6H_5.IO+C_6H_5.IO_2+Ag\ OH=Ag\ IO_3+HO.I.(C_6H_5)_2$. If a mixture of these iodized benzenes in proper proportion be mixed with silver oxide and agitated for three hours and then filtered, the clear solution on adding potassium iodide yields over ninety per cent of the theoretical quantity of crystals of diphenyl-iodonium iodide. The salts of the iodonium bases strongly resemble those of silver, lead and thallium. The diphenyl iodide forms large and beautifully grouped acicular crystals fusing at 175°–6° and passing into the polymeric mono-iodo-benzene C_6H_5I. The aqueous solution of the free base is very stable, is strongly alkaline and absorbs carbon dioxide. Sodium sulphide precipitates a yellow and ammonium sulphide an orange sulphide.—*Ber. Berl. Chem. Ges.*, xxvii, 426, 502, Feb. Mch., 1894. G. F. B.

5. *Diminution of the force of gravity with the height, determined by weighing.*—FRANZ RICHARZ and OTTO KRIGAR MENZEL communicate some preliminary results obtained, from a very complete experimental station established in the fortifications at Spandau. Each of the two pans of a balance were provided with rods 2 meters long; upon these rods other scale pans were hung. A direct determination of the difference of weight in these scale pans was made. Futhermore a mass of lead weighing 100,000 kilograms was placed in the space between the two vertical pans. On the upper pan the force of the earth and the attraction of the lead mass act in the same direction. On the lower pan they act in opposite directions. A complete description is given of the installation of the apparatus in a room of the fortress. Unusual precautions were taken to avoid changes of temperature. Only at short intervals, however, could concordant observations be taken. A discussion of the method of weighing is given. The difference of weight obtained was $g_u-g_0=0{\cdot}0_5 6523\ m/\text{sec}^2$ while the calculated value was $g_u-g_0=0{\cdot}0_5 697\ m/\text{sec}^2$.

The observed value was thus smaller than the calculated value. The authors are now in a condition to carry the investigation to a successful conclusion.—*Ann. der Physik und Chemie*, pp. 559–583, No. 3, 1894. J. T.

6. *A law of candle flames.*—P. GLAN, after a careful examination of the illuminating power of candle flames in comparison with their dimensions concludes that equal portions of the flame of different candles radiate the same amount of light. The value of the lighting power of a cubic centimeter of a candle flame can be expressed in terms of $0{\cdot}7035^{cm}$ flame volume of a *Walratkerze.*—*Ann. der Physik und Chemie*, pp. 564–590, No. 3, 1894. J. T.

7. *A ring magnet for obtaining intense magnetic fields.*—Very little attention has been paid to the better construction of powerful electromagnets for physical experiments. In most physical cabinets will be found the Ruhmkorff magnet which was designed before clear ideas of the magnetic circuit had been obtained. H. DuBois has therefore designed a ring-formed electromagnet by means of which experiments with powerful magnetic fields can be carried out. The entire magnet constructed under his direction weighed between 500 and 600 pounds—between suitable conical pole pieces a field of 40,000 C. G. S. units was obtained, over a space whose diameter varied from three to five millimeters.—*Ann. der Physik und Chemie*, pp. 537–549, No. 3, 1894. J. T.

II. Geology and Mineralogy.

1. *The age of the White Limestones near Warwick, Orange Co., N. Y.*—An examination of the geological structure, and a petrographical study, of the white and blue crystalline limestones and associated granites of the regions about Mounts Adam and Eve have been made by Messrs. J. F. Kemp and Arthur Hollick. This is the northern extension of the belt of limestones described by F. L. Nason in the New Jersey Annual Report for 1890 under the title of "The Post-Archæan age of the white limestones of Sussex Co., N. J." (see this Journal, vol. xlii, p. 70, 1891.) The authors of the present paper are "on the whole forced to the opinion that the white limestone is metamorphosed blue," which in its extension in New Jersey contains Cambrian fossils, and think it most reasonable to attribute the change to the granite intrusions. "The limestones near the contact become charged with silicates, either in bunches and irreglar masses or else in general dissemination. These masses are chiefly brownish-green hornblende of a peculiar tint, dark brown biotite or phlogopite, light green pyroxene, titanite, calcite, pyrite and some scapolite. Chondrodite, at times thickly charges the limestone and with it spinel. The white limestone graduates into blue with transitional graphitic forms, and the remote blue limestone shows no metamorphism, and the same belt in New Jersey contains Cambrian fossils." The facts in the case do not seem, to the writer of this article, to warrant the conclusion that the white limestone is of Cambrian age. The presence of Cambrian fossils in a limestone of the same region but everywhere distinctly different from it in color, texture and contained minerals, leave the presumption that it is distinct in age as it is distinct in lithological character from the blue limestone, so long as there is neither fossil evidence to determine any age, nor continuity in the sedimentation to show stratigraphical sequence. I have examined in Arkansas two examples of unaltered, stratified limestones of different geological age, appearing in the same section, with only slight difference in texture, color or position of bedding, which were classified by careful geologists as one continuous limestone. In one case the fossils on one side

the line of separation were found to be of Ordovician age, those on the other side Upper Silurian. In the other case the fossils from below were Silurian and, with only a slight interval between, the strata above contained Carboniferous fossils. In the light of such facts it would seem more reasonable to regard these white limestones of New York and New Jersey as distinct from the blue limestones of the same regions because of their persistent lithological differences until actual evidence in the shape of fossils proves their geological age. The presumption is in favor of the theory of their different age until they can be shown to be continuous, and in the absence of such evidence it is unprofitable to confuse them. A valuable *List and Bibliography of the minerals occurring in Warwick Township*, by HEINRICH RIES, is appended to the paper.—*Granite at Mounts Adam and Eve, Warwick, Orange Co., N. Y., and its contact phenomena.—Ann. New York Acad. Sci.*, vol. viii, pp. 638–654. H. S. W.

2. *The Cretaceous Flora of Long Island.*—Mr. HOLLICK has increased our knowledge of this flora by descriptions of forty-six species, nine of which are new species, in a paper entitled *Additions to the Paleobotany of the Cretaceous formation on Long Island.* Bull. Torr. Bot. Club, by ARTHUR HOLLICK. Vol. XXI, pp. 47–65 and Plates 174–180, Feb. 1894; and in a second paper: *Some further notes on the Geology of the North Shore of Long Island,* Trans. N. Y. Acad. Sci., xiii, pp. 122–132, 1894, has shown the relations of 50 determined species, 23 species being identified with species of the Dakota group, of western North America, 16 also are identified with the lower Atane flora, and 7 with the Patoot flora of Greenland, and a few with other fossil floras.

3. *A Monograph of the Devonian Fauna of the south of England;* by G. F. WHIDBORNE. Vol. I, pp. 1–344 and Plates I–XXXI; Vol. II (parts i to iii), pp. 1–160, and Plates I–XVII. Paleontographical Society, London, 1889–1893.— Prof. Phillips' "Paleozoic Fossils of Devon and Cornwall," in 1841, defined the stratigraphy and paleontology of the Devonian System of England, and has since that time served as the basis for the identification of the system in other regions. The faunas of the Rhenish Devonian, of the Hartz, of Belgium and of France and Spain, of Russia, and of New York and several other tracts in North America have been exhaustively studied, and described, while this typical fauna of the Devonian has, as a whole, remained with little more elaboration than it had fifty years ago. This monograph of Mr. Whidborne's will therefore be of special importance in determining the precise fauna of the original Devonian limestone. The author has confined his descriptions to the fauna of the limestone of Lummaton, Wolborough, Chircombe Bridge and Chudleigh :—thus restricting the monograph to a single fossil fauna. When this shall have been completed we will have before us a definite standard for comparison and correlation.

In vol. i, a single vertebrate bone fragment, 20 species of Trilobites and 15 other Crustacea, 60 species Cephalopods, 116 Gastropods, are described. The second volume begins with the Lamellibranchs, of which 56 species are described, and the Brachiopods are partly done, 86 species having already been noticed. Davidson, in 1882, in the supplement to the monograph on British Devonian Brachiopoda, gave a list of sixty-two species from Lummaton, based upon the material in Mr. Whidborne's and in Mr. Vicary's collections, and some of the species were then described, but here the species are figured and their relations to other allied forms discussed. The monograph is a valuable contribution to the precise definition of one of the standard faunas of the geological time scale; discussion of the fauna itself is reserved for a future communication. H. S. W.

4. *Topaz from Texas;* by GEORGE F. KUNZ, (communicated).—Five crystals, all more or less rolled, showing that they had been taken from the bed of some stream or brook, were lately sent to Messrs. Tiffany & Company, of New York, on the supposition that they might be diamonds. Four of these proved on examination to be topaz crystals. The largest one, of a faint pale green color, with dull rubbed surfaces, somewhat rolled and fractured, and slightly etched faces, resembled the more highly modified crystals of this species from Alabashka in the Urals, and Colorado. Its size was $17 \times 16 \times 12^{mm}$. The following faces have been identified, and verified by measurements with the hand goniometer:—the base, 0.0.1, domes 0.21, and 0.4.1, pyramids 1.1.1, and .121, and prisms 1.1.0, and 1.2.0.

Two crystals were white, with very little form, save that the strong basal cleavage was very apparent. One of the smaller ones was about 10^{mm} in diameter, very much etched, and resembled the etched wine-colored crystals from Cheyenne Mountain, Colorado. No other information was given about them than that they came from near Palestine, Texas,—evidently from the granite rocks.

This is the first noted occurrence of topaz in Texas; and its presence suggests that it may probably be found in connection with other minerals associated with topaz and peculiar to the Urals, Madagascar, Ceylon, and Oxford County, Maine.

In December, 1893, my attention was called by Prof. William H. Hobbs, Professor of mineralogy and metallurgy in the University of Wisconsin, at Madison, to a diamond that had been found in Oregon township, two and one-half miles southwest of Oregon village in Dane County, Wisconsin. Through his courtesy, the stone was sent to me by the finder, Mr. Charles Devine of the place just named. The diamond was found by him while husking corn in October, 1893, in a rough, stony field which had been under the plough for forty years. The bank of clayey earth in which it was found contained a large number of rounded pebbles of quartz, but no other of the associated minerals of the diamond; and as the entire district consists of glacial drift coming from the north, a diamond-bed is not likely to exist in the immediate vicinity, but is rather to be looked for in the direction from which the drift came. The diamond is a rhombic dodecahedron, deeply pitted with circular, elongated, reniform markings. In color it is slightly grayish-green. It is one of the kind of diamonds, however, of which the color is likely to be superficial, and it would probably cut into a rounded stone. Its weight is three and three-quarters and one-sixteenth ($3\frac{3}{4}$ $\frac{1}{16}$) karats. This is the second authentic occurrence of diamond in Oregon, Wis., the other occurrence being that of three small stones, the largest of which weighed ($\frac{25}{32}$) twenty-five thirty-seconds of a karat. A 16-karat diamond was reported to have been found, also in the glacial drift at Waukesha, Wis., in 1884. Some litigation resulted from its finding, and considerable doubt was expressed at the time as to the genuineness of the discovery.

5. *Les Enclaves des Roches Volcanique;* by A. LACROIX (*Ann. de l'Acad. de Macon.* Tome X, 1893, pp. 710).—Nothing perhaps marks more clearly the great advance that is being made in the science of petrology than the appearance of a handbook like this, devoted to a special phase of the subject. The inclusions occurring in volcanic rocks have been previously studied by Professor Lacroix (Bull. de la Soc. Geol. de France, vol. xviii, p. 845, 1890), but in the present memoir he has greatly extended his own work and adds a resumé of the observations of others. According to his method of classification the inclusions are divided into two classes, those whose origin is known or supposed to be not the same as that of the rock in which they occur, as a fragment of schist in basalt, which are called enallogenetic (énallogene), and those whose origin is inferred to be similar, as sanidinite in phonolites and trachytes. These are called homogenetic. The volcanic rocks, for classificatory purposes, are also divided into two classes, the basaltic ones, those of dark color, basic in composition, and which have been reproduced artificially, and trachytic rocks, chiefly feldspathic, which have not yet been made by artificial processes. It is evident that the study of inclusions of the first class is that of extreme contact metamorphism. Many interesting results and theories are given which it would be impossible to discuss here. The volume is well illustrated by a large number of cuts and beautiful colored plates. It will prove of great service to all working petrographers. L. V. P.

6. *The Laramie and the overlying Livingston Formation in Montana*, by WALTER HARVEY WEED, with *Report on Flora*, by FRANK HALL KNOWLTON, (Bull. U. S. Geol. Survey, No. 106.) pp. 68, 6 pl. 1893.—The authors of these papers have given valuable descriptions of the geology and of some of the fossil plants from the rocks studied in the region along the base of the mountains south of the Yellowstone, near Livingston, Montana. The total section in the vicinity of Livingston and in the canyon of the Yellowstone consists of Algonkian schists at the base; 835 feet Cambrian shale, limestones, with some quartzites at the base;

450 ft. Devonian, limestones and some shales; 1900 ft. Carboniferous, limestone below and quartzites and sandstones above; 460 ft. Jurassic sandstones and limestones; 4700 Cretaceous, made up of Dakota sandstones and conglomerates, 600 ft.; 1600 ft. Colorado, argillaceous limestone and bituminous shales, 1500 ft. Montana, sandy shales and argillaceous shales, 1000 Laramie, coal bearing sandstones and shales, capped by 7000 feet of sandstone grits, conglomerates and clays, mainly debris of lavas and volcanic rocks, which the authors have named the *Livingston formation.*

The change in the lithology—rounded Archæan sand and pebbles of the Laramie being capped by the angular volcanic ejectamenta of the higher beds, together with evidence of at least local unconformity, are the characters chiefly relied on by the authors for calling the Livingston formation post-Laramie.

The plant remains are shown to have some Laramie affinities but represent more strongly the Denver flora. Of the 22 species of the Livingston beds having a distribution outside the area examined, 17 are found, as the authors remark, "either exclusively in the Denver or have their greatest development in this formation"; but we notice, also, that 12 of these same 22 species are also found in the Laramie, and 4 other species, not ranging outside this area, are also found in the underlying Bozeman-Laramie. So far, then, even if the horizon be correlated with the Denver beds, the plants rather confirm Dr. White's interpretation of the Denver formation as being equivalent to upper Laramie and not to post-Laramie. The only reported fossil fauna seems to us to weaken the conclusion of the authors. It comes from a "white calcaerous sandstone interbedded with the characteristic dark colored sandstone grits and shale beds of the Livingston about 500 feet above the base." Mr. Stanton has identified the fossils as undoubted Laramie fossils.

Whatever change, therefore, is represented by the passage from rounded water-worn Laramie sands and pebbles to angular volcanic ejectmenta and local unconformity, the fact that the same fauna appears 500 feet above the break shows conclusively that, biologically measured, the time interval was insignificant, and the change in the flora is more likely to have been the result of the climatal changes incident to the volcanic eruptions than to any considerable evolution of the total land floras of the continent. Although we should interpret the Livingston beds to be upper Laramie according to the evidence adduced, rather than post-Laramie as the authors maintain, this does not detract from the value of this excellent contribution to the geology of an interesting region. H. S. W.

III. Miscellaneous Scientific Intelligence.

1. *Bulletin of the American Museum of Natural History*, Vol. V, contains the following articles of geological interest: Art. 1, *Artionyx, a new genus of Ancylopoda*, by H. F. Osborn and

J. L. Wortman, pp. 1–18; Art. IX, *On the divisions of the White River or lower Miocene of Dakota*, by J. L. Wortman, pp. 95–106; Art. XI, *Ancestors of the Tapir from the Lower Miocene of Dakota*, by J. L. Wortman and Charles Earle, pp. 159–180; Art. XVII, *Fossil Mammals of the upper Cretaceous beds*, by H. F. Osborn, pp. 311–330; Art XVIII, *Characters of Protoceras (Marsh), the new Artiodactyl from the lower Miocene*, by H. F. Osborn and J. L. Wortman, pp. 351–372.

2. *Biological Lectures delivered at the Marine Biological Laboratory of Wood's Holl*, in the summer session of 1893. 242 pp. Boston, 1894 (Ginn & Co.).—This is a series of lectures by original investigators discussing the live problems in the several fields of their work, designed particularly for special students already acquainted with the principles of biological research.

The subjects discussed are the Mosaic Theory of Development, by E. B. Wilson; The Fertilization of the Ovum, by E. G. Conklin; On some facts and principles of Psychological Morphology, by J. Loeb; Dynamics in Evolution, by J. A. Ryder; On the nature of Cell organization, by S. Watasé; The inadequacy of Cell-theory of Development, by C. O. Whitman; Bdellostoma Dombeyi, Lac., by Howard Ayres; The influence of external conditions on Plant Life, by W. P. Wilson; Irrito-contractility in Plants, by J. Muirhead Macfarlane; The Marine Biological Stations of Europe, by Bashford Dean; and an appendix on the Work and Aims of the Marine Biological Laboratory, by C. O. Whitman, the Director.

3. *Star Catalogue.*—The late Dr. Peters and his assistant, Charles A. Borst, at the Litchfield Observatory were preparing an extensive Star Catalogue. The ownership of the manuscript and of the Catalogue has been the subject of legal contest.

The decision was in favor of Dr. Peters; but the Court of Appeals has recently reversed the decision and ordered a new trial. It is to be hoped that under some agreement of the parties the Catalogue may now be completed by Mr. Borst, and published without further delay. H. A. N.

The Rensselær grit Plateau in New York, by T. Nelson Dale. Extracts from the 13th Ann. Rept. of the Director, U. S. G. S. 1891–2, pp. 291–340, with Plates XCVII–CI.

Washburn Observatory of the University of Wisconsin. Vol. VIII. Meridian circle observations 1887–1892. Part I. Results of meridian circle observations, 1888–1890, by Prof. S. J. Brown, U. S. N., Albert Flint and H. V. Egbert. With an introduction by George C. Comstock, Director. pp. 1–300, 1892. Part II, Meridian circle observations of Mars at the opposition of 1892, prepared for publication by Albert S. Flint, Assistant Astronomer, pp. 301–327, 1893.

Ein geologischer querschnitt durch die Ost-Alpen nebst anhang über die sog. Glarner doppelfalte, by A. Rothpletz.—(E. Schweitzerbart'sche Verlangshandlung, Stuttgart. 1894. pp. 268. 1 long plate and 115 cuts in the text.)

A Treatise on Elementary Hydrostatics, by John Greaves, 204 pp., Cambridge, 1894. (Macmillam & Co., New York, price $1.00.)

APPENDIX.

Art. XLVII.—*Restoration of Elotherium*; by O. C. Marsh. (With Plate IX.)

The genus *Elotherium*, established by Pomel in 1847, represents a family of extinct mammals, all of much interest. They were first found in Europe, but now are known in the Miocene of North America, not only on the Atlantic coast, but especially in the Rocky Mountain region, and still further west. This family includes several genera, or subgenera, and quite a number of species, some of which contain individuals of large size, only surpassed in bulk among their contemporaries by members of the *Rhinoceros* family, and of the huge *Brontotheridæ*.

Remains of this group have thus been known for nearly half a century, yet, until recently, comparatively little had been determined with certainty regarding the skeleton, or of the skull except the dentition, although Aymard, Leidy, Kowalevsky, and others, have made interesting contributions to the subject. In a late paper,* the writer gave figures of a finely preserved skull, and also of a fore and hind foot, of one of the largest species, *Elotherium crassum*, Marsh, and in the present article an attempt is made to restore the entire skeleton of this animal, to serve as a typical example of the group.

The restoration, one-twelfth natural size, given on Plate IX, represents a fully adult individual, which, when alive, was more than seven feet in length and about four feet in height. The basis of this restoration is the type specimen of *Elotherium crassum*, which was found by the writer in 1870, in the Miocene beds of northeastern Colorado, and described in 1873.† A number of other specimens since obtained in the same region, and still others from essentially the same horizon in South Dakota, all evidently pertaining to this species, were likewise used in the restoration.

* This Journal, vol. xlvi, p. 408, plate viii, November, 1893.
† *Ibid.*, vol. v, p. 487, June, 1873.

The type specimen, although incomplete, includes portions of the skull, with various vertebræ and bones of the limbs and feet, and these were sufficient to determine the general form and proportions of the animal here restored. The additional specimens used are mostly in good preservation, and some of them are almost as perfect as in life. Hence, the skeleton, as represented on Plate IX, is believed to be correct in all its essential features.

Looking at the skeleton, as here shown, it is evident that the most striking features are the large and peculiar skull, and the elongate and slender limbs and feet, characters that do not in themselves suggest the suilline affinities of the animal, which a closer study brings to light. The most notable points in the skull, as here indicated, are the long, pendent process of the malar bone, characteristic of some of the sloths, and the strong projections on the lower jaw. The latter supplement the malar process, but are developed to a greater degree than in any other mammals. Another feature of the skull to which the writer has already called attention is the very small brain-case, which proves that the brain itself was very diminutive. This was also true of the other known species, and was probably the main reason which led to the early extinction of the whole group.

The slender, highly specialized limbs and feet are likewise particularly noticeable in the restoration. They indicate clearly that the animal was capable of considerable speed, and this must have been of great service as a protection from its enemies. It will be seen that in each foot there are only two functional digits, corresponding to the third and fourth in man. The first digit is entirely wanting, and only remnants remain of the second and fifth.

Such reduction was, of course, a gradual process, extending over long geological periods. It indicates clearly a change of environment from the swampy home of the primitive five-toed suilline to the elevated, firm upland of later times, over which the present species and its near allies doubtless roamed. A parallel instance, still more striking, is seen in the gradual change which took place in the equine mammals, as first shown by the writer more than twenty years ago.*

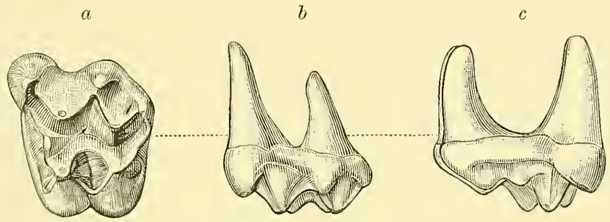
The *Elotheridæ* were evidently true suillines, but formed a collateral branch that became extinct in the Miocene. They doubtless branched off in early Eocene time from the main line, which still survives in the existing swine of the old and new worlds.

Yale University, New Haven, Conn., April 12, 1894.

* This Journal, vol. vii, p. 257, March, 1874.

ART. XLVIII.—*A New Miocene Mammal;* by O. C. MARSH.

VARIOUS remains in the Yale Museum seem to indicate a new ungulate mammal, apparently allied to *Hyopotamus.* The specimens, although distinctive, were not found together, and their relation to each other cannot now be determined. A very perfect last upper molar, which may be taken as the type, is shown natural size in the accompanying figures. Its crown is composed of the same main elements as in the corresponding tooth of *Hyopotamus*, but all the five cusps are much less elevated. In addition, the basal ridge of the outer margin is swollen into two high pointed cusps, making seven in all, and this has suggested the generic name.



Upper molar of *Heptacodon curtus*, Marsh. Natural size. *a*, seen from below; *b*, outer view; *c*, front view.

Of the outer cusps, or buttresses, the anterior one is the larger, and is situated well forward and partly outside of the main body of the crown. The antero-median cusp is well developed, triangular in outline, and situated somewhat in advance of the other two anterior cusps, as shown in figure *a*. The two interior cones are connected near their inner margins by a low ridge, and their summits are joined by a high outward-curved ridge, which extends nearly to the centre of the crown. The crown itself is very short, considerably shorter than in the molars of *Hyopotamus*.

The animal thus indicated, which may be called *Heptacodon curtus*, was somewhat larger than a sheep. The known remains are from the upper Miocene of South Dakota.

Yale University Museum, April 14, 1894.

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[THIRD SERIES.]

Art. XLIX.—*Notes from the Bermudas*; by Alexander Agassiz.*

. . . . Before completing my article on the Bahamas I was anxious to visit the Bermudas. I have spent about a month in their examination and find that the story of their present condition is practically that of the Bahamas, with the exception that at the Bermudas we have an epitome as it were of the physical changes undergone by the Bahamas. One cannot fail to be struck with the insignificance of the corals as compared with those of Florida, of the Bahamas and of the Windward islands. It is true that on the ledge patches inside of the so-called "ledge-flats" the Gorgonians and Millepores are very flourishing, but the development of the true reef builders, of the massive corals, is insignificant; while the absence of Madrepores is remarkable and changes the whole aspect of the coral growth.

I shall have little to add to the description of the Bermudas as given by Nelson, Rein, Thomson, Rice and Heilprin, but I am inclined to take a different view of the part which the corals now growing have played in the formation of the reef ledge flats. The corals have not added any material part to the reefs, they form only a thin veneer over the disintegrated ledges of æolian rocks which constitute the so-called reef off the south shore of Bermuda and the ledge flats of the outer reef ring near the edge of the Bermuda Bank. Æolian rock ledges underlie the growth of corals not only on the patches off the south shore and on the ledge flats of the outer reef but they

* From a letter to Professor James D. Dana, dated Bermuda, March 12th, 1894.

also underlie the so-called patches and heads forming the flats which extend on both sides of the main channel and divide the interior waters of the Bank into irregular sounds like Murray anchorage. The passage of the shore æolian rock ledges into the coral patches can easily be traced both off the north and south shores.

I fully agree with those who before me have examined the Bermudas and who consider that subsidence has brought about the existing outlines of the islands. But that is a very different thing from assigning to the corals now growing the formation of the islands owing to this subsidence. That the protobermudian land was of elliptical shape and owed its existence to the action of winds sweeping over an extensive coral beach from which was gathered the materials which now form the solidified æolian hills of Bermudas no one can question. But there is no evidence to show that the original annular coral reef was formed during subsidence. That reef has disappeared and nothing is left of it except the remnants of the æolian ledges extending to 16 or 17 fathoms outside of the reef ledge flats, ledges which owed their existence to the material derived from it: the former æolian hills of the protobermudian land. Remnants of such ledges and former æolian hills are the rocks forming the outer ledge flats, the breakers all along the south shore, the Mills breaker, the North Rocks, the Chub-heads, the South-west breaker and others.

The Bermudas and Bahamas offer an example of the thickness of a recent limestone deposit during a period of rest. Assuming a probable subsidence of 70 feet and a greatest elevation of 260 feet we get a coral limestone of 330 feet in thickness, the material of which has all come from a reef which itself was probably not thicker than 120 feet or a total thickness of 450 feet. In the case of the Bahamas the maximum height of the æolian hills is stated to be about 400 feet and the greatest subsidence was probably as much as 200 feet which with the thickness of the reef would give a thickness of 720 feet of coral limestone. This thickness or a great part of it moreover is not limited to a circumscribed area but extends, as is the case of the Bahamas, over a wide region. When we remember how readily these coral limestones are changed into hard ringing rocks we introduce a new element into the discussion of the mode of formation of huge masses of limestone especially in the region of the trade winds.

Solution has undoubtedly played some part in producing the fantastic outlines of the limestone ledges as well as of the shore rocks below low-water mark but the solvent action of the salt water cannot be compared in efficiency to the destructive mechanical action of the sea. This has to a great extent been arrested by the covering coat of Gorgonians, Millepores, Algæ, and Corallines as well as of the more massive corals found thriving upon the heads, patches, ledges and ledge flats of the inner and outer waters of the Bermudas. But these heads, ledges, etc. do not as has been stated by former observers, owe their existence and their gradual increase to the corals, as they only form a protecting veneer over their surface, viz: a coral growth and not a coral reef.

The so-called Serpulæ reefs described before by previous observers, are perhaps the most interesting structures of the Bermuda reefs. They are most numerous off the south shore, constituting miniature atolls, barrier and fringing reefs apparently formed by the upward growth of Serpulæ. While Serpulæ undoubtedly cover a great part of the surface of the structures, yet Algæ, Corallines, barnacles, mussels and other invertebrates are found to be fully as abundant as the Serpulæ which in many cases play a secondary part. In fact it would be as correct in some localities to call them Algæ or Coralline atolls. Neither the Serpulæ nor the Algæ or other organisms have built up to any considerable extent the vertical walls of the different kinds of diminutive reefs so characteristic of the south shore. The Serpulæ, Algæ, Corallines and other growths have only protected the surface of the æolian rock ledges which form these structures from the action of the breakers. They have not built up the raised rims of the atolls, of the crescent or of the horseshoe-shaped reefs, or the vertical walls forming the irregular convolutions and curves of the broader ledges.

All these structures from a circular or elliptical atoll to a barrier or fringing reef with all their possible modifications, are due to the action of the surf and the wash of the sea in eating away the surface of the mushroom-shaped rocks which is either softer than the surrounding parts or is not protected by the covering coat of Algæ, Corallines or Serpulæ. One can off the south shore trace the whole process from the time when the large fragments of shore æolian rocks fall by undermining into the sea, until they are changed by the action of the surf into mushroom-shaped ledges surmounted by pinnacles, next into the stage when the pinnacle has in its turn been undermined and dropped alongside of the ledge to become the holding ground of coral and other growth. The surface of the flat ledge which formed the base of the pinnacle is now freely acted upon by the breakers. According to the nature of the upper crust and to the extent of protection given to it by the covering coat of animal and vegetable life the sea acts upon it and we have hollowed out atolls of diminutive size, crescent or horseshoe-shaped structures as well as the curved, straight or convoluted or looped vertical walls of broader ledges which stand up from the bottom and seem to have been built up by the organisms covering their surface. Taking this for granted as had been done by previous observers, I was greatly surprised on hammering at some of these structures, to find the vertical walls composed of æolian rocks and to discover that in many cases the elevated rim was protected by the hard ringing crust so characteristic of limestones exposed to the action of the sea, and further to find that the coating of Serpulæ, of Algæ, of Corallines and Nullipores was quite superficial. It soon became evident that these diminutive atolls were large pot holes excavated by the surf and sand and that the varied forms of crescent-shaped reef of barrier reefs and all the possible modifications one finds on the south shore of the Bermuda are all due to the mechanical action of the surf.

The following diagrams will explain their mode of formation better than any lengthy description I can give.

AB (fig. 1) is a piece of shore cliff which has become isolated, the æolian lamination is clearly seen above high water mark. Below high water mark it is honeycombed and eaten away, leaving the æolian pinnacle supported only by a slender stem rising from an extensive base more or less covered with Algæ, Serpulæ and other growth. The surface of the ledge as well as the base of the mass extending below low water mark is more or less eaten away and when the æolian pinnacle (A) has fallen off a mushroom-shaped mass is left, the upper surface of which may be above or below low water mark. All trace of æolian stratification has been obliterated by the cementing and solving action of the sea water. If the base, the mushroom-shaped ledge, is stratified horizontally (fig. 2) the result of the wash of the breakers upon any part of the top left unprotected will be to dig out circular or elliptical atolls (fig. 3) like A or B. In one case A the atoll will have a rim of nearly the same width, while in the other case B, if the

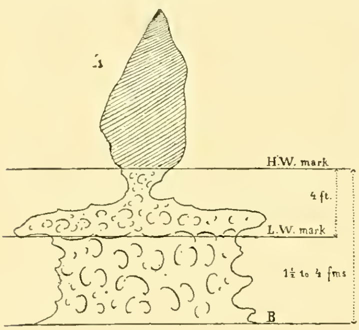
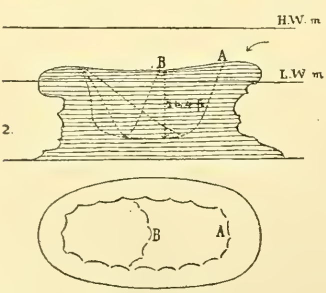


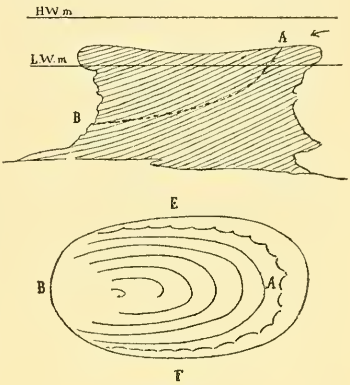
Fig 1.



Figs. 2–3.

softer parts of the top are on the lee side, the atoll will have a wider rim on the weather side from B to A. The pot holes of these circular atolls are usually from three to four feet in the depth. But in some cases I have measured them between five and six feet and even more. In others they are only a few inches deep. I have not observed any growth of Serpulæ of greater thickness than from 12 to 18 inches.

Should the æolian strata dip towards the lee side (fig. 4) a horseshoe-shaped atoll is formed as indicated by the dotted line AB. The rim is widest at A, fig. 5, gradually becoming narrower towards the lee side as it nears B, the whole or the greater part of the ledge having been carried away by the pounding of the surf, leaving a high narrow wall with a deep opening at B between its extremities. Should the surf break through the sides at E or F or both, we should have curved vertical walls left, apparently built up by Serpulæ, in reality walls of æolian rocks which may be dug out as I have suggested, either in the case of fig. 2 or of fig. 4.



Figs. 4–5.

In the case of a long and wide ledge we have formed upon it a number of secondary pits and atolls or pot holes as indicated by the heavy lines of fig. 6. Let the walls of these break through and form connecting pot holes of irregular outlines and we obtain a vertical wall such as is indicated by the dotted line of fig. 6. Such a figure is a diagram of one of the ledges of the outer reef off the south shore.

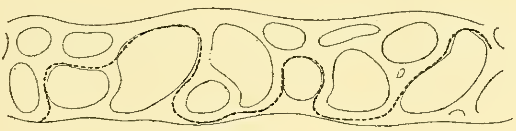


Fig. 6.

A flat ledge projecting from the base of a shore cliff is eaten into in the same way by the surf (fig. 7) and we have formed a circular reef with vertical walls, of which the top is protected by Algæ and Corallines or Serpulæ with a pot hole at its deepest part of 8 feet. We might call this a diminutive barrier reef.

Before seeing these Serpulæ atolls and reefs I had come to the conclusion that the Hogsty Reef atoll (Bahamas) may have been formed in the same way, by the mechanical action of the surf over a reef which was in great part a veneer on the æolian ledges of its bank, the scour of the mass of water poured into the lagoon gradually hollowing it out. The Hogsty reef is about $4\frac{1}{4}$ miles long and $2\frac{1}{2}$ miles wide, the depth of the lagoon varies from 2 to 3 fathoms off the platform at the weather extremity to 7 fathoms at the entrance to the lagoon. That water falling can dig out to such a depth is of course well known. On a small scale this can be observed at the foot of every sluice of a draining or irrigating ditch. How deep can it act on a large scale so as to produce an effective result?

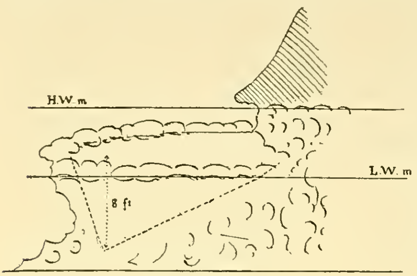


Fig. 7.

Art. L.—*Discovery of Devonian Rocks in California;** by J. S. Diller and Charles Schuchert.

Part I.

Dr. J. B. Trask† was the first to definitely determine by paleontological evidence the geological age of any portion of the auriferous slates of California. He recognized the Carboniferous on the McCloud River. The Geological Survey of California under Prof. Whitney‡ found the Carboniferous in other localities and discovered the Jurassic and Triassic rocks of Mariposa and Plumas Counties. Dr. C. A. White suggested that a part of the Auriferous slates are older than the Carboniferous.§

The present writer, from a study of the structure of the northern end of the Sierra Nevada concluded as follows: "The stratigraphic relations are such as to render it very probable that there is a great thickness of paleozoic strata exposed in the region and that a large part of the gold-bearing slates are

* Published with the permission of the Director of the U. S. Geological Survey. Read before the Geological Society of Washington, D. C., April 25, 1894.

† Report on the Geology of the Coast Mountains, State Senate of California, Document No. 14, Session of 1855, p. 50.

‡ The Auriferous Gravels of the Sierra Nevada of California, p. 34, etc.

§ U. S. Geological Survey Bulletin, No. 15, p. 25. See, also, U. S. G. S. Bull. 19, p. 21, by G. F. Becker.

older than the Carboniferous limestone* and "possibly pre-Carboniferous."†

Since then Silurian rocks have been discovered in that region.‡ Important contributions concerning the identification and distribution of the Carboniferous, Triassic and Jurassic rocks of northern California have recently been made by Becker,§ Turner,§ Lindgren,§ Hyatt,‖ Fairbanks,¶ Mills,** and Smith.††

A great advance in the study of the Auriferous slates of the Pacific coast is made by Mr. Schuchert in discovering Devonian fossils among the collections of the U. S. Geological Survey from northern California. In 1884 the writer found a number of coraliferous limestones three miles southwest of Gazelle in Siskiyou County and on the eastern branches of Soda Creek about five miles N.E. of Lower Soda Springs (Castle Crag) in Shasta Co. Mr. H. W. Fairbanks‡‡ in 1891 discovered a limestone rich in corals about three miles N.W. of Kennet on the divide between Backbone and Little Backbone Creeks in Shasta Co. Before Mr. Fairbanks' results were published he kindly called the writer's attention to this locality. In October, 1893, accompanied by Mr. T. W. Stanton the writer made collections there and since then other exposures of the same coraliferous limestone have been found and collections made on Hazel Creek a few miles east of Southern's.

All fossils collected in 1884 and 1893, at the localities mentioned, were referred to Mr. Schuchert who has definitely determined them to be Devonian as stated in his portion of this communication.

The outcrop of Devonian rocks three miles southwest of Gazelle is one of the best and most accessible for study yet known in California. They are brought to the surface by an eroded arch which exposes the following series in descending order: quartz and other schists; 70 feet of fossiliferous gray limestone succeeded by a few feet of compact limestone and a thick mass of basic eruptives.

West of the axis of the fold this series of Devonian rock dips westward and appears to pass beneath the Scott Mountains. This view is strengthened by the fact that near Parker's on

* U. S. Geological Survey Bulletin, No. 33, p. 18.

† U. S. Geological Survey, 8th Annual Report, p. 407.

‡ Bull. Geol. Soc. of Am., vol. iii, p. 376.

§ U. S. Geol. Survey, Sacramento and Placerville Atlas sheets, also American Geologist. May, 1893, pp. 307–324 and 425 and April, 1894, pp. 248–249.

‖ Bull. Geol. Soc. of Am., vol. iii, pp. 395–412 and vol. v, pp. 395–434

¶ American Geologist, March, 1892, p. 153, February, 1893, p. 69; this Journal, vol. xlv, p. 473, June, 1893; Eleventh Report of the State Mineralogist of Cal., 1893, pp. 24–120.

** Bull. Geol. Soc. of Am., vol. iii, pp. 413–444.

†† Bull. Geol. Soc. of Am., vol. v, pp. 243.

‡‡ Eleventh Report of State Mineralogist of Cal. (1893), p. 48.

the road to Callahan's, about thirteen miles southwest of Gazelle, and also near Oro Fino in Scott Valley, fossiliferous limestone occurs with *Pentacrinus* and appears to be Triassic.

The Devonian limestone four to six miles northeast of Castle Crag, is a veritable coral reef about 60 feet in thickness. It overlies a great mass of dark shales which are apparently older than any of the rocks exposed near Gazelle. This view is sustained by Mr. Schuchert who gives paleontological evidence to show that the fossiliferous rocks of Kennet, Hazel and Soda Creeks belong to a lower horizon in the Devonian than those of Gazelle. The slates, overlying the limestones are much less crystalline than near Gazelle and no eruptives were noticed in the immediate vicinity. These rocks, as well as those near Gazelle, were formerly supposed to be Carboniferous.*

There are two outcrops of Devonian limestone on Hazel Creek about four and five miles respectively east of Southern's. They have a number of fossils in common and probably exposed the same limestone. It overlies a large mass of black slate and dips easterly beneath the Carboniferous, which contains fossils on Tom Dow's Creek. The strike of the Carboniferous at that point is east of north, dipping towards the southeast and probably connects with the well known locality of Grizzly Peak about fourteen miles further to the northeast.

According to Mr. Storrs, who collected the fossils on Hazel Creek, the dip of the limestone is easterly and overlies a great mass of black slate. Its strike is a little east of north, connecting it directly with that of the same horizon on Soda Creek as well as that near Kennet further southward.

Three miles west of Kennet, a mile beyond Mr. Matson's lime kiln at a locality discovered by Mr. Fairbanks,† the limestone in places is composed almost wholly of branching corals and is in reality a coral reef about 50 feet in thickness. It is much warped but generally dips to the eastward beneath the Carboniferous which occurs along the McCloud River.

The region directly westward of the great bend of Pitt River has yielded many fossils belonging to the Jurassic, Triassic, Carboniferous and Devonian systems. All of which are arranged in successive belts increasing in age westward in the Klamath Mountains, indicating the presence of rocks of still greater age about the central portion of that mass. The general strike of the Devonian rocks from near Kennet is about north 18° east, which is in line with the outcrop of Hazel Creek and Soda Creek, over thirty miles away. If they are really continuous for this distance as appears probable it suggests as previously urged by the writer that the axis of folding joins the Klamath Mountains to the Coast Range rather than to the Sierra Nevada. J. S. D.

* U. S. Geological Survey, Bull. 33, p. 11.

† Eleventh report of the State Mineralogist of Calif., p. 48.

Part II.

During the field seasons of 1884 and 1893, the U. S. Geological Survey acquired six lots of Devonian fossils, collected by Messrs. Diller, Stanton, and Storrs, from six localities in Shasta and Siskiyou counties, California.

These fossils, comprising about thirty species, most of which are corals, demonstrate the undoubted presence of middle Devonian deposits in California where rocks of this age have long been looked for by geologists, more particularly since the recent discovery of Silurian fossils.* In the geological literature treating of California, the writer finds that Mr. Fairbanks was probably the first to refer certain strata provisionally to the Devonian. He says: "In my former paper I traced the Paleozoic rocks of Shasta county, part Carboniferous and part probably Devonian, south along the main Coast range to San Francisco Bay."† This is the only specific reference to probable Devonian rocks in California. The locality on which Mr. Fairbanks based his conclusions is near Kennet on the Sacramento River, and is described by him as follows: "The fossils in the limestone [of Backbone Creek] are exclusively corals, and in places the branching stems [*Cladopora*] form almost the complete mass and weather out finely on the surface. In fact the great mass of the limestone seems to be made of corals."‡

The most southerly of these localities (No. 1 of the annexed table) is three miles northwest of Kennet. The next two (Nos. 4 and 5) are about twenty-two miles north on Hazel Creek, and two others (Nos. 2 and 3), ten miles above the latter on one of the branches of Soda Creek, about five miles northwest of Castle Crag. This fauna indicates a single terrane, since the localities each have from one to four species in common, as the annexed list of fossils shows.

About thirty miles to the northwest of the Hazel Creek localities, at a place three miles southwest of Gazelle, Siskiyou county (locality 6), there is another outcrop of Devonian limestone yielding a larger fauna of corals and some Mollusca. Fossils were collected from this limestone, both in 1884 and in 1893. This horizon appears to be higher or younger faunally than that just mentioned, since but one of its species is known to occur in the Devonian limestone of Shasta county. All of the fossils studied are from limestone, and nothing as yet is known of a sandstone or shale fauna.

* Geol. of the Taylorville region of Cal., by J. S. Diller. Bull. Geol. Soc. America, vol. iii, p. 376, 1892.

† American Geologist, vol. xi, p. 70, 1893.

‡ Eleventh Rep. State Mineralogist of Cal., p. 48, 1893.

Notes on the fossils.

Favosites canadensis, *Cladopora labiosa*, *C. acupicta*, and *Syringopora maclurii*, are characteristic forms of the great coral reef of the Corniferous limestone, as developed in eastern North America. The material from the Shasta county localities agrees closely with the descriptions of these species, and the identifications, therefore, are regarded as fairly accurate. Associated with these fossils are a number of other corals, which could not be identified specifically, however, since some are new and of others the material is not well preserved. These corals are given in the first five columns of the annexed list.

The *Alveolites* provisionally referred to *A. minimus* Davis, is represented in Nevada by *A. multilamella* Meek.* The corallites in the California specimens are quite tortuous, and have thinner walls, thus differing distinctly from Meek's species. Externally the present specimens agree with the figures of *A. minimus*, but, no positive identification can be made as Davis† gives no description of any of his species and usually no figures of their internal structure.

Acervularia pentagona Goldfuss, sp., as identified by Meek,‡ occurs at "Treasure Hill, Nevada, in silver bearing Devonian Beds." The California specimens are found in masses six inches in diameter, and appear to have a somewhat larger number of septa than the Nevada form. These differences, however, are not sufficient for specific separation. All the other known species of American *Acervularia* have larger corallites than *A. pentagona*.

The California examples of *Diphyphyllum fasciculum* Meek,§ agree fairly with the Nevada specimens from "Argyle and Treasure Hills, White Pine Mining District." A closely related form, with fewer and not so closely approximating corallites, also occurs at localities 2 and 3. Meek has united these in his *D. fasciculum*.

The *Endophyllum* occurring near Gazelle is interesting since it is the first known occurrence of this genus in America. It differs chiefly from *E. bowerbanki* and *E. abditum* Edwards and Haime,‖ of the Devonian of Devonshire, in having much smaller corallites.

A form of *Gypidula* from the same locality may prove to be the same as *Pentamerus comis* or *P. lotis* Walcott,¶ occur-

* Op. cit., p. 25, Pl. II, figs. 7–7b.

† Kentucky Fossil Corals; Kentucky Geol. Survey Reports, 1885.

‡ Geol. Expl. 40th Paral., vol. iv, 1877, p. 31. Pl. II, figs. 5, 5a.

§ Op. cit., p. 29, Pl. II, figs. 4–4b.

‖ Mono. British Fossil Corals, Pt. IV, p. 233, 1853.

¶ Mono. viii, U. S. Geol. Survey. pp. 159–161, 1884.

ring respectively in the Eureka and White Pine Mining Districts of Nevada. The California specimens consist of separated and distorted valves.

Correlation with other regions.

The corals of the Devonian limestone of Shasta county are believed to indicate the lower portion of the middle Devonian or approximately the Corniferous terrane as developed in New York, Kentucky, Michigan, and Ontario. It should be borne in mind, however, that since many species of corals have a great geographical and considerable vertical distribution, great reliance cannot always be placed on them for limited correlation. Mr. Walcott* has identified twenty-five species of this class in the Devonian of Nevada. Some of them hold a different stratigraphic position from the same species in eastern America. He writes: "Among the corals, *Cladopora pulchra*, *Syringopora hisingeri*, and *Cyathophyllum corniculum*, of the great Corniferous coral reef of the east, occur at the upper horizon, and *Syringopora perelegans*, of the same formation in New York, ranges throughout the group in Nevada."†

The fossils from near Gazelle, in Siskiyou county, here considered as of later or younger age than those of the Shasta county limestone agree, in a few cases specifically with the Devonian fauna of the White Pine Mining District in Nevada. Two species, *Acervularia pentagona* and *Diphyphyllum fasciculum*, certainly occur in both regions, while *Pentamerus comis* or *P. lotis* also seems to be present. A single small *Bellerophon* was found with these species, and may prove to be a young specimen of *B. perplexa* Walcott, as found in the Eureka District of Nevada. The Devonian strata of the White Pine Mining District are silver-bearing, while the middle Devonian horizons of Shasta and Siskiyou counties are a part of the Auriferous series of California.

List of species known to occur in the Devonian of California.

	(Shasta County.)					
	1	2	3	4	5	6
Favosites clelandi Davis?	×					
" *canadensis* Billings	×	--	--	×		
" species No. 1	--	--	--	--	--	×
" " No. 2	--	--	--	--	--	×
" " No. 3	--	--	--	--	--	×
" " No. 4	--	--	--	--	--	×
Cyathophyllum robustum Hall, 1876?	--	--	--	×		
" branching form No. 1	--	?	×			
" " " No. 2	×	--	--	?	×	

* Mono. viii, U. S. Geol. Survey, pp. 100–106, 1884.
† Op. cit., p. 4.

List of species known to occur in the Devonian of California.

	(		Shasta County.		)	
	1	2	3	4	5	6
Diphyphyllum, sp. undet., or *Syringopora*	--	×				
" *fasciculum* Meek	--	?	?	--	--	×
Acervularia pentagona (Goldfuss) Meek	--	--	--	--	--	×
" sp. undet	--	--	--	--	--	×
Endophyllum, n. sp.	--	--	--	--	--	×
Cladopora acupicta Davis	×					
" *labiosa* Billings	×	--	--	×		
Alveolites cfr. *minimus* Davis?	×	--	×	--	×	
Syringopora Maclurii Billings	--	--	--	×		
Monticulipora, species No. 1	×	--	--	×		
" " No. 2	--	×				
Leptotrypa	--	--	×			
Gypidula cfr. *comis* Owen, and *G. lotis* Walcott	--	--	--	--	--	×
Conchidium? A small strongly plicated form	--	--	--	--	--	×
Terebratuloid cfr. *Newberria*	--	--	--	--	--	×
Loxonema cfr. *delphicola* Hall	--	--	--	--	--	×
" or *Murchisonia*	×					
Murchisonia	--	--	--	--	--	×
Bellerophon, much like the Russian *B. septentrionalis* Tschernyschew, but may be a young specimen of *B. perplexa* Walcott	--	--	--	--	--	×
Mytilarca sp. undet.	--	--	--	--	--	×
Orthoceras	--	--	--	--	--	×
Large crinoid columns	×	--	--	--	×	×
	9	4	4	6	3	17

C. S.

U. S. Geol. Survey, Washington, D. C., March 14, 1894.

Art. LI.—*On the Blue Iodide of Starch;* by Charlotte F. Roberts.

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

The interesting article by Mylius* on the composition of blue iodide of starch, and the reply to the same by Stocks,† have suggested to me a few simple experiments, the record of which will perhaps be interesting to others who, like myself, may have been puzzled to decide between the adverse views, especially since the papers above referred to are somewhat lacking, in certain portions, in experimental evidence of the facts stated.

Mylius derives as the formula for the blue iodide of starch $(C_6H_{10}O_5I)_nHI$, in which n probably equals 4, and states that it

*Ber. d. d. chem. Gesell., xx, 688. † Chem. News, lvi, 212.

is formed by the union of the colorless, or yellow, compound $C_6H_{10}O_5I$ with hydriodic acid or one of its salts. He affirms that a pure solution of iodine and starch gives no blue color, but that the liquid must contain an iodide, a trace of which is sufficient to bring about the desired result.

My own study of the blue iodide of starch may be considered under two heads:

1st. Its Decompositions.

2d. The Conditions of its Formation.

1. *Decomposition of Starch Blue.*

(*a*) By heat. The effect of heat on the blue iodide of starch is well known. If moderately heated, the blue color returns on cooling, but if strongly heated in an open vessel, it remains permanently colorless. The explanations of this change, however, have been varied, some authorities stating that all of the iodine is driven off by the stronger heat, others that it is converted into iodic acid, and still others that the product of the reaction is hydriodic acid. Stocks affirms the last, and a very simple experiment seems to support this view. If to the cooled, colorless liquid, a few drops of iodic acid be added, the clear blue color is immediately restored. This experiment was performed in a platinum vessel, and the same results were obtained whether iodic acid were used alone or mixed with dilute sulphuric acid, though the latter acid by itself has no effect in restoring the color. That unaltered starch remains in this solution after heating, is proved by the fact that a drop of iodine colors the cold solution blue.

While the fact that hydriodic acid is split off from the iodide of starch under the influence of heat cannot be used as an argument either for or against Mylius's views, these phenomena are perhaps what might be expected if his views be correct. The first effect of heat seems to be to produce a kind of dissociation, the hydriodic acid splitting off from the rest of the molecule and going back into it when cooled, but upon longer heating the iodine which is directly united with the starch molecule is either driven from the liquid or converted into hydriodic acid. Upon the addition of iodic acid, some iodine is set free which, along with the hydriodic acid, unites with the starch to form the blue color. These phenomena are thus shown to be in harmony with Mylius's theory, although no proof of its correctness.

(*b*) By iodic acid. If some blue iodide of starch be precipitated and well washed with dilute sulphuric acid, and then iodic acid added, the solid dissolves to an apparently colorless liquid. That this solution, however, contains free iodine, may be proved by adding chloroform, which becomes tinged a decided pink. This would indicate that the iodic acid acted by withdrawing hydriodic acid from the molecule, thus setting free iodine.

(*c*) By a solution of a silver salt. One of the strongest proofs which Mylius gives for the correctness of his views is that the blue color is destroyed by a silver salt, that the addition of pure iodine now does not restore the color, only turning it yellow, but that the addition of hydriodic acid or potassium iodide gives the blue at once.

I have found, in fact, that a single drop of a very dilute solution of silver nitrate is sufficient to destroy the deep blue color in a test-tube full of liquid. A natural explanation, in the light of the preceding experiments, is that the silver nitrate withdraws hydriodic acid; and the ease and completeness of the change supports the view that this exists as such in the molecule, since in many organic compounds, the halogen is extracted only with difficulty if at all by silver nitrate. This view is still further supported by the fact that the blue color is immediately restored by the addition of a little hydriodic acid. The color is also restored, though not to its former depth, by the addition of a few drops of strong hydrochloric acid, or by a larger quantity of the dilute acid, though it is not affected by sulphuric acid. This can readily be explained on the supposition that the silver iodide is partially decomposed by the hydrochloric acid, giving sufficient hydriodic acid to form some of the blue iodide. That this is the correct explanation rather than that hydrochloric acid can be substituted for hydriodic in the starch compound without changing its color is proved by filtering after adding silver nitrate. and adding hydrochloric acid to the filtrate, when no blue color is produced.

If we concede that in all three of these cases, the decomposition has been effected by a withdrawal of hydriodic acid, it certainly shows a tendency for that portion of the molecule to split off, which is suggestive of its existing already formed as such in the molecule, and in so far is in harmony with Mylius's views, though the mere fact that hydriodic acid is withdrawn is no proof that it goes into the molecule as such. The only portion of the above which can be considered at all as direct proof of Mylius's statement is that after the blue color has been destroyed by silver nitrate, it can be reformed by the addition of hydriodic acid. This would seem certainly a strong argument in support of Mylius.

We pass next to the consideration of

2. *The Conditions of Formation of Blue Iodide of Starch.*

Mylius makes three statements in regard to this which may be quoted here.

(1) An aqueous solution of iodine cannot color starch blue, but the color appears immediately if a trace of hydriodic acid or potassium iodide be added.

(2) Iodine solutions which color starch blue contain hydriodic acid or one of its salts.

(3) The presence of substances which destroy hydriodic acid, as, for example, chlorine and iodic acid, prevents the formation of starch blue.

These different statements will be considered in the order in which they are here quoted, but (1) and (2) are so nearly identical that they cannot be kept separate.

I have never succeeded in obtaining aqueous solutions of iodine and starch which, upon being mixed, did not produce a blue color, although great care was taken to avoid the possibility of any alkali from glass getting into the solutions. According to Mylius, this is the great cause of the presence of iodide in an iodine solution. In my experiments, the iodine was powdered, left standing for some time in a mixture of iodic and sulphuric acids, then washed thoroughly with water, and finally dissolved in water, all of these processes being carried on in a platinum dish. An emulsion of arrow-root, also well washed, was made in a platinum dish, and the two solutions were mixed in a platinum crucible. Notwithstanding all of these precautions, the blue color appeared immediately. This would seem to indicate that Mylius's views were erroneous, but on the other hand, I was able to prove the presence of hydriodic acid in my aqueous solution, even thus carefully prepared. I did this by shaking the solution with chloroform and separating the two liquids with a separating funnel, and repeated this until the chloroform added remained perfectly colorless. Then, upon the addition of a few drops of iodic acid, and shaking, the chloroform became faintly but undoubtedly tinged with pink. It is proved, then, that this liquid which colored starch contained hydriodic acid, but it still remains an open question whether this iodide was an impurity in the iodine, not removed by its repeated washings, which seems hardly probable, or whether it is formed whenever iodine dissolves in water, and is therefore, in traces, a necessary accompaniment of every iodine solution.

That glass has a more powerful action on an iodine solution than has generally been supposed cannot however be doubted. My own attention has been drawn to this fact by the difference in behavior of the liquid which results when starch blue is heated in a glass tube and that which is formed when the same compound is heated in a platinum vessel. In the first case the cold, colorless solution is turned blue by the addition of any acid, whereas in the latter case, iodic acid is the only one which has this power. In case sulphuric acid is added to the liquid before heating in the test-tube, the color is not restored by any acid, even iodic.

Although I have found it impossible to mix carefully prepared solutions of iodine and starch without getting a blue color, if only a drop or two of iodine be added to an excess of starch, the blue formed where the liquids first touch, disappears in the mass of the liquid, and then the addition of hydriodic acid brings out the blue color distinctly. This is in harmony with Mylius's statements, and also with the fact that in working with dilute solutions in a large bulk of alkaline liquid, the delicacy of the starch test for iodine is increased by the addition of two or three grams of potassium iodide.

In a further effort to prepare iodine free from iodides, I have taken an iodine solution, shaken it with chloroform, rinsed with water, and finally drawn off the chloroform solution. Then, upon adding pure water and shaking some of the mixture with starch, the starch remains uncolored. If, however, this mixture of iodine in chloroform and pure water be heated and then cooled, or if it be exposed to the sunlight in a platinum dish for about an hour, the mixture acquires the power of coloring starch immediately, and the colorless aqueous portion of yielding iodine to chloroform when treated with iodic acid. The appearance of free iodine, indicated by the chloroform, showed that hydriodic acid had been formed by the iodine and water on heating or in sunlight.

It has just been shown that if a solution of iodine in chloroform be washed with water, separated from the aqueous portion, and starch added, there is no immediate change of color; but the blue color may be brought out in three different ways:

(1) By addition of a drop of dilute hydriodic acid.
(2) By heating and then cooling the liquid.
(3) By long standing.

The evidence of (1) is a direct support of Mylius's views, and (2) and (3) may be considered as indirectly indicative of the same, since they give conditions under which hydriodic acid might presumably be developed. Further evidence in the same direction may be found in the following experiment. An emulsion of starch in chloroform was made, and to this a solution of iodine in chloroform added. The color remained unaltered, but the addition of a little potassium iodide, either in the solid form or in aqueous solution, immediately produced the blue color. The addition of pure water failed to give the blue color until after standing for several hours.

There seems, then, to be sufficient evidence that all solutions which form starch blue contain an iodide, and also, considering the experiments with chloroform, that solutions freed from hydriodic acid cannot produce that color, although in my experiments I have not been able to make an *aqueous* solution of iodine which did not turn starch blue, and which did not contain hydriodic acid.

We pass now to the third argument of Mylius quoted above, viz: the deterrent action of chlorine and iodic acid on the formation of starch blue.

In regard to the action of chlorine, Stocks quotes the suggestion of Miller that it may be due to the formation of iodine chloride, which is well known to have a destructive effect on the blue iodide of starch. But even granting this as an explanation, two questions remain to be answered; first, how is the iodine chloride formed, and second, what is its action on starch blue? It can hardly be supposed that the chlorine withdraws the iodine bodily from the organic molecule. A much more natural assumption would be that the chlorine decomposes hydriodic acid, setting free iodine; and here we have sufficient cause for the destruction of the blue color. But granting that the reaction may go farther, and the iodine thus set free unite with an excess of chlorine to form iodine chloride, is not this also a body which might be expected to act by destroying hydriodic acid? I have found, in fact, that when iodine chloride is added to starch blue, iodine is set free, the result which might be expected if the iodine chloride acts upon the hydriodic acid in the compound according to the reaction:

$$HI + ICl = HCl + I_2$$

This experiment was performed as follows: Iodine chloride was prepared by putting together potassium iodide and hydrochloric acid in an excess of iodic acid. It was then separated from the other bodies by extraction with ether, and to the ethereal solution, starch blue was added. The color was taken from the starch, and the ether became darker and brown. To prove that this change in the ether was really due to free iodine, it was left standing over pure water for some time, with occasional shaking. Finally, some of this aqueous portion was shaken with chloroform, to which it gave the characteristic pinkish tinge. As iodine chloride gives no color to chloroform, this shows conclusively that iodine had been set free.

There remains to be considered only the action of iodic acid on the iodide of starch. Its action on the precipitated blue after formation has already been referred to, so that at this point, we need only consider its action in preventing the formation of starch blue.

It is an undeniable fact that when dilute solutions of iodine are used, iodic acid in sufficiently large quantities prevents the formation of starch blue both when used alone, and when used with other acids, but a much smaller amount of iodic acid is necessary if mixed with another acid, as for example, sulphuric acid. This may be explained either on the assumption of a more rapid action when sulphuric acid is used, as Landolt* has found to be the case in the reaction between iodic acid and sulphurous oxide, or in the case of ordinary iodine solutions prepared and kept in glass vessels, it may be supposed due to the fact that the liquid contains iodides and iodates derived from the glass. I have tried bringing together extremely dilute solutions of iodic acid and of potassium iodide, and found that no perceptible amount of iodine is set free, though in more concentrated solutions, the iodine is set free in nearly the quantitative yield represented by the equation:

$$5KI + 6HIO_3 = 5KIO_3 + 3H_2O + 3I_2$$

In this reaction, however, the amount of iodine found is always a trifle too low, probably due to the fact above shown, viz: that in very dilute solutions, the iodide and iodic acid do not react on each other, except in presence of another acid. The dilute sulphuric acid alone when added to starch blue does not bleach the color, but diminishes the intensity to an appreciable degree.

The amount of iodic acid necessary to prevent the formation of the blue color depends not only on the amount of other acid present but also on the order in which the reagents are put together. Thus I have found in several cases that, with a definite amount of iodic acid and iodine, there was no color produced if the iodine, iodic acid, and sulphuric acid were mixed first, and left standing for some minutes or half an hour before adding the starch; whereas, if the starch were put in first and the other three constituents added directly, a blue color would result which could only be destroyed on long standing and shaking, if at all.

In general, the amount of iodic acid necessary to prevent the formation of the starch blue seems in very great excess of that which would be necessary to destroy all of the hydriodic acid which can possibly be present. It is only by following the precautions suggested above that the iodic acid needed can be made to bear any reasonable relation to this hydriodic acid. I have dissolved iodine in a mixture of iodic and sulphuric acids, and added starch and obtained immediately a blue color, though naturally not as deep and intense as would be obtained without the iodic acid. This solution was as strong as possible of iodine, being made up with powdered iodine in a platinum dish, and containing always some of the undissolved solid. The liquid poured off from this, whether filtered or not, and

* Ber. d. d. chem. Gesell., xx, 745.

even when it had considerable iodic acid added to it, refused under any circumstances to give a colorless liquid with starch; and the same was found true even when it was left standing with additional iodic acid for half an hour before the starch was added.

These facts and the fact that the purest possible, freshly prepared aqueous solution of iodine may be shown to contain hydriodic acid, have suggested to me the possibility that hydriodic acid may be constantly forming in traces when iodine dissolves in water, and that, therefore, no aqueous solution can be free from it whether kept in glass or not, though there is no doubt that the glass may greatly increase the amount. So many facts seem to point to the truth that hydriodic acid or one of its salts is taken up as such into the molecule of the blue iodide of starch that the fact of the large amount of iodic acid necessary to prevent its formation can hardly be considered a sufficient argument against that belief, though we naturally question what may be the reason for this necessary excess. There seem to me to be two possible explanations, either the iodic acid destroys hydriodic acid much less readily in dilute solutions than has been generally supposed, or some hydriodic acid is constantly being formed in an iodine solution, and perhaps the correct explanation lies in the union of these two.

Landolt* has made some investigation of the reaction between iodic acid and hydriodic acid in dilute solutions, and has found that in an extremely dilute solution, nineteen seconds may elapse before the formation of iodine makes itself manifest by the blue color given to starch. I have used even diluter solutions than he, and found that with ·000009 grams iodic acid and ·000033 grams potassium iodide in 20 cubic centimeters of water, no color appeared with starch until several minutes had elapsed if only a small quantity of sulphuric acid was present, whereas if one-fourth of the liquid consisted of dilute sulphuric acid, a blue tinge appeared immediately. The completeness of the reaction in a given time, then, is seen to depend on the amount of sulphuric acid present, and there is nothing to show whether it is finally complete or whether there may be left traces of undecomposed hydriodic acid.

If we assume that hydriodic acid is constantly being formed in traces in an iodine solution, and remember that the reaction between hydriodic acid and iodic acid is not an immediate one in the presence of a large quantity of water, we can understand why a considerable excess of iodic acid must be used in order to destroy completely the last traces of hydriodic acid and thus entirely prevent the formation of starch blue.

* Ber. d. d. chem. Gesell., xix, 1317.

ART. LII. — *Beaver Creek Meteorite*; by EDWIN E. HOWELL.

IN the number of "Science" dated July 21st, 1893, I gave a brief history of this meteorite as then known, and proposed the above name from the stream near which it fell.

The accompanying cut gives a fair idea of the stone as first seen by me. It measured 6×7×9½ inches and weighed 22½ pounds. About 3 or 4 pounds had been broken from the bottom as shown in the cut. The original weight must have been approximately 26 pounds and the length 12 inches.

After repeated efforts and much correspondence I have been unable to secure any more of the fall. The reports at first stated that two smaller pieces of a few pounds each were seen to fall. This however seems to have been a mistake, as only one other piece of 4 or 5 pounds so far as I can learn was seen. A portion at least of this smaller piece was broken into fragments and distributed the same as the most of that which was broken from the larger mass before it came into my possession, July 6th, 1893, by purchase from Mr. James Hislop, a Civil Engineer, who found and dug it up the morning after it fell and brought it to Washington. It buried itself in the earth about 3 feet—2 feet in soil and 1 foot in hard pan.

The direction of the hole was south 60° east, true meridian, and at an angle of 58° with the horizon. Fresh earth was scattered about the hole in all directions, but farthest (10 feet) in the direction from which the stone came.

It fell between the hours of 3 and 4 P. M. May 26th, 1893, near Beaver Creek, West Kootenai District, British Columbia, a few miles north of the U. S. Boundary and about ten miles above where the creek joins the Columbia River.

The report was heard by persons within a radius of nearly twenty-five miles, and it was believed by many who heard it that larger pieces must have fallen than those secured. The stone is a typical aerolite of very pronounced chondritic structure, has the usual fused black crust, but has one feature unlike any other meteorite with which I am familiar. Beneath the crust there is a slight oxidation for a distance of from one-half to three-quarters of an inch which seemingly must have occurred before it struck the earth, and for which thus far no satisfactory explanation is suggested.

There is no occasion to further describe the character of this stone as that part will be found fully discussed in the accompanying papers by Drs. Hillebrand of the U. S. Geological Survey and Merrill of the U. S. National Museum.

Chemical Discussion; by Dr. W. F. Hillebrand.

The material received for chemical examination was in a crushed state, much of it in fine powder, being the waste resulting from cutting the rocky mass. There was scattered throughout it some organic matter derived from a burnishing brush, which, though insignificant as regards weight, rendered useless any attempt to look for organic matter proper to the meteorite itself.

Of this mass, 26·1892 grams, after repeated separation under alcohol by an electro-magnet, yielded 5·0710 grams of magnetic material which still contained over 10 per cent of unmagnetic substance, as shown by the following analysis:

Analysis of magnetic material.

Fe	80·21	88·456 (Fe, Ni, Co, Cu)
Ni	7·78	
Co	·44	
Cu	·026	
Silicates*	5·17	
SiO_2†	1·31	
MgO	1·31	
FeO‡	1·20	
Fe_3O_4	·83	
FeS§	·77	
P_2O_5¶	·057	
Al_2O_3, CaO, Alk. and loss, by diff.	·897	
	100·000	

The metallic part therefore comprises 17·13 per cent of the meteorite and is composed as follows:

* Insoluble in dilute HCl.

† Total silica from decomposed silicates.

‡ Calculated from the composition of soluble silicates, as given in a subsequent analysis.

§ Found by treatment of the magnetic part with dilute HNO_3, followed by separation by an electro-magnet from unattacked silicates. Hydrochloric acid was then used to free it from a small residue of insoluble silicates, and from this solution the iron was precipitated by ammonia and weighed, whence the weight of Fe_3O_4 was calculated.

‖ By estimation of sulphur (·28 per cent).

¶ A portion of the phosphorus may very possibly be derived from schreibersite.

Fe	90·68
Ni	8·80
Co	·49
Cu	·03
	100·00

By the procedure outlined in one of the footnotes to the foregoing analysis the isolation of magnetite from all but a very small proportion of siliceous matter is easy. It then appears under the microscope as irregular grains of a dull black lusterless surface. Only one grain presented an apparently octahedral aspect.

The main portion of the meteoric material, now freed from all magnetic matter, was thoroughly mixed and pulverized. Its composition follows:

Analysis of unmagnetic material.

S	2·21	6·08 troilite.
Fe	3·87	
FeO	·24	·75 chromite.
Cr_2O_3	·51	
SiO_2	45·87	
TiO_2	·09	
Al_2O_3	2·30	
FeO	12·44	
NiO	·07	
MnO	·26	(too low).
CaO	1·96	
MgO	28·24	
K_2O	·15	
Na_2O	·98	
Li_2O	none	
H_2O above 100° C.	·34	
P_2O_5	·30	
Cl	trace	
	99·83	

The assumption of FeO as the sole divalent element in the chromite is entirely arbitrary. Qualitative tests on a minute quantity separated from the silicates showed that the mineral carried magnesia and alumina also. The extremely weak magnetism of the troilite appears clearly from the fact that the electro-magnet produced only a barely perceptible concentration of it in the magnetic mixture, as shown by comparing the percentages of troilite and of silicates therein with those just above.

A portion of the unmagnetic powder was then divided into a soluble and an insoluble part by digesting for a few hours with dilute hydrochloric acid on the water bath, filtering, separating gelatinized silica by dilute solution of potassium hydroxide, and repeating the treatment of the residue with acid and alkali. In this way there was decomposed 51·11 per cent of the whole. The composition of both soluble and insoluble parts as actually found by analysis is as follows, the S and P_2O_5 being taken from the previous analysis, as also the water of the soluble part after allowing for the trifle belonging to the insoluble portion.

	Soluble portion, 51·11 per cent.		Insoluble portion, 48·89 per cent.	
S	2·21	} 6·08 troilite.		
Fe	3·87			
FeO	·01	} ·04 chromite	·23	} ·73 chromite.
Cr_2O_3	·03		·50	
SiO_2	17·03		27·74	
TiO_2	----		·09	
Al_2O_3	·25		2·34	
FeO	8·69		3·85	
NiO	·04		trace	
MnO	·12		·17	
CaO	·46		1·65	
MgO	17·24		11·14	
K_2O	·01		·12	
Na_2O	·06		·90	
H_2O above 100° C.	·31		·03	
P_2O_5	·30		--	
Cl	trace		--	
Loss	·48		·13	
	51·11		48·89	

Excluding troilite and chromite, but including phosphate, the percentage composition of the soluble and insoluble mixtures is as follows:

	Soluble portion.	Insoluble portion.
SiO_2	38·26	57·75
TiO_2	----	·18
Al_2O_3	·56	4·89
FeO	19·52	8·02
NiO	·09	trace
MnO	·27	·35
CaO	1·03	3·44
MgO	38·73	23·19
K_2O	·02	·25
Na_2O	·13	1·87
H_2O above 100° C.	·70	·06
P_2O_5	·68	----
Cl	trace	----
	99·99	100·00

Whether the titanium belongs to the pyroxene or is to be credited to a special titaniferous mineral, such as ilmenite for instance, the analysis does not show. The siliceous constituents of the stony matter appear from the analysis to be chiefly olivine and the bronzite variety of enstatite. In order to throw further light, if possible, on the character of the mineral or minerals in the insoluble part, a portion of the latter was subjected to prolonged treatment with hydrochloric acid followed by dilute potassium hydroxide solution, after which an attempt was made to effect further separation by the Sonnstadt solution with very limited success. The main portion thus finally obtained was analyzed. It gave the following composition:

FeO	·31	·96 chromite.
Cr_2O_3	·65	
SiO_2	56·48	
TiO_2	·19	
Al_2O_3	2·65	
FeO	9·14	
NiO	?	
MnO	·46	
CaO	2·97	
MgO	25·86	
K_2O	·18	
Na_2O	1·20	
H_2O	?	
	100·09	

Comparison of this with the preceding analysis of the insoluble part of the meteorite shows unquestionably that its siliceous component is a mixture and that the effect of the second acid and subsequent mechanical treatment was to remove partially a relatively soluble alkali-lime-alumina silicate. That this more soluble ingredient is largely of feldspathic nature is, however, negatived by the fact that the last analysis, omitting chromite and titanium, affords almost exactly a metasilicate ratio, and by the failure of Dr. Merrill to identify any feldspathic mineral constituent in more than mere traces.

From the data at hand the composition of the meteorite as a whole resolves itself as follows, assuming for the mixed silicates in the magnetic portion the same composition as that shown by the non-magnetic mixture:

Nickel-iron	17·13	
Magnetite	·16	
Troilite	5·05	(·15 in magnetic, 4·90 in non-magnetic part)
Soluble silicates and phosphate	37·23	
Insoluble silicates and chromite	40·43	
	100·00	

Microscopical Discussion; by Dr. Geo. P. Merrill.

The stone is of a gray color and granular structure, quite fine grained and friable but showing to the unaided eye a finely granular groundmass studded with small spherules or chondri in sizes rarely if ever exceeding 2^{mm} in greatest diameter, and averaging not more than half that amount. With the pocket lens it is seen that the groundmass is also largely chondritic, but interspersed with granular material and glistening metallic particles. So far as material is at hand for comparison, the stone macroscopically most resembles that of New Concord, Ohio, but is much more granular and friable, as well as more pronouncedly chondritic. In the thin section under the microscope it presents no features not common to stones of its class, and various portions of the field show structures in every way similar to those of the meteorites of Mezo-Madras, Homestead, and Dhurmsala as figured by Tschermak* or that of the San Emigdio stone as described by myself.† There are the usual monosomatic and polysomatic chondri sometimes of olivine alone, enstatite alone, or olivine and enstatite together, in granular or porphyritic forms with glassy base, or radiating and barred forms. The olivines not infrequently occur with interiors made up of small rounded granules imbedded in a glass base, but extinguishing simultaneous with the outer portion. In many respects the microstructure closely simulates that of the San Emigdio stone, but the apparent fragmental nature is less conspicuously marked. In two instances small irregular colorless granules were observed giving faintly the twinning striæ and inclined extinctions characteristic of plagioclase feldspars. It is not possible from the examination of the two slides at command to state more definitely as to the presence or absence of this or of silicate minerals other than those mentioned.

* Die Mikroskopische Beschaffenheit der Meteoriten, etc. Plates VII and VIII.
† Proc. U. S. National Museum.

Art. LIII.—*On Allanite Crystals from Franklin Furnace, N. J.;** by A. S. Eakle.

Allanite, as a rock constituent, has been shown to be very widespread in its occurrence and the crystallographic properties of the mineral from many localities, have been determined. The present article is the result of an examination of a large number of crystals coming from the Trotter Mine, Franklin Furnace, N. J.

The presence of allanite at Franklin Furnace was first reported in 1850, by C. T. Jackson,† who published a short description of its occurrence and an analysis. His crystals came from a different locality, being in the feldspar of the old magnetite mines, while those described here occur with the zinc ores, in a great granite dyke.‡

The crystals are coal-black in color, very brittle, and occur in the common, flat, tubular forms, elongated parallel to the ortho-axis. The faces of the crystals are, in general, dull, and when magnified appear to be much pitted, so that reflections with the Fuess goniometer are poor. Imperfect cleavage occurs parallel to the basal- and ortho-pinacoid faces and more perfect in the direction of the prism face, but varying about 6° 30′ from parallelism. An average of several readings gives an angle of 47° 56′ between this cleavage face and the ortho-pinacoid.

Fourteen forms, in all, occur on the crystals, none of them, however, being new. The forms are the following:

$a = \infty P\bar{\infty}\ (100)$	$n = P\ (\bar{1}11)$
$c = 0P\ (001)$	$o = P\grave{\infty}\ (011)$
$d = -P\ (111)$	$r = P\bar{\infty}\ (\bar{1}01)$
$e = -P\bar{\infty}\ (101)$	$u = \infty P\bar{2}\ (210)$
$i = \frac{1}{2}P\bar{\infty}\ (\bar{1}02)$	$w = -2P\bar{2}\ (211)$
$l = 2P\bar{\infty}\ (\bar{2}01)$	$s = \frac{1}{3}P\bar{\infty}\ (\bar{1}03)$
$m = \infty P\ (110)$	$x = -\frac{1}{2}P\bar{\infty}\ (102)$

The forms *x*, *i* and *o* are less common, and *w* and *s* are rare. The remaining faces are quite common to the species, not alone in this locality, but in general. On the "bucklandite" (allanite) of the Laacher See,§ and later on the allanite from Vesuvius,‖ Dr. G. vom Rath has described a large series of forms, most

* Published in the Trans. N. Y. Acad. Sci., Nov. 27, 1893.

† Allanite from Franklin Furnace, N. J., C. T. Jackson. Proc. A. A. A. S., 1850, p. 323.

‡ Kemp, J. F., Trans. N. Y. Acad. Sci., Oct. 30, 1893.

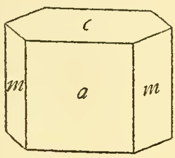
§ G. vom Rath, Ueber die Krystallform des Bucklandits vom Laacher See, Pogg. Ann. Phys. und Ch., vol. cxiii, p. 281.

‖ G. vom. Rath, ibid., vol. cxxxviii, p. 492.

of them being common on the Franklin crystals. Later, W. C. Brogger* has determined about the same faces on the allanite crystals of southern Norway.

In the drawings accompanying this paper are shown the various combinations. They are all drawn from the individual crystals, with the faces possessing the same relative dimensions.

1



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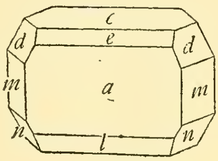

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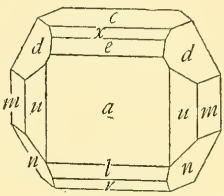
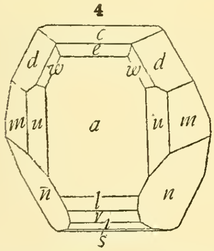


Fig. 1 shows the simplest form, consisting merely of the basal pinacoid (*c*)OP(001), the ortho-pinacoid (*a*)$\infty P\bar{\infty}$(100) and the prism (*m*) ∞P(110). This simple combination rarely occurs.

Fig. 2 is a combination showing forms (*e*)$-P\bar{\infty}$(101), (*d*)$-$P(111), (*n*)+P($\bar{1}$11) and (*l*)2P$\bar{\infty}$(201) in addition to those in fig. 1. This crystal is the largest terminated one in the lot examined and the angles were measured with a contact goniometer.

Fig. 3 shows a much more general combination. The forms occurring are (*c*)OP(001), (*x*)$-\frac{1}{2}P\bar{\infty}$(102), (*e*)$-P\bar{\infty}$(101), (*a*) $\infty P\bar{\infty}$(100), (*d*)$-$P(111), (*n*)+P($\bar{1}$11), (*u*) $\infty P\bar{2}$(210), (*m*) ∞P (110), (*l*)2P$\bar{\infty}$($\bar{2}$01) and (*r*)P$\bar{\infty}$($\bar{1}$01). This combination is similar to the one on the large allanite crystal from Moriah, N. Y., described by E. S. Dana,† lacking only the clino-dome P$\grave{\infty}$(011).

4



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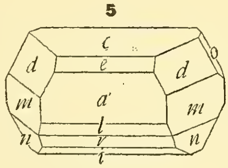

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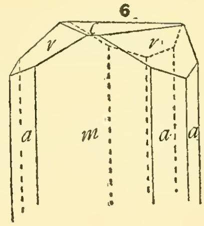


Fig. 4 shows the largest number of forms in combination. All of the forms shown in fig. 3, with the exception of $-\frac{1}{2}P\bar{\infty}$ (102) occur, and in addition (*i*)$\frac{1}{2}P\bar{\infty}$($\bar{1}$02), and the rarer forms (*s*)$\frac{1}{3}P\bar{\infty}$($\bar{1}$03) and (*w*)$-2P\bar{2}$(211).

* W. C. Brögger, Mineralién der sudnorweg augitsyenits, Zeit. für Krys., xvi, 95, 1890.

† E. S. Dana, Allanite, Min. Notes. This Journal, III, vol. xxvii, p. 479.

Fig. 5 is a combination having part of the forms shown in fig. 4, with the addition of the clino-dome (*o*)P $\grave{\infty}$(011).

The following is a list of the angles measured and calculated:

Faces.	Angles meas.	Angles calc.*
001 : 100	65° 2′	64° 59′
001 : 101	34 50	34 53
001 : 102	22 36	22 36½
001 : $\bar{2}$01	89 2	89 1
001 : $\bar{1}$01	63 26	63 24
001 : $\bar{1}$02	34 15	34 15½
001 : $\bar{1}$03	21 22	22 10
001 : 011	58 5	58 2⅔
001 : 111	52 8½	52 9
001 : $\bar{1}$11	74 50	74 49
100 : 101	29 56	30 6
100 : 210	35 42	35 5¾
100 : 111	49 35	49 40
100 : 211	34 9	34 15
100 : 110	54 26	54 34
100 : $\bar{2}$01	25 59	26
210 : $\dot{1}$10	19 23	19 28¼
111 : $\bar{1}$11	61 41	61 38
102 : 101	12 18	12 16½
$\bar{2}$01 : $\bar{1}$01	25 27½	25 37
$\bar{1}$01 : $\bar{1}$02	28 13	28 8½
$\bar{1}$02 : $\bar{1}$03	12 27	11 56½
211 : 111	15 8	15 25

Reflections were so poor in some cases that only approximate readings could be made but a sufficient number of these readings were taken to establish with certainty the identity of all the forms.

The mineral is so opaque and brittle that very thin sections are difficult to obtain. The sections are brown in transmitted light and show strong pleochroism from deep brown to yellowish brown: $\mathfrak{a}$ = yellowish brown; $\mathfrak{b}$ = dark red brown; $\mathfrak{c}$ = dark grayish brown. Absorption $\mathfrak{c} > \mathfrak{b} > \mathfrak{a} >$. The index of refraction is high while the double refraction appears to be weak. Sections parallel to the orthopinacoid show complete parallel extinction. In the clino-pinacoidal section, the extinction is about 36° from *c* in the acute angle β. One section, cut parallel to the basal pinacoid, shows a patchwork of reddish-brown and yellowish-green colors resembling an intergrowth. The crystals are abundantly seamed with cleavage cracks and contain many inclusions of the associated feldspar. The optical character of the mineral was not determined.

* E. S. Dana, New System of Mineralogy, 1892, Allanite, p. 522.

On Tourmaline.

An examination was also made of some large tourmaline crystals which came from Rudeville, N. J. This place is about three and one-half miles northeast of Franklin Furnace, and on the same belt of white limestone that contains the zinc ores. The limestone here is pierced by a large dike of so-called mica-diabase, as described by F. L. Nason* and which has lately been shown to contain more or less altered leucites.† The tourmalines occur near the dike and their formation is apparently due to its action. Other green and brown ones of great perfection have been obtained in the white limestone quarry near the furnace at Franklin. They are there associated with a granite dike.

Most of the crystals are dark brown in color and have well defined faces. The largest one in the lot has the common triangular form of prism, bounded by three broad ∞P faces, measuring four inches in width, and narrower $\infty P2$ faces. The prism is capped by the negative rhombohedron $-R$, and a large basal plane which completely cuts off the polar edges of the rhombohedron. This crystal is shown in fig. 6—$m = \infty P(10\bar{1}0)$; $a = \infty P2(11\bar{2}0)$; $r = -R(01\bar{1}1)$; $c = OP$ (0001).

All of the forms identified on the crystals are as follows:

$\infty P(10\bar{1}0)$	$R(10\bar{1}1)$
$OP(0001)$	$-R(01\bar{1}1)$
$\infty P2(11\bar{2}0)$	$-2R(02\bar{2}1)$
$\infty P\frac{5}{4}(41\bar{5}0)$	$R^5(32\bar{5}1)$

Much assistance has been rendered by Prof. J. F. Kemp, of Columbia College, by suggestions and by the loan of the crystals of allanite and tourmaline which he collected. The writer takes this opportunity to express his acknowledgments.

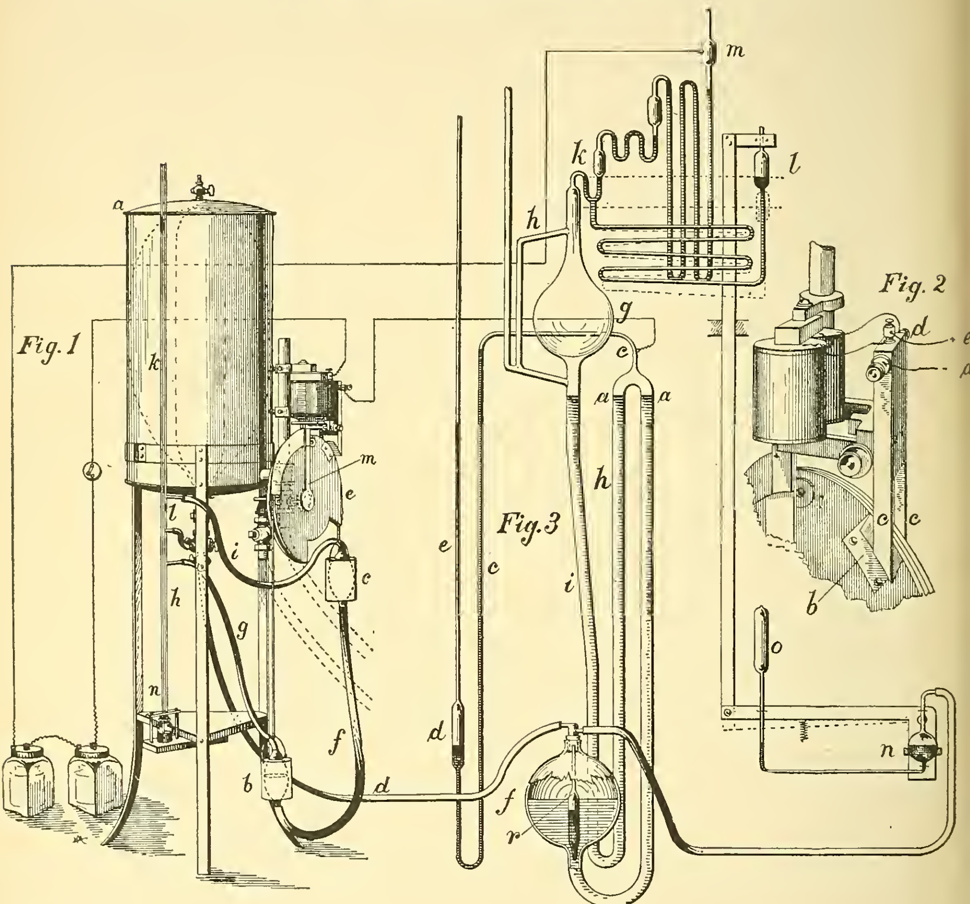
Geological Laboratory, Cornell University.

Art. LIV.—*A Self-Acting Mercurial Air pump;* by Edward W. Morley, Cleveland, Ohio.

Raps has devised an excellent self-acting Toepler air pump. But a different method of driving such a pump is sometimes convenient. For instance, the water pressure in my laboratory is not enough to actuate a mercurial air pump, while in the lowest story of the building it will fairly suffice. It is therefore desirable to drive the pump, placed on an upper

* Ann. Rep. State Geologist of N. J., 1890, pp. 35–36.
† J. F. Kemp. This Journal for April, 1894.

floor, by means of an air compressor in the basement. In such a case the apparatus of Raps cannot be used. But with my apparatus, the air compressor and air pump may be separated to any reasonable distance. Further, one air compressor may drive now one air pump and now another, or may drive



several at once, with no change of adjustment other than turning a stopcock and an electrical switch. Also, my apparatus requires no rubber tube in contact with the mercury of the pump.

Two air compressors and three pumps driven by them are in constant and satisfactory use in my laboratory. It is not claimed that the apparatus is superior to the admirable device of Raps, but only that its peculiarities may in some cases be advantageous.

Fig. 1 shows a perspective view of the air compressor. *a* is a copper cylinder: it contains a caoutchouc gas bag which is fastened to a brass tube ending in three stopcocks seen just beneath the cylinder. To two of these are secured tubes which lead to two Toepler pumps: *d* is one of these tubes.

The pulley *e* is attached to the key of a common three-way stopcock. In the position shown, water is admitted to the cylinder; if the pulley and stopcock were turned one-quarter revolution towards the right, the escape would be opened.

The force for turning the pulley is supplied by the weight of mercury in one or the other of the small glass globes *b* and *c*. These are suspended from the pulley by a wire cord: they are connected beneath by the flexible tube *f*. The top of *c* is connected by a flexible tube *i* to a glass tube closed at *l*, and open above. The top of *b* is connected by a flexible tube *g* to the tube *h* and thus to the air in the gas bag in *a*.

The three way stopcock is shown at the instant of opening the admission of water to *a*. The air in the gas bag is therefore at the pressure of the atmosphere, and the mercury stands at the same level in *b* and in the tube *f*. As the air in *a* is compressed, and as the air in the connected Toepler pump is raised, the mercury in *b* is also driven into *c*, and at length fills *c* and rises into the tubes *i* and *l*; *c* thus becomes heavy enough to turn the pulley and stopcock unless prevented. When it is permitted to turn it by descending nearly to the level to which *b* rises, water escapes from the cylinder. The air in the gas bag expands, permitting not only the descent of the mercury in the Toepler pump, but also of the mercury from *c* to *b*. The latter then becomes heavy enough to turn the pulley into its present position; and so the process may be indefinitely repeated.

The release of the pulley when in its present position is controlled electrically. At *m* is a radial arm turning with the pulley and stopcock. It is prevented from turning to the right by the armature of an electro-magnet. The circuit through the coils of this magnet is completed through the mercury of the Toepler pump when this finishes its stroke and discharges itself of air. Some little time before this instant, the loading of *c* is completed: accordingly, at the instant of the discharge and the consequent completion of the circuit, the three-way stopcock turns quickly to the right, water escapes from *a*, the air pressure is relieved, and the mercury descends in the Toepler, and also in the globes *b* and *c*.

It is important that the next ascent of mercury should not begin too soon, but that time should be given for air to flow into the vacuous body of the pump. This is managed by retarding the flow of mercury from *c* back into *b*: they are therefore placed so as not to differ much in level when *b* is up and *c* is down. The tube *f* is also made rather small, and may be pinched. It is thus easy to make the ingress of air last two seconds, or ten, or a hundred.

Most of the work of my pumps is done during the night and without attention: it is accordingly necessary to restore any air lost from the gas bag by leakage through connections. The tube *h* therefore conveys the air pressure to a small bottle containing mercury. When the air in the system is compressed, this mercury rises in *n*; when the pressure is relieved, this mercury again descends; if air has escaped, the negative pressure on the gas bag caused by the outflow of water draws in air through *n*, and thus keeps up the supply for compression.

It is desirable that no considerable sparking should take place within the Toepler pump. A small current may be sent through a relay, so that the spark in the pump is very small; or the circuit may be broken outside of the pump before it is broken within it. The latter method is used in the air compressor from which the drawing was made. Fig. 2 shows the device used. In the position seen, the circuit is completed from *a*, through the springs *c c* to *d*, by means of the contact piece *b*. If now the circuit is also completed through the pump, the magnet will lift its armature. The pulley will then turn; but before the release of air pressure has begun, the contact piece *b* will have moved away from *c*, and the spark on opening the circuit will therefore occur between *b* and *c* and not within the Toepler pump.

An air trap for Toepler pumps.

In some of the work in my laboratory, a mercurial air pump is required to transfer gas from one vessel to another without admixture with air. To do this with a Toepler pump of the ordinary pattern is practically impossible. Air intrudes between the rubber tube and the mercury which it contains. As soon as the glass tube is slightly fouled, this air insinuates itself between the mercury and the glass and soon rises into the pump body. But a not very complicated addition to the Toepler pump avoids this source of leakage.

The pump from which fig. 3 was drawn avoids contact of rubber and mercury; and it is possible that this source of leakage may not exist. But it nevertheless contains the modification just mentioned. This consists of a second small Toepler pump designed to free from air the mercury which enters the major pump.

The mercury holder *f* is connected to the pump body *g* by a glass tube bent as shown. When the atmospheric pressure obtains in *f*, the upper level of the mercury is at *a a*. The small tube *c c* is bent upward again, widened at *d*, and continued upward in *e*. When the pump is in action, the space above *a a* is a tolerable vacuum except when filled with mercury. If now air rises with the entering mercury, it is caught in the bend above *a*: it is driven into *c*, forced out to *d*, and escapes through *e*. This being repeated at every stroke of the major pump, no such accumulation of air can take place above *a* as to make possible its passage down *h* and up *i*. This device not only enables me to transfer gas from one vessel to another without admixture, but it contributes to the ease of making high vacua. Some of my work would have been impossible without it.

Discharge of Toepler pump with no compression.

When a Geissler pump is furnished with three stopcocks as is usual now, the pump body is emptied not into the atmosphere but into a good vacuum, and, what is important, the air is discharged without resistance and without consequent compression to a very small volume. But when a Toepler pump is discharged, even with any auxiliary vacuum heretofore described (as far as is known to me), the discharge takes place against the pressure of a short column of mercury, and the air is therefore compressed. There accordingly comes a time when this compressed air has no longer a volume sufficient to ensure its discharge. For instance, one of my pumps will carry an exhaustion to about one part in five million. The amount to be discharged becomes at this tenuity so small that its volume when compressed forms only a little bubble adhering to the side of the tube through which it ought to be discharged. But in my laboratory a device has been used for many years which empties the Toepler pump as completely as the Geissler pump is emptied; and lately this device has been made self-acting. It so much increases the degree of exhaustion which can be attained that it may be useful for some purposes, and is shown in fig. 3. *k* is an enlargement of the tube by which air is discharged from *g*. It is connected by a small glass tube with *l*: the tube is so flexible that *l* can be moved also into the dotted position. To explain its action, let us suppose that the pump is filled with mercury to *m*, and that *l* and the slender connecting tube are also so filled. When now *g* is emptied of mercury, *l* having been placed in the dotted position, will remain filled with mercury to the level of the upper dotted line, and *k* will be shut off from *g*. If now *l* is raised to the upper position, mercury will run out of it, but the passage from *g* to *k* will remain closed. Now, when the mercury rising for the next stroke has partly filled the pump body *g*, let *l* be lowered; the mercury which fills the passage from *g* to *k* will run into *l* and so open this passage. The air in *g* will therefore be freely discharged into *k*. The simple raising and lowering of *l* performs the same function as the use of the third stopcock of the Geissler pump; and it introduces no source of leakage. It very greatly increases the perfection of the vacuum which can be attained with a Toepler pump.

It was hoped to give here the result of a measurement of the efficiency of the same pump with this device alternately active and inactive; but a serious accident makes it at present impossible.

The means by which the motion of *l* is made automatic is shown at *u* and *o*. *n* contains mercury; it is connected with *o* and pivotted near *n*. The air pressure which works the pump is conveyed to *n*. When the mercury of the pump rises in *g*, mercury is also driven from *n* to *o*; this becomes heavy, draws *l* downward, and so opens the passage from *g* to *k*. This passage as well as *l* is filled when the air is discharged into *k*, and remains full when *l* is raised, to be opened again at the next stroke. The device will no doubt be thought rather fragile: but out of some twenty-five or thirty breakages of Geissler and Toepler pumps in my laboratory, it is the whimsical fact that this is the only part which has not yet been broken.

One less important matter may be mentioned. About twenty Toepler pumps have been broken in my experiments by the impact of ascending mercury against the upper part of the pump body. It was better economy of time to break them than to drive them slowly: but very vexatious. If the attempt is made to avoid breakage from this cause by elongating the upper part of the pump body, so as to give a slow motion to the ascending mercury, a contrary evil is introduced. The descending mercury clings in the tube, and at last falls so heavily as to split the tube *p*; as has happened to me several times. Now a contrivance has been in use which it is hoped may prevent breakage without retarding the action of the pump. It consists of a float seen at *r*, fig. 3. This is so adjusted as to settle into the neck of *f* just before the mercury in *g* rises to the danger point. The flow of mercury is then checked by the loosely fitting float, and, what is more important, oscillation is prevented. It works well so far, although it has not been long enough in use to warrant confident recommendation. But of the air compressor here described it is proper to speak confidently. The one which has been in use longest often makes twenty thousand strokes without failure or readjustment.

Thos. D. Walcott

ART. LV.—*New Method of determining the relative Affinities of certain Acids;* by M. CAREY LEA.

[Read before the National Academy, April, 1894, by Prof. Ira Remsen.]

THIS method of measuring affinities is based on the principle that *the affinity of any acid is proportionate to the amount of base which it can retain in the presence of a strong acid selected as a standard of comparison for all acids.* The standard acid being in all cases kept exactly at the same dilution.

An example will make this clearer. Sulphuric acid is here taken as the standard and its presence or absence in the free state is ascertained by means of the herapathite test (described in this Journal, June, 1893). For simplicity we will suppose that the quantity taken is always a gram molecule at a fixed rate of dilution. It is evident that two gram molecules of sodium hydroxide would exactly saturate it. If now we take a given acid we may find that a quantity of its sodium salt corresponding to three gram molecules of sodium hydroxide will exactly extinguish the reaction of a gram molecule of free sulphuric acid. With still another acid we may find that a quantity of its sodium salt corresponding to four gram molecules of sodium hydroxide are needed to extinguish the sulphuric reaction. Then the affinity of the second acid is exactly twice as great as that of the first. At the point where the free sulphuric acid reaction was extinguished the second acid under examination retained twice as much sodium as the first and this quite independently of any question of comparative basicity.

Throughout the series of determinations here to be described the sulphuric acid was used invariably at the same degree of dilution, otherwise the results would not be strictly comparative. Having obtained normal acid by titration with pure sodium carbonate this was further diluted to $\frac{N}{8}$ and 50 to 100^{cc} were found a convenient quantity to employ. The salt to be tested was finely powdered and thoroughly dried at 100°, or at whatever higher temperature it could support. It was then placed in a weighing bottle and cooled in a dessicator and kept there except for a few moments at a time. By using the dry salt the dilution of the acid was kept constant. When the point of extinguishment seemed to be reached, at least four final crystallizations were made. Great care is necessary to seize the exact point of extinguishment. The quantity of the salt found is then reduced to correspond with one gram molecule of sulphuric acid. It is next divided by its own molecular weight; this gives the number of molecules of the salt needed to extinguish the reaction in one molecule of sulphuric acid. In order to make it possible to compare acids of different basicities, the figures thus obtained must next be modified to correspond with the basicity of the acid used. If the acid is bibasic no change will be needed. If monobasic the figures obtained must be divided by 2. If tribasic they must be multiplied by $\frac{3}{2}$ etc. Finally as the quantity characteristic of the acid is the excess of the quantity found, over the amount equivalent to one molecule of sulphuric acid, unity is deducted from the amount obtained and the residue thus found represents the comparative affinity of the acid and may be called its *index*.

This may be rendered more clear by one or two instances.

In the case of hydrochloric acid there was needed as a mean of many determinations 29·37 gram molecules of sodium chloride to extinguish the reaction in one gram molecule of sulphuric acid. At this point the solution necessarily contained,

$$Na_2SO_4 + 2HCl + 27{\cdot}37NaCl.$$

This is proved beyond question by the fact that the solution no longer gives a trace of reaction of free sulphuric acid. The quantity 27·37 gram molecules of sodium chloride is the proportion of undecomposed sodium chloride that must remain in the solution in order that the sulphuric acid may be completely converted into sodium sulphate and may remain as such in the solution in a condition of equilibrium.

This number 27·37 therefore represents the strength of the affinity of hydrochloric acid for sodium. But in order to compare acids of different basicities it is convenient to refer them all to bibasic sulphuric acid and therefore the number just found must be divided by 2. Therefore 13·68 may be taken as the index of the affinity of hydrochloric acid in comparison with those of other acids determined in like manner.

Similarly with pyrophosphoric acid. The mean value found for the quantity necessary to extinguish the free sulphuric acid in one gram molecule of sulphuric acid was found to be 0·963 gram molecules of sodium pyrophosphate. At this point the liquid contains

$$Na_2SO_4 + \tfrac{1}{2}(H_4P_2O_7) + {\cdot}463(Na_4P_2O_7)$$

in equilibrium. The number ·463 therefore represents the comparative affinity of pyrophosphoric acid except that as the acid is quadrobasic the number found must be multiplied by 2 in order to bring it into comparison with bibasic acids. Therefore the index of pyrophosphoric acid is ·926. This acid being quadrobasic half a molecule contains the quantity of sodium requisite to saturate a molecule of sulphuric acid and therefore only half a molecule of pyrophosphoric acid is set free.

In other words: it is found by experiment that the quantity of sodium pyrophosphate necessary to extinguish the reaction for free sulphuric acid with 1000 molecules of that acid is 963 molecules; out of this, 500 molecules of pyrophosphoric acid are set free as just mentioned and there remain 463 molecules of undecomposed pyrophosphate. This number 463 multiplied by 2 because of the basicity of the acid and divided by 1000 to make it correspond to one molecule of sulphuric acid gives ·926 as the index of pyrophosphoric acid.

The state of equilibrium is always conditioned by the degree of concentration. If to any solution of sulphuric acid a salt is added in just sufficient quantity to extinguish the sulphuric acid reaction, it is then only necessary to add a little water and the equilibrium is at once changed: a certain portion of the salt that had been added is re-formed and the sulphuric reaction reappears. In order therefore to obtain true comparative results it is necessary to use the sulphuric acid always at exactly the same dilution and to add the dry salt to it.

The affinity of sulphuric acid for water is a most important factor in all determinations of this nature. Mendeleef indeed expresses the opinion* that most of the affinities hitherto determined are unreliable for want of sufficient exactitude in this respect.

To show how much precaution is needed, the following reactions may be mentioned.

When 4^{cc} of normal sulphuric are added to 40^{cc} of normal solution of sodium nitrate not a trace of free sulphuric acid can be detected in the liquid. In consequence of the large excess of sodium salt the sulphuric acid has been completely taken up by the sodium with of course an expulsion of an equivalent quantity of nitric acid.

But when instead of 4^{cc} of normal sulphuric acid we use 40^{cc} of decinormal acid then although the quantities of acid and of salt are exactly the same the equilibrium is completely changed. The greater quantity of water present by reason of its affinity for sulphuric acid counteracts to some extent the affinity of the sodium. Free sulphuric acid exists in the solution and is abundantly indicated by the herapathite test.

This difference may be even more strikingly shown in the following manner. Taking the mixture of 4^{cc} of normal sulphuric acid and 40^{cc} of normal solution of sodium nitrate let a

* Principles of Chemistry, English ed., vol. i, p. 377, footnote.

drop be placed in each of two small porcelain basins previously slightly warmed. To one of them let a single drop of distilled water be added and then the herapathite test to both. In a few minutes the one which has received the drop of water will show well marked crystallizations of herapathite whilst the other will not show a trace.

The effect of dilution in changing the equilibrium of the solution of a base with mixed acids is thus made visible to the eye by a chemical reaction. Hitherto it has been a deduction from physical changes requiring great delicacy of measurement. Results of a precisely similar character were obtained when potassium bromide was substituted for sodium nitrate and are no doubt of general occurrence.

The applicability of this method proved to be a good deal restricted owing to the tendency of many acids when set free to decompose the herapathite reagent. For this reason the affinities of hydrobromic, hydriodic, chloric, iodic and nitric acids could not be measured with accuracy, although many attempts, sometimes as many as 30 or 40 or more were made to get reliable results. This work, however, was not entirely thrown away. It demonstrated that *chloric acid* has the strongest affinity for bases of any known acid. It might have been expected *a priori* that a highly oxidized acid of chlorine would have stronger affinities than chlorine hydride. It also showed that the comparative affinity of nitric acid has hitherto been placed somewhat too high. Taking hydrochloric acid as 100, nitric acid scarcely exceeds 75.

The weaker acids, being for the most part without action on the test solution, give satisfactory results. Oxalic and tartaric acids must, however, be excepted, the acid set free tends to form acid salts of sparing solubility, these are precipitated, thus the conditions are changed.

The results obtained are here tabulated.

Hydrochloric acid	29·37	13·68	100
Succinic	1·21	0·21	1·54
Acetic	2·28	0·14	1·02
Citric	1·02	0·53	3·87
Pyrophosphoric	0·963	0·926	6·77
Tungstic	1·2	0·2	1·46

The first column of this table shows the absolute number of molecules of the sodium salt which must be added without regard to the basicity of its acid in order that one molecule of sulphuric acid may be so completely saturated with base as no longer to give a reaction for free sulphuric acid.

In the second column these numbers are modified in such manner as to cause them to justly represent the comparative affinity of the acid. With monobasic acids the number of molecules is divided by 2, with quadrobasic acids it is multiplied by 2. For a tribasic acid it is multiplied by $\frac{4}{3}$. Bibasic acids only, remain unchanged. Next, unity is subtracted because it is always the excess of the salt which must be present in order to keep the sulphuric acid saturated with base that gives the measure of the affinity of the acid. Were this correction not applied the entire result would be vitiated.

The third column gives the numbers as they appear when hydrochloric acid is taken as 100.

Instead of adding salts of different acids to sulphuric acid, we may add various acids to a salt formed by the union of sulphuric acid to a strong base, for example, to sodium sulphate.

Sulphuric acid is now recognized as being a weaker acid than hydrochloric, and yet we have seen that it is able to detach a certain quantity of base from a chloride. Further, that if the chloride is present in sufficient excess, the sulphuric acid may take up enough base to completely saturate itself. The general fact that a certain quantity of an acid may be expelled from a salt by another acid, even much weaker than the first, has been shown by the researches of Thomsen and of Ostwald. So that if for example we add acetic acid to a solution of sodium sulphate a distinctly recognizable quantity of sulphate is decomposed and converted into acetate. A condition of equilibrium is produced in which the liquid contains both acids in a free state and both salts. In some way that we do not yet understand the presence of the free acid maintains the combined acid in its combination. The sodium acetate exists only by virtue of the free acetic acid present.

The existence of this state of equilibrium was first proved by Thomsen who deduced it from the thermochemical changes which took place on mixing the solutions. Ostwald reached similar conclusions by making accurate determinations of the changes of volume and consequently of specific gravity which resulted from the mixing of the solutions, and in other ways.

In both these cases the conclusions are reached by logical deductions from the phenomena observed. But with the aid of the herapathite test the expulsion of sulphuric acid by a very much weaker acid can be rendered immediately evident to the eye. Thus if to the solution of sodium sulphate we add acetic acid and place two or three drops of the mixture in a warm porcelain basin and add some of the test liquid to it, in a few minutes we have great number of small black rosettes of herapathite which crystallize out. Solution of sodium sulphate not containing acetic acid gives no such reaction with the herapathite test. It dries up to a pale yellow residue.

Acids vary very much in their ability to detach sulphuric acid from sodium. The following acids when added to sodium sulphate and tested by the herapathite test, give the results here noted.

Malic acid, gives an abundant crystallization.

Succinic acid, acts similarly.

Lactic acid, a moderate reaction.

Mucic acid, about the same as lactic.

Vanadic acid, traces.

Arsenic acid, abundant crystallization.

Hippuric acid, distinct traces.

Salicylic acid, distinct crystallization.

Of course the stronger organic acids, tartaric, oxalic and citric separate sulphuric acid with abundant crystallizations of herapathite when they are made to act on sodium sulphate and the test is applied. It was observed that an acid oxalate acts like a free acid. Thus when a solution of potassium binoxalate or quadroxalate is added to one of sodium sulphate, sulphuric acid is detached precisely as if free oxalic acid had been used.

It is clear that extremely weak acids such as hippuric and salicylic are able to take a certain quantity of base even from so strong an acid as sulphuric, setting free a recognizable quantity of this latter acid. Carbonic acid is still weaker than these. Ostwald in determining the relative affinities of acids by the rate of the decomposition of acetamide and by the inversion of cane sugar found no appreciable effect from carbonic acid. It therefore became of interest to ascertain if any sensible decomposition of sodium sulphate would result from the action of this acid.

Perfectly pure carbonic anhydride was passed for a long time through a solution of sodium sulphate without setting free a recognizable trace of sulphuric acid. This was expected, the experiment was only preliminary to its repetition under pressure.

For this purpose sodium sulphate with the test solution was placed in one leg of a bent tube, in the other leg was placed sodium bicarbonate; and the tube was sealed. Heat was gradually applied to the bicarbonate. In the second trial the pressure was raised so high that the stout glass tube was ultimately shattered with violence. The leg containing the test liquid and sulphate had been secured in a clamp and remained uninjured. The liquid therefore had been subjected to the action of carbonic anhydride at a high pressure—it however gave no indications of a separation of traces of sulphuric acid under its action. It is to be remarked that this test is more decisive than if a solution of sodium sulphate had been used and had been tested afterwards. For in this last case, on release of the pressure, the reaction might readily be reversed with recombination of sulphuric acid, had any been liberated. But with the test liquid present during the pressure this reversal could not take place.

Carbonic anhydride, therefore, does not even under pressure, set free any portion of sulphuric acid from sodic sulphate.

The reactions described in this paper indicate:

1st. That when to free sulphuric acid a salt is added in sufficient quantity to cause the whole of the sulphuric acid to saturate itself with the salt-base, it is possible by means of the herapathite test to determine the exact point of such saturation. At this point there will necessarily be as much of the acid at first combined with the base, now free in the solution, as corresponds to one molecule of a bibasic acid, that is two of a monobasic acid, half a molecule of a quadrobasic acid, etc. From this we can deduce the exact nature of the resulting equilibrium.

2. That a series of equilibria thus obtained with different salts, enables us to determine the comparative strength of the affinities of the acids of those salts.

3. That the fact, already proved in other ways, that even small quantities of weak acids, added to sulphates will set free a certain quantity of sulphuric acid, can by means here given be for the first time rendered visible to the eye by a well marked chemical reaction.

Art. LVI.—*On Argyrodite and a new Sulphostannate of Silver from Bolivia*; by S. L. Penfield.

In the August number of this Journal, 1893, page 107, the author described as a new species a germanium mineral from Bolivia, to which the name canfieldite was given. It was shown that the mineral was identical with argyrodite in chemical composition, but differed apparently in crystallization, canfieldite being isometric while argyrodite was monoclinic, according to the description of Weisbach.* The discovery of the isometric mineral was communicated by letter to Professor Weisbach, and soon after the publication of the author's article a reply was received from him, in which it was stated that

* Jahrb. f. Min., 1886, ii, p. 67.

better crystals of the Freiberg argyrodite than those originally described had been examined, and the results had shown that they were isometric and tetrahedral. These conclusions have since been published.* The forms *m* and *o* of Weisbach† are regarded as the dodecahedron (110), *f* and *k* as the tetrahedron $\varkappa(\bar{1}11)$, $\frac{1}{2}$ and *v* as the negative pyramidal-tetrahedron $\varkappa(3\bar{1}1)$ $-\frac{3\text{-}3}{2}$. Argyrodite being isometric it is evident that the Bolivian mineral is not a new species and the name canfieldite is therefore withdrawn. For the sake of simplicity it is a satisfaction to have the Bolivian mineral identical with that from Freiberg, and it is regretted that the isometric character of argyrodite was not made known before the publication of the canfieldite paper. It was hoped that by the present time some definite information could be given concerning this new occurrence of argyrodite, but as yet no data have been received other than that it is a well known silver ore in the mines at Potosi.

There has also recently come into the authors possession, through the kindness of Mr. Wm. E. Hidden of New York, a specimen from La Paz, Bolivia, which was supposed to be argyrodite. Its total weight was a little over seven grams and it consisted of a few attached octahedrons, modified by dodecahedron planes, the largest crystal measuring 13^{mm} in axial diameter. The only visible impurity was a very little metallic silver in wire form, deposited in a few places on the outside of the crystals. The mineral is almost identical with argyrodite in all of its physical properties. The luster is brilliant metallic. Color black with the same bluish to purplish tone observed on argyrodite. The fracture is irregular to small conchoidal. Very brittle. Hardness $2\frac{1}{2}$–3, specific gravity 6·276, that of argyrodite from Bolivia being 6·266. Heated before the blowpipe on charcoal at the tip of the blue cone the mineral fuses at about 2 and yields a coating of the mixed oxides of tin and germanium. This is white to grayish near the assay, tinged on the outer edges with yellow. By continued heating a globule of silver results but this is covered by a scale or coating of tin oxide. If the coating on the charcoal is scraped together and fused in the reducing flame with sodium carbonate globules of tin are formed. In the closed tube sulphur is given off and at a high temperature a slight deposit of germanium sulphide, which fuses to globules, is formed near the assay. In the open tube sulphur dioxide is given off but no sublimate is deposited.

The following method was adopted for the analysis. The mineral was oxidized by concentrated nitric acid and the excess

* Jahrb. f. Min., 1894, i, p. 98.

† Compare figure in Dana's Mineralogy, sixth edition, p. 150.

of the latter removed by evaporation. The residne after moistening with nitric acid was digested with boiling water for some time and the insoluble meta-stannic acid filtered off. This was transferred while still moist to a beaker and treated with strong ammonia into which hydrogen sulphide was conducted until the meta-stannic acid had gone into solution. A slight insoluble residue was filtered off at this point which contained about 0·10 per cent of tin and 0·40 per cent of silver. From the ammonium sulphide solution the tin was precipitated by addition of a little snlphuric acid and weighed as oxide. The filtrate from the stannic sulphide was evaporated and yielded a little germanium which had not been separated from the tin by the nitric acid treatment. In the original filtrate from the meta-stannic acid silver was precipitated by means of hydrochloric acid and weighed as chloride. The sulphur was next precipitated by barium nitrate, and after purifying by fusion with sodium carbonate weighed as barium sulphate. Before evaporating the filtrates hydrochloric acid and barium were removed by precipitation with silver nitrate and sulphuric acid. The excess of silver was finally removed by ammonium thiocyanate and the germanium obtained from the filtrate as described in a previous communication.* The results of the analysis are as follows:

		Ratio.			Theory for $Ag_8(SnGe)S_6$ where Sn : Ge = 12 : 5.
S	16·22	·507		5·92	16·56
Sn	6·94	·0589	·0842	0·98	7·18
Ge	1·82	·0253			1·83
Ag	74·10	·686		8·00	74·43
Zn and Fe	·21				----
	99·29				100·00

In this compound tin is undoubtedly isomorphous with germanium, and the two are present in about the proportion 12 : 5. The ratio of S : Sn + Ge : Ag in the analysis is very close to 6 : 1 : 8, indicating that the formula is $Ag_8(SnGe)S_6$ or $4Ag_2S.(Sn.Ge)S_2$. The agreement between the theory and the analysis is satisfactory.

The only sulpho stannates thus far known to occur in nature are the rare species *stannite*, Cu_2S, FeS, SnS_2, *franckeite*, 5PbS, Sb_2S_3, $2SnS_2$ and *plumbostannite* a mineral of doubtful composition containing Pb. Fe. Sb. and S, described by Raimondi.† Franckeite has recently been described by Stelzner‡ and in it Winkler was able to identify a small amount of ger-

* This Journal, xlvi, p. 111, 1893.
† Zeitschr. Kryst., vi, p. 632, 1882.
‡ Jahrb. Min., 1893, II, p. 114.

manium, probably about 0·10 per cent. These authors call attention to the fact that since tin and germanium belong to the same chemical group they are isomorphous with one another and suggest the probability of finding in Bolivia a sulpho-stannate of silver isomorphous with argyrodite. The new mineral described in this article corresponds precisely to this idea. As the Freiberg argyrodite has been shown to be isometric, and the name *canfieldite* cannot therefore be applied to the germanium compound, it is proposed now to transfer the name to the new isomorphous tin compound. It is not probable that this will cause confusion as the name as at first applied was not long in use and has never been introduced into any of the text-books or systems of mineralogy, and especially as it is now transferred to a species which is very closely related, and should come next to argyrodite in a natural system of classification. It is probable that various mixtures of argyrodite Ag_8GeS_6 and the molecule Ag_8SnS_6 will be found and it would seem best to consider this latter as the canfieldite molecule, while the intermediate isomorphous mixtures would be called argyrodite or canfieldite, according as the germanium or the tin molecule predominated.

Regarding the crystallization of the argyrodite and canfieldite from Bolivia the specimens examined by the author, are apparently holohedral. The octahedron faces are equally developed and have the same luster. There is, however, on each of the dodecahedral faces of the canfieldite specimen a distinct furrow or slight depression running in the direction of the longest diagonal. This may indicate a twinning which has given rise to the apparently holohedral form, or the latter may of course have resulted from an equal development of positive and negative tetrahedrons.

Laboratory of Mineralogy and Petrography,
Sheffield Scientific School, New Haven, April, 1894.

Art. LVII.—*On the Damping of Bell-magnets and Ring-magnets by surrounding copper;* by Arthur Kendrick.

This paper presents the results of some observations made by the writer at various times upon the damping of bell-magnets and ring-magnets in copper boxes with the view of ascertaining roughly the relations between magnetic moment, inertia moment, and size and shape of the surrounding copper.

The accompanying figures show at a glance the dimensions of the magnets and some of the boxes used. Figures 1, 3, 4 and 9 show vertical and horizontal sections, fig. 2, a horizontal

Fig. 1.

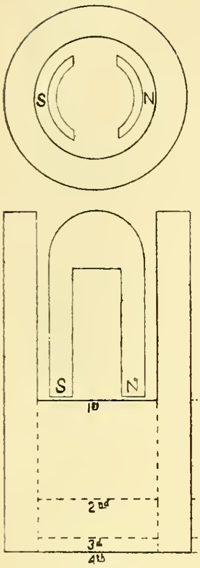
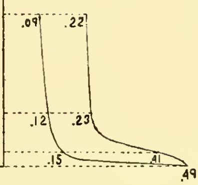



Fig. 2.

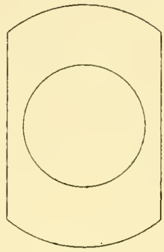


Fig. 3.

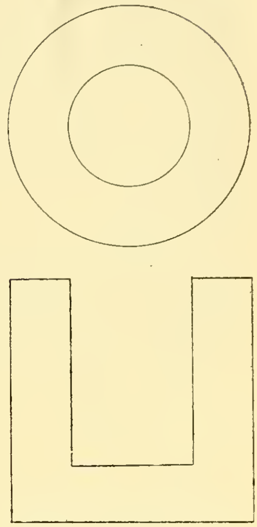


Fig. 5.

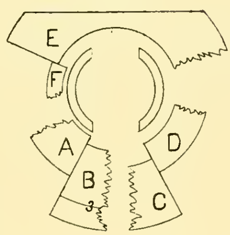


Fig. 4.

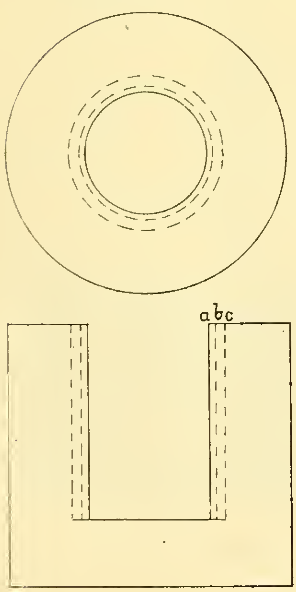
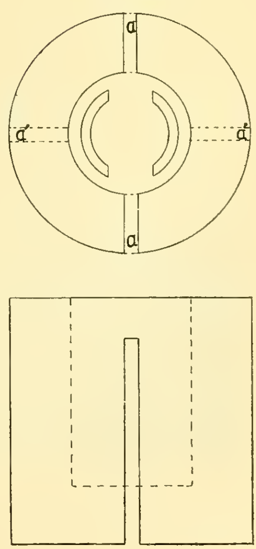


Fig. 6.



section, and fig. 6, horizontal section and side elevation (without perspective) of cylindrical boxes for the bell-magnets. Similarly the bell-magnets are shown, p. 461, by horizontal sections and side elevations. The suspension was a raw silk fiber whose torsional effect can practically be ignored, though it was quite appreciable in the cases of the smallest magnets. The restoring force, unless otherwise stated, is understood to be the earth's field, which has at the point where the needles were suspended a horizontal intensity of about .16 dyne per unit pole.

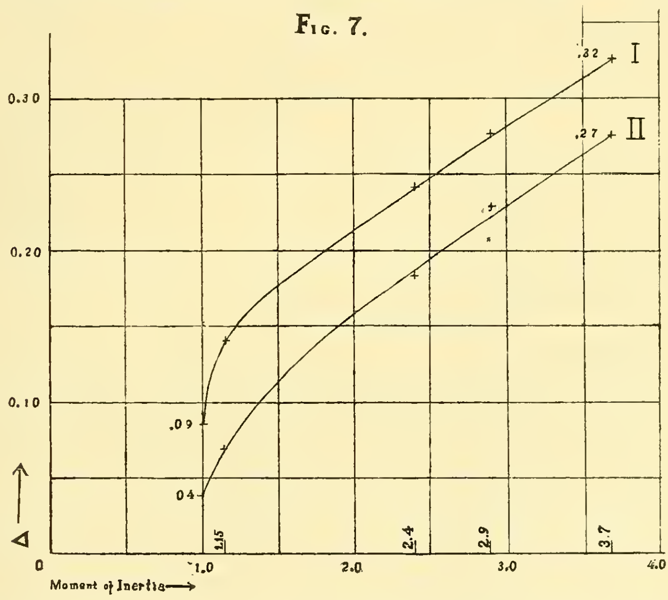
As a measure of the damping that occurs in a succession of vibrations, I will use the average of the ratios of each amplitude to the preceding amplitude taken from a number of successive swings and call this Δ. Its reciprocal is approximately the logarithmic decrement, but this ratio is more convenient, especially for plotting, as the values must lie between 0 and 1, instead of between ∞ and 1. The lower limit signifies "dead-beat" vibration, and the upper limit, no damping. A value of Δ less than 0·1 means for most work very good damping. Since some of the following comparisons are made by referring to the number of swings (half vibrations) that the needle, after disturbance, makes before coming to rest, it may be useful to write a table giving approximately the values of Δ corresponding to these. The scale used in reading deflections was divided into millimeters (scale distance about 65^{cm}), and the readings made to two-tenths of a millimeter. Then with a moderate initial disturbance of the needle, say about 200^{mm}, if the vibrations decease to less than two-tenths of a millimeter in

5	swings,	Δ is	about	0·20
6	"	"	"	0·25
7	"	"	"	0·35
8	"	"	"	0·40
10	"	"	"	0·45
11	"	"	"	0·50
15	"	"	"	0·60
20	"	"	"	0·70
33	"	"	"	0·80

Let any copper box be designated by the number of the figure that represents it, and any magnet by its letter.

Magnet Q was used under a larger variety of conditions than any of the others. These varying conditions were: five different moments of inertia of relative values 1·0, 1·15, 2·4, 2·9, 3·7, the first being that of the magnet, mirror and suspension, and the others were produced by the addition of inertia discs; three magnetic moments of relative values 0·44, 0·68, 1·0, the latter being, apparently, the greatest possible permanent moment for Q, its value, about 52^{cgs} units; the earth's field and a considerably weakened field; a variety of shapes and sizes of the copper boxes, and one box of brass. Box 1 was bored to successive depths 1st, 2d, 3d, 4th as shown in fig. 1, the 4th meaning that it was bored quite through. Box 4 was given successive interior diameters, *a*, *b*, *c*. With 1 (1st), 3 and 4 (*a*), all of the same interior diameter, the Δ's were found for the five different inertia moments and the three magnetic moments. Using the Δ's for ordinates and the relative inertia moments for abscissas and plotting a curve for each of the three boxes for each magnetic moment there results nine curves, or three sets (corresponding to the magnetic moments) of three curves each (each curve of a set corresponding to a box). Fig. 7 presents two of these curves. I is plotted from

Fig. 7.



Δ's given by Q in box 1 (1st) with relative magnetic moment 1·0, and II, from Q in boxes 3 and 4 (*a*), (these two giving nearly the same damping). The two other sets of curves from relative magnet moments 0·68 and 0·44 would be located respectively above curves I and II and are very similar to them. The relative moments of inertia are plotted as abscissæ and the Δ's as ordinates. Plotting the relative magnetic moments of Q as abscissæ and the Δ's as ordinates, and using relative inertia moment 3·7 and box 1 (1st), we get I of fig. 8;

with box 1 (1st) and inertia moment 1·0, curve III; and similarly with box 3 (or 4*a*) curves II and IV respectively for the inertia moments 3·7 and 1·0. [The ordinate of the lower end of curve II, fig. 8, should read ·27 instead of ·21.]

Fig. 8.

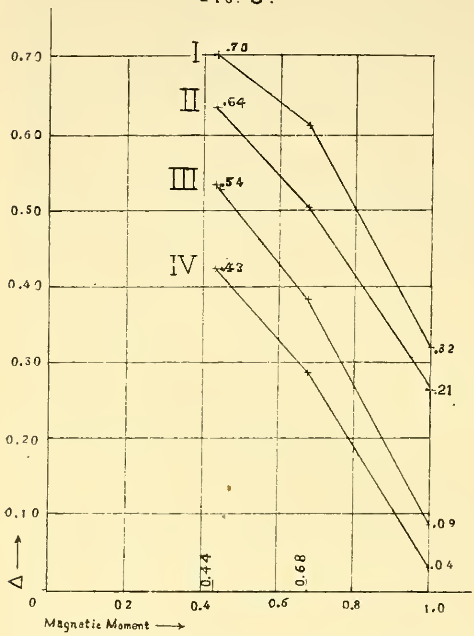
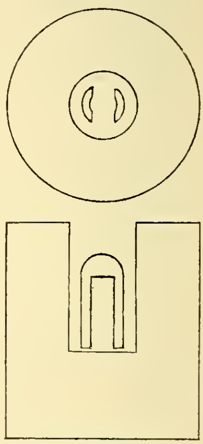


Fig. 9.



Several things appear from these curves. The damping due to these boxes is similar; it is appreciably less in box 1 than in 3 and 4 (*a*), and almost inappreciably less in 3 than in 4 (*a*), so the extra thickness of 4*a* is superfluous; when the moment of inertia and magnetic moment are both 1·0, box 1 (1st) gives $\Delta = 0·09$ and boxes 3 and 4 (*a*) give $\Lambda = 0·04$, the latter practically aperiodic, and the former very satisfactory damping; a comparatively slight increase of the greatest magnetic moment or slight decrease of the least inertia moment would give "dead-beat" vibration; the rate of decrease of Δ with respect to increase of relative magnetic moment is greater than the rate of decrease of Δ with respect to decrease of relative inertia moment.

In what follows Q is used with relative inertia moment and relative magnetic moment each equal to unity.

The effect of the thickness of the copper in the bottom of these boxes is indicated by fig. 1. Box 1 was used successively with the three thicknesses of bottom shown in fig. 1, and fourthly with the bottom bored through. The Δ's as abscissæ and thicknesses of bottom as ordinates give the first curve on the right in fig. 1, and the second curve is for the values of Δ when the needle was at the same heights and the bottom bored through. The advantage of having at least a slight thickness of copper in the bottom is evident from the curves. The effect of a thick plate of copper alone such as box 3 inverted under the needle is slight, Δ being about 0·75.

An idea of the relative effect of various outside and inside diameters of the damping boxes is given by fig. 5, where each pair of adjacent segments represents sections of those boxes that give nearly the same damping effects. Thus, A and B give Δ=0·04, C and D give Δ=0·12, E and F give Δ=0·18. D is box 1 (2d), C is 4 (*c*); B is 3 and 4 (*a*), and A is a box of outside diameter equal to D but smaller inside diameter. E is box 2, described in the following paragraph, and F is box A turned down to smaller outside diameter. The thickness of the bottom of all these is about the same. The space for the magnet in A and F is too small for convenient leveling, in C it is larger than necessary.

Box 2 is of like dimensions with 3 but planed down on two faces. This gave Δ=0·18, and the direction of the longer transverse axis was immaterial. It should not be inferred, of course, from this that the same effect would be obtained from a circular cylinder of the radial dimensions of the shorter axis. In fact very nearly the same damping was given by a circular box of 2^{mm} thickness and inside diameter of 2^{mm} less than that of box 2. This is shown by E and F of fig. 5.

Fig. 6 gives horizontal section and vertical elevation of a box like 3, but slit nearly through vertically. *aa* and *a′a′* are positions of the slit respectively perpendicular and parallel to the needle's magnetic axis when at rest. In the position *aa* Δ was 0·60, and in the position *a′a′* Δ was 0·04, the same as when there was no slit. This box was afterward slit completely through. With both halves in position *a′a′* the needle came to rest in 4 swings, with one-half in 7 swings. In position *aa*, both halves, 19 swings; one-half, 37 swings.

With a brass box of same outside diameter as 3, bored through, inside diameter 2^{mm} less than that of 3, Δ was about 0·80. Comparing this with 1 (4th), brass is seen to be decidedly inferior to copper as a damping material.

With a stronger field the Δ's are of course larger, with a weakened field smaller, and for Q in all of the above mentioned boxes, except the brass one, the swing may be made "dead-beat." The time of swing is, however, lengthened with increased damping, and this is the more noticeable the smaller the moment of inertia. This seems to show that the effect of reducing the inertia moment below the point required for "dead-beat" vibration would be to increase the time of coming to rest. With a field of about $\frac{1}{10}$ the value of the earth's field, the time of a half vibration of Q in air was 5 seconds, and in box 4, the vibration being "dead-beat," it required about 30 seconds to come to rest, but with an inertia disc, that increased the time in air to 10 seconds, the time of coming to rest was about 30 seconds. In 4 (*c*) in the same field without the inertia disc, the vibration being also "dead-beat," the time was lengthened only about 2 seconds.

The foregoing results were, as above stated, obtained by using the magnet Q only, and similar action would naturally be expected from other bell-magnets and corresponding boxes, but it may be of interest to mention other forms and sizes that were tried. T is of about one-half the linear dimensions of Q (thickness about the same). Its time of swing in air was nearly the same as that of Q when in the same field, hence the ratio of inertia moment to magnetic moment for the two suspended systems was about the same. But the magnetic moment of T is about $\frac{1}{10}$ of that of Q, hence the inertia moment is about $\frac{1}{10}$ that of Q. Supposing Q in box 1 (1st), if reduced to $\frac{1}{10}$ in relative magnetic moment and relative inertia moment, to represent T in box 7. Producing curve III of fig. 8, so that it will include the point where the magnetic moment is 0·1, we find the corresponding Δ is about 0·65. We see from curve I of fig. 7 that a reduction of the moment of inertia to 0·1 would *at least* reduce Δ from 0·09 to 0, and, without attempting to make any allowance for a further effect, if we subtract 0·09 from 0·65 we get as an estimated value of Δ for T in box 7 something less than 0·6. It was found to be slightly under 0·50. S is twice as long as T, and slightly thicker. The time of swing is a trifle less than that of T, and so its magnetic moment is greater in proportion to its inertia moment; also, since its inertia moment is necessarily somewhat greater than that of T, the magnetic moment is greater, and in the same box, 7, we should expect a value of Δ noticeably less than for T. The observed value is 0·40. In a weakened field, the vibration of T became aperiodic in box 7 and the time of coming to rest was very long. P had a magnetic moment of about $\frac{9}{10}$ that of Q, and an inertia moment about 3·8 times that of Q. Estimating from the curves II of fig. 7 and IV of fig. 8, one would say that the Δ of P in 4 (*c*) might be about 0·40. It came to rest in 11 swings, or Δ was approximately 0·5. U has about $\frac{1}{3}$ the moment of inertia of Q, and about $\frac{4}{10}$ its magnetic moment; 0·4 would be the estimate for Δ of U in box 3, and 10 swings or approximately 0·45 for Δ was the actual damping. R has a moment of inertia about $\frac{6}{10}$

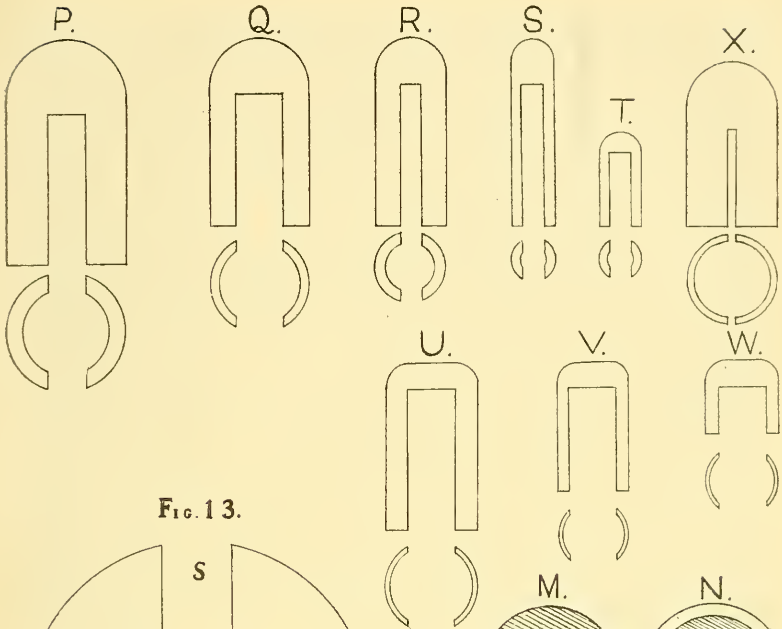
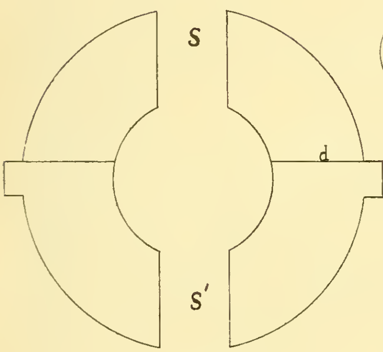


Fig. 13.



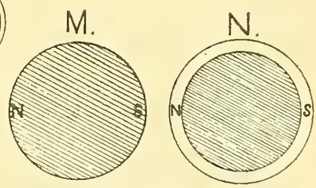


Fig. 11

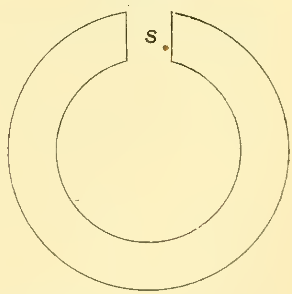
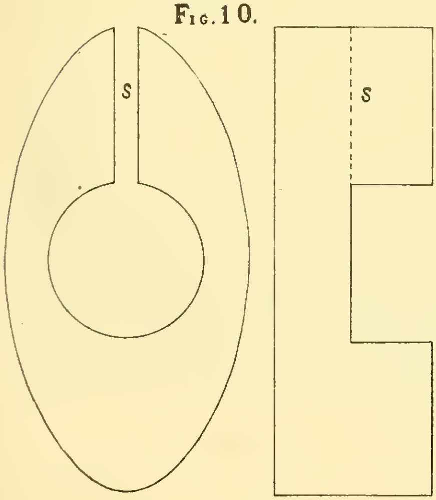


Fig. 10.



11.

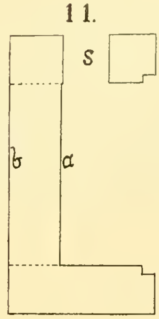


Fig 12.

that of Q and a magnetic moment of about $\frac{8}{17}$ that of Q. Δ would be estimated at about 0·35, and from observation it is 0·33. In the series of magnets U, V, W, the magnetic moment is not reduced as rapidly as the inertia moment, and consequently the damping is maintained, the values of Δ in box 3 being given by 10, 10, 11 swings respectively. X has a magnetic moment about equal to that of W. Its inertia moment is evidently far greater than W's. It came to rest in box 3 in 25 swings. Though these estimates of probable damping in the cases just cited are extremely rough, they seemed to the writer to confirm the natural assumption that the damping of any one of these bell-magnets under varying conditions would be typical, and the results would be applicable in general.

Fignres 10 and 11 show transverse vertical sections of copper boxes for the circular magnets M and N, 10 belongs to a galvanometer of F. Kohlrausch's pattern. The slot, *s*, is for the suspension wire and fiber, and extends inward from the front face to the same depth as the hole in which the needle swings. 11 (*a*) is a copper cylinder of the same outside diameter as 4. The suspension hangs through a small hole, *s*, in the top, 11 (*b*) is the same but bored through. 12 is similar to 11 (*a*) but smaller. 13 is a vertical section through the center of a spherical copper box, with spherical cavity. The shell is divided in two by a horizontal plane, *d*, just above the flange, the upper portion resting on the lower. Here also *s* and *s'* are holes for the suspension and support respectively. M is a circular steel mirror $0{\cdot}8^{mm}$ thick. N is a ring of rectangular cross section 2^{mm} thick, with plane glass mirror within. The magnetic moment of M was about $12{\cdot}7^{cgs}$ units, and of N, $17{\cdot}2^{cgs}$ units. The ratio of the moments of inertia of N to M was estimated at abont 3÷5. The following table gives in number of swings the damping of each needle by each of these boxes (excepting M in 11 (*b*)).

	Box 10.	Box 11 (*a*).	Box 11 (*b*).	Box 12.	Box 13.
M	7	10	--	7	15
N	5	7	8	5	10

From this it is readily seen that the damping of this ring was more rapid than that of the mirror, that the elliptical box is not superior to the smaller circular box, that the boring through of 11 (*b*) did not render it much inferior to 11 (*a*). One would suppose that the slot in the upper part of 10 would perceptibly impair its damping effect. Accordingly a box like 9 (*a*) was taken and the bottom wall slit through vertically from front to back. The damping of N in this is represented

Albright, Walton

by 8 swings, in 11 (*a*) by 7 swings. The same slit was continued through the back and the result was 13 swings. With another box the side walls were slit horizontally, result 11 swings. These horizontal slits were then continued through the back nearly meeting, result 18 swings. With the slit extended through and the upper half alone used the number of swings was 34. The faces of the plane *d* of 13 had been lacquered, and the effect of the horizontal slitting just described would indicate that this separation of the halves of the sphere has a very noticeable effect in reducing the damping power.

These observations do not furnish sufficient data for attempting to express in the differential equation of motion of a vibrating magnet the functions representing the damping, but they may possibly prove useful in the way of practical suggestion, and it is with that hope that the paper is written.

Jefferson Physical Laboratory, Cambridge, March, 1894.

Art. LVIII.—*On Thallium Triiodide and its Relation to the Alkali-Metal Triiodides;* by H. L. Wells and S. L. Penfield.

The well-known resemblance between the thallous salts and many of the corresponding alkali-metal salts has led us to prepare thallium triiodide and to compare its crystalline form with that of the alkali-metal triiodides.* As a result, it has been found that TlI_3 agrees, with remarkable closeness, in form with RbI_3 and CsI_3, and thus a case of isomorphism is established between the higher iodides of thallium and the alkali-metals.

This isomorphism is of special interest because our study of the trihalogen compounds of cæsium has led us to the conclusion that these have the structure of double-salts. We consider the evidence of this double-salt structure as very strong, and since it seems necessary to infer that isomorphism indicates the same arrangement of the atoms, we are obliged, in spite of the apparent trivalence of thallium in thallic compounds, to conclude that TlI_3 is also a double-salt, to which the formula $TlI . I_2$ should be given. It is not safe to assert at present that all thallic salts must be similarly constituted, for it is possible that thallium triiodide is not a true thallic compound at all, and that thallic sulphate, nitrate, etc., have an entirely different kind of structure. If it is granted that

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

thallium triiodide is a double-salt, it seems probable that many other compounds, which are considered as showing higher valence of elements, may in reality have the structure of double-salts or "addition products."

Thallium triiodide was first described by Nicklès* who prepared it by evaporating an etherial solution of thallous iodide and iodine. Nicklès states that he did not obtain it in a pure condition, but that his product always contained an excess of iodine. He described its crystalline form, and his results will be mentioned beyond.

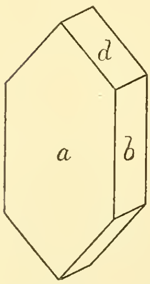
We have modified Nicklès' method by using alcohol as a solvent and have encountered no difficulty in obtaining a pure product. The amount of iodine used was slightly in excess of the calculated quantity, and the solution, produced after long digestion, was evaporated over sulphuric acid until crystallization took place. The resulting crystals were frequently of large size, perfectly black with a magnificent luster which was slowly lost upon exposure. A sample of the salt, simply pressed upon paper, gave the following results upon analysis:

	Found.	Calculated for TlI_3.
Thallium	34·22	34·87
Iodine	64·80	65·13

An examination of the crystals has shown that they are orthorhombic and isomorphous with the orthorhombic alkali-metal trihalides. Moreover, all the forms which have been observed have also been found on the alkali-metal salts, and are as follows:

a, 100, *i*-*ī*	*c*, 001, *o*	*d*, 011, 1-*ĭ*	*p*, 111, 1
b, 010, *i*-*ĭ*	*g*, 012, ½-*ĭ*	*e*, 102, ½-*ī*	

1.



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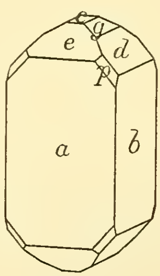

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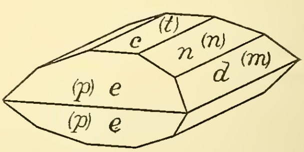


The habit is shown in figures 1 and 2, the latter being remarkably like that of CsI_3 when this had been crystallized

* J. Pharm. [4], 1, 25.

from alcohol. The measurements which were chosen as fundamental are $d \wedge d$, $011 \wedge 0\bar{1}1 = 96° \ 34'$ and $e \wedge e$, $102 \wedge \bar{1}02 = 78° \ 48'$ giving the axial ratio :

$$\breve{a} : \bar{b} : \acute{c} = 0{\cdot}6828 : 1 : 1{\cdot}1217$$

The dome g was determined by the measurement $g \wedge g$, $012 \wedge 0\bar{1}2 = 58° \ 34'$, calculated $58° \ 34'$ and the pyramid p by its position in the zones $a-d$ and $d-e$.

A description of this salt, including a figure, has been given by Nicklès. His salt, crystallized from ether, had the habit shown in fig. 3, the letters in brackets being those used by him and the position being changed to correspond with the orientation of the alkali metal trihalides. He considered p as a prism, t as a macropinacoid and m and n as brachydomes. No calculations are given and only the following four measurements :

Nicklès.	Measured.	Calculated from author's measurement.
$p \wedge p$ =	100° 15′,	101° 12′ for $e \wedge e$, $102 \wedge 10\bar{2}$
$p \wedge t$ =	39 22,	39 24 " $e \wedge c$, $102 \wedge 001$
$p \wedge m$ =	61	59 3 " $e \wedge d$, $102 \wedge 011$
$n \wedge t$ =	19 25,	20 30 " $013 \wedge 001$

The agreement between the measured and calculated angles is not very close, but Nicklès' measurements cannot be very exact, for if we take $p \wedge t = 39° \ 22'$ and $n \wedge t = 19° \ 25'$ as fundamental, we find by calculation $p \wedge p = 101° \ 16'$ and $p \wedge m = 57° \ 55'$, which vary considerably from his measurements. Nicklès crystals differ from ours not only in habit but in having the one-third brachydome n, 013, which has not been observed either in the TlI_3 prepared from alcohol or on any of the alkali-metal trihalides prepared by us.

The very close agreement between the forms of rubidium, cæsium and thallium triiodides is to be seen from the following table of axial ratios :

RbI_3	$\breve{a} : \bar{b} : \acute{c}$ =	0·6858 : 1 : 1·1234
CsI_3	" " " =	0·6824 : 1 : 1·1051
TlI_3	" " " =	0·6828 : 1 : 1·1217

Our previous observation, that the exchange of one metal for another in the trihalogen compounds usually has little or no effect upon the crystalline form, is strongly confirmed by these ratios, and the remarkable agreement between the rubidium triiodide and the thallium compound is very striking when the great difference between the atomic weights of the two metals is considered.

It was hoped that a pentaiodide of thallium could be prepared in order that its form might be compared with that of cæsium pentaiodide, but by the use of increasing proportions of iodine with thallium triiodide in alcoholic solutions no evidence of the existence of such a compound could be obtained.

The remarkably close relations of thallium to the alkali-metals as far as the thallous compounds are concerned, and the additional resemblance which has been pointed out in the present communication, have led us to consider the possibility that thallium has been wrongly placed in the periodic system of the elements and that it really belongs to the alkali-metals. There are two vacancies in Mendeléeff's table in the alkali-metal group corresponding to atomic weights of about 170 and 220. One of these is smaller, the other larger than the accepted atomic weight of thallium, so that, as far as these numbers are concerned thallium might be composed of two alkali-metal elements. Although the probability that thallium was composed of two elements seemed very slight from other considerations, we have deemed it desirable to test the question experimentally.

About 200 grms. of thallium were converted into the nitrate and this was systematically fractionated by crystallization until about one-twentieth of the salt remained as a repeatedly recrystallized portion and about another twentieth was contained in a final mother-liquor. From each of these two fractions thallous chloride was prepared by converting into sulphate, precipitating impurities with hydrogen sulphide, and finally precipitating thallous chloride by means of hydrochloric acid. The preparations were carefully washed, dried at 100°, and the chlorine was determined as silver chloride in order to get the atomic weight of the metal in each fraction. The silver chloride was weighed in the Gooch crucible, a method which can be most highly recommended for accurately weighing this substance. The following results were obtained, the weights being given as taken in air.

	Crystallized End.	Soluble End.
TlCl taken	3·9146 g.	3·3415 g.
AgCl obtained	2·3393	1·9968
Atomic weight of Tl, (O = 16),	204·5	204·5

It was not expected that absolute accuracy in the atomic weight of thallium would be attained, but since the same method of purification and analysis was used in both cases the two results are comparable with each other, and their exact agreement shows that the fractionation of the nitrate gives no change in the atomic weight of thallium, and no evidence has been obtained that thallium is not homogeneous.

Sheffield Scientific School, New Haven, Conn., January, 1894.

Art. LIX.—*Notes on the Gold Ores of California;* by H. W. Turner.

As is well known gold occurs chiefly in quartz veins and these in California have been found to be largest and richest in the slate series of the Sierra Nevada, but gold occurs in a great variety of rocks and associated with very different minerals.

The occurrences will be grouped geologically.

Veins in the auriferous slate series.—Most of the richest gold mines of California occur in the auriferous slates, and in the associated greenstone slates which are, to a considerable extent, metamorphic forms of diabases and porphyrites. The richest single belt of mines is that along the Mother lode, which consists of a series of quartz veins chiefly in a belt of clay slates of Jurassic age, which are designated on the maps of the United States Geological Survey as the "Mariposa slates." The quartz veins are not, however, entirely in these clay slates. In the southern part of Calaveras county and in part of Tuolumne county, the lode lies to the east of this clay slate belt, chiefly in amphibolite-schists. At many points, as at Carson hill in Calaveras county and at Quartz mountain in Tuolumne county, the quartz masses are very large. At other points the quartz occurs in little veins and stringers, through a mineralized zone of the black slate, which then forms part of the vein. In some such occurrences the iron sulphurets containing gold are found both in the slate and in the quartz, and all the material is treated as ore.

Accompanying the Mother lode quartz veins at many points is a green micaceous mineral, containing chromium and called mariposite by Silliman,* who states that so far as he observed, this mineral accompanied the quartz veins only in the neighborhood of magnesian and chloritic rocks.

Prof. Silliman also states that the white magnesian mineral associated with the mariposite is ankerite. Other minerals found by the same author along the Mother lode are ordinary iron and copper sulphides, antimonial copper sulphides, antimonial lead sulphides, and various tellurides. Prof. Silliman also identified somewhat doubtfully tetrahedrite or gray copper ore at the Rawhide mine in Tuolumne county.

Prof. F. A. Genth† states that petzite, telluride of gold and silver; calaverite, telluride of gold; altaite, telluride of lead; and melonite, telluride of nickel, occur at various mines of the Mother lode in the area of the Stanislaus drainage.

* Proc. Cala. Acad. Sci., vol. iii, p. 381.
† This Journal, vol. xlv, II, p. 321.

Prof. W. P. Blake* states that blende and tetrahedrite are found at Carson hill, and in the Pine Tree mine in Mariposa county. The latter mine directly adjoins the Josephine.

Associated with Mariposite at the Josephine mine in Mariposa county, and at Quartz mountain in Tuolumne county, is a white mineral which at some points appears to form veins in the mariposite. This is probably the mineral called ankerite by Silliman. An examination of this material by Dr. Hillebrand shows that it is ordinary dolomite mixed with quartz and not ankerite. In the Josephine mine erythrite, a hydrous arsenate of cobalt, forms on surfaces and in seams of the rock adjoining the vein.

In addition to the ordinary iron sulphurets, the writer has observed in the Mother lode ores in Amador county, galena, blende, and arsenical sulphurets in small amounts. As a general rule the ore of the large mines of the Mother lode show no free gold and only iron sulphurets. Specimens showing free gold and other than iron sulphides are not abundant. All of the Mother lode ore would be called free milling.

In the Paleozoic schists to the east of the Mother lode there are numerous gold veins which have been worked with varying success. One of the most profitable of this group of mines is the Sheep ranch mine of Calaveras county. The country rock of this mine is a mica-schist. The mines about Summersville in Tuolumne county are also in mica-schist. In these mines likewise the sulphurets do not exist as a rule in large amount and the ores may be classed as free milling. One of the most interesting of the mines of this group is the Blue Wing vein of the Willard Mining Company, north of Murphy's, Calaveras county. Here in limestone is a quartz vein which in places is accompanied by brown vein jasper. In the Blue Wing vein are found the sulphides of mercury and antimony and lead. Birdseye porphyry, in this case probably an altered diorite, cuts the limestone in dikes. In the highly altered slates and eruptive rocks to the west of Blue mountain in Calaveras county are a group of mines, the ores of which are very basic. Sulphides containing lead, silver, zinc, arsenic and iron are found in the ore. At the Bonanza mine at Sonora in Tuolumne county the ore occurs in pockets along a diorite dike in the slates. Large masses of free gold with tellurides occur here and iron and copper sulphides.

At the Ilex mine in Calaveras county in Paleozoic mica-chlorite-schist there is a large quartz vein having a course N. 80° E. Tetrahedrite and sulphides of lead, zinc and copper, as well as free gold, are found sparingly in the ore.

* California Minerals, Sacramento, 1866.

Forming the crest of the Sierra Nevada to the east of Yosemite valley is a belt of schists of unknown age. Mt. Dana and Mt. Lyell are culminating points of this area of schists, which extends at least twelve miles northwest of Mt. Dana and judging from the reports of the State Mineralogist at least as far south as the Minarets. This schist belt contains deposits of base ores at numerous points. Specimens obtained by the writer from the Tioga district to the northwest of Mt. Dana, and from Mono pass, show that the bulk of the ores are very rich in sulphides and would probably be difficult of reduction. These ores contain gold and silver, cobaltite, and sulphides of antimony, lead, zinc, copper and iron. One specimen of quartz from the Tioga mine shows a notable quantity of pyrrhotite.

The report of Mr. E. B. Preston* on the silver ores of the Minarets mining district indicate that the ores are very similar to those above described.

At Mineral King, about fifteen miles southwest of Mount Whitney is a body of Triassic schists enclosed in the granite, and containing some gold quartz veins. At the upper workings of the Empire mine there is a small quartz vein in crystalline limestone.

Blende and galena occur in the limestone and blende in the quartz. The mines at Mineral King have not proved profitable, but the district about Tioga and Lundy is a promising one.

Veins in the Granite.—The greater portion of the higher part of the Sierra Nevada and nearly the entire mass of it to the south of Mariposa county is composed of granite. In this large granite area very few auriferous quartz veins have been found. In many of the smaller areas, however, entirely or partly enclosed in the auriferous slate series, there are numerous veins frequently containing abundant gold. Two of these enclosed granite areas have been extensively exploited, that about West Point in Calaveras county and about Soulsbyville in Tuolumne county.

In a general way the ores of the granite districts are very base, and need chlorination to obtain the gold, but this rule is by no means universal.

The ores of the mines of the Soulsbyville district in many cases contain a galena-like mineral which gives blowpipe reactions for lead and antimony. Copper and iron sulphurets, magnetic iron pyrite or pyrrhotite, and blende are abundant. The vein of the Black Oak quartz mine is accompanied by a dark, fine grained slaty rock called "slate" by the miners. This in thin section is seen to contain a large amount of fibrous green hornblende in ragged prisms lying at all angles,

* 11th Ann. Rep. State Mineralogist of California, p. 222.

and in radiating tufts, and is presumably an altered dike rock, perhaps a fine grained diorite. There is also a fine grained dike? rock next to the vein of the Platt and Gilsen mine, which contains a good deal of a brownish mica, specks of iron disulphide and chlorite in minute veins. This rock is also called "slate" by the miners. The ore of the Hyde mine which is also in granite in the Soulsbyville district, is free milling. It contains the same sulphurets as the other mines above mentioned but in smaller amount.

In the West Point mining district, the ore contains abundantly ordinary iron and copper sulphides and magnetic iron pyrite or pyrrhotite. Cutting the vein of the Lockwood mine are dikes of a fine grained diorite of the camptonite series. The vein was said to have been richer where cut by these dikes.

To the north of Merrimac in Butte County, similar dikes accompany some of the gold quartz veins in the granite.

Gold in albite.—As is well known free gold usually occurs associated with quartz as a gangue. Instances are on record, however, of its occurrence in various materials, as talc, calcite, etc. Recently a series of specimens was sent to the writer by Mr. Leo Von Rosenberg of New York city, from the Shaw mine in Eldorado county, about four miles southwest of Placerville. This deposit occurs in clay slates associated with a dike or dikes of a feldspathic rock, which appears to be devoid of bisilicates. Judging from the specimens forwarded, the dike rock is more or less decomposed, and is at some points replaced by secondary white feldspar, which at other points cuts the dike rock in little seams. This feldspar is well crystallized, and with the aid of a lens striations may be noted on the crystals. In thin section these feldspars are seen to be twinned polysynthetically with extinctions proper to albite, and a partial chemical analysis by Dr. Hillebrand of the U. S. Geological Survey shows that it contains soda, no lime, and about 19 per cent of alumina. It is therefore albite. In two specimens of this crystallized albite there is free gold. Another interesting specimen is of a dark fine grained rock which appears to be an aphanitic form of the dike-rock in a seam of which free gold with a little calcite has been deposited.

The following is a partial analysis by George Steiger of the feldspar of the grayish-green dike rock forming part of the Shaw mine lode.

(No. 452 Sierra Nevada collection.)

Alumina	about 20·00
Lime	·49
Potassa	1·15
Soda	8·72

This would indicate that the feldspar of the dike rock is also albite although not so pure as the secondary albite that occurs in veins cutting the dike rock.

The feldspathic lode of the Shaw mine is cut by little veins of quartz, but judging from the specimens sent these are not very abundant, and do not seem to be connected with the deposition of the gold.

The quartz veins cut the veins of secondary albite showing that they were formed later than the albite. In one specimen there seemed to be an intermingling of quartz and albite, pointing to contemporaneous deposition. But in thin section, the idiomorphic albite crystals were plainly seen to be enclosed in the quartz, as if there had been a little fissure, the walls of which were coated with albite crystals and the open spaces in the middle between the albite crystals later filled in with quartz. All of the material of the lode, except perhaps the quartz, contains iron disulphide scattered through it in minute cubes, and calcite in little rhombs and particles.

Orofino gold mine.—One and a half miles northeast of Mount Aigare in Eldorado county on the west side of Big Cañon creek is a dike of rock about 1500 feet long with a nearly north and south strike but curving to the southwest at the south end. This dike is much broken up, and re-cemented into a breccia. One of the specimens of the dike collected there by the writer in 1889 is a quartz-diorite, containing specks of iron disulphide and calcite ; another specimen which seemed to grade over into the diorite is composed of a plagioclase feldspar probably albite, calcite, and grains of iron disulphide, and strongly resembles in thin section the vein material of the Shaw mine. This last specimen has a brecciated structure. It is auriferous and is the ore of the mine known as the Orofino gold mine. The country rock of the mine is clay slate, the same belt as at the Shaw mine, and is probably Carboniferous in age.

The gold deposits of both the Shaw and the Orofino mines are of such an unusual nature as to deserve further investigation.

Petre's River mine.—One mile northwest of the town of Mokelumne Hill in Calveras county on the north bank of the Mokelumne river is a quartz mine, owned by Mr. R. W. Petre. There are here two quartz veins which have a northwesterly strike and dip southwesterly about 80°. The veins are very irregular in width opening out into lens-shaped bodies, and quickly pinching out again. Mr. Petre stated that one of these lenses contained $10,000 in gold, but that most of the quartz was of low grade. The country rock of the mine is a quartz-diorite. Some granite schistose material occurs along the main veins. A microscopic examination of this shows that it is practically a chlorite-schist. It is composed of a schistose aggregate of minute grains of feldspar, with much chlorite, and calcite. This schist is doubtless an attrition product, formed by movement along the walls of the vein. In one part of the vein there is a good deal of a hard white material, which the microscope shows to be largely feldspar, presumably albite. The feldspar occurs in unstriated interlocking grains with occasional twinned prisms. There is a good deal of calcite, pyrite, and muscovite, and foils of a green chloritic mineral. In the quartz-diorite country rock near the vein are a number of rounded bodies of calcite, some three feet in diameter. This calcite was doubtless deposited in pre-existing cavities.

Gold with barite.—Mr. W. Lindgren* has described an interesting deposit at Pine Hill, Cala. In a zone of decomposed and kaolinized diabase are irregular veins or seams of barite with which gold is associated. Other similar associations are noted.

Mr. Wirt Tassin of the U. S. National Museum kindly called my attention to a paper by Henry Louis† on the mode of occurrence of gold. Mr. Louis gives a list of 77 species of minerals, some of which however are formed from the decomposition of previously existing minerals that are found in gold veins. Only one feldspar is noted, orthoclase from Colorado. The exact locality is not given. The author further says that while iron pyrite is an almost universal constituent of gold quartz veins, marcasite seems never to occur; and in conclusion suggests that the gold and quartz have been simultaneously deposited in veins from alkaline solutions.

Gold in calcite.—The Yellowstone mine at Bear valley, Mariposa county, is in diabase. The course of the vein is about W. 20° S. The ore occurs in the altered diabase broken up along the vein and re-cemented with quartz and calcite. A specimen of the ore presented by the superintendent, Mr. McDonald, to the National Museum shows spots of free gold at numerous points associated with white quartz and calcite. According to Mr. Hall, the former owner, in the upper workings a good deal of the gold occurred in calcite.

In the collection of the U. S. National Museum there is a specimen of calcite in which are threads of native gold. This was collected by Dr. W. H. Melville from the Bannock mine, Montana.

Gold with quartz in rhyolite.—One mile east of Onion valley in Plumas county, California, is a dike of rhyolite in

* This Journal, vol. xliv, 1892, pp. 92–96.
† Mineralogical Magazine, vol. x, 1893, pp. 241–247.

the auriferous slate series at the headwaters of Poorman creek, in a decomposed portion of which free gold occurs associated with little veins of quartz. As the gulch was very rich below this dike, it is possible that much of it came from the rhyolite. The occurrence is remarkable inasmuch as the rhyolite is probably of Tertiary age. This rhyolite is a white rock with abundant foils of a brown mica, and phenocrysts of sanadine and plagioclase with a few rounded quartzes in a microcrystalline groundmass.

Gold with cinnabar.—Besides the Blue Wing vein locality previously noted, gold occurs with cinnabar in a vein in diabase near Coulterville. The cinnabar is in large fine crystals. The mine is the property of C. L. Mast and is the one referred to by Becker.*

Free gold is found with cinnabar in the Manzanita mine in Colusa county in the Coast ranges in metamorphosed strata containing *Aucella piochi* Gabb; a fossil characteristic of the lowest Cretaceous.

ART. LX.—*A recent analysis of Pele's Hair and a Stalagmite from the lava Caves of Kilauea;* by A. H. PHILLIPS.

THE Pele's Hair was collected the past summer by Prof. Libbey during his recent trip to Hawaii. In both cases the finely powdered substance was dried at 100° C. On subsequently igniting the stalagmite became reddish and increased in weight due in all probability to the oxidation of the ferrous iron present.

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	P_2O_5	CaO	MgO	Ma_2O	K_2O	Total.
Peles' Hair,	50·76	14·75	2·89	9·85	·41	·26	11·05	6·54	2·70	·88	100·09
Stalagmite,	51·77	15·66	8·46	6·54	·82	--	9·56	4·95	2·17	·96	100·89

The above analysis of Pele's Hair does not differ in any essential respect from that of Prof. O. D. Allen's,† but there is quite a large difference, both in the amount of alumina and potassa when compared to that of D. E. Cohens.‡ In the latter the alumina is only 9·14 per cent while the potassa is 3·06 per cent. These variations may be explained by the fact that, the fused lava charge of Kilauea is drawn off every few years by some subterranean channel and is again slowly refilled by a new supply.

The stalagmite is of the kind, so characteristic of the lava caverns of Kilauea and Mount Loa; while it has not been pos-

* Quicksilver Deposits, p. 383. † This Journal, 1879, III, xviii, p. 134.
‡ Quoted in Characteristics of Volcanoes, Dana, p. 348.

sible to find an analysis of a stalagmite with which to compare it, but in comparison with that of Pele's Hair, their similarity is very striking, differing from it not as much as do the several analyses of Pele's Hair do from each other. With the one exception, the iron in the stalagmite has been further oxidized, but even here the FeO exists in larger proportions as compared to the Fe_2O_3 than it does in magnetite and could still undergo oxidation to a considerable extent before it would exist or could be represented by the formula Fe_3O_4. Both from the physical character and chemical composition of these stalagmites, it seems impossible to think of them as being formed from solution alone. Some other cause must be sought for as the chief factor in their formation. They are almost without exception, both stalactites and stalagmites, porous and vesicular though being quite solid on the surface, while the stalactites are of nearly the same diameter throughout their entire length, which in some cases may reach thirty inches. Two characters very hard to find if at all in a stalactite known to be formed from solution without doubt.

The stalagmites in particular are suggestive of fused drops, which falling one on the other are at the time sufficiently plastic to be quite firmly welded together and congealed in a slightly drooping position, while gases liberated internally and being held there by the more viscous external portions of the drop, would form vesicles. Then too the condition of iron oxides point to some other mode of formation than that of pure solution, for certainly a solution of ferrous iron flowing in a thin film down the sides of a stalactite, then dropping from its point to the stalagmite would be oxidized to a far greater extent than this analysis shows. Unless surrounded by an atmosphere strongly reducing in character it would pass to ferric iron. True the analysis by J. C. Jackson given by Brigham contains no ferrous iron, but then this was of a solid stalactite, which may have been one of solution.

Again any solvent must show some selective character in the substances it dissolves, but here all constituents are carried down to the stalagmite in the same proportion as they exist at least in Pele's Hair. I hope soon to be able to draw a closer comparison by making, as soon as the material can be obtained, an analysis of a stalactite and the lava above it from which it is supposed to have originated by solution. In all probability they will show no marked differences but everything will be found in the same proportions in the stalactite as in the lava. What the principal factor in the production of their peculiar formation is; if they are not formed while still in a fused or plastic condition. It certainly is other than by solution alone.

John C. Green School of Science, Princeton, N. J., Mar. 19th, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Mass of a Liter of Normal Air.*—The mass of oxygen in the air at Sorbonne has been found by Leduc to vary from 23·14 to 23·20 per cent; and since this difference corresponds to a tenth of a milligram in the mass of a liter of air, he regards it as useless to attempt any higher degree of accuracy in such determinations without at the same time determining the composition of the air examined. He finds that the mass of a liter of the average air at Paris, at 0° and 760^{mm} is 1·29315 gram. Defining normal air to be air collected on a plain in calm weather at a distance from a town, which contains a little more than 23·2 per cent of oxygen by mass or almost precisely 21·0 per cent by volume, the author finds that the mass of a liter of such air at 0° and 750^{mm} is 1·2932 grams; and at 0° and under one c. g. s. atmosphere, 1·2758 grams. In estimating the densities of gases, he prefers to take nitrogen as the standard because, not only is it readily procurable in a state of purity but it has a density so nearly that of air that no appreciable error is caused by the presence of a small quantity of air in the apparatus. The mass of a liter of nitrogen at Paris under normal conditions is 1·2570 grams; its mass under a pressure of one c. g. s. being 1·24006 grams.—*C. R.*, cxvii, 1072, December 1893. G. F. B.

2. *On the Preparation of Nitrogen monoxide.*—It has been observed by W. Smith that a mixture of ammonium sulphate and sodium nitrate, kept at 215° for two or three hours, decomposes for the most part into sodium sulphate and ammonium nitrate; and further that if the mixture be more strongly heated, nitrogen monoxide begins to be evolved at 230° and comes off quite rapidly at 240° to 250°. A little ammonia is evolved however during the heating, the more ammonia being lost the longer the mixture is kept between 220° and 230°. Consequently if at the outset the mixture has been made in molecular proportions, this evolution of ammonia leads to the setting free of some of the higher nitrogen oxides towards the end of the reaction. To remedy this the author increases the proportion of ammonium sulphate; and now the mixture having 5 per cent additional sulphate, yields a larger quantity of nitrogen monoxide than is obtained ordinarily from the equivalent quantity of ammonium nitrate. The evolution of gas goes on more regularly than with ammonium nitrate itself which at 240° is liable to decompose with almost explosive violence.—*J. Soc. Chem. Ind.*, xii, 10, January 1893. G. F. B.

3. *On the Conversion of Yellow Phosphorus into the Red variety.*—When yellow phosphorus is crystallized from the ordinary organic solvents of this substance, best by cooling a hot solution of it, it is generally conceded that the crystals are

dodecahedrons. Retgers however has experimented with essential oils used as solvents and has not been able to confirm the production of dodecahedrons under these circumstances. Indeed it would appear that under certain conditions the yellow variety of phosphorus is amorphous; as when it is obtained in a thin layer between two slips of glass. With reference to the action of heat on this substance, the author observes that when heated phosphorus passes through three stages of change. In the first it becomes yellow to brown, though still remaining regular and transparent. In the second a granular, undoubtedly crystalline segregation occurs, red opake phosphorus being formed. And in the third there is produced a graphitic chocolate-colored phosphorus. The first production of a true modification occurs at the second stage. Light was observed to produce a similar series of changes, these changes not being confined to the surface. The character of the white crust which forms on phosphorus when submerged in water, the author has not finally determined though he considers it a hydrate rather than a different modification. Since the properties of an amorphous modification so far as known, are never intermediate between those of two crystalline modifications, this rule would be violated if red phosphorus were amorphous; for the density of red phosphorus is 2·148 and that of yellow phosphorus is 1·826; while that of the chocolate-colored hexagonal variety is 2·34.—*Zeit. Anorg. Chem.*, v, 211, October 1893. G. F. B.

4. *On the Behavior of Carbon, Boron and Silicon in the Electric Furnace.*—In continuing his experiments with the electric furnace Moissan has now subjected carbon, boron and silicon to the action of the electric arc. At a somewhat high temperature, the diamond under those circumstances becomes incandescent and swells up without melting, covering itself with black particles entirely consisting of hexagonal plates of graphite easily convertible into graphitic oxide. When placed in a small carbon crucible and acted on by an arc produced by 70 volts and 400 amperes, the diamond first breaks up into fragments along the planes of cleavage and then swells up as the temperature rises and is completely converted into graphite. Hence it appears that the stable form of carbon is graphite, even at the temperature of only a moderately intense electric arc. If heated in a carbon enclosing vessel, in a jet of oxygen and hydrogen gases, however, the diamond is sometimes covered with a black adhering mass which slowly dissolves in a mixture of nitric acid and potassium chlorate but which is not graphite. Amorphous boron volatilizes without fusion in the electric arc, the ends of the electrodes being converted into semi-crystallized boron carbide. Silicon thus treated melts and then boils, covering the ends of the carbon electrodes with pale green crystals of carbon silicide.

This carbon silicide Moissan has studied more carefully. He finds that when carbon is dissolved in fused silicon in a wind furnace, crystals of carbon silicide several millimeters in length can be obtained; showing that these two elements combine readily in a fused medium at 1200° to 1400°. This compound can be produced much more easily however by heating a mixture of 12 parts of carbon and 28 parts of silicon in the electric furnace, the resulting product being treated first with a mixture of nitric and hydrofluoric acids and then with one of nitric acid and potassium chlorate. Generally the crystals are yellow; but when the operation is conducted with silicon as free as possible from iron, in a closed crucible, the crystals are transparent and sapphire blue in color. Carbon silicide has the composition CSi, has a density of 3·12, and acts strongly on polarized light. The crystals are very hard and scratch chrome steel and rubies. The silicide is not affected by oxygen or by sulphur vapor at 1000°, though chlorine decomposes it at 1200°. Fused niter, or potassium chlorate, boiling sulphuric, nitric or hydrochloric acids, aqua regia and even mixtures of nitric and hydrofluoric acids do not attack it. It is gradually converted by fused potassium hydroxide into potassium carbonate and silicate.

The latest form of Moissan's electric furnace consists of a rectangular block of Courson limestone, containing a large rectangular cavity, lined with alternating plates of magnesia and carbon about a centimeter thick, the magnesia being in contact with the limestone and the carbon lining the interior of the cavity. A lid, also of alternating plates of magnesia and carbon covers the cavity, a block of the same limestone resting upon the lid. The electrodes, which are both movable, pass through slots cut in opposite sides of the furnace. A carbon tube one or two centimeters in diameter passes through the furnace at right angles to the electrodes being so arranged as to be a centimeter below the arc and the same distance above the bottom of the cavity. When this tube is inclined at an angle of about 30°, the furnace may be made to work continuously, the reducible material being introduced at the upper end and the product of reduction being drawn off at the lower. With a current of 600 amperes and 60 volts, two kilograms of fused metallic chromium can be obtained in about an hour, the metals being received in a crucible made of chromic oxide. The metal is white and very hard, is finely granular and takes a high polish. In this furnace both silicon carbide and vanadium carbide can be easily obtained by directly combining the vapors of silicon and vanadium with the vapor of carbon. The plates of magnesia are prepared by heating the basic carbonate, digesting with ammonium carbonate, again strongly heating and then compressing into blocks.—*C. R.*, cxvii, 423, 425, 679, Sept., Nov. 1893. G. F. B.

5. *On Crystallized Silicon carbide or Carborundum.*—Experiments somewhat analogous to those of Moissan have been made by Mühlhäuser. By mixing together fine coke, sand and salt, packing the mixture round a carbon rod in an oblong box of fire brick, and connecting the ends of the carbon core with the terminals of a transformer, the entire mass could readily be raised to a

white heat. After the reaction had ceased, a transverse section showed that surrounding the carbon rod, was (1) a zone of adhering graphite, (2) a zone of crystallized silicon carbide, (3) a zone of amorphous silicon carbide, (4) a zone containing pockets of fibrous material, (5) a zone of the original mixture only slightly altered and, (6) a hard external layer consisting almost entirely of salt. The graphite had all the properties of the natural mineral, but had the crystalline form of the silicon carbide; indicating that the latter is first formed and then loses its silicon by volatilization. The outer portion of this graphite zone gave 33·71 per cent of variously colored crystals containing 30·49 per cent of silicon and 68·26 of carbon. The second zone constituted the chief product of the reaction. On breaking up the mass in a mortar, the separate crystals were obtained, bluish or yellowish-green in color, and varying in size from microscopic dimensions to several millimeters in diameter. To purify it, it was heated to dull redness in oxygen, boiled with potash solution, washed, digested with hydrochloric acid and finally treated with hydrofluoric acid. It then has the composition SiC, and a density of 3·22 at 15°. Under the name of *carborundum* it has come into use in the arts to replace emery.—*Zeit. Anorg. Chem.*, v, 105, October 1893. G. F. B.

6. *On Antimony-Blue.*—According to SEBOR, antimony-blue may be prepared by dissolving antimony sulphide in concentrated hydrochloric acid, and, after filtering, adding to the boiling liquid a concentrated solution of potassium ferrocyanide and some potassium chlorate or nitric acid. The precipitate is dried at 100°. Another antimony-blue may be obtained by mixing antimony chloride and potassium ferrocyanide and adding a large quantity of water. When prepared in this way however, it contains some basic antimony chloride. A sample of pure antimony-blue yielded on analysis Fe 30·28, Sb 2·422, H_2O 5·828, Cl 0·712, O 0·323, and Cy 60·435 per cent. Antimony-blue is insoluble in cold hydrochloric, sulphuric and nitric acids, and yields hydrogen cyanide when boiled with hydrochloric or sulphuric acid. Warm dilute sodium and potassium hydroxides attack it, and nitric acid on heating converts it into a grayish-green compound. Unlike Prussian blue it is not soluble in a solution of an oxalate or a tartrate.—*Chem. Centr.*, ii, 318, 1893; *J. Chem. Soc.*, lxvi, i, 3, Jan. 1894. G. F. B.

7. *On the Nitro-metals.*—The researches of SABATIER and SENDERENS upon the nitro-metals have been continued and they now report the discovery of nitro-cobalt, nitro-nickel and nitro-iron. Nitro-cobalt is best prepared from cobalt reduced at a low temperature, by passing over it nitrogen peroxide suitably diluted with nitrogen. Black nitro-cobalt CO_2NO_2 is thus produced, upon which water acts vigorously, but gives less nitrogen dioxide than nitro-copper; producing a solution of cobalt nitrate, containing very little nitrite. Heated in nitrogen nitrous fumes are evolved and then decomposition takes place with almost explosive

violence. It explodes when mixed with combustible matter. Nitro-nickel is similarly prepared and has similar properties. Nitro-iron is more difficult to prepare, deflagration taking place after the absorption of a portion of the peroxide.—*Bull. Soc. Chim.*, III, ix, 669, Sept. 1893. G. F. B.

8. *On the Preparation of Ethyl ether.*—It has been pointed out by KRAFFT that in the preparation of ether by means of sulphuric acid, the acid is partly reduced to sulphurous acid by the alcohol. Since the aromatic sulphonic acids are more stable in presence of alcohol, the author proposes their use for the continuous etherification of alcohol. Using ethyl alcohol and benzene-sulphonic acid for example the reaction is: (1) $PhSO_2 . OH + EtOH = PhSO_2 . OEt + H_2O$; and (2) $PhSO . OEt + EtOH = PhSO_2 . OH + Et_2O$. In practice the alcohol is dropped on the benzene-sulphonic acid heated to 140°. Methyl-propyl ether was thus produced and boiled at 36·6°–37·4°.—*Ber. Berl. Chem. Ges.*, xxvi, 2829, Dec., 1893. G. F. B.

9. *Line Spectrum of Oxygen.*—M. EISIG has taken up the subject anew with the aid of a Rowland concave grating and with Rowland's map of the solar lines. An analysis of the work of Schuster, Deslandres, Trowbridge and Hutchins, and Hartley and Adeney is made, and the author is forced to the conclusion that there is no positive evidence that oxygen exists in the sun.—*Ann. der Physik und Chemie*, No. 4, 1894, pp. 747–760. J. T.

10. *Lilienthal's experiments on flying.*—With the conviction that the flight of birds is an art which must be carefully studied, LILIENTHAL has practised himself in taking advantage of the remarkable fact discovered by Langley and by himself that with certain angles of inclination of wings to the direction of the wind, not only does the horizontal component of the wind disappear, but even may become negative, that is the fans which act as wings fly against the wind and can be raised by it. He accordingly selects a gentle incline free from woods or other obstruction to the free movement of the wind. This incline was usually not more than 10 or 15° to the horizon and ran against the direction of the wind. After some experience Lilienthal was enabled to soar distances of 120 to 150 meters against the wind. Professor A. du Bois Reymond states that after only four or five trials he was enabled to take leaps of from 15 to 20 meters long. Lilienthal by means of stronger winds has been enabled to soar in circles like those of birds similar to the hawk. If this practise of soaring is introduced as a sport, its use and the accumulated experience of many young athletes, may lead to our learning the art of flying. Prof. du Bois Reymond calls attention, in this connection, to the great skill that has been acquired in the art of balancing oneself on bicycles and similar machines.—*Physical Society of Berlin*, Dec. 15, 1893. *Ann. der Physik und Chemie*, No. 4, 1894, p. 42. J. T.

11. *Apparatus for the demonstration of Ampere's laws.*—In order to avoid the disturbances which arise from the use of mer-

cury cups, in the ordinary form of lecture apparatus for showing Ampere's laws, RAPS has devised a system of two rolling metallic contacts, by means of which the electric current can be led to and away from the model. To show the applicability of the apparatus he instances this case. A solenoid of 15^{cm} diameter, 40^{cm} in length, with 70 turns of aluminum wire, with a current of 6 amperes, places itself in the magnetic meridian.—*Physical Society of Berlin*, Oct. 20, 1893. *Ann. der Physik und Chemie*, No. 4, 1894, p. 29. J. T.

12. *Magnetisation of Iron by rapid Electrical Oscillations.*—KLEMENCIC, at a recent meeting of the Kaiserliche Akademie der Wissenschaft of Vienna, read a paper on this subject. The value of μ, the magnetic permeability was determined by a heat method. The following are some of the values obtained for μ: Soft iron 118, soft steel wire 106, hard steel wire 115, soft Bessemer steel 77, hard 74, nickel 27. These values agree fairly well with those of Rayleigh and Bauer for very feeble magnetising forces. It appears that Bauer and Rayleigh's results for longitudinal magnetism also apply to circular magnetism.—*Nature*, April 26, 1894, p. 607. J. T.

II. GEOLOGY AND MINERALOGY.

1. *On the Straining of the Earth resulting from Secular Cooling;* by CHARLES DAVISON. Read before the Royal Society, London, January 10, 1894. (Abstract.)—If the coefficient of dilatation (e) and the conductivity (k) are constant for every point within the earth, and if the temperature (V) was initially the same throughout, the depth of the surface of zero-strain after 100 million years is 2·17 miles, the total volume of the crust folded and crushed above that surface is about 184,500 cubic miles, and the mean thickness of the crushed rock spread over the whole surface of the earth is 4·95 ft. (taking $e=0·0000057$), $k=400$, $V=7000°$ F.). The smallness of these figures has been claimed by some geologists as a new and strong argument against the contraction theory of mountain evolution.

In the present paper the problem is reconsidered on the supposition that the coefficient of dilatation is not constant, but increases with the temperature, the change in the former varying as the corresponding change in the latter. It follows, from experiments made by Fizeau, that, for a rise of one degree in temperature, the coefficient of dilatation increases on an average by about 1/888. Adopting this value, and taking the other constants as above, it is found that, after 100 million years, the depth of the surface of zero strain is 7·79 miles, the total volume of crust-folding about 6,145,000 cubic miles, and the mean thickness of the layer formed by spreading it over the whole earth 164·7 ft.

If the conductivity increases with the temperature, or if the material which composes the earth's interior be such that the conductivity and coefficient of dilatation are greater in it than in the surface rocks, or if initially the temperature increased with the depth, the figures given in the preceding paragraph must be still further increased. It follows, therefore, that calculations as to the alleged insufficiency of the contraction theory to produce mountain ranges are at present inadmissible.

2. *Appendages of Trilobites.*—As the result of study of some specimens of *Triarthrus Bechi*, C. D. WALCOTT has prepared a *note on some appendages of the trilobite* with a plate illustrating the structures and diagrammatic restorations of the thoracic limbs. Mr. Walcott shows the antennæ to arise from the under side of the head near the postero-lateral angle of the hypostoma. He would make classes of the Trilobita and Merostomata; the Trilobita and Phyllopod branches diverging from a common Crustacean base of precambrian time, the descendants of the Phyllopod branch being the modern Crustacea, while the Trilobita became extinct at the close of the Paleozoic.—*Proc. Biol. Soc.*, Washington, vol. ix, pp. 89–97, Pl. I, March 30, 1894.

3. *Geological Surveys in Alabama;* by EUGENE A. SMITH: The Journal of Geology, vol. ii, pp. 275–287, April–May, 1894.—A brief synopsis of the history of the geological work done in the State of Alabama is given in this article by the present State Geologist.

4. *Tertiary Tipulidæ, with special reference to those of Florissant, Colorado;* by S. H. SCUDDER (Proc. Amer. Philos. Soc., vol. xxx, 83 pp., Plates I–IX.—In this memoir, presented on the occasion of the celebration of the 150th anniversary of the foundation of the American Philosophical Society, Dr. Scudder has figured and described a series of beautifully perfect crane-flies (Tipulidæ) from the Tertiary beds of Florissant, Colorado. Most of the specimens show the venation of the wings and their most delicate markings, and on some of them the fragile legs, thin hairs, the antennæ and even the facets of the compound eyes are preserved.

Some of the more important conclusions reached as a result of the study of this interesting fauna are as follows: The general facies of the Tipulid fauna of our western tertiaries is American and agrees best with the fauna of about the same latitude in America; all the species are extinct and the fauna is presumably of Oligocene age; no species are identical with described European Tipulidæ; eight out of the fifteen genera are extinct; all the existing genera (except one, Cladura) in the American tertiaries are genera common to the north temperate zone of Europe and America, and are either confined to these regions or the vast proportion of their species are so confined, indicating a similar climate, at least there is no certain evidence of a warmer climate.

W.

A paper by the same author on the *American Tertiary Aphidæ*, with several beautiful plates, is contained in the forthcoming 13th Ann. Report of the Director of the United States Geological Survey.

5. *Shawangunk Mountain.*—Under this title N. H. DARTON gives his interpretation of the structure and topography of the mountain, the surface being mainly the expression of plications of the thick Shawangunk grit overlying the soft shales of the Hudson River epoch, whose erosion has determined the more abrupt eastern slopes of the mountain mass.—*The National Geographic Magazine*, vol. vi, pp. 23–34, Pls. 1–3, March, 1894.

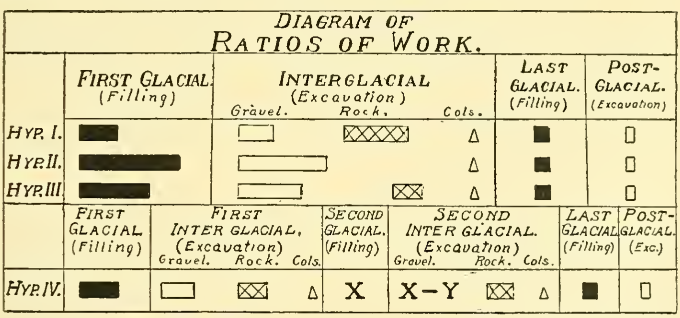
6. *Geological Section of the Alps.*—A. ROTHPLETZ has published a report which will be of much value to geologists crossing the Alps, or wishing to gain a vivid idea of their structure. In "*Ein geologischer Querschnitt durch die Ost-Alpen nebst anhang über der sog. Glarner doppelfalte* (pp. 268, 2 plates and 115 figures, Koch, Stuttgart, 1894), a section is run from near Tölz across to Bassano nearly along the meridian of Munich, 260 kilometers in length. A topographical map of the region is accompanied by a long colored profile section (over 11 feet in length) on a scale 1 : 75000, exhibiting clearly the general structure. The details of structure are well elaborated by figures distributed throughout the text.

7. *The Arkansas Coal Measures.*—In a paper *on the Arkansas Coal Measures in their relations to the Pacific Carboniferous Province*, J. PERRIN SMITH has made an analysis of the faunas of the several divisions of the Arkansas Coal Measures and has discussed their relations to the Carboniferous and Permian deposits of the Pacific province of North America and of China, India and Brazil, explaining in an interesting way the geological events which account for the correlations of the organisms of the several regions.—*Journ. Geol.*, vol. ii, pp. 187–204, Feb., March, 1894.

8. *The Crinoidea of Gotland.* Pt. I. *The Crinoidea inadunata;* by F. A. BATHER, pp. 182, Plates I–X. Kongl. Svenska Vetenskaps-Akademiens Handlingar, vol. xxv, No. 2, Stockholm, 1893.—This work is not only a thorough review of the species of Angelin's "Iconographia," but after a careful study of rich collections made by Angelin and now in the Stockholm Museum, the author has with exquisite delicacy developed the minute structure of the species studied, and with the assistance of an artist equally accurate with himself (Mr. J. Liljevall) has produced a monograph thoroughly up to the needs of modern science. Among the more valuable additions to knowledge are the reconstruction of the genus *Pisocrinus*, determining its true relations with other Monocyclica; the revision of the genera of Calceocrinidæ based upon a full delineation of the skeletal elements; the account of the morphology of the genus *Herpetocrinus* (=*Myelodactylus*); the revision of the Inadunata, resulting in the abolishing of the suborders Larviformia and Fistulata, and the erection of the divisions Monocyclica and Dicyclica separated according to the presence or absence of infrabasals. The Dicyclica are also revised as the result of fuller knowledge of their ventral and anal structures. H. S. W.

9. *Die Vorwelt und ihre Entwickelungsgeschichte;* by Ernst Koken, pp. 654, 1893.—Professor Koken has produced an elaborate treatise on the development of the earth and its inhabitants, beginning with a discussion of the interior condition of the earth and of the crust, devoting a chapter to mountain building, another to estimates and notions of time in geology, and in the remainder of the book elaborating step by step the development of the formations, by deposition, growth of continents by earth movements, and by surface shaping up to the present condition of the earth. Under each system is added a general review of the history of organisms for the period discussed as faunas and floras, the species being named but not described, with account ot their distribution and relations to other faunas and floras and to those which have preceded and succeeded them. A great amount of information is brought together about geology and paleontology, carefully arranged in a systematic manner, with running commentary by the author.

Correction.—In the paper entitled "*Further Studies of the Drainage Features of the Upper Ohio Basin*" in the April number of this Journal, a serious error occurs in figure 5, page 282, which the authors desire to correct. In the second column of the diagram, which represents interglacial excavation, the unit of filling was employed in draughting, instead of the unit of excavation, thus doubling the amount, since it happens that the valley-filling of late glacial gravels was just about twice the volume of the postglacial erosion. The error crept in during the re-drawing and reduction of the diagram for the Journal, and escaped detection until some time after publication. It did not appear in the original diagram used at the Boston meeting of the Geological Society of America, nor in the computation of the authors. The diagram is herewith reproduced in the corrected form.



T. C. Chamberlin.

III. Miscellaneous Scientific Intelligence.

1. *Watson Gold Medal of the National Academy of Sciences.*—This medal, which was awarded 1888, April 19, to Dr. Edward Schöenfeld of Bonn, and which was conferred 1891, April 22,

upon Dr. ARTHUR AUWERS of Berlin,—was unanimously voted 1894, April 17, to Dr. SETH C. CHANDLER of Cambridge, for his investigations and discoveries concerning the Variation of Latitude, and his researches relative to Variable Stars.

2. *The use of Governmental Maps in School;* by WM. M. DAVIS, C. F. KING and G. L. COLLIN, pp. 65 (Henry Holt & Co.), 1894.—This is a handy descriptive list of some of the more useful maps of the United States, with brief directions for obtaining them, grouped under the following heads, the geological survey, the Coast and Geodetic Survey, the Mississippi River Commission, the Missouri River Commission, the Survey of the Northern and Northwestern Lakes, the State Topographical Surveys, the Weather Bureau and the Hydrographic office. Though primarily designed for schools, the Report will be useful to all persons interested in the geographical features of the country.

W.

3. *National Academy of Sciences.*—The following is a list of the papers presented at the April meeting held at Washington, April 17 to 20:

G. L. GOODALE: Histological Characteristics of Certain Alpine Plants. Corrorosions by Roots.

GEORGE C. COMSTOCK: An Investigation of the Aberration and Atmospheric Refraction of Light, with a Modified Form of the Loewy Prism Apparatus.

JOSEPH LE CONTE: Biographical Memoir of John Le Conte.

A. AGASSIZ: The Coral Reefs of the Bermudas. The So-called Serpulæ Reefs of the Bermudas. The Bathymetrical Extension of the Pelagic Fauna.

M. CAREY LEA: New Method of Determining the Relative Affinities of Certain Acids.

A. M. MAYER: On the Change of Young's Modulus of Elasticity with Variation of Temperature, as Determined by the Transverse Vibration of Bars of Various Temperatures. On the Production of Beats and Beat-tones by the Covibration of two sounds, so high in pitch, that when separately sounded they are inaudible. On the Motions of Resonators and Other Bodies Caused by Sound Vibrations, with Experimental Illustrations; also a Reclamation.

S. C. CHANDLER: On Late Researches on the Variation of Latitude.

S. P. LANGLEY: On the Infra-red Spectrum. The Internal Energy of the Wind.

J. S. BILLINGS: The Bacteria of River Water. The Influence of Light Upon the Bacillus of Typhoid, and the Colon Bacillus.

T. C. MENDENHALL: Recent Gravity Instruments and Results.

THEO. GILL: The Geographical Distribution of Fresh-water Fishes.

C. S. HASTINGS: Note on a Possible Increase in the Ultimate Defining Power of the Microscope.

OBITUARY.

SAMUEL WHITE BAKER, the African explorer, died Jan. 20, 1894, at the age of 73.

VERNON LOVETT CAMERON, another of the leaders of discovery in Africa, died March 26, 1894, at the age of 50.

WILLIAM PENGELLY, the English Archæologist, died March 16, 1894, at the age of 82.

GEORGE POUCHET, the author in 1858 of "De la pluralité des races humaines," died in March, 1894, aged 61.

CHARLES EDOUARD BROWN-SÉQUARD, the eminent French physiologist, died April 1, 1894, at the age of 77.

JOSEPH DE SZABO, geologist and mineralogist of Buda Pest, died April 10, 1894.

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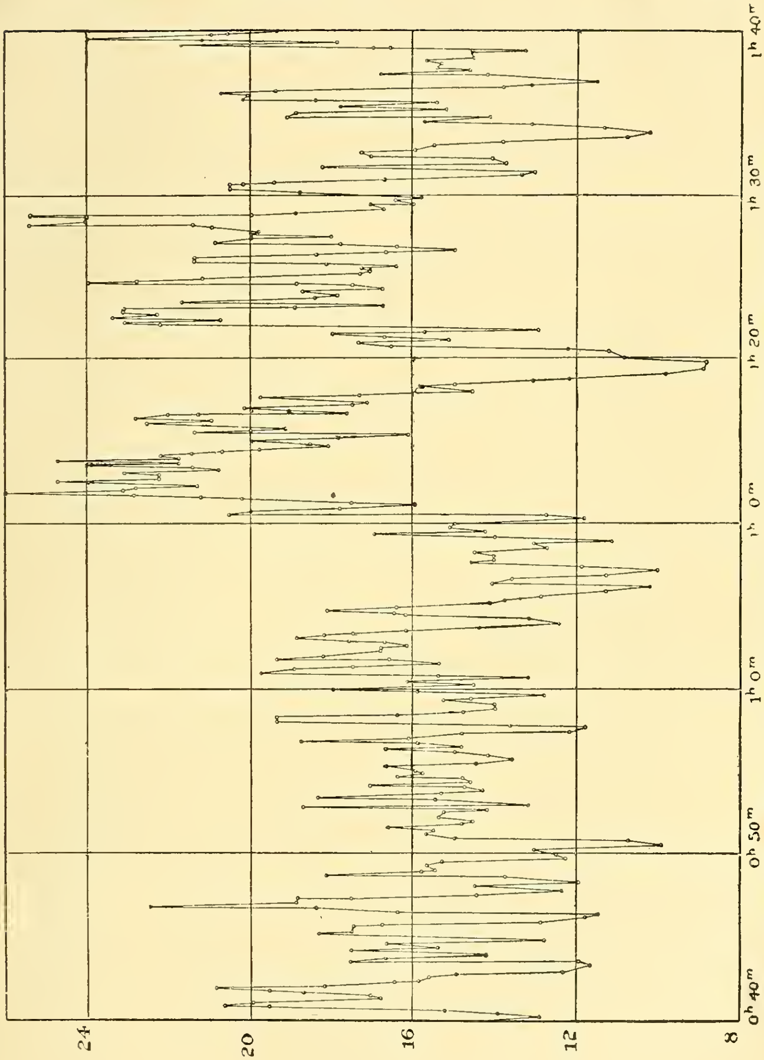
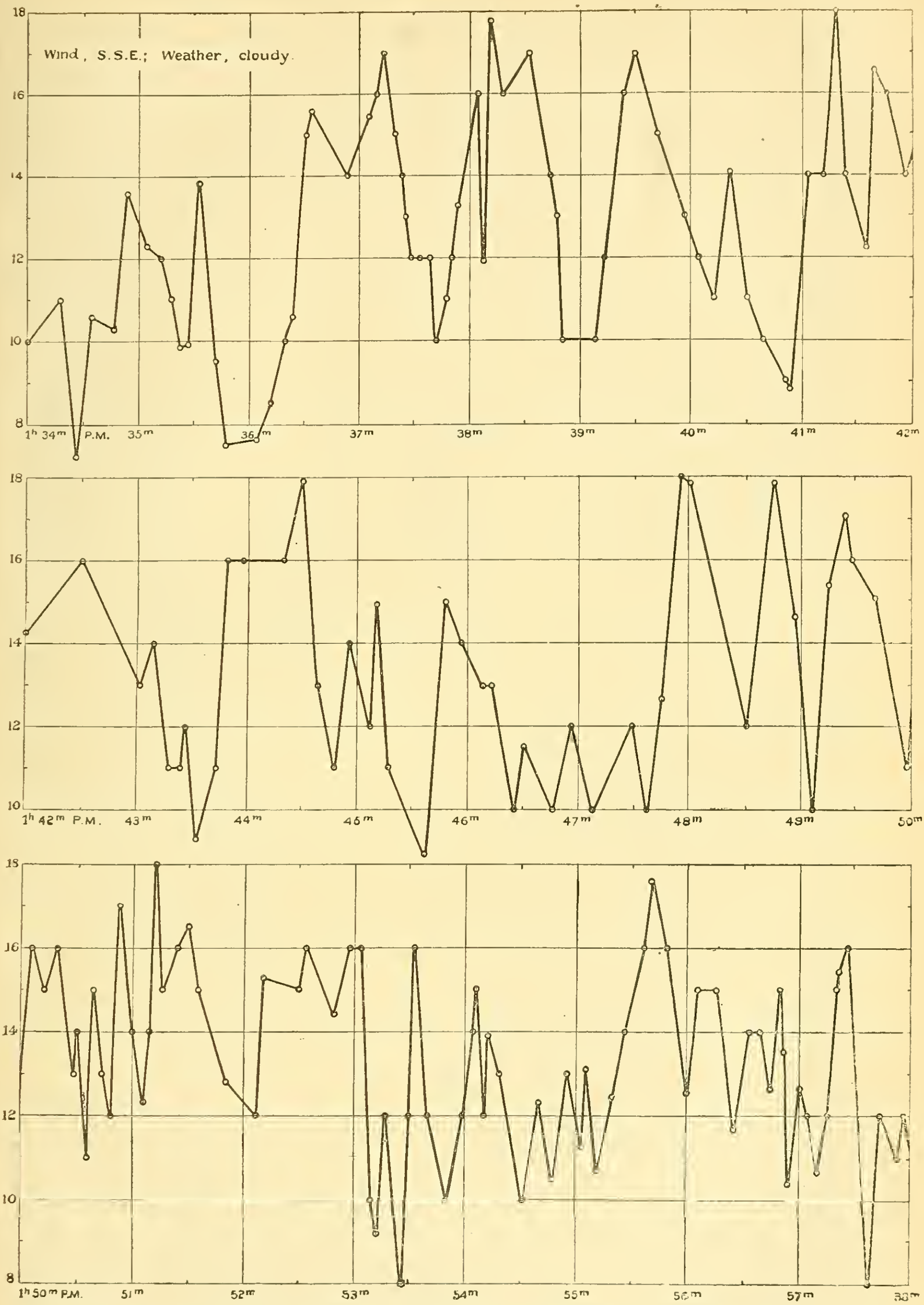


Wind velocities recorded July 16, 1887, at the Allegheny Observatory, with a Robinson anemometer registering every 25 revolutions.

Abscissae = Time.

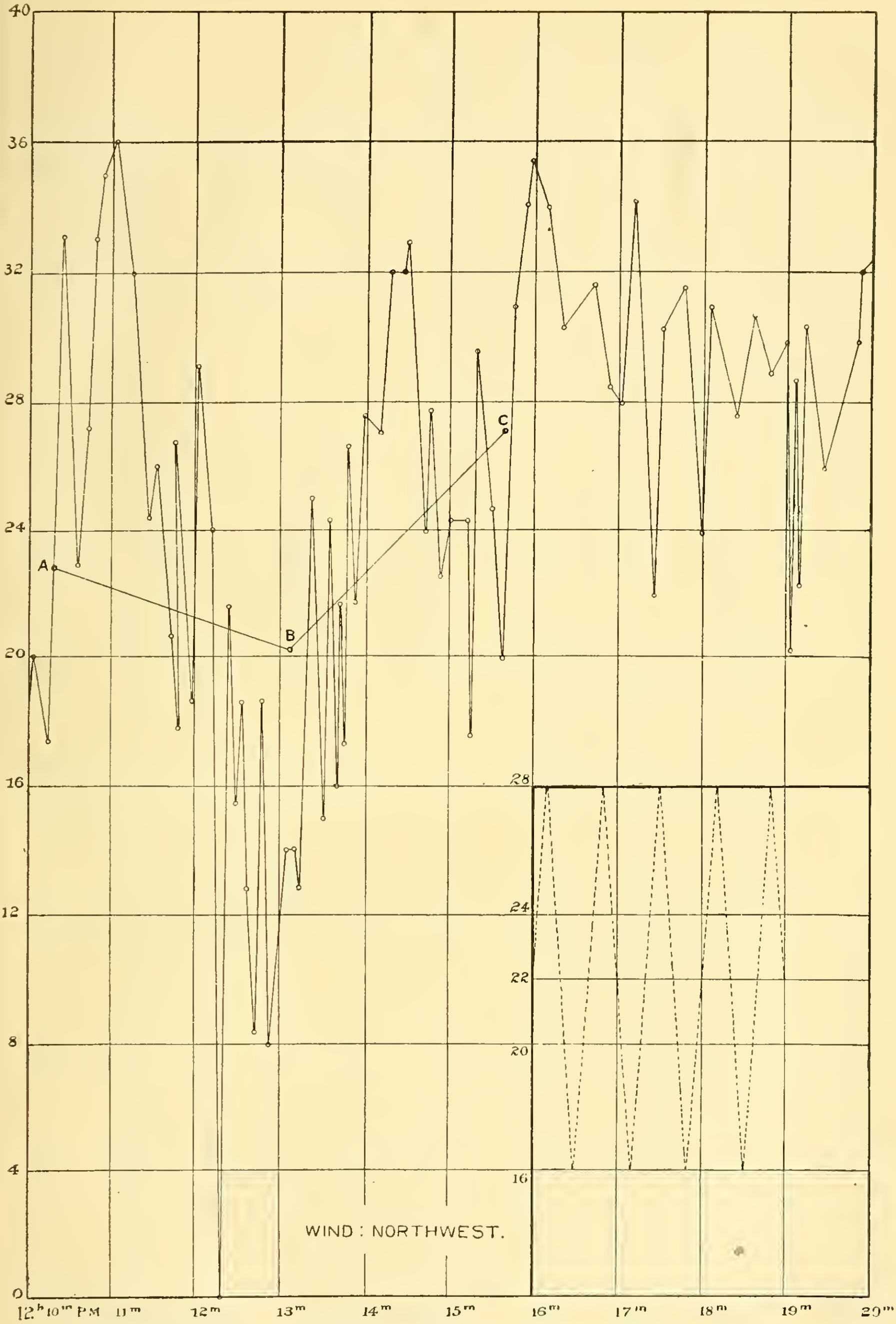
Ordinates = Wind velocities in miles per hour.



Wind velocities recorded January 14, 1893, at the Smithsonian Institution, with a light Robinson anemometer (paper cups) registering every revolution.

Abscissae = Time.

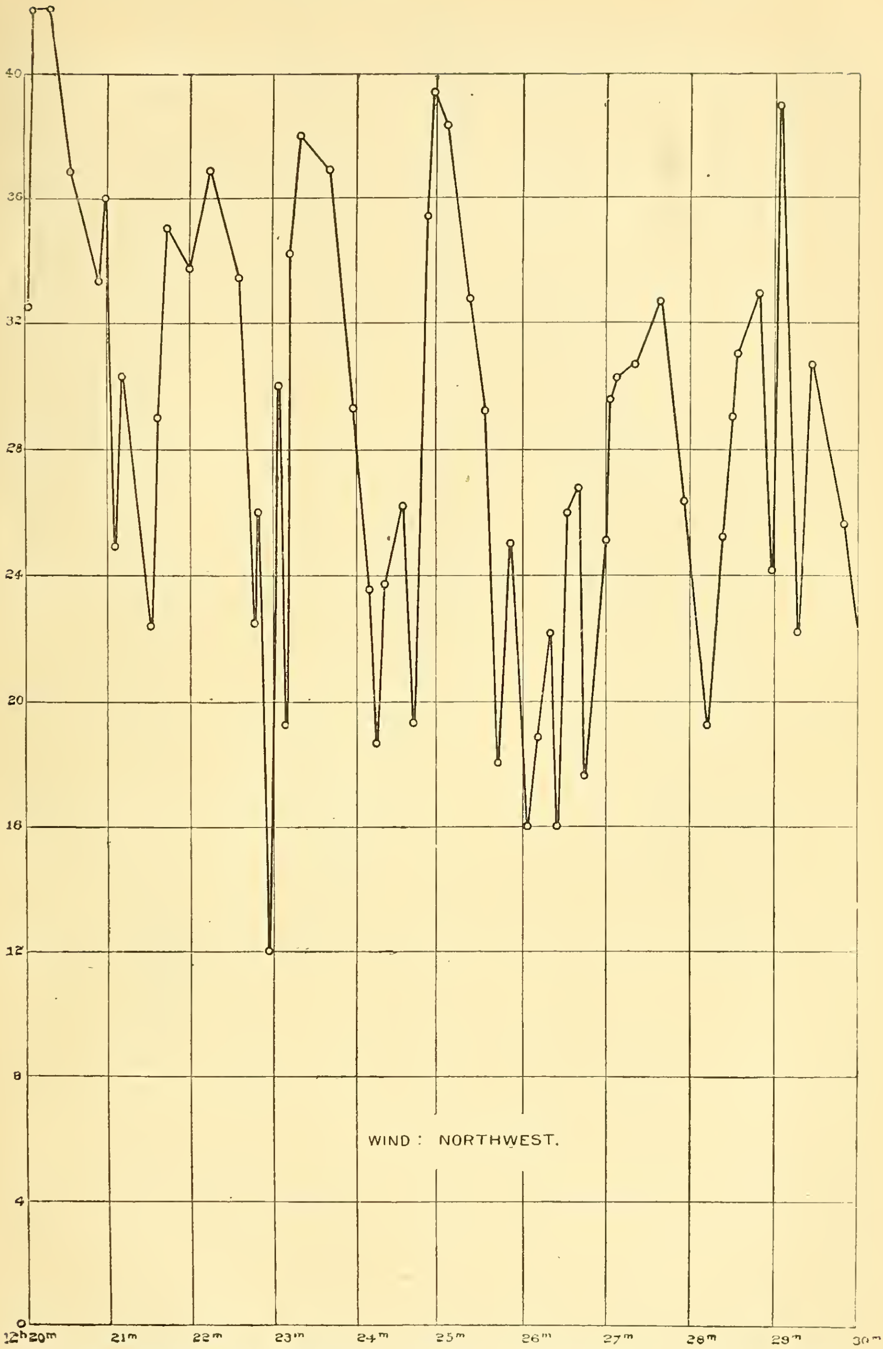
Ordinates = Wind velocities in miles per hour.



Wind velocities recorded February 4, 1893, at the Smithsonian Institution, with a light Robinson anemometer (paper cups) registering every revolution.

Abscissae = Time.

Ordinates = Wind velocities in miles per hour.



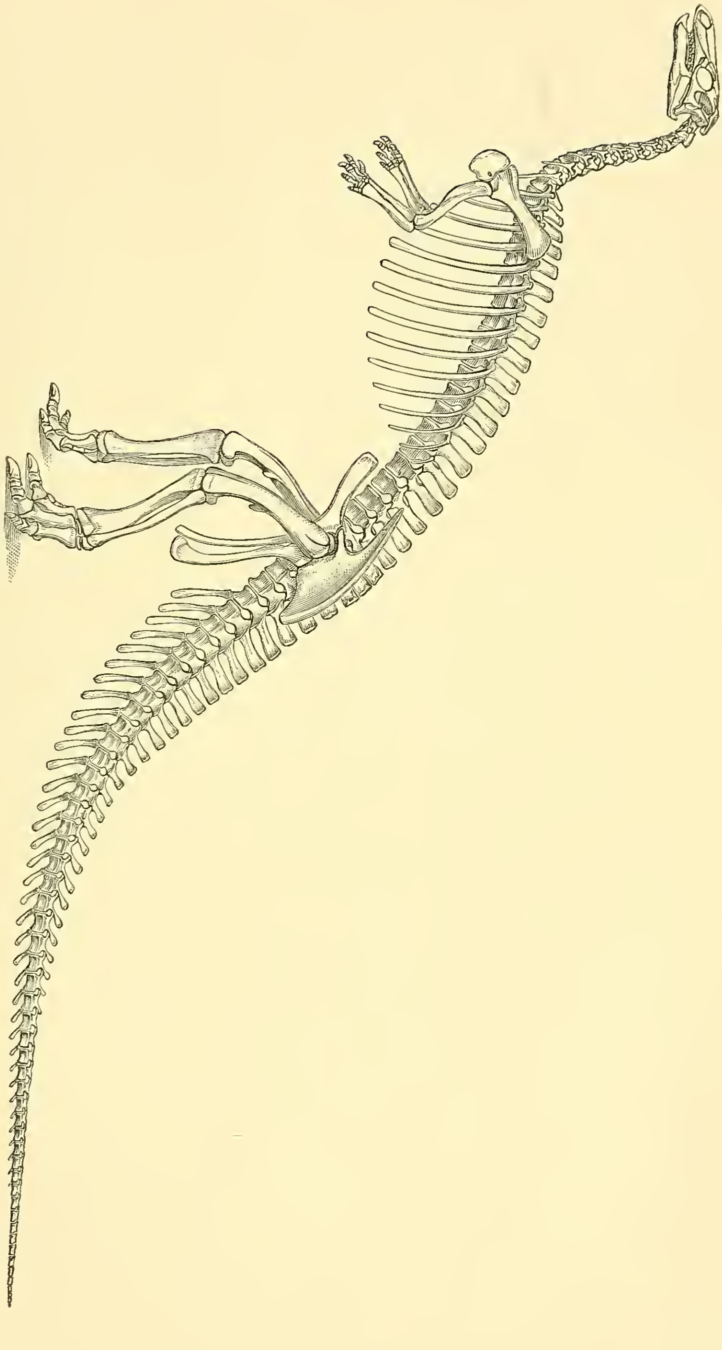
Wind velocities recorded February 4, 1893, at the Smithsonian Institution, with a light Robinson anemometer (paper cups) registering every revolution.

Abscissae = Time.

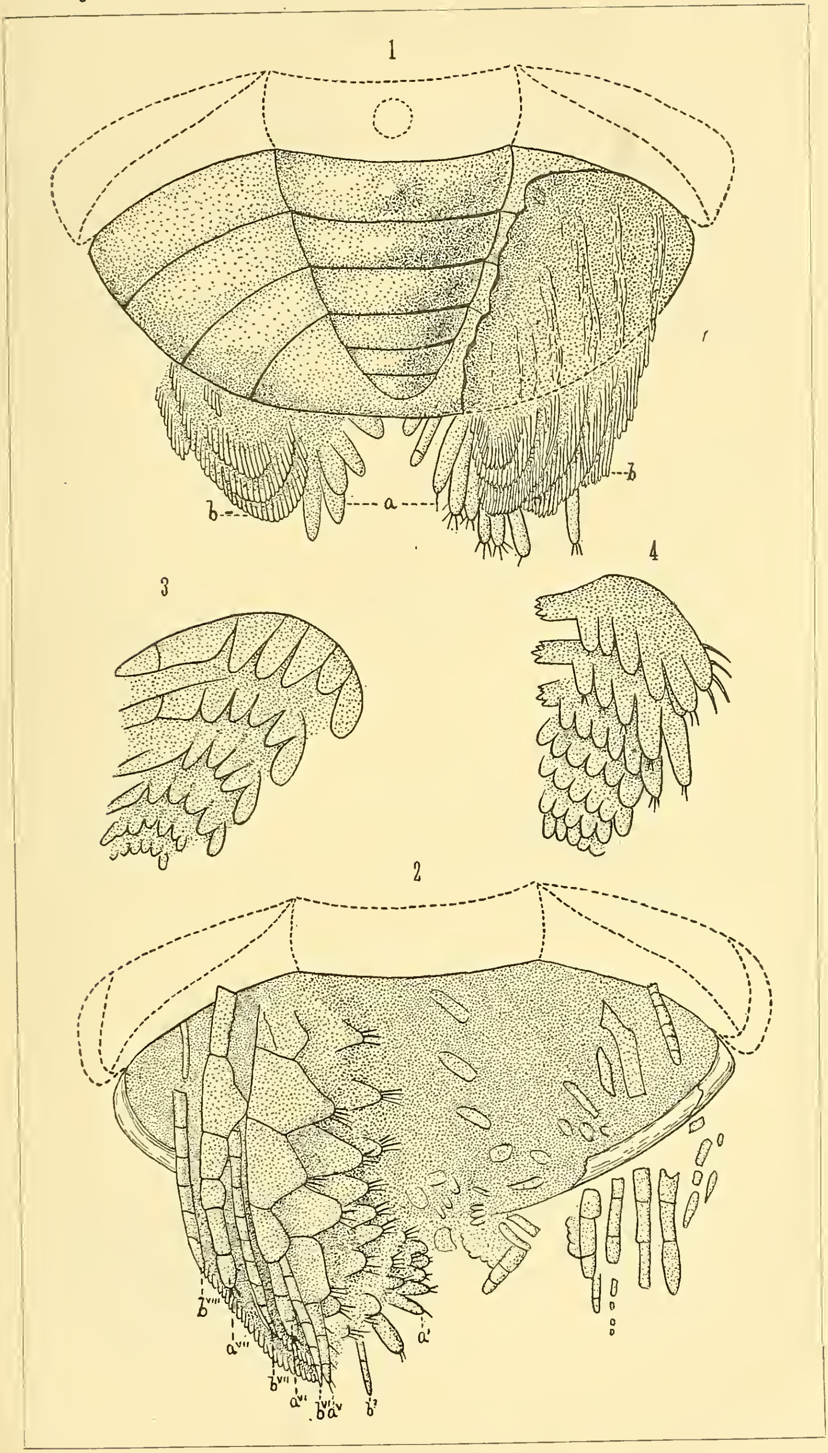
Ordinates = Wind velocities in miles per hour.

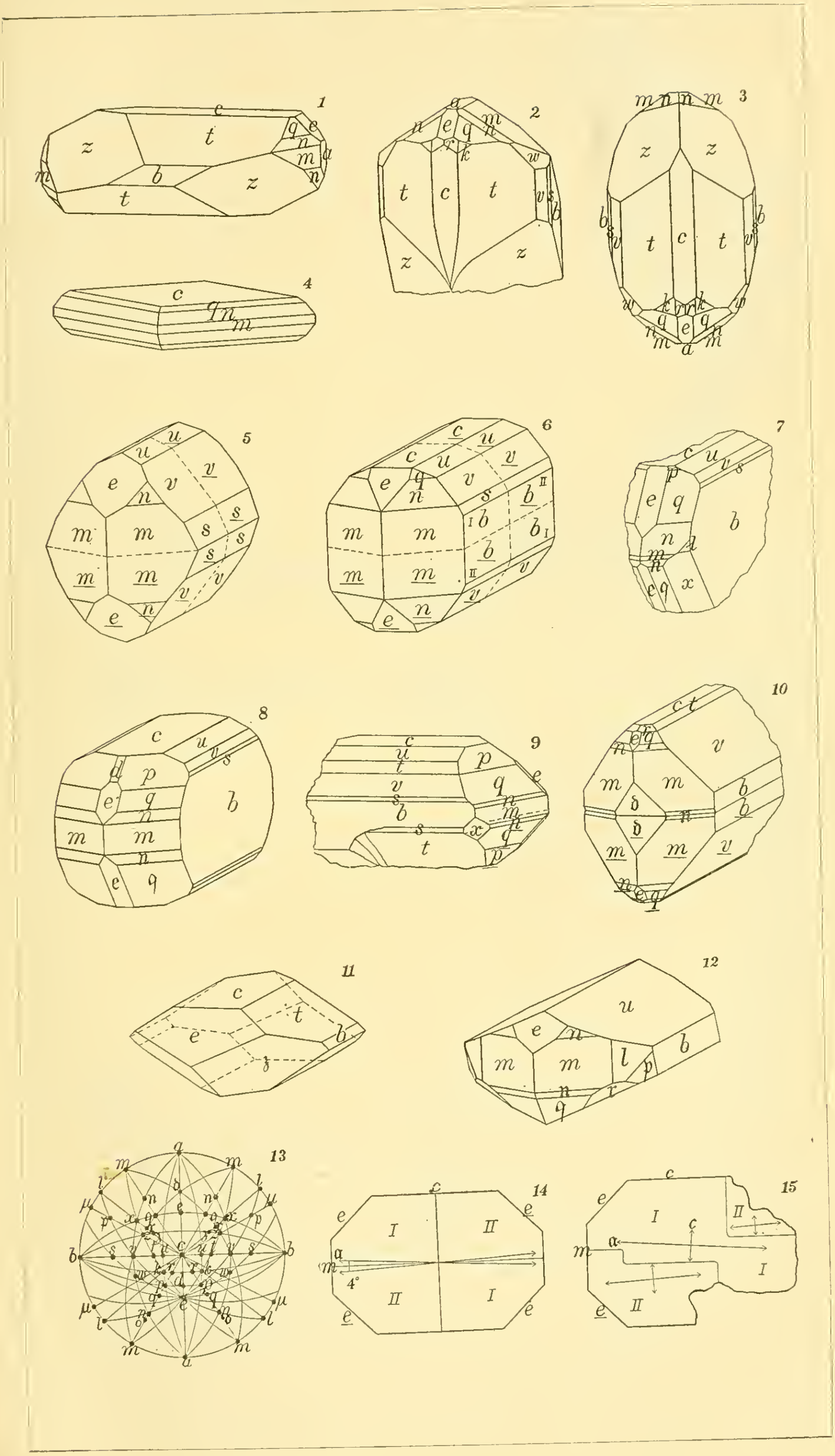
Wind velocities observed at Smithsonian Institution, February 20, 1893, with a Robinson anemometer (aluminum cups) registering every five revolutions.

Abscissae = Time.
Ordinates = Wind velocities in miles per hour.



Restoration of CAMPTOSAURUS DISPAR, Marsh. One-thirtieth natural size.


1
a
b
3
4
2


1
2
3
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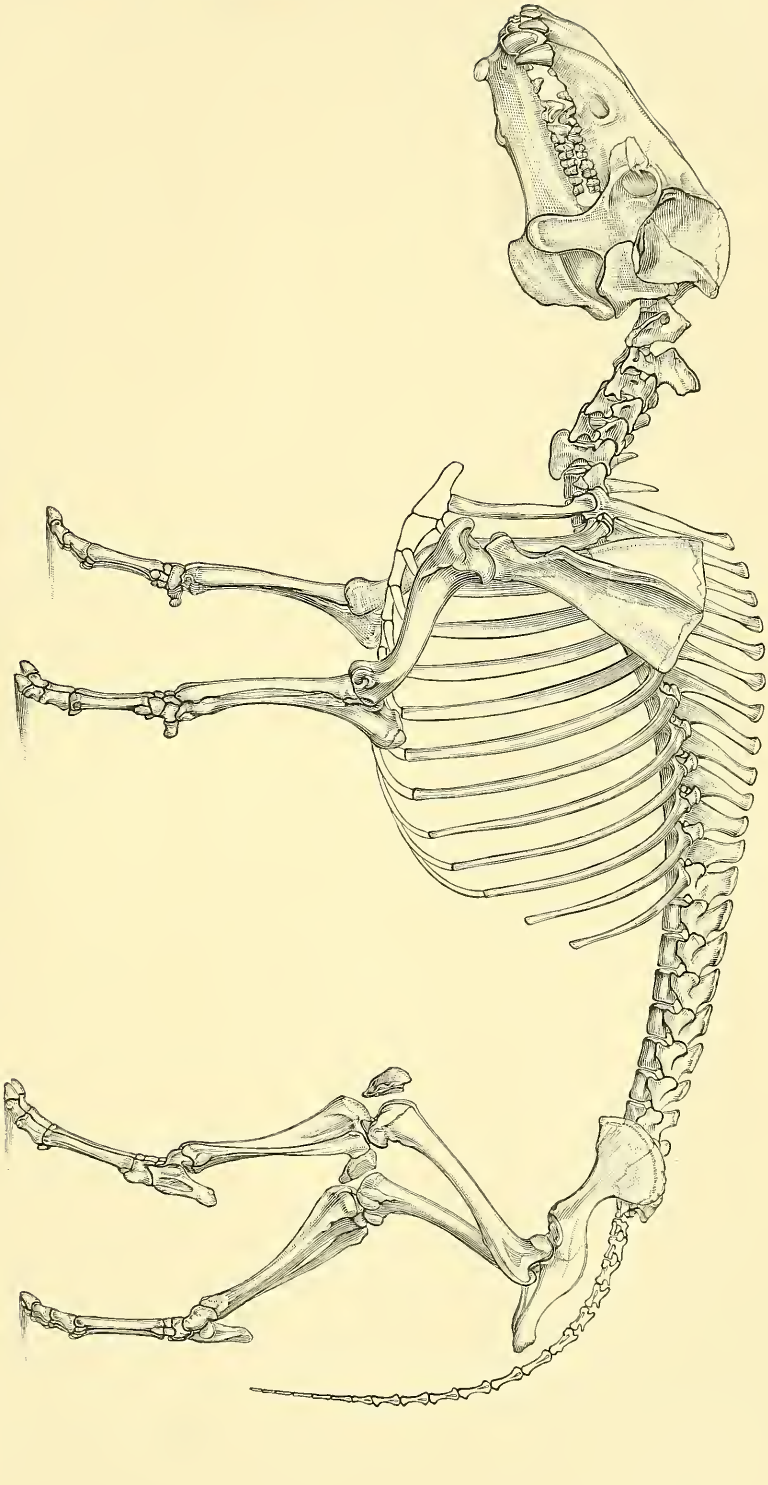
15



Restoration of ELOTHERIUM CRASSUM, Marsh. One-twelfth natural size.

Sample page from Classified List of Species, Geo. L. English & Co.'s Catalogue of Minerals.

3. HELVITE GROUP. Isometric, Tetrahedral.

366. **Helvite**; isometric; H=6–6.5; G=3.16–3.36; orthosilicate of manganese, beryllium and iron, with sulphide of manganese; $(Mn, Fe)_2(Mn_2S)Be_3(SiO_4)_3$.

Achtaragdite, a pseudomorph, perhaps after Helvite.

367. **Danalite**; isometric; H=5.5–6; G=3.42; orthosilicate of iron, zinc, beryllium and manganese, with sulphide of zinc and iron; $(Fe, Zn, Mn)_2([Zn, Fe]_2S)Be_3(SiO_4)_3$.

368. **Eulytite**; isometric; H=4.5; G=6.106; orthosilicate of bismuth; $Bi_4(SiO_4)_3$.

369. **Zunyite**; isometric; H=7; G=2.875; a highly basic orthosilicate of aluminum; $(Al[OH,F,Cl]_2)_6Al_2(SiO_4)_3$.

4. GARNET GROUP. Isomeiric, Holohedral.

370. **Garnet**; isometric; H=6.5–7.5; G=3.15–4.3; an orthosilicate of one or more of the bivalent elements calcium, magnesium, ferrous iron or manganese, combined with one or more of the trivalent elements aluminum, ferric iron, chromium, or titanium; general formula, $\overset{II}{R}_3\overset{III}{R}_2(SiO_4)_3$.

1. Aluminum Garnet.

Sub-Species I. Grossularite; Calcium-Aluminum Garnet: $Ca_3Al_2(SiO_4)_3$; G=3.55–3.66. *Var.* (a) *Wiluite* is pale, gooseberry green; (b) *Essonite* or *Cinnamon-Stone* is cinnamon brown to wine yellow; *Hyacinth* belongs here; (c) *Succinite* is amber-colored; (d) *Romanzovite* is brown; (e) *Rosolite* or *Rose Garnet* is rose pink, from Mexico.

Sub-Species II. Pyrope; Magnesium-Aluminum Garnet; $Mg_3Al_2(SiO_4)_3$; G=3.70–3.75; color deep to dark red; when transparent it is called *Precious Garnet.*

Sub-Species III. Almandite; Iron-Aluminum Garnet; $Fe_3Al_2(SiO_4)_3$; G=3.9–4.2; color deep red to violet; when transparent it is called *Precious Garnet* or *Almandine Garnet;* if cut en cabochon, *Carbuncle;* when opaque and brownish-red it is called *Common Garnet.*

Sub-Species IV. Spessartite; Manganese-Aluminum Garnet; $Mn_3Al_2(SiO_4)_3$; G=4.0–4.3; color dark hyacinth to brownish-red.

2. Iron Garnet.

Sub-Species V. Andradite; Calcium-Iron Garnet; $Ca_3Fe_2(SiO_4)_3$; G=3.8–3.91. *Var.* (a) *Simple Calcium-Iron Garnet;* includes: 1. *Topazolite,* crystallized, lemon-yellow; *Demantoid* is in pebbles, grass- to emerald-green, and highly-prized as a gem; 2. *Colophonite* is granular, brownish, resinous; 3. *Melanite* is crystallized, black; *Pyreneite* is a grayish-black Melanite; 4. *Jelletite* is a green or yellowish variety in small crystals (from Switzerland); *Calderite* is massive (from India), one kind resembles Colophonite. (b) *Manganesian Calcium-Iron Garnet;* includes: 1. *Rothoffite* and *Allochroite,* massive and brown, yellowish or reddish-brown; *Polyadelphite* is brownish-yellow from Franklin Furnace; *Bredbergite* is from Sala; 2. *Aplome* is a dodecahedral, striated, brown to yellowish-green variety. (c) *Titaniferous Garnet;* graduates towards Schorlomite, $Ca_3(Fe,Ti,Al)_2([Si,Ti]O_4)_3$; color black. (d) *Yttriferous Calcium-Iron Garnet* or *Yttergarnet,* contains yttria.

3. Chromium Garnet.

Sub-Species VI. Uvarovite; Calcium-Chromium Garnet; $Ca_3Cr_2(SiO_4)_3$; H=7.5; G=3.41–3.52; color emerald-green, crystallized. *Trautwinite* is an impure variety.

371. **Schorlomite**; isometric; H=7–7.5; G=3.81–3.88; a titano-silicate of calcium, iron and titanium; $Ca_3(Fe,Ti)_2([Si,Ti]O_4)_3$. *Ivaarite* is probably identical, or a variety.

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